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Contact Information

For more information contact:

Publications Coordinator
Phone: (360) 407-6764

Author: Pamela B. Marti, Hydrogeologist
Washington State Department of Ecology
Environmental Assessment Program
Phone: (360) 407-6768
Address: PO Box 47600, Olympia WA 98504-7600

Washington State Department of Ecology - www.ecy.wa.gov

- Headquarters, Olympia (360) 407-6000
- Northwest Regional Office, Bellevue (425) 649-7000
- Southwest Regional Office, Olympia (360) 407-6300
- Central Regional Office, Yakima (509) 575-2490
- Eastern Regional Office, Spokane (509) 329-3400

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**Black Lake Grocery
Groundwater
Confirmational Monitoring**

August 2011 to May 2012

by

Pamela B. Marti, Licensed Hydrogeologist

Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

Waterbody Number: WA-23-9010

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Abstract

Black Lake Grocery is an active gas station and convenience store located on the northwest shore of Black Lake, Thurston County, WA. In 1989, soil and groundwater beneath the site were found to be contaminated with gasoline-range petroleum hydrocarbons. The source of the contamination was leaking underground storage tanks that were removed in June 1995 along with a large amount of contaminated soil. In 2004 a treatment wall was installed along Black Lake's shoreline to passively remediate contaminated groundwater flowing toward the lake.

Groundwater from on-site monitoring wells had been sampled and analyzed for petroleum constituents from November 1993 to June 2009. To characterize current contaminant concentrations, the Washington State Department of Ecology (Ecology) collected groundwater samples from 11 monitoring wells quarterly from August 2011 to May 2012. Samples were primarily analyzed for benzene, toluene, ethylbenzene, and xylene (BTEX), and total petroleum hydrocarbons as gasoline (TPH-G).

Water quality results for the 2011-2012 monitoring period confirm that the near surface aquifer continues to be contaminated in both the upper and lower portions of the site. Concentrations have decreased since 1995 but continue to exceed established cleanup levels in several of the sampled wells.

Wells downgradient of the treatment wall and along the shoreline also have BTEX concentrations that exceed cleanup levels. This may be an indication that the treatment wall is losing its capacity to remediate the contaminated groundwater. The presence of high contaminant concentrations in wells near the shore suggests that petroleum constituents from the site are migrating to Black Lake.

Groundwater monitoring downgradient of the treatment wall should continue to determine if the reactive materials remain effective in remediating the contaminated groundwater.

Background

Black Lake Grocery is an active gas station and convenience store located on the northwest shore of Black Lake (Figure 1). The store is situated on a 5.2-acre parcel of land approximately 100 feet from the lakeshore. In 1989, during a geotechnical study performed for Thurston County as part of a planned expansion of Black Lake Boulevard, soil and groundwater beneath the site were found to be contaminated with gasoline-range petroleum hydrocarbons (Dames and Moore, 1990).

In 1992, the Washington State Department of Ecology (Ecology) conducted a site hazard assessment. The site was ranked on Ecology's Hazardous Site List as a "2" (a rank of 1 is the highest priority relative to other statewide sites; 5 is the lowest).

In June and July 1995, at the time of the Black Lake Boulevard expansion, seven underground storage tanks and 1200 cubic yards of petroleum-contaminated soils were removed from the site as an interim action. The excavated area was in the northeast portion of the site and encompassed the area between the grocery store to the property boundaries at Goldsby Road and Black Lake Boulevard (Figure 2). The depth of the excavation ranged from approximately 10 to 13 feet below ground surface. Soils from the edge of the excavated area were still found to exceed the Model Toxics Control Act Method-A cleanup levels for benzene, toluene, ethylbenzene, and xylenes (BTEX) and total petroleum hydrocarbons (TPH). The contaminated soils beyond the excavated area could not be removed because it was not accessible below the adjacent county roads (Summit, 2000).

The remedial investigation/feasibility study was completed in 2001. The selected remedial alternative was installation of a treatment wall at the distal end of the contaminant plume, along the shore of Black Lake. The treatment wall was intended to passively remediate the contaminated groundwater flowing toward the lake. Constructed in November 2004, it is approximately 120 feet long, 5 feet wide and 12 feet deep and is composed of a reactive material (an engineered sphagnum peat moss). Because the treatment wall treats only the distal end of the plume, natural attenuation mechanisms are relied upon to mitigate the groundwater plume upgradient of the wall. Natural attenuation processes include a variety of physical, chemical, and biological processes that under favorable conditions reduce the mass, toxicity, mobility, volume or concentration of contaminants in soil and groundwater (EPA, 2004).

In 2005, Ecology collected sediment and surface water samples near the lake shoreline to determine if petroleum products had migrated into Black Lake. BTEX and TPH-G were not detected in any of the sediment or water samples collected from the study area (Coots, 2005).

Groundwater at the site was sampled and analyzed for petroleum constituents between November 1993 and June 2009. Overall, concentrations have decreased since excavation and removal of contaminated soils and installation of the treatment wall. However, concentrations still exceeded the MTCA cleanup levels in several of the sampled wells. To characterize current contaminant concentrations, the Washington State Department of Ecology (Ecology) collected quarterly groundwater samples from August 2011 to May 2012 from on-site monitoring wells, results of which are discussed in this report.

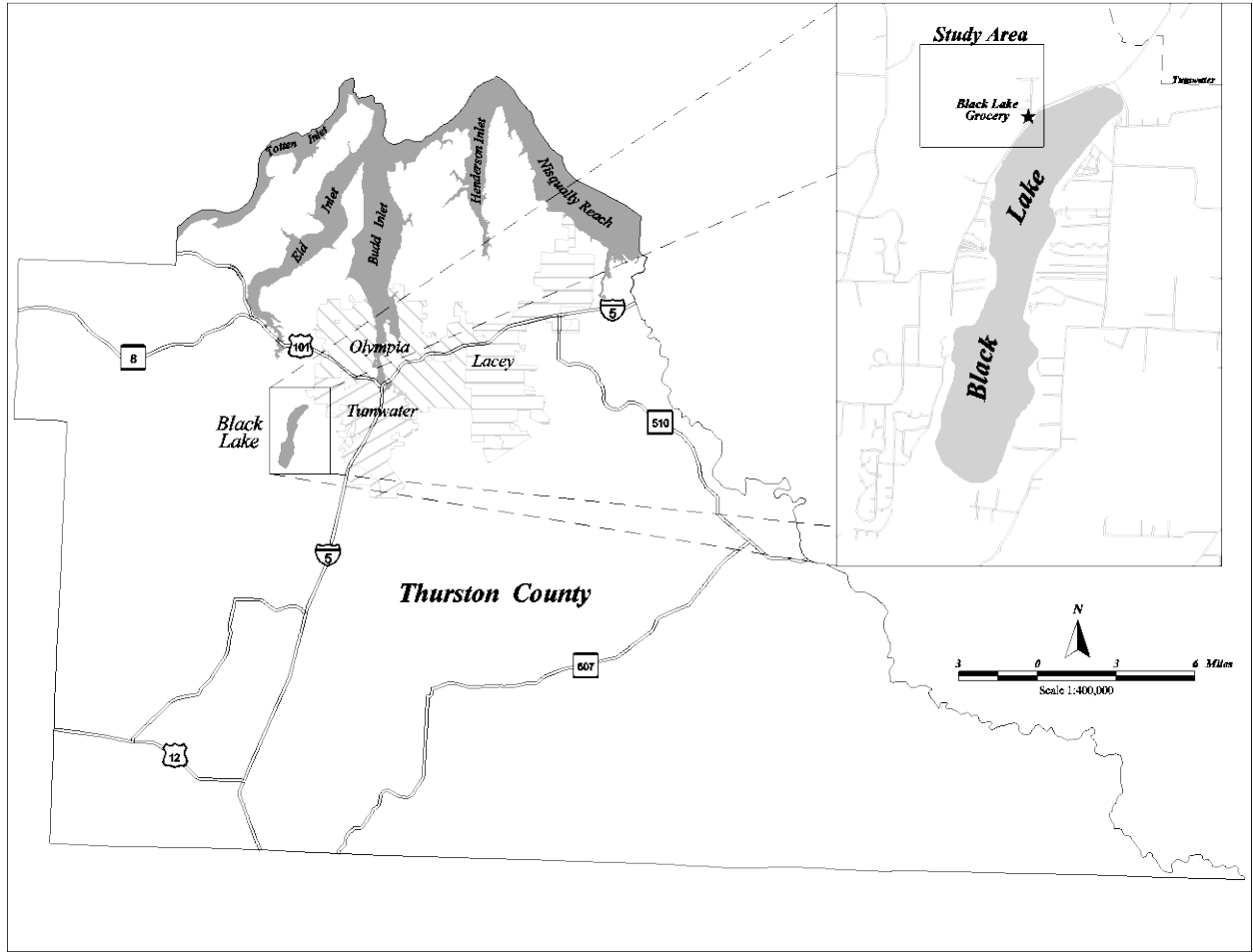


Figure 1. Location of the Black Lake Grocery Site.

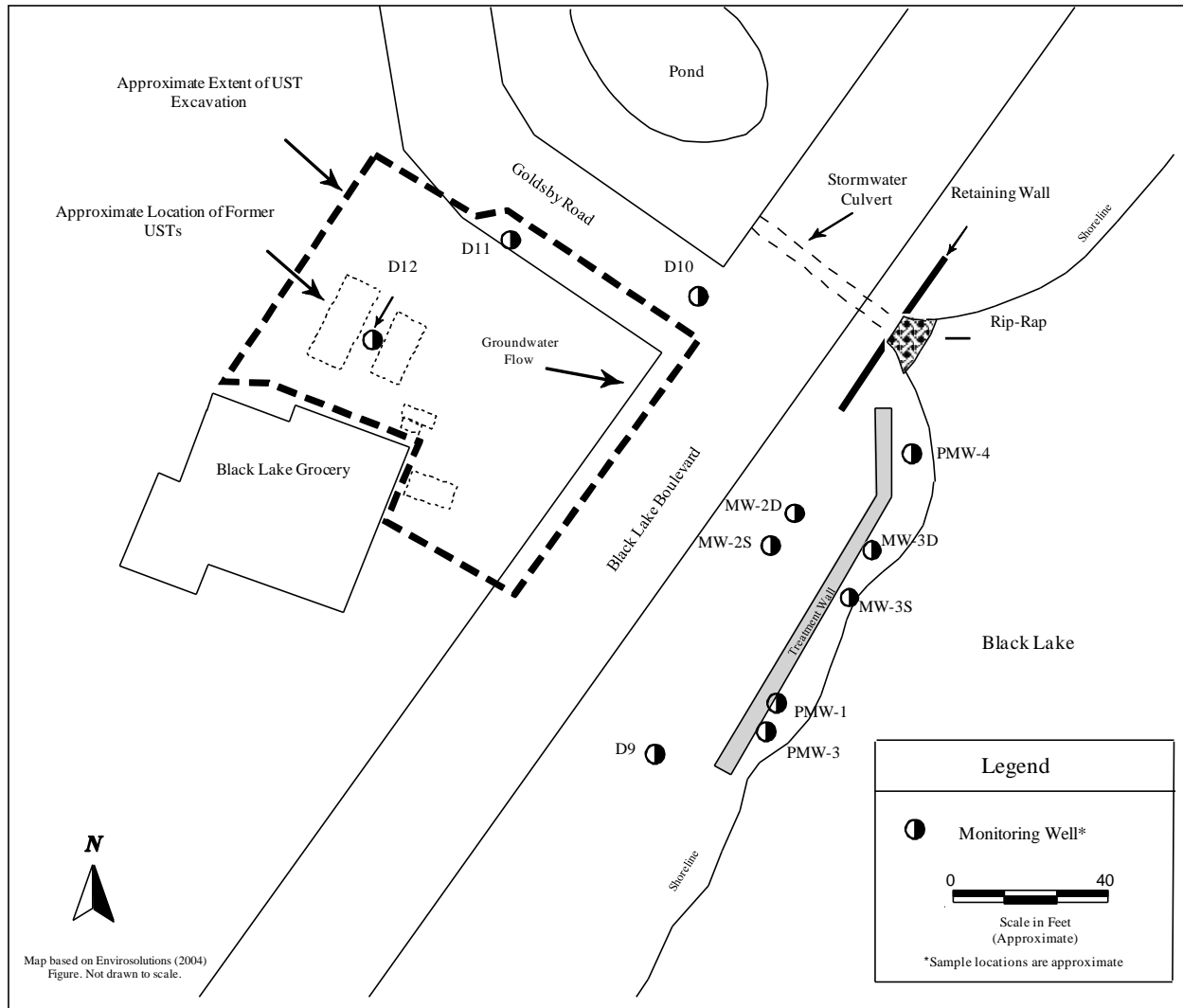


Figure 2. Black Lake Grocery Sample Locations.

Physical Description

Black Lake Grocery sits on a small bluff, about 10 feet above the shore of Black Lake at an approximate elevation of 138 feet. Physically the bluff separates the site into an upper and lower area. Black Lake Grocery, the source of the contamination, is located on the upper portion of the site, while the treatment wall is located on the lower portion of the site.

The geology of the area is composed of Vashon glacial drift deposits. These deposits consist of (from youngest to oldest) recessional outwash, till, and advance outwash and extend from the ground surface to a depth of approximately 60 to 80 feet. The Vashon deposits unconformably overlie recessional outwash deposits of the Salmon Springs Formation which are approximately 70 to 80 feet thick, and extend to approximately 130 to 140 feet below ground surface. The Salmon Springs deposits lie unconformably on Tertiary volcanic rocks (Noble and Wallace, 1966; Wallace and Molenaar, 1961). In addition to Vashon glacial drift, ancestral lacustrine deposits (Lake Russell) are also present in the area surrounding the site. These deposits exist as a relatively thin mantle of clay found up to an elevation of about 150 feet and underlain by Vashon glacial drift.

Geology of the upper portion of the site contains deposits of silt and fine sand. These deposits are mapped by Noble and Wallace (1966) as recessional outwash of the Vashon deposits. However, the location and texture of the deposits, such as well-sorted sands, indicate the deposits may represent former shoreline deposits. Geology of the upper area has been altered with the removal of contaminated soils and subsequent backfilling of the excavated area.

Test borings drilled in the 1990s (Blazer, 1994; Summit, 2000) on the lower portion of the site indicate the area is underlain by fine-grained lacustrine deposits (silts and clays). Soil borings advanced at the site report clay and silty clay present from approximately 5 to 35 feet below ground surface.

The general direction of groundwater flow beneath the site is to the east toward Black Lake. Groundwater appears to be moving relatively slowly, approximately 1.8 to 3.7 feet per year based on water level measurements and slug tests (Summit, 2005).

Methods

Groundwater Sampling

The primary contaminants of concern for this study are gasoline-range hydrocarbons, which include: benzene, toluene, ethylbenzene, and xylene (BTEX), plus total petroleum hydrocarbons as gasoline (TPH-G). To characterize current contaminant concentrations, Ecology collected quarterly groundwater samples between August 2011 to May 2012 for BTEX and TPH-G analysis from 11 monitoring wells (Figure 2). Samples were also collected and analyzed for conventional parameters twice during the monitoring period to provide the Toxics Cleanup Program with data to evaluate the natural attenuation properties of the site.

The sampled wells were installed between 1993 and 2004. All but one of the wells are constructed of 2-inch PVC and range in depth from approximately 5 to 16 feet below ground surface. The remaining well is also constructed of PVC but is 4 inches in diameter. Well construction details are provided in Appendix A.

Samples collected from the monitoring wells are assumed to be representative of groundwater quality at the site. Due to the topography of the site and various phases of remediation, the sampled wells fall into the following categories:

- The upper portion of the plume (D10, D11, and D12).
- The shallow and deep groundwater immediately upgradient of the treatment wall (D9, MW-2S, and MW-2D).
- Groundwater conditions within the treatment wall (PMW-1).
- The shallow and deep groundwater immediately downgradient of the treatment wall (PMW-3, PMW-4, MW-3S, and MW-3D).

Ecology measured static water levels in all sampled wells prior to well purging and sampling. Measurements were collected according to standard operating procedure (SOP) EAP052 (Marti, 2009).

Ecology sampled all wells in accordance with Ecology's SOP EAP078 (Marti, 2011).

The monitoring wells were purged and sampled using a peristaltic pump with dedicated tubing for each well. The tubing intake was placed near the bottom of the screened interval due to the fine-grained formation materials in the screened intervals and the low yields of most of the wells. Wells were purged at a rate of 0.5-liter/minute or less. The purge water was routed through a closed atmosphere flow cell where field parameters (pH, dissolved oxygen (DO), specific conductance, and temperature) were measured. Purging continued until all field parameters stabilized. Water removed from the well during the purging process was collected and stored on site in a 55-gallon drum. Purge water waste transport and disposal procedures followed Washington State regulations (Chapter 173-303-400 WAC).

At the completion of purging, the flow cell was disconnected. Samples were then collected directly from the well's dedicated pump discharge tubing into the appropriate sample containers (Table 1). Sulfate, nitrite, nitrate and dissolved iron samples were field-filtered, using a clean, high-capacity, in-line 0.45-micron membrane filter. DOC samples were also field-filtered using a 0.45-micron membrane syringe filter. Samples were collected in the order listed on Table 1.

Table 1. Sample Containers and Preservation

Parameter	Matrix	Container	Preservative
BTEX	Groundwater	Three 40 mL vials with Teflon-lined septa caps. No Headspace	Preserve to pH < 2 with 1:1 HCl Cool to ≤6°C
TPH-Gx	Groundwater	Three 40 mL vials with Teflon-lined septa caps. No Headspace	Preserve to pH < 2 with 1:1 HCl Cool to ≤6°C
Total Iron	Groundwater	500 mL HDPE bottle	Pre-acidified with HNO ₃ Cool to ≤6°C
DOC	Groundwater, Filtered	60 mL narrow-mouth polyethylene bottle	Pre-acidified with 1:1 HCl Cool to ≤6°C
Sulfate	Groundwater, Filtered	500 mL wide-mouth polyethylene bottle	Cool to ≤6°C
Nitrite	Groundwater, Filtered	125 mL amber wide-mouth polyethylene bottle	Cool to ≤6°C
Nitrate-N	Groundwater, Filtered	125 mL clear wide- mouth polyethylene bottle	Pre-acidified with H ₂ SO ₄ Cool to ≤6°C
Dissolved Iron	Groundwater, Filtered	500 mL HDPE bottle	Pre-acidified with HNO ₃ Cool to ≤6°C
Turbidity	Groundwater	500 mL wide-mouth polyethylene bottle	Cool to ≤6°C

All samples were labeled and stored in an ice-filled cooler pending transport to Ecology's Operation Center (OC) in Lacey, Washington. Samples were kept in a walk-in cooler at the OC until they were picked up by the laboratory courier and transported to the Ecology/EPA Manchester Environmental Laboratory (MEL) in Manchester, Washington. Chain-of-custody procedures were followed per Manchester Laboratory protocols (Ecology, 2008).

Analysis

Standard methods and reporting limits used for analysis of all groundwater samples are shown in Table 2. MEL analyzed all the laboratory samples. Because they perform all the requested analysis on a routine basis, no problems with the laboratory methods were expected.

Table 2. Field and Laboratory Methods.

Field Measurements	Instrument Type	Method	Accuracy
Water Level	Solinst Water Level Meter	SOP EAP052	±0.03 feet
pH	YSI ProPlus with Quatro Cable	EPA 150.1 (EPA, 2001a)	±0.2 std. units
Dissolved Oxygen	YSI ProPlus with Quatro Cable	EPA 360.1 (EPA, 2002)	±0.2 mg/L
Specific Conductance	YSI ProPlus with Quatro Cable	EPA 120.1 (EPA, 2001b)	±10 umhos/cm
Temperature	YSI ProPlus with Quatro Cable	EPA 150.1	±0.2 °C
Laboratory Analytes	Reference	Method	Reporting Limit
BTEX	EPA 1996	EPA SW-846 Method 8021B	1 ug/L
TPH-G	Ecology 2008	NWTPH-Gx	0.14 mg/L
Total Iron	Std. Methods 20 th ed.	EPA Method 200.7	0.05 mg/L
Dissolved Iron	Std. Methods 20 th ed.	EPA Method 200.7	0.05 mg/L
Nitrite	Std. Methods 20 th ed.	SM 4500-NO3- I	0.01 mg/L
Nitrate	Std. Methods 20 th ed.	SM 4500-NO3- I	0.01 mg/L
Sulfate	Std. Methods 20 th ed.	EPA Method 300.0	0.5 mg/L
Dissolved Organic Carbon	Std. Methods 20 th ed.	SM 5310B	1 mg/L
Turbidity	Std. Methods 20 th ed.	SM 2130	0.5 NTU

SOP: standard operating procedure.

EAP: Environmental Assessment Program.

EPA: U.S. Environmental Protection Agency.

Results

Data Quality Assessment

Field quality control samples for this project consisted of blind field replicates from well PMW-4 and filter blanks.

Ecology collected field replicates by splitting the pump discharge between two sets of sample bottles. Tables 3 and 4 show results of the replicate samples and the corresponding relative percent difference (RPD). RPD is calculated as the difference between replicate sample results, divided by the replicate mean with the result expressed as a percentage. The RPD calculation provides a measure of the overall sampling and analytical precision. Precision estimates are influenced not only by the random error introduced by collection and measurement procedures, but also by the natural variability of the concentrations in the media being sampled.

Table 3. Relative Percent Difference (RPD) of Replicate BTEX and TPH-G Sample Results (ug/L), August 2011 to May 2012.

Sample ID:	RPD Target	PMW -4	PMW -4A	RPD (%)	PMW -4	PMW -4A	RPD (%)	PMW -4	PMW -4A	RPD (%)	PMW -4	PMW -4A	RPD (%)
		8/11			11/11			2/12			5/12		
Benzene	30%	160	140	13	210	210	0	100	110	9	180	190	5
Toluene	30%	55	39	34	30	33	9	10 U	11	--	51	54	6
Ethylbenzene	30%	320	240	29	300	320	6	33	41	22	360	390	8
m,p-Xylene	30%	730	530	32	640	680	6	76	99	26	930	1000	7
o-Xylene	30%	130	91	35	110	120	9	28	36	25	190	210	10
TPH-G	40%	5500	3900	34	5100	5600	9	730	940	25	7800	8500	9

PMW-4A: The replicate sample identification. U: Analyte was not detected at or above the reported value.

Table 4. Relative Percent Difference (RPD) of Replicate Natural Attenuation Site Characterization Sample Results (mg/L), November 2011 and May 2012.

Sample ID:	RPD Target	PMW-4	PMW-4A	RPD (%)	PMW-4	PMW-4A	RPD (%)
		11/11			5/12		
Total Iron	20%	25.2	23.9	5	33.6	33.1	1
Dissolved Iron	20%	20.8	19.3	7	12.8	12.9	1
Nitrite-N	20%	0.01 U	0.01 U	--	0.01 U	0.01 U	--
Nitrate-N	20%	0.04 UJ	0.04 UJ	--	0.01 U	0.012	--
Sulfate	20%	3.04	2.93	4	0.32	0.3 U	--
DOC	20%	45.2	40.1	12	46.6	51.3	10
Turbidity (NTU)	NA	3.8	2.8	30	2.6	3.1	18

PMW-4A: The replicate sample identification. NA: Not Applicable.

U: Analyte was not detected at or above the reported value.

UJ: Analyte was not detected at or above the reported estimated value.

With the exception of the August 2011 BTEX results, all of the replicate results met the measurement quality objectives established in the Quality Assurance Project Plan (Marti, 2011) and are considered good and usable as qualified. The RPDs for the August replicate BTEX results were slightly above the project data quality objectives. Still, the sample concentrations are within the range of results reported for well PMW-4 during the rest of the monitoring period. Because the exceedance is slight for this single duplicate pair the data are considered usable without further qualification.

The filter blanks were prepared in the field with laboratory-grade deionized water and were filtered, where appropriate, in the same manner as the samples. None of the filter blanks contained detectable levels of target analytes.

A review of the data quality control and quality assurance from laboratory case narratives indicates that overall analytical performance was good. The reviews include descriptions of analytical methods, holding times, instrument calibration checks, blank results, surrogate recoveries, and laboratory control samples. No problems were reported that compromised the usefulness or validity of the sample results; therefore, all results are usable as qualified. Quality assurance case narratives and laboratory reporting sheets are available upon request.

All field measurements and analytical result data are available in electronic format from Ecology's EIM data management system: www.ecy.wa.gov/eim/index.htm. Search study ID, PMART007.

Field Observations

Ecology measured depth-to-water in each of the sampled monitoring wells prior to purging. The end-of-purge pH, dissolved oxygen, and specific conductance readings are listed by well in Table 5. Because temperatures measured in a flow cell are influenced by ambient air conditions, they are generally not considered to be representative of in-situ groundwater conditions and have been omitted from Table 5.

Completion depths for the monitoring wells range from approximately 6 to 17 feet. During the monitoring period depth-to-groundwater below the land surface ranged from about 2 to 8 feet in the upper portion of the site and about 1 to 3.5 feet in the lower portion of the site.

Groundwater pH had an average range of 6.0 to 6.9. Well PMW-1 fell outside the range, with an average pH of 5.5. Well PMW-1 is located within the treatment wall. Dissolved oxygen measurements from most of the wells were low, near or below 1 mg/L, suggesting anaerobic or reducing conditions. DO values below 0.5 mg/L indicate an anoxic environment. Well D12 was the exception with DO range of 4.6 to 7.5 mg/L indicating aerobic conditions in this portion of the site. Well D12 is located in the former tank area where the contaminated soils were excavated and the area backfilled. Specific conductance measurements had a mean range of 137 to 717 umhos/cm. The average groundwater temperatures measured in the flow cell ranged from 14.7°C in August to 9.4°C in February.

While purging at the lowest flow possible, water levels dropped in all the wells. Wells MW-2S and MW-2D purged dry the first time the wells were sampled in August 2011. Well MW-3S purged dry during all four sample rounds. This well required several hours to recover enough water for sample collection.

Table 5. Summary of Field Parameter Results, August 2011 to May 2012.

Well Sample ID	Total Depth (feet) ¹	Depth-to-Water Below Ground Surface (feet)				pH (standard units)					Dissolved Oxygen (mg/L)				Specific Conductance (umhos/cm)				
		8/11	11/11	2/12	5/12	8/11	11/11	2/12	5/12	Ave.	8/11	11/11	2/12	5/12	8/11	11/11	2/12	5/12	Ave.
Upper portion of the plume																			
D10	11.40	7.85	6.59	6.10	6.31	6.6	6.6	6.5	6.6	6.6	0.58	0.81	0.78	0.83	765	705	729	668	717
D11	13.92	5.04	5.23	4.05	3.43	6.4	6.3	6.2	6.3	6.3	0.41	0.43	0.29	0.31	558	551	530	524	541
D12	9.06	5.05	3.70	1.85	2.60	6.1	5.9	5.9	6.0	6.0	6.4	4.6	7.4	7.5	143	162	122	121	137
Shallow and deep groundwater immediately upgradient of the treatment wall																			
D9	15.05	3.61	2.39	1.99	2.21	6.1	6.3	6.2	6.3	6.2	0.48	1.2	1.1	0.52	304	331	326	317	320
MW-2S ⁽²⁾	7.07	3.15	--	1.49	1.46	6.4	6.3	6.2	6.2	6.3	--	0.42	0.31	0.47	690	663	647	638	660
MW-2D ⁽²⁾	17.12	3.10	1.32	0.85	1.13	6.9	6.8	6.7	6.9	6.8	0.59	2.7	0.76	0.51	338	334	334	334	335
Groundwater within the treatment wall																			
PMW-1	11.47	3.42	1.79	1.59	1.78	5.4	5.7	5.3	5.6	5.5	0.33	0.5	0.43	0.27	201	242	211	219	218
Shallow and deep groundwater immediately downgradient of the treatment wall																			
PMW-3	12.15	3.62	1.90	1.53	1.67	5.9	6.0	5.9	6.1	6.0	0.3	0.42	0.5	0.28	351	372	315	308	337
PMW-4	10.42	2.65	1.21	0.81	--	6.5	6.2	6.3	6.4	6.4	0.2	0.51	0.23	1.7	595	588	345	630	540
MW-3S ⁽²⁾	5.80	2.86	1.97	1.17	2.04	6.0	5.8	5.8	6.2	6.0	--	0.26	0.41	0.32	594	618	736	828	694
MW-3D	13.37	2.66	1.60	0.85	1.17	6.9	6.9	6.8	6.9	6.9	0.34	1.2	0.45	0.27	322	314	313	316	316

¹ Measured from top of casing.

² Well purges dry.

Analytical Results

Analytical results for BTEX and TPH-G are summarized in Tables 6 and 7 and are compared to both the sites Cleanup Action Plan (CAP) cleanup levels and the MTCA Method A cleanup levels. Results for select wells are presented graphically in Figure 3. Natural attenuation site characterization results for November 2011 and May 2012 are summarized in Table 8.

For ease of discussion, project results have been divided into sections representing monitoring well orientation to the separate areas of the contaminant plume. These sections include: the upper portion of the plume, shallow and deep groundwater immediately upgradient of the treatment wall, groundwater conditions within the treatment wall, and shallow and deep groundwater immediately downgradient of the treatment wall.

As stated in the Methods section, these wells were sampled with a peristaltic pump. There can be significant changes in solution chemistry with suction lift devices such a peristaltic pump. Because peristaltic pumps apply a vacuum, they can cause depressurization and degassing of the sample and thus may not be suitable for volatile and gas sensitive analytes since sample results could be biased low. However, the possible effects of the pressure change for this project may be small due to the shallow water depths and the expected high contaminant concentrations in several of the wells.

Upper Portion of the Plume

Three wells are located in the upper portion of the project area, wells D10, D11, and D12 (Figure 2). Well D12 is located within the excavated and backfilled area; D11 on the northern edge of the excavated area; and D10 in the portion of the plume that was beyond the area that could be removed.

Well D12 had no detectable concentrations of BTEX or TPH-G. Wells D10 and D11 had some of the highest BTEX and TPH-G concentrations (Tables 6 and 7). High concentrations of petroleum contaminants in these wells caused the practical quantitation limits for BTEX and TPH-G analysis to increase. Benzene concentration in wells D10 and D11 exceeded both the Cleanup Action Plan (CAP) cleanup level (5 ug/L) and the MTCA Method A cleanup level (5 ug/L). Well D10 had the second highest benzene concentrations in all the sampled wells (2000 to 5800 ug/L over the study period). Toluene concentrations in wells D10 and D11 exceeded the CAP cleanup level (40 ug/L), but were below the MTCA cleanup level (1000 ug/L). With the exception of two detections, ethylbenzene exceeded both cleanup levels (30 ug/L and 700 ug/L, respectively) in both wells. Xylene concentrations in well D10 exceeded the CAP cleanup level (20 ug/L) but were below the MTCA cleanup level (1000 ug/L), while the majority of the xylene concentrations in well D11 exceeded both cleanup levels.

TPH-G concentrations in both wells D10 and D11 likely exceeded both cleanup levels during all four sample rounds. However, the high level of petroleum contamination in well D11 resulted in a high TPH-G practical quantitation limit for the August 2011 sample (Table 7).

Table 6. BTEX Results (ug/L) for Black Lake Grocery Wells, August 2011 to May 2012.

Analyte:	Benzene				Toluene				Ethylbenzene				m,p-Xylene				o-Xylene			
CAP:	5 µg/L				40 µg/L				30 µg/L				20 µg/L							
MTCA:	5 µg/L				1000 µg/L				700 µg/L				1000 µg/L							
Date:	8/11	11/11	2/12	5/12	8/11	11/11	2/12	5/12	8/11	11/11	2/12	5/12	8/11	11/11	2/12	5/12	8/11	11/11	2/12	5/12
Upper portion of the plume																				
D10	4400	2700	5800	2000	120	100 U	100 U	58	700	360	910	410	400	200 U	750	450	100 U	100 U	100 U	10 U
D11	550	900	1100	850	100	140	340	220	1200	1600	1900	1600	550	1000	2600	2800	100 U	100 U	160	140
D12	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U	2 U	2 U	2 U	1 U	1 U	1 U	1 U
Shallow and deep groundwater immediately upgradient of the treatment wall																				
D9	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U	2 U	2 U	2 U	1 U	1 U	1 U	1 U
MW-2S	6100	6000	6900	5900	5200	5400	5900	5200	2900	2600	3300	3000	9400	9100	11,000	9900	3600	3800	4400	3800
MW-2D	1 U	19	50	30	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U	2 U	2 U	2 U	1 U	1 U	1 U	1 U
Groundwater within the treatment wall																				
PMW-1	1 U	2.5	1.9	1.3	1 U	6.6	18	9.5	1 U	4.2 J	2.3	4.0	2 U	8.1 J	5.3	7.2 J	1 U	1.3	1 U	1 U
Shallow and deep groundwater immediately downgradient of the treatment wall																				
PMW-3	1 U	1 U	1 U	1 U	1 U	5.4	1 U	1.5	1 U	1 U	1 U	1 U	2 U	2 U	2 U	2 U	1 U	1 U	1 U	1 U
PMW-4	160	210	100	180	55	30	10 U	51	320	300	33	360	730	640	76	930	130	110	28	190
MW-3S	680	640	660	610	120	87	97	88	1000	780	860	860	3100	2700	2800	2800	1200	1000	1000	1100
MW-3D	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U	2 U	2 U	2 U	1 U	1 U	1 U	1 U

CAP: Cleanup Action Plan.

MTCA: MTCA Method A Cleanup Level.

U: Analyte was not detected at or above the reported value.

J: Analyte was positively identified. The associated numerical result is an estimate.

Bold: Analyte was detected.

Shade: Values are greater than MTCA cleanup levels.

Table 7. TPH-G Results (ug/L) for Black Lake Grocery Wells, August 2011 to May 2012.

Analyte:	WTPH-G			
CAP:	1000 ug/L			
MTCA:	800 (1000*) ug/L			
Date:	8/11	11/11	2/12	5/12
Upper portion of the plume				
D10	3300	2300	4700 J	2500
D11	14,000 U	13,000	20,000	22,000
D12	140 U	40 U	70 U	70 U
Shallow and deep groundwater immediately upgradient of the treatment wall				
D9	140 U	40 U	70 U	70 U
MW-2S	70,000	63,000	77,000	73,000
MW-2D	140 U	40 U	70 U	70 U
Groundwater within the treatment wall				
PMW-1	140 U	110	92	83
Shallow and deep groundwater immediately downgradient of the treatment wall				
PMW-3	140 U	40 U	70 U	70 U
PMW-4	5500	5100	730	7800
MW-3S	11,000	10,000	16,000	13,000
MW-3D	140 U	40 U	70 U	70 U

CAP: Cleanup Action Plan.

MTCA: MTCA Method A Cleanup Level.

* MTCA Method A cleanup level for TPH-G is 1,000 ug/L if benzene is not detectable in groundwater.

U: Analyte was not detected at or above the reported value.

J: Analyte was positively identified. The associated numerical result is an estimate.

Bold: Analyte was detected.

Shade: Values are greater than cleanup levels.

Shallow and Deep Groundwater Upgradient of the Treatment Wall

Wells D9, MW-2S, and MW-2D located at the base of the bluff and immediately upgradient of the treatment wall were sampled. BTEX and TPH-G were not detected in well D9. This well is located at the southern end of the treatment wall. Petroleum compounds were last detected in well D9 in 2005.

The highest concentrations of petroleum-related contaminants were detected in groundwater samples collected from monitoring well MW-2S, the shallow well immediately upgradient of the treatment wall. Well MW-2S had BTEX and TPH-G concentrations which exceeded both the CAP and MTCA cleanup levels during all four sample rounds (Tables 6 and 7). Benzene concentrations ranged from 5900 to 6900 ug/L. This well is located downgradient of the former tank area.

In contrast, deep well MW-2D had only three benzene detections, ranging from 19 to 50 ug/L, which exceeded both the cleanup levels of 5 ug/L. Other petroleum analytes, including TPH-G, were not detected in this well.

Groundwater within the Treatment Wall

Well PMW-1 is described as being located within the treatment wall. BTEX and TPH-G were detected in this well but at concentrations below both the CAP and MTCA cleanup levels (Tables 6 and 7).

Shallow and Deep Groundwater Downgradient of the Treatment Wall

Of the four wells (PMW-3, PMW-4, MW-3S, and MW-3D) that were sampled downgradient of the treatment wall, elevated concentrations of petroleum-related contaminants were detected in monitoring wells PMW-4 and MW-3S. Well PMW-4 is located at the north end of the treatment wall. Benzene concentrations exceeded both cleanup levels and ranged from 100 to 210 ug/L. Overall, the toluene, ethylbenzene, and xylene concentrations in well PMW-4 were above the CAP cleanup levels but below the MTCA cleanup levels. TPH-G concentrations exceeded both cleanup levels in three of the four sample rounds.

Well MW-3S is also located downgradient of the former tank area. Over the monitoring period benzene concentrations in well MW-3S ranged from 610 to 680 ug/L, exceeding both cleanup levels. Ethylbenzene, xylene, and TPH-G also exceeded both cleanup levels, while toluene only exceeded the CAP cleanup level. Groundwater contaminant concentrations decreased significantly after passing through the treatment barrier; however, concentrations still far exceed the established cleanup levels for this site.

BTEX and TPH-G were not detected in deeper well MW-3D. Toluene was the only petroleum compound detected in well PMW-3 at concentrations slightly above the detection limit of 1 ug/L.

August 2011 to May 2012 BTEX results for select wells are shown in Figures 3.

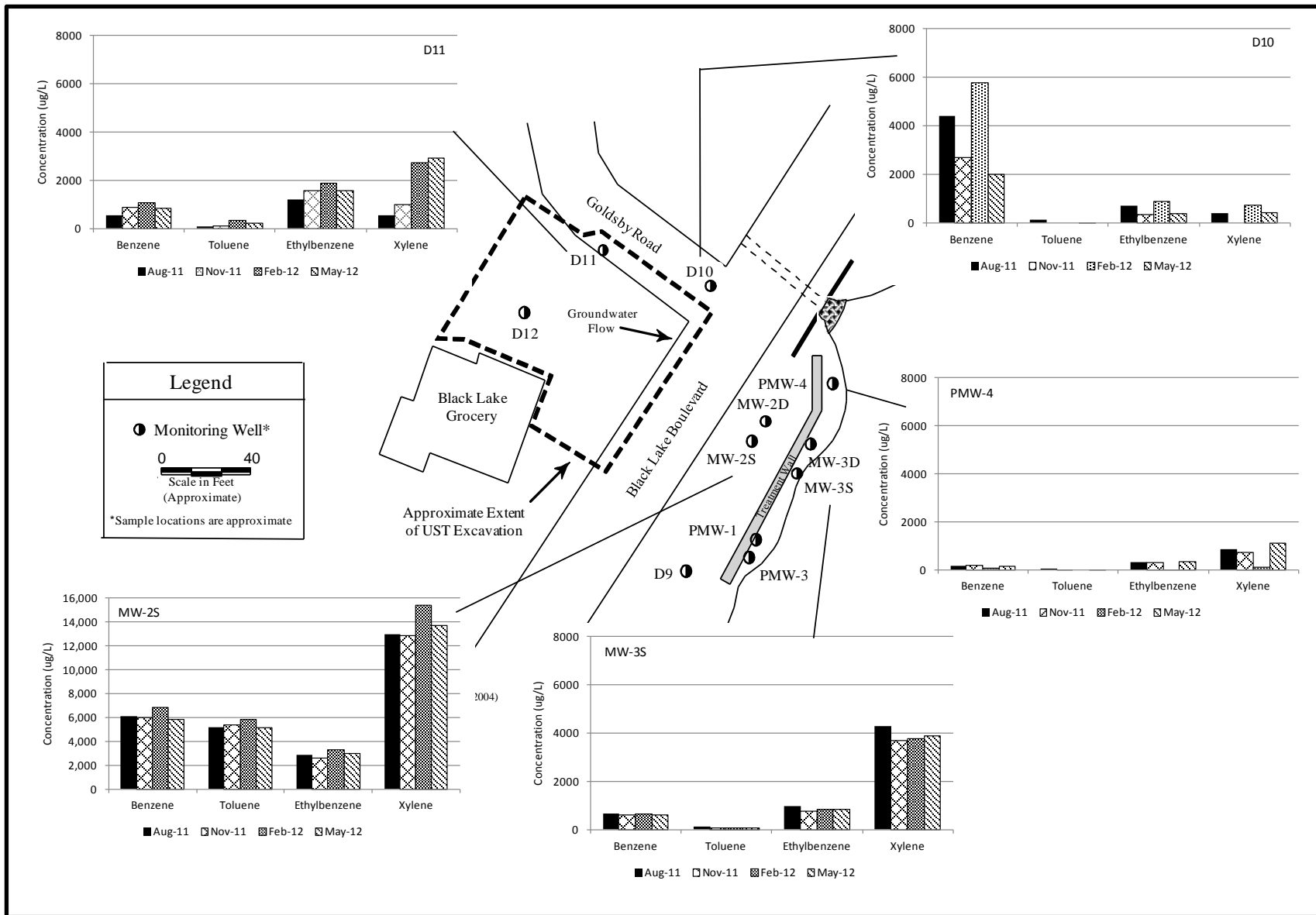


Figure 3. BTEX Results (ug/L) for Select Wells, August 2011 to May 2012.

Natural Attenuation Site Characterization Parameters

Groundwater samples were also collected for conventional parameters so that the Toxics Cleanup Program can evaluate the natural attenuation properties of the site. As mentioned previously, natural attenuation encompasses a variety of processes that can naturally reduce contaminants in soil and groundwater. For petroleum hydrocarbons, biodegradation is the most important attenuation mechanism since it is the only natural process that results in the actual mass reduction of petroleum hydrocarbon contamination (EPA, 2004). Samples for natural attenuation evaluation were collected in November 2011 and May 2012 from 10 of the 11 wells (Table 8).

In the upper portion of the site samples were collected from wells D11 and D12. Well D12 is located within the excavated and backfilled area. Dissolved oxygen (DO) measurements in this well indicate aerobic conditions in this portion of the site. This well also had high sulfate concentrations compared to most of the other wells and is one of the few wells with detectable levels of nitrate. Conversely, well D11 which is located at the edge of the excavated area had low DO concentrations (less than 0.5 mg/L indicating anoxic conditions). Total and dissolved iron as well as dissolved organic carbon (DOC) were found at relatively high concentrations, while nitrite, nitrate, and sulfate were below detectable levels.

Wells in the lower portion of the site all had low DO levels, again indicating anoxic to anaerobic conditions. The wells immediately upgradient of the treatment wall had low total and dissolved iron concentrations. Iron concentrations increased substantially for the wells within and downgradient of the treatment wall. DOC results are similar, with concentrations increasing as the groundwater passes through the treatment wall. Similar to well D11, nitrite, nitrate and sulfate were below or near the detection limits. Wells MW-2D and MW-3D are the exceptions to the wells in this portion of the site; they are generally characterized by low concentrations of iron and DOC, but higher sulfate concentrations.

Table 8. Natural Attenuation Site Characterization Results, November 2011 and May 2012.

Analyte:	Total Iron		Dissolved Iron		Dissolved Nitrite-N		Dissolved Nitrate-N		Dissolved Sulfate		Dissolved Organic Carbon		Turbidity	
	mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		NTU	
Date:	11/11	5/12	11/11	5/12	11/11	5/12	11/11	5/12	11/11	5/12	11/11	5/12	11/11	5/12
Upper portion of the plume														
D10	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D11	9.24	6.45	8.08	6.59	0.013 UJ	0.01 U	0.026 UJ	0.01 U	0.3 U	0.3 U	11.8	9.1	11	4.7
D12	0.071	0.03	0.05 UJ	0.05 U	0.01 U	0.01 U	1.03	1.35	9.19	8.42	1.5	1.2	0.9	0.5 U
Shallow and deep groundwater immediately upgradient of the treatment wall														
D9	0.191	0.025 U	0.121	0.05 U	0.01 UJ	0.01 U	0.01 U	0.013	0.73	2.77	1 U	1.9	0.9	1.2
MW-2S	0.893	1.84	0.579	1.64	0.013 UJ	0.01 U	0.013 UJ	0.01 U	0.3 U	0.3 U	16.8	15.5	8.9	8.0
MW-2D	0.761	1.14	0.504	0.129	0.01 U	0.01 U	0.01 U	0.01 U	7.77	7.12	1.4	2.0	5.9	8.9
Groundwater within the treatment wall														
PMW-1	20.2	19.6	24.6	21.1	NC	0.15 U	0.037 UJ	0.018	0.41	0.3 U	83.1	91.3	5.6	2.2
Shallow and deep groundwater immediately downgradient of the treatment wall														
PMW-3	10.1	7.85	9.99	7.82	0.019 UJ	0.01 U	0.027 UJ	0.01 U	0.76	0.3 U	13	7.7	12	3.5
PMW-4	25.2	33.6	20.8	12.8	0.01 U	0.01 U	0.044 UJ	0.01 U	3.04	0.32	45.2	46.6	3.8	2.6
MW-3S	17.6	11.4	13.9	7.77	NC	0.05 U	0.01 U	0.01 U	0.45	0.36	195	116	7.1	6.1
MW-3D	0.037	0.049	0.05 U	0.05 U	0.01 U	0.01 U	0.016 UJ	0.01 U	12.1	12.1	1 U	1.3	0.5 U	0.6

U: Analyte was not detected at or above the reported value.

UJ: Analyte was not detected at or above the reported estimated value.

NC: Not calculated due to excessive matrix interference.

Bold: Analyte was detected.

Discussion

High concentrations of gasoline-range petroleum hydrocarbons are present in the near surface aquifer in both the upper and lower portions of the site. The source of the contamination was from leaking underground storage tanks that were removed in the summer of 1995 along with a large amount of contaminated soil. Although a significant portion of the source material was removed, contaminant concentrations exceeding site cleanup levels were still present at the limits of the excavated area. In an attempt to remediate the remaining contaminants, a treatment wall was installed along Black Lake's shoreline in 2004 to passively treat the contaminated groundwater flowing toward the lake. Treatment of soils and groundwater upgradient of the wall was expected to occur through natural attenuation.

Analytical results for the 2011-2012 monitoring are discussed, along with past project data for comparison. All project BTEX data are presented as tables and graphs in Appendix B.

Upper Portion of the Plume

Data collected from wells D10 and D11 by Ecology confirm that the shallow groundwater in the upper portion of the site is still contaminated with petroleum products. Of the wells sampled, D10 and D11 had some of the highest BTEX concentrations. Concentrations have decreased since 1995 (Figures B-1 and B-2). One of the largest decreases occurred in well D10 in February 2005, six months after the treatment wall was installed. Benzene concentrations in well D10 have fluctuated, but have shown a decrease of 30% to 70% since monitoring began. Benzene concentrations have decreased 70% in well D11. Although BTEX concentrations have decreased, they continue to exceed the CAP and MTCA cleanup levels.

Shallow and Deep Groundwater Upgradient of the Treatment Wall

Well MW-2S had the highest BTEX concentrations of the sampled wells. Well MW-2S is located at the base of the bluff, about 100 feet downgradient of the former tank area and is one of two shallower wells that were sampled (approximately 5 feet deep).

As with well D10 there was an initial decrease in BTEX concentrations in well MW-2S soon after the treatment wall was installed (Figure B-5). However, concentrations quickly rebounded. Benzene concentrations in this well continue to be high and fairly stable. Benzene concentrations have decreased about 15% since monitoring began in 1996.

In well MW-2D concentrations have decreased substantially since samples were first collected in 1996 (Figure B-6). This well is approximate 15 feet deep and is part of the well nest upgradient of the treatment wall. For this monitoring period average benzene concentrations in shallow well MW-2S were 6200 ug/L, decreasing to approximately 25 ug/L in well MW-2D. This supports previous results which suggest that contaminant concentrations decrease with depth. Samples collected at multiple depths during the 1995 investigation indicated that concentrations were

generally below detection limits at depths greater than 15 feet (Summit 2001). Benzene is the only contaminant that has been detected in this well since June 2009.

Shallow and Deep Groundwater Downgradient of the Treatment Wall

Well MW-3S also had elevated BTEX concentrations during this monitoring period. Well MW-3S is the other shallow well which is located about 20 feet south east of well MW-2S, on the downgradient side of the treatment wall.

In December 1996 BTEX concentrations in well MW-3S were similar to those detected in well MW-2S. Concentrations in well MW-3S decreased by 99% in samples collected in February 2005, six months after the treatment wall was installed (Figure B-10). Since 2005, BTEX concentrations have steadily increased in Well MW-3S. Although concentrations are still much lower than those detected in well MW-2S; recent results for benzene, ethylbenzene, and xylene consistently exceed both the CAP and MTCA cleanup levels.

Well MW-3D is part of the well nest downgradient of the treatment wall and is approximately 14 feet deep. For this monitoring period average benzene concentrations in shallow well MW-3S were 650 ug/L, decreasing to below the detection limit of 1 ug/L in well MW-3D.

Well PMW-4 is located downgradient of the north end of the treatment wall and was installed in 2004. Since February 2005 benzene and toluene concentrations have decreased, while ethylbenzene and xylene concentrations have increased. Benzene concentrations measured at well PMW-4 consistently exceed both the CAP and MTCA cleanup levels.

The treatment wall was installed to act as a passive barrier that remediates the contaminated groundwater as it flows toward Black Lake. The barrier is composed of an engineered sphagnum peat moss that is known to both absorb and degrade petroleum hydrocarbons. Data from wells PMW-4 and MW-3S confirm that contaminant concentrations do decrease on the downgradient side of the wall; however, concentrations still consistently exceed the established cleanup levels for this site. Contaminant concentrations in well MW-3S also appear to be steadily increasing. This may indicate that the treatment wall is losing its sorptive or reactive capacity.

The presence of petroleum hydrocarbons in wells PMW-4 and MW-3S also suggests the contaminant plume extends to Black Lake. In March 2005, five months after the treatment wall was installed, Ecology collected near-shore sediment and surface water samples. BTEX and TPH-G were not detected in the sediment or water samples collected from the study area (Coots, 2005). However, as stated previously, contaminant concentrations in well MW-3S appear to be increasing since 2005. Wells MW-3S and PMW-4 are less than 10 feet from the shoreline. The presence of such high contaminant concentrations so close to the lake strongly suggest that petroleum contaminants are migrating to Black Lake.

Figure 4 shows estimated benzene concentration contours in shallow groundwater for the 2011-2012 monitoring period. Contaminant concentrations remain elevated downgradient of the source area in wells D10, D11, MW2S, MW-3S and PMW-4.

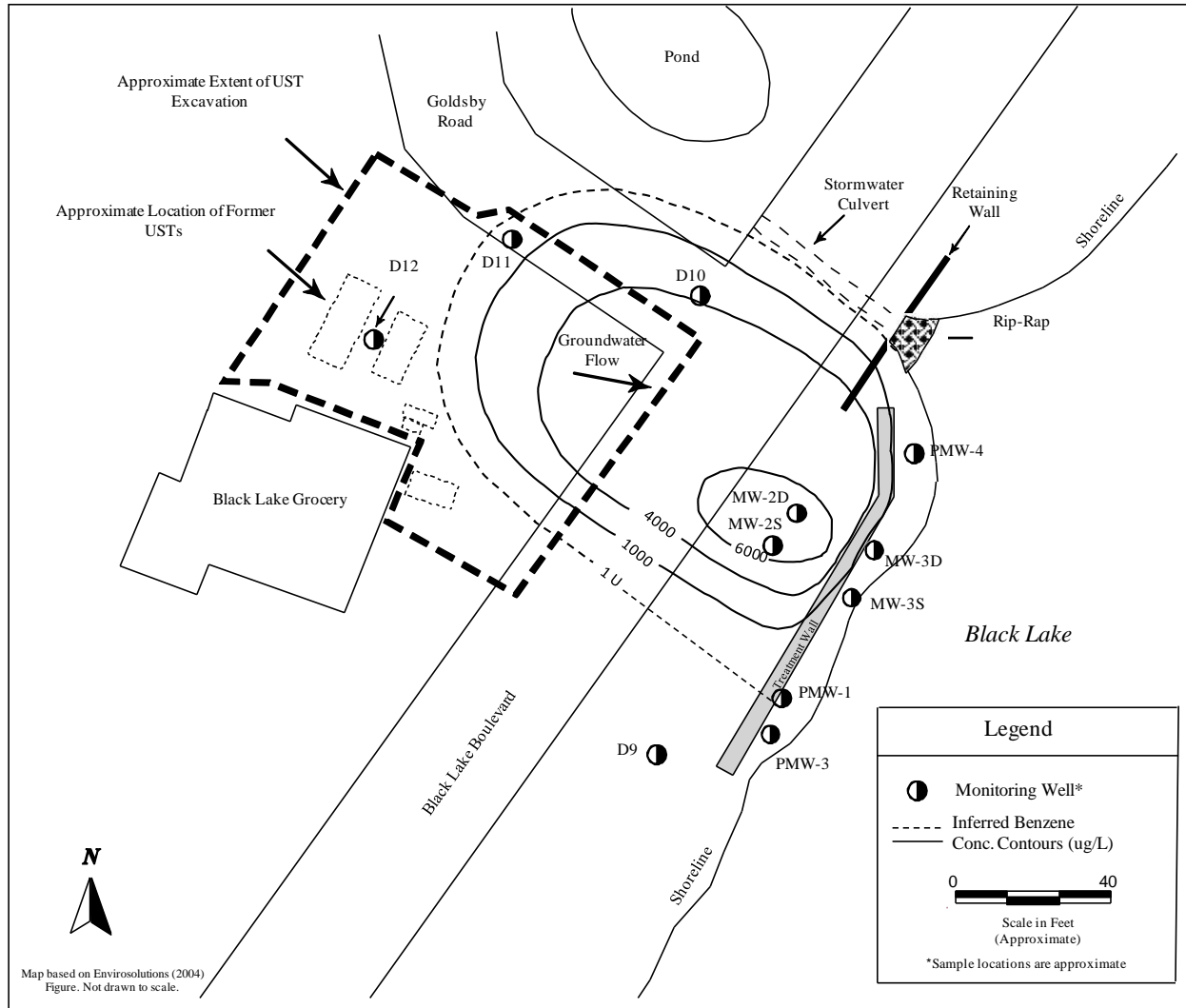


Figure 4. Inferred Benzene Groundwater Concentration Contours (ug/L) 2011/12.

Conclusions and Recommendations

Conclusions

Water quality results over the 2011-2012 monitoring period confirm that the near surface aquifer is contaminated with gasoline-range petroleum hydrocarbons in both the upper and lower portions of the site. Concentrations have decreased since excavation and removal of contaminated soils and installation of the treatment wall. However, groundwater contaminant concentrations continue to exceed the cleanup levels established for this site in several of the sites monitoring wells.

Treatment of the remaining contaminated soils and groundwater were expected to occur through natural attenuation and the passive treatment barrier installed along the lake shoreline.

During the remediation design it was predicted that concentrations of the petroleum contaminants would decrease naturally with time due to removal of the source material and natural biodegradation processes. Overall, conventional parameters that were collected to evaluate natural attenuation properties of the site were characterized by low dissolved oxygen, nitrate/nitrite, and sulfate with elevated concentrations of iron. Under these conditions the petroleum hydrocarbons should be subject to a variety of biodegradation processes such as iron or sulfate reduction. Previous project data seems to indicate that natural breakdown of the petroleum hydrocarbons has been occurring. BTEX concentrations in well D9 decreased substantially between 1993 and 1996, and have not been detected in this well since 2005. Benzene concentrations have also decreased, most notably in wells D11 and D10. The effects of biodegradation were expected to be most noticeable at the limits of the excavated area and proceed downgradient over time. It was estimated that contaminant concentrations would be below cleanup levels within 10-25 years (Summit, 2005).

The second part of the remediation is the treatment wall that was installed in fall of 2004. The materials of the treatment wall are meant to absorb or react with the contaminated groundwater as it flows through the barrier, removing the petroleum hydrocarbons from the water. The sorptive and reactive capacity of treatment barriers is limited. Once the capacity of the material is reached, contaminant breakthrough can occur. Contaminant concentrations in well MW-3S appear to be steadily increasing. This may be evidence of decreased effectiveness of the trench.

In addition, even though the 2005 Ecology study did not detect any BTEX or TPH-G in near-shore sediment and water samples, the presence of high contaminant concentrations in wells PMW-4 and MW-3S, which are less than 10 feet from the shore, strongly suggest that petroleum contaminants are migrating to Black Lake.

Recommendations

Based on the results of the 2011-2012 monitoring, the following recommendations are provided:

- Groundwater monitoring downgradient of the treatment wall should continue to determine if the contaminant removal capability of the reactive materials remain effective in remediating the contaminated groundwater. If the treatment wall materials are no longer effective they may need to be replaced.
- Re-evaluate the natural attenuation properties of the site to determine if site cleanup levels will be reached in a timely manner. It was estimated that contaminant concentrations would be below cleanup levels within 10-25 years (Summit, 2005).
- In the 2005 Ecology study, BTEX and TPH-G were not detected in the near-shore sediment and surface water samples. The installation of shallow near-shore piezometers could provide more accurate data to determine if groundwater contaminants from the site are reaching Black Lake.

References

APHA, AWWA, and WEF, 1998. Standard Methods for the Examination of Water and Wastewater 20th Edition. American Public Health Association, Washington, D.C.

Blazer, 1994. Phase I Site Investigation of Blake Lake Grocery, 4409 Blake Lake Boulevard SW, Olympia, WA 98502, DOE Site 4100355. Agreed Order No. DE93TC-S171. Prepared by Blazer Construction, Olympia, WA.

Coots, Randy, 2005. Investigation of Petroleum Products in Black Lake Sediment and Surface Water Adjacent to an Underground Storage Tank Site. Washington State Department of Ecology, Olympia, WA. Publication No. 05-03-030.

<https://fortress.wa.gov/ecy/publications/SummaryPages/0503030.html>

Dames and Moore, 1990. Addendum Report of Geotechnical Services, Blake Lake Boulevard Expansion for Thurston County Department of Public Works, Thurston County, Washington, Job No. 8538-003-016. Prepared by Dames and Moore, Seattle, WA.

Ecology, 2008. Manchester Environmental Laboratory Lab Users Manual, Ninth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

EPA, 1996. Test Methods for Evaluating Solid Waste, SW-846. Office of Emergency Response, U.S. Environmental Protection Agency, Washington D.C.
www.epa.gov/SW-846/pdfs/0100.pdf.

EPA, 2001a. Method 150.1, Determination of pH. Environmental Monitoring Systems Laboratory, Office of Research and Development, U.S. Environmental Protection Agency.

EPA, 2001b. Method 120.1, Determination of Conductivity. Environmental Monitoring Systems Laboratory, Office of Research and Development, U.S. Environmental Protection Agency.

EPA, 2002. Method 360.1, Determination of Dissolved Oxygen. Environmental Monitoring Systems Laboratory, Office of Research and Development, U.S. Environmental Protection Agency.

EPA, 2004. Performance Monitoring of MNA Remedies for VOC in Ground Water. Office of Research and Development, U.S. Environmental Protection Agency, Washington D.C.
EPA/600/R-04/027.

Marti, Pamela, 2009. Standard Operating Procedure for Manual Well-Depth and Depth-to-Water Measurements. Washington State Department of Ecology, Olympia, WA. SOP Number EAP052, Version 1.0. www.ecy.wa.gov/programs/eap/quality.html.

Marti, Pamela, 2011. Quality Assurance Project Plan: Black Lake Grocery Groundwater Confirmation Monitoring. Washington State Department of Ecology, Olympia, WA. Publication No. 11-03-114.

<https://fortress.wa.gov/ecy/publications/SummaryPages/1103114.html>

Noble, John B., and E. Wallace, 1966. Geology and Groundwater Resources of Thurston County, Washington. Volume 2. State of Washington, Department of Conservation, Division of Water Resources. Water Supply Bulletin No. 10. Division of Water Resources, Olympia, WA

Summit, 2000. Final Remedial Investigation and Feasibility Study, Black Lake Grocery, Olympia, Washington. Prepared by Summit Envirosolutions, Inc. for Man K. Pak. August, 2000.

Summit, 2004. Compliance Monitoring Plan, Blake Lake Grocery, Olympia, Washington. Project Number 0551-002. Prepared by Summit Envirosolutions, Inc. for Man K. Pak. August 2000.

Summit, 2005. Engineering Design Report, Blake Lake Grocery, Olympia, Washington. Project Number 0551-002. Prepared by Summit Envirosolutions, Inc. for Man K. Pak. March 2005.

WAC 173-303. Dangerous Waste Regulations. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/laws-rules/ecywac.html

Wallace, Eugene F., and D. Molenaar, 1961. Geology and Groundwater Resources of Thurston County, Washington. Volume 1. State of Washington, Department of Conservation, Division of Water Resources. Water Supply Bulletin No. 10. Division of Water Resources, Olympia, WA.

Appendices

Appendix A. Well Construction Details

Table A-1. Well Construction Details.

Well #	Well Installation Date	Latitude (decimal degrees)	Longitude (decimal degrees)	Ground Surface Elevation (feet)	PVC Stickup (feet)	PVC Elevation (feet)	Casing Diameter (inches)	Well Depth Measured (feet)	Screen Depth ¹	
									Top (feet)	Bottom (feet)
D9	10/1993	47.00727	-122.97616	132.34	-0.54	131.80	2	15.05	2	12
D10	10/1993	47.00761	-122.97612	138.01	-0.42	137.59	2	11.4	8	18
D11	10/1993	47.00763	-122.97637	136.08	-0.35	135.73	2	13.92	5	15
D12	6/1995	47.00756	-122.97646	138.17	-0.50	137.67	4	9.06	5	10
MW-2S	12/1996	47.00740	-122.97604	131.97	1.79	133.76	2	7.07	2	5
MW-2D	12/1996	47.00742	-122.97601	132.77	2.20	134.97	2	17.12	12	15
MW-3S	12/1996	47.00738	-122.97599	131.11	-0.22	130.89	2	5.80	2	5
MW-3D	12/1996	47.00740	-122.97596	130.38	-0.21	130.17	2	13.37	12	15
PMW-1	11/2004	47.00729	-122.97610	131.11	-0.45	130.66	2	11.47	5	10
PMW-3	11/2004	47.00729	-122.97613	131.96	-0.09	131.87	2	12.15	5	10
PMW-4	11/2004	47.00744	-122.97594	132.14	-0.46	131.68	2	10.42	5	10

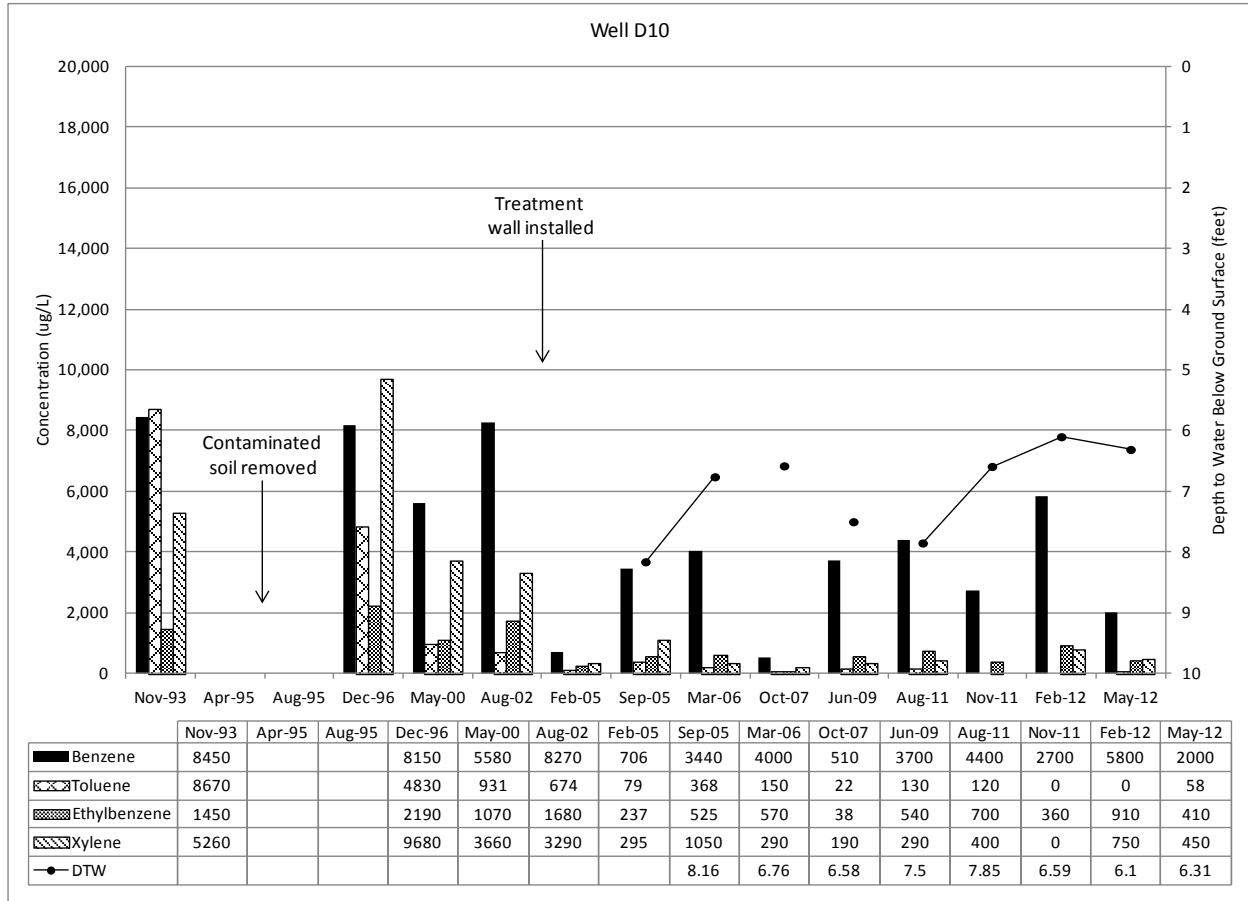
VERTICAL DATUM: N.A.V.D. '88. Vertical accuracy measure +/- 10 ft (3m).

HORIZONTAL DATUM: NAD '83/'91. Horizontal accuracy measure +/- 10 ft (3m).

¹ Screen interval provided in Summit 2005 report. Depths have not been verified.

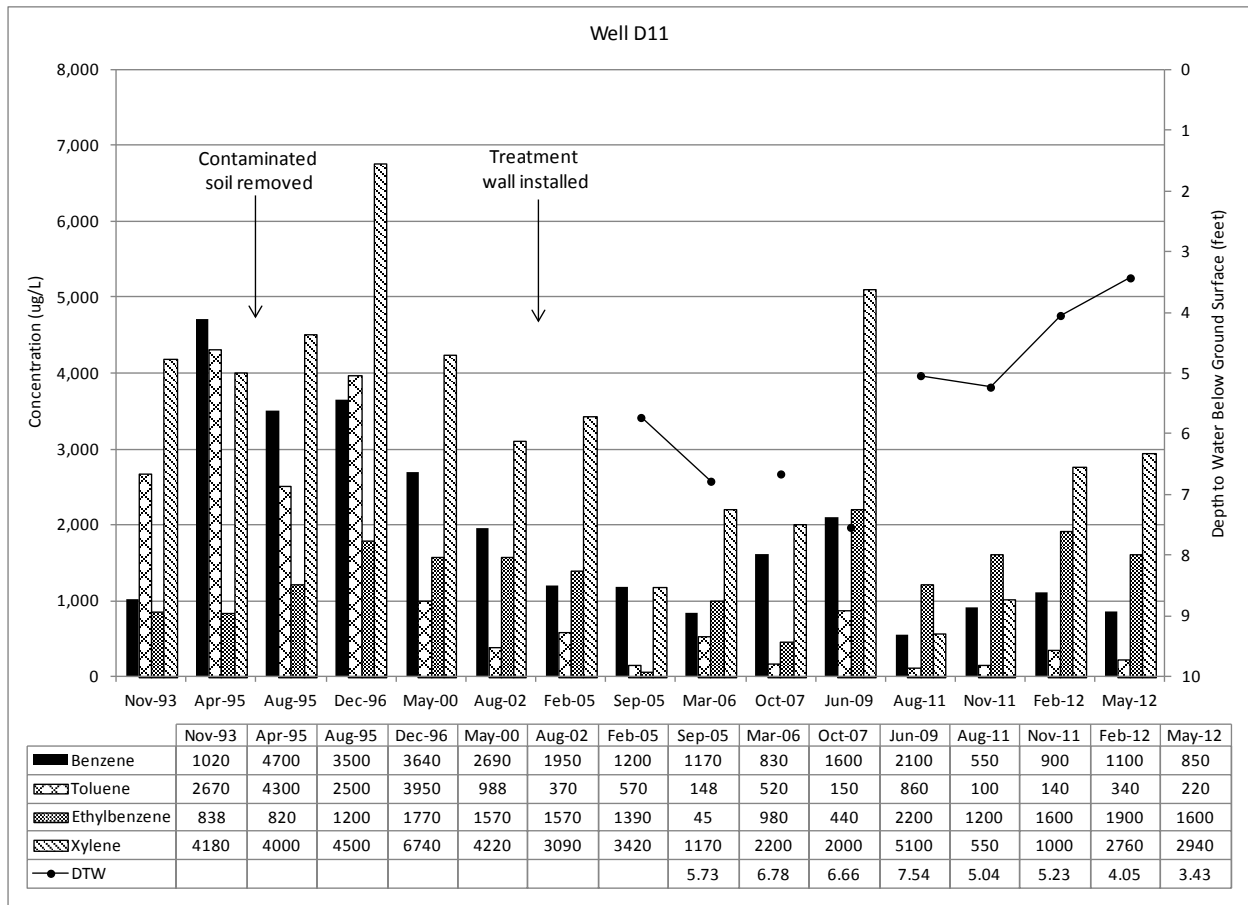
Appendix B. BTEX Results, November 1993 to May 2012

Upper Portion of the Plume – Wells D10, D11, D12



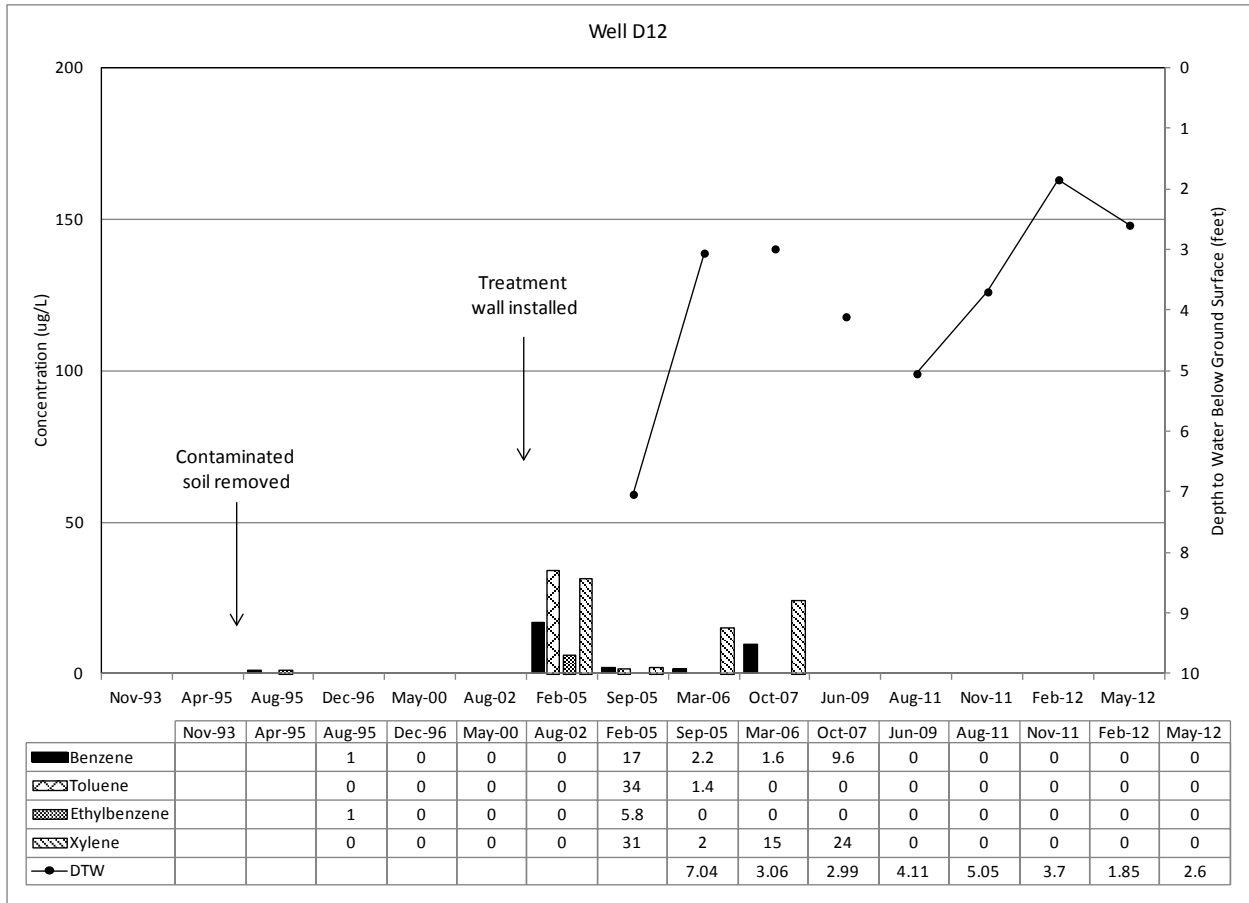
0: Analyte was not detected at or above the laboratory reporting value.
 Blank: not sampled or measured.

Figure B-1. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well D10, November 1993 to May 2012.



Blank: not measured.

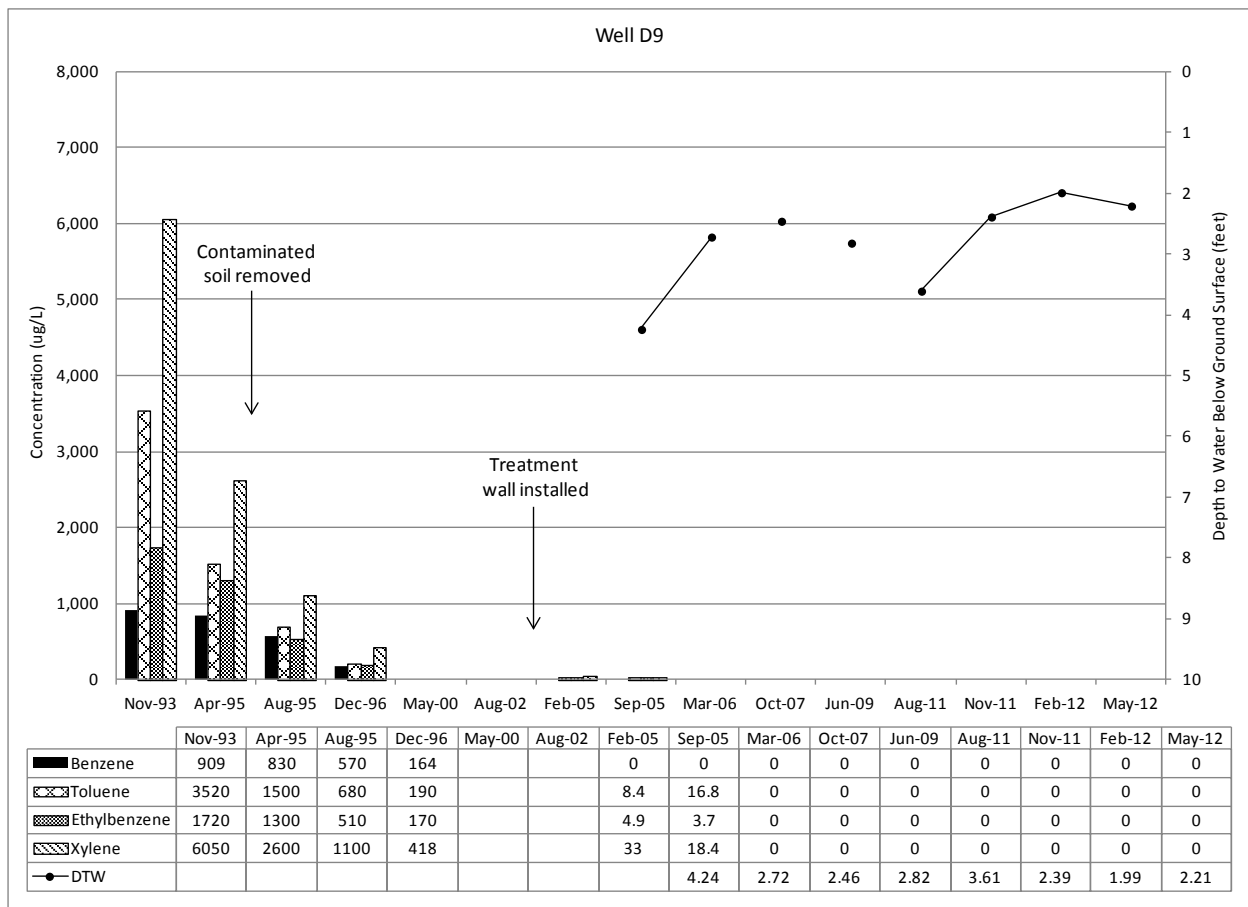
Figure B-2. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well D11, November 1993 to May 2012.



0: Analyte was not detected at or above the laboratory reporting value.
 Blank: not measured. Well installed June 1995.

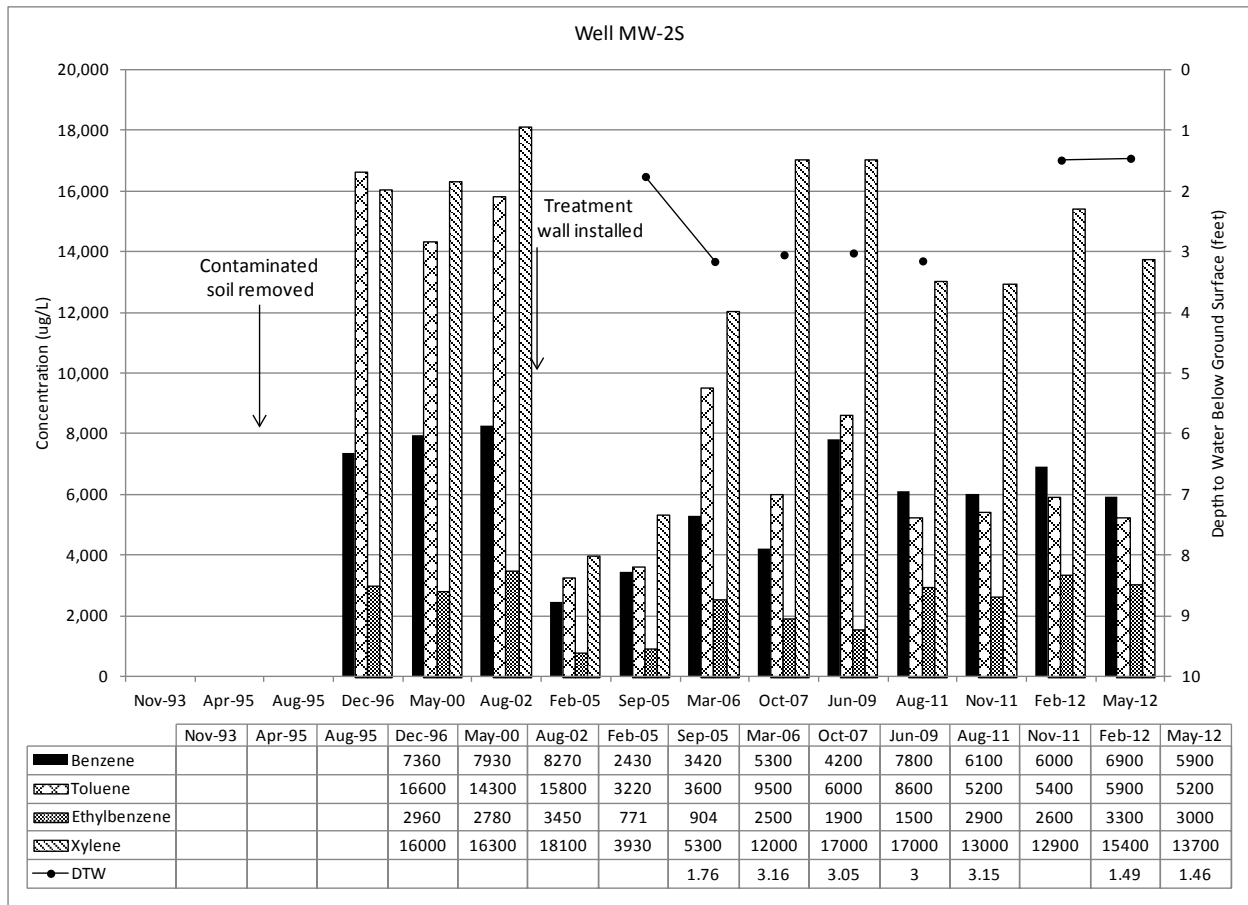
Figure B-3. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well D12, November 1993 to May 2012.

Shallow and Deep Groundwater Upgradient of the Treatment Wall – Wells D9, MW-2S, MW-2D



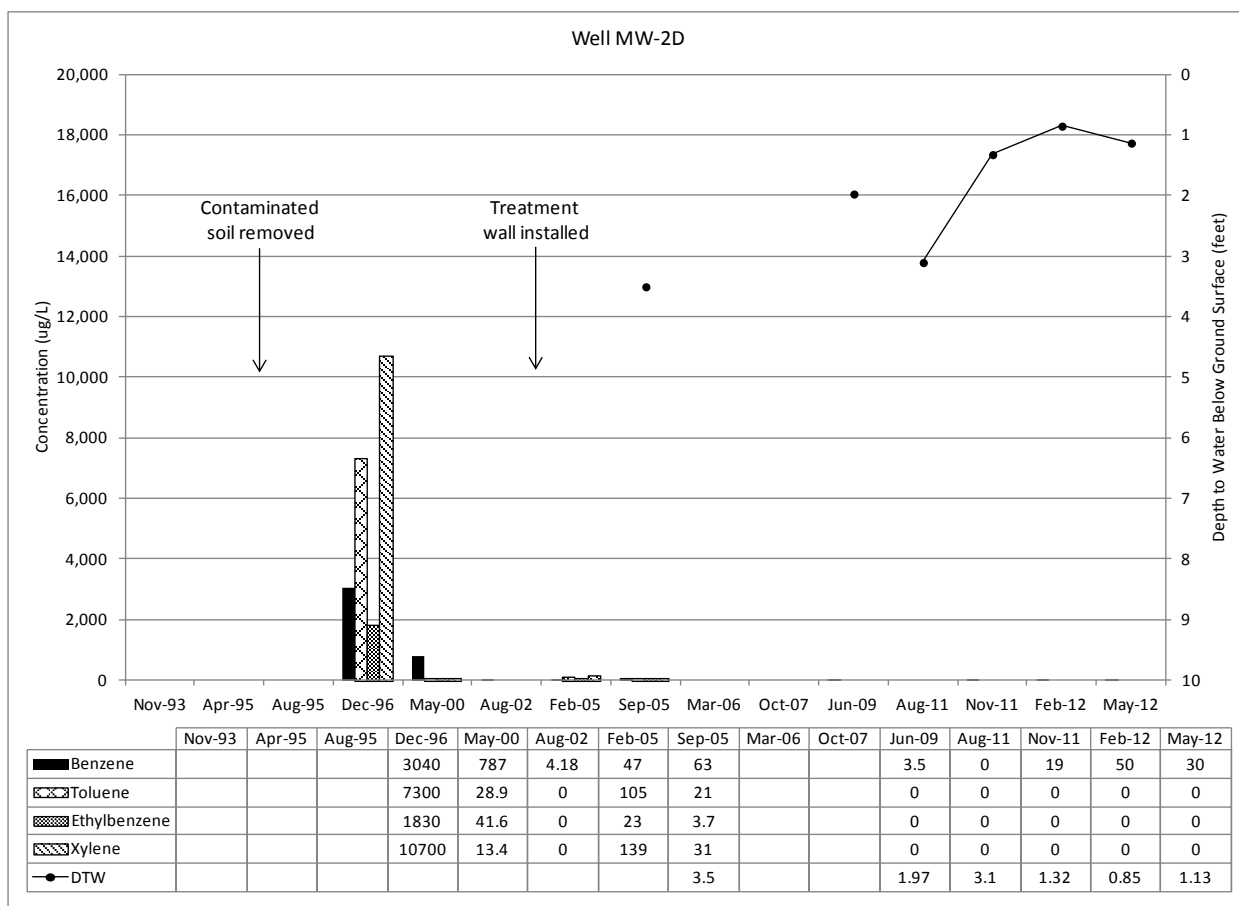
0: Analyte was not detected at or above the laboratory reporting value.
Blank: not sampled or measured.

Figure B-4. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well D9, November 1993 to May 2012.



Blank: not measured. Well installed in December 1996.

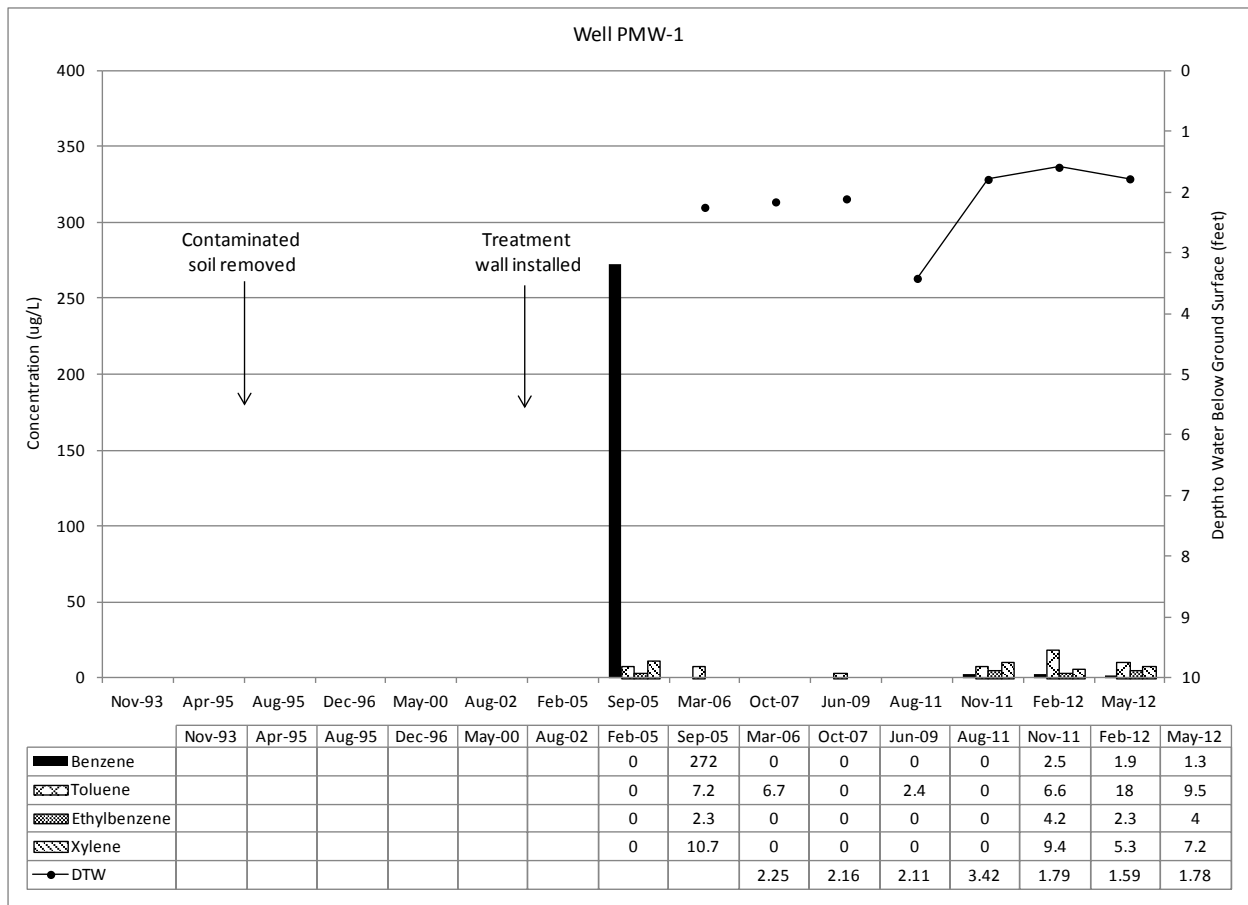
Figure B-5. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well MW-2S, November 1993 to May 2012.



0: Analyte was not detected at or above the laboratory reporting value.
 Blank: not sampled or measured. Well installed in December 1996.

Figure B-6. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well MW-2D, November 1993 to May 2012.

Groundwater within the Treatment Wall – Well PMW-1

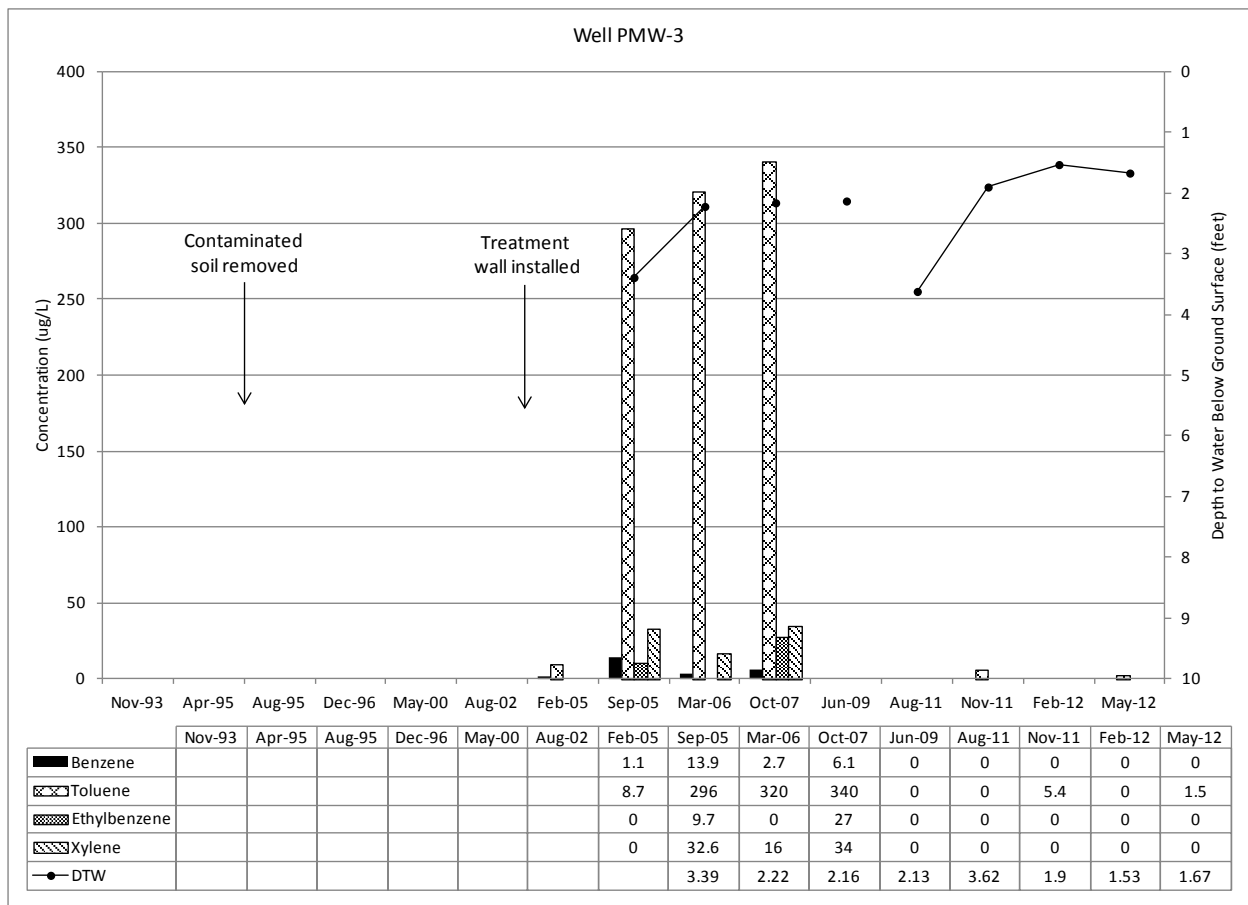


0: Analyte was not detected at or above the laboratory reporting value.

Blank: not measured. Well installed in November 2004.

Figure B-7. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well PMW-1, November 1993 to May 2012.

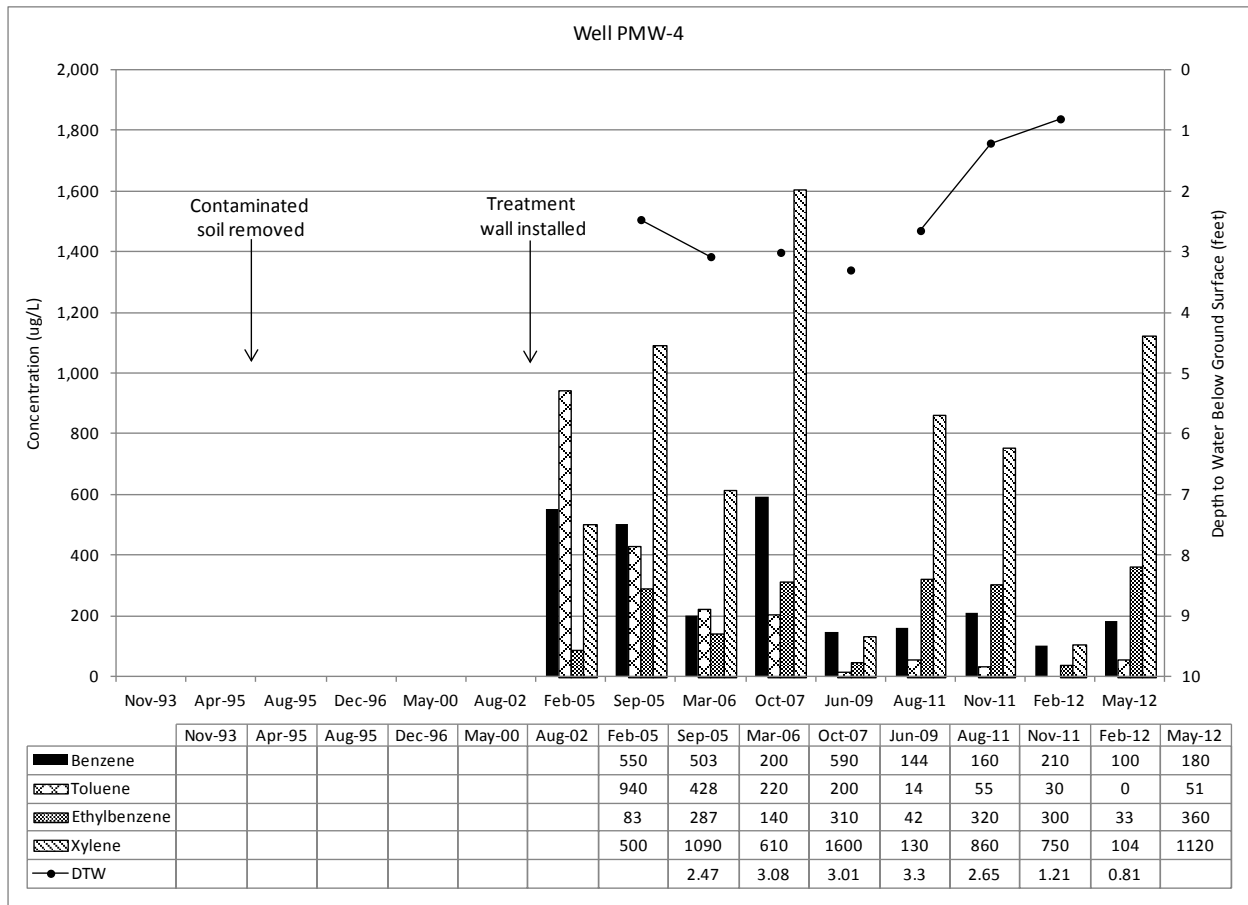
Shallow and Deep Groundwater Downgradient of the Treatment Wall – Wells PMW-3, PMW-4, MW-3S, MW-3D



0: Analyte was not detected at or above the laboratory reporting value.

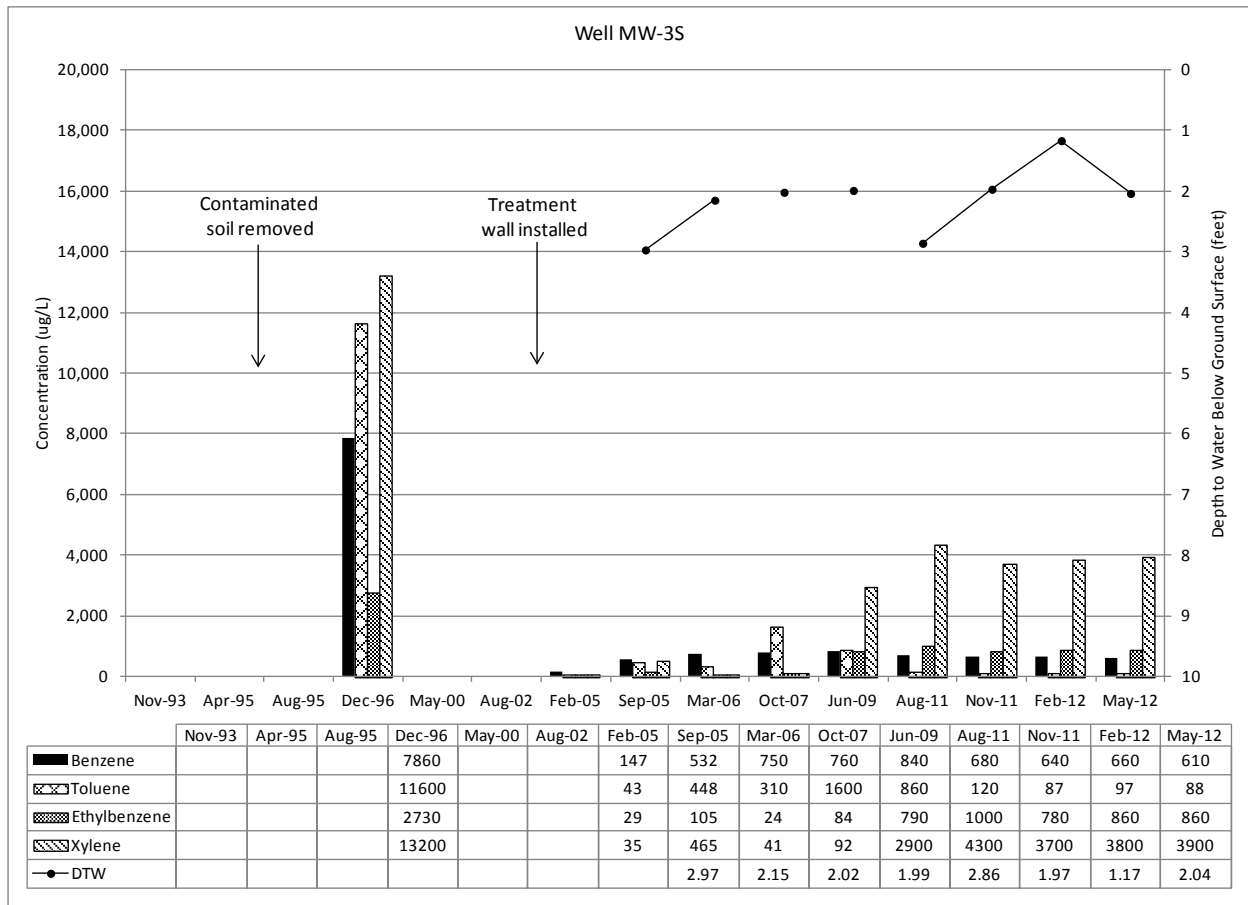
Blank: not measured. Well installed in November 2004.

Figure B-8. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well PMW-3, November 1993 to May 2012.



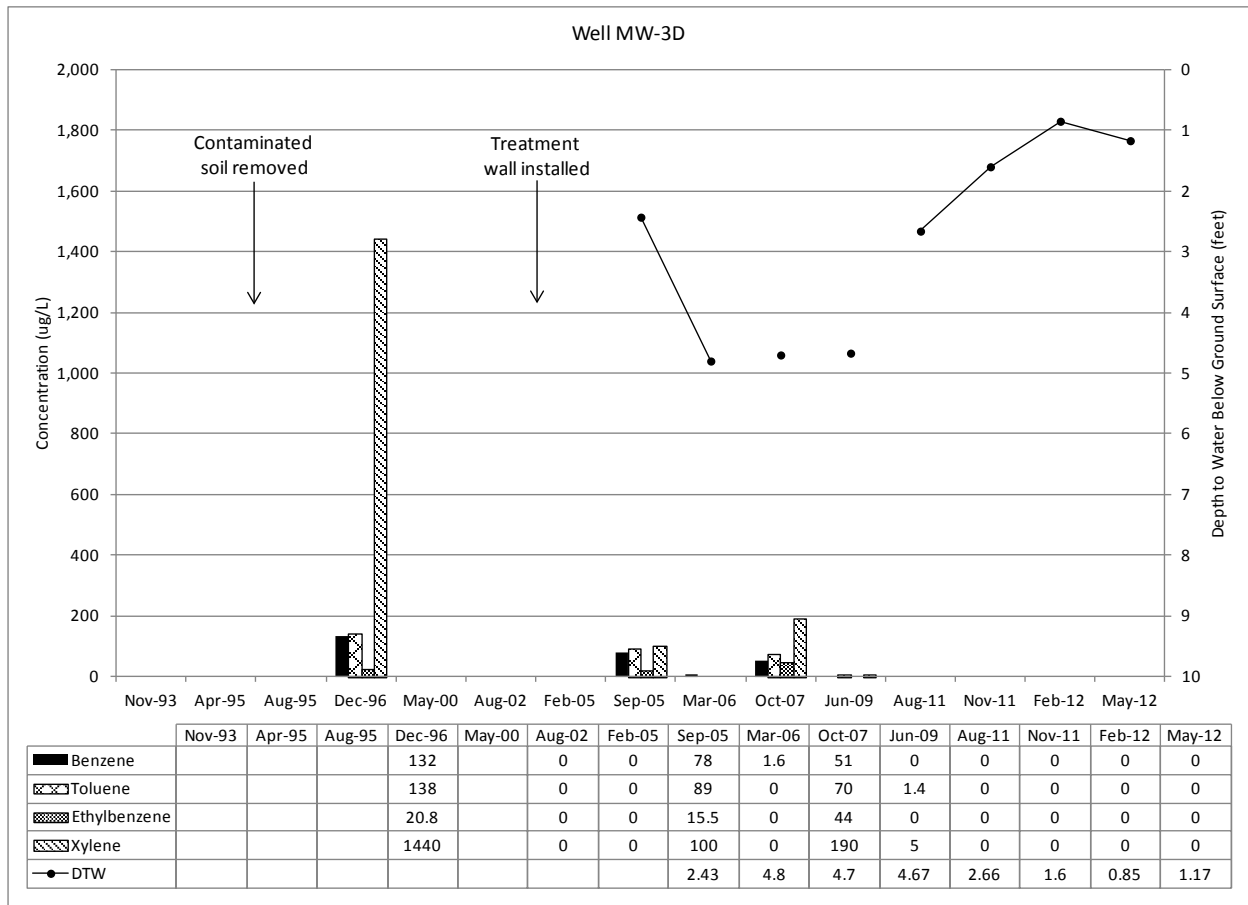
0: Analyte was not detected at or above the laboratory reporting value.
 Blank: not measured. Well installed in November 2004.

Figure B-9. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well PMW-4, November 1993 to May 2012.



0: Analyte was not detected at or above the laboratory reporting value.
 Blank: not sampled or measured. Well installed in December 1996.

Figure B-10. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well MW-3S, November 1993 to May 2012.



0: Analyte was not detected at or above the laboratory reporting value.
 Blank: not sampled or measured. Well installed in December 1996.

Figure B-11. BTEX Results (ug/L) and Depth-to-Water Measurements (feet) for Well MW-3D, November 1993 to May 2012.

Appendix C. Acronyms and Abbreviations

BTEX	Benzene, toluene, ethylbenzene, and xylene
CAP	Cleanup Action Plan
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management
EPA	U.S. Environmental Protection Agency
MTCA	Model Toxics Control Act
PVC	Polyvinyl chloride
RPD	Relative percent difference
SOP	Standard operating procedure
TPH-G	Total petroleum hydrocarbons as gasoline

Units of Measurement

NTU	nephelometric turbidity units
ug/L	micrograms per liter (parts per billion)
umhos/cm	micromhos per centimeter