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Shelton Laundry and Cleaners
Groundwater Monitoring Results

October 2010 and June 2011

by

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Waterbody No. WA-14-0110

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Abstract

Tetrachloroethene (PCE) contamination of shallow groundwater underlying Shelton Laundry and Cleaners was discovered in 1997. The source of contamination was assumed to be a 1993 solvent spill outside the dry cleaner's commercial building. Monitoring of four shallow wells in 1998 detected PCE in the local aquifer at concentrations as high as 280 ug/L in the well located nearest to the reported spill location (4W). The Washington State Model Toxic Control Act (MTCA) Method A cleanup level for PCE is 5 ug/L.

In 2002, the Washington State Department of Ecology (Ecology) installed four additional deep wells and began monitoring the groundwater quality of all eight wells. From 2002 to 2005, PCE was consistently detected in well 4W over a concentration range of 10 to 25 ug/L. PCE was detected in one other shallow well, located near well 4W, but at concentrations below 1 ug/L. PCE was not detected in any of the other wells.

In June 2005, in an attempt to remediate the contamination, Ecology contractors injected a hydrogen release compound (HRC®) into the groundwater around well 4W. Following the HRC injection, groundwater monitoring results indicated that the HRC was temporarily effective in reducing the contaminant concentrations. However, since August 2006, concentrations have gradually increased, returning to their pre-HRC injection concentrations.

This report describes the water quality results for groundwater samples collected in October 2010 and June 2011 from three of the shallow wells and two of the deep wells. PCE was detected in well 4W at concentrations ranging from approximately 24 to 35 ug/L. Trichloroethene (TCE) and cis-1,2-dichloroethene (cis-DCE) were also detected in well 4W, at concentrations near the reporting limit of 1 ug/L. PCE, TCE, and cis-DCE were not detected in any of the other sampled wells.

Groundwater monitoring should continue in well 4W for the next year since PCE concentrations remain above the MTCA Method A cleanup level of 5 ug/L in well 4W.

Introduction

Background

Tetrachloroethene (PCE) contamination of shallow groundwater was discovered in 1997 during an environmental site assessment of a commercial property in Shelton, Washington. The most likely source of the contamination was identified as a dry cleaning facility, located adjacent to the property where the site assessment was conducted (Building Analytics, 1997) (Figure 1).

Based on the environmental assessment report, which was submitted to the Washington State Department of Ecology (Ecology), Shelton Laundry and Cleaners was listed on Ecology's *Confirmed and Suspected Contaminated Site List* in December 1997.

A commercial laundry and dry cleaning facility has been in operation at the site since 1935. In 1993, an unknown quantity of dry cleaning solvent was reportedly spilled in the alley between the two commercial properties during the removal of an old dry cleaning machine (GeoEngineers, 1998). This spill event is assumed to be the source of the groundwater contamination.

Several environmental investigations were conducted at the Shelton Laundry and Cleaners site between 1997 and 2000. These investigations concluded that PCE contamination was present in the shallow groundwater in the southeastern portion of the site beneath the alley (GeoEngineers, 2000). Groundwater samples collected from shallow (approximately 15 feet deep) monitoring wells showed PCE contamination was primarily detected in the well located nearest to the reported spill location (4W) (Figure 2). PCE concentrations in this well decreased from 280 ug/L (July 1998) to 25 ug/L (September 2000) (GeoEngineers, 2000).

Ecology conducted a follow-up investigation in 2002 to determine the status of the PCE groundwater contamination. Ecology installed four deeper monitoring wells to gain a better understanding of contaminant concentrations at greater depths. PCE was not detected in any of the four deep wells during the 2002 monitoring.

Ecology continued to monitor the water quality in both the shallow and deep wells. From July 2002 to April 2005, PCE concentrations in well 4W ranged from approximately 10 to 25 ug/L.

In an effort to remediate the contamination, in June 2005, a Hydrogen Release Compound (HRC®) was injected into the shallow aquifer. HRC produces hydrogen that fuels the anaerobic biodegradation processes in soil and groundwater which is the mechanism by which chlorinated compounds are biodegraded into less harmful constituents. The HRC was injected below the water table at depths of 5 to 20 feet below ground surface (bgs) at 16 boring locations between wells 4W and 7W (Figure 2) (Balaraju, 2005).

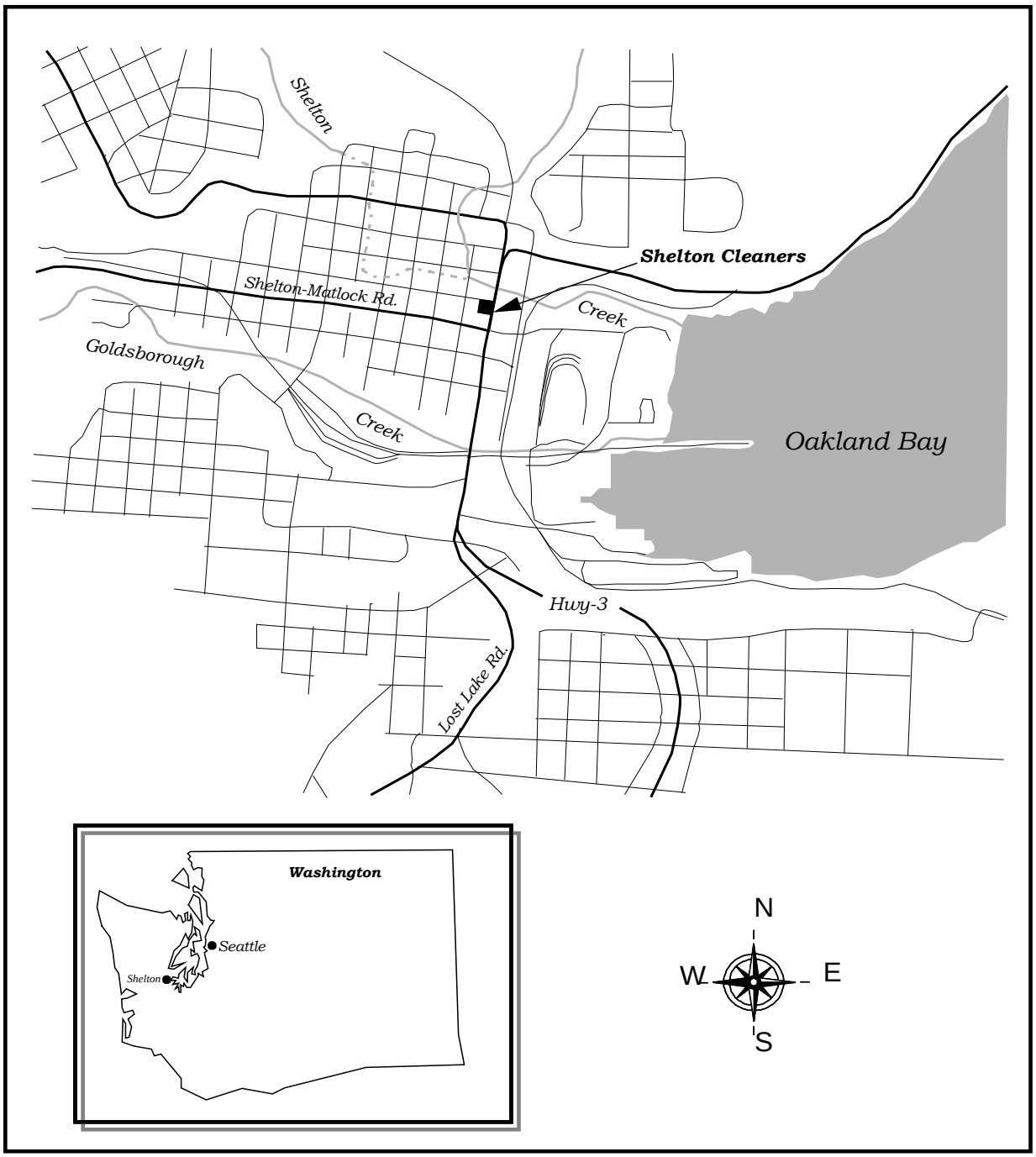

Figure 1. Shelton Laundry and Cleaners Site Location in Shelton, Washington.

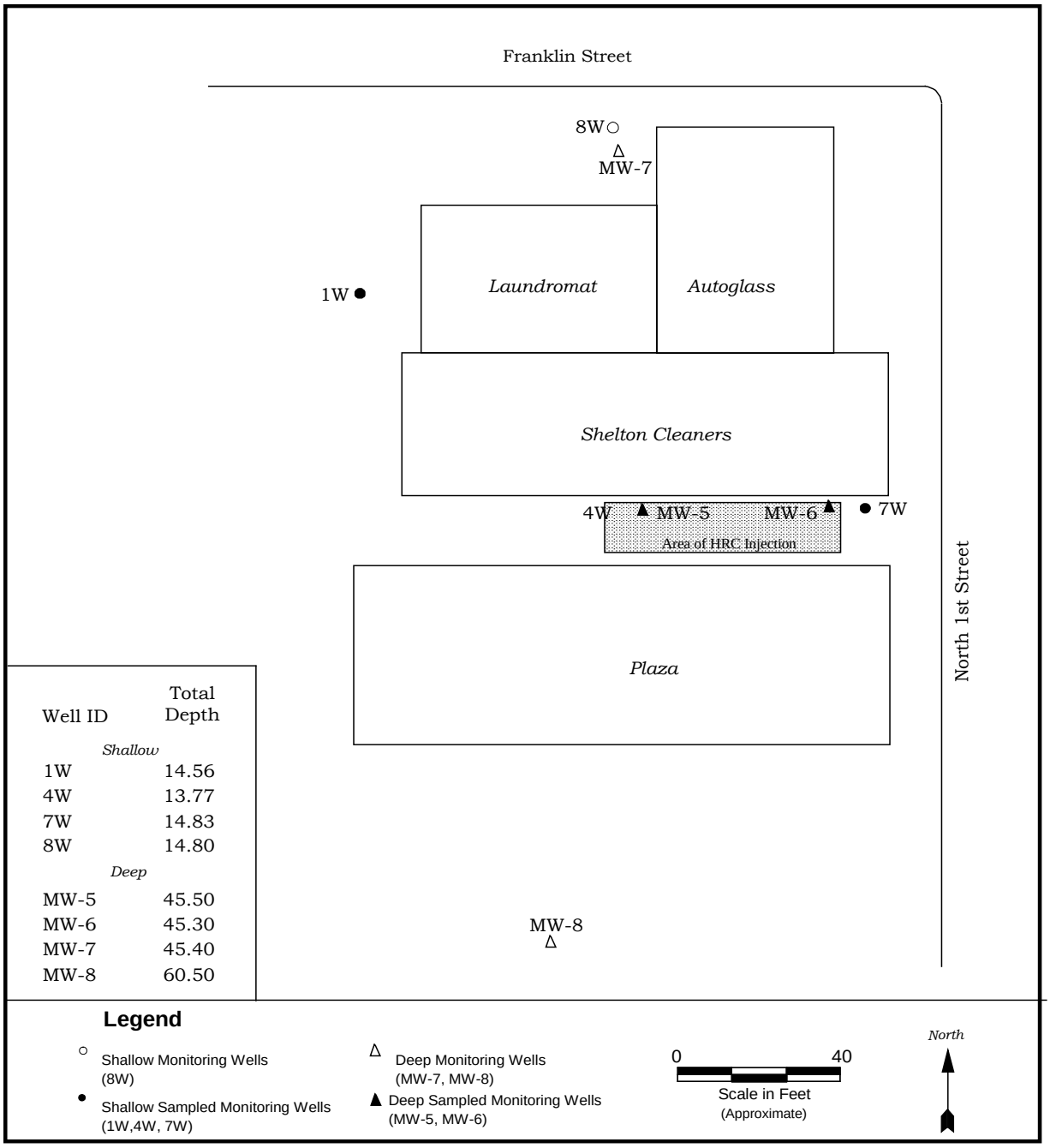

Figure 2. Shelton Laundry and Cleaners Sample Locations, October 2010 and June 2011.

Prior to the HRC injection, Ecology collected shallow groundwater and soil samples from the temporary remediation borings near well 4W. Groundwater samples were collected from five borings at depths of 10 to 13 feet bgs. PCE was detected primarily east of well 4W at a concentration of 27 ug/L. The remaining three detections were below 1 ug/L. Soil samples were collected from four borings at two depths, 4 to 8 feet and 12 to 16 feet bgs. PCE was detected in the two shallow soil samples nearest to well 4W at concentrations of 88 and 269 ug/Kg. PCE concentrations decreased to an estimated 0.65 and 1.2 ug/Kg in deeper soil samples from the same borings.

Results from the first year of monitoring following the HRC injection suggest that enhanced degradation was occurring. PCE and trichloroethene (TCE) concentrations decreased while cis-1,2-dichloroethene (cis-DCE)(a breakdown product) concentrations increased. The contaminant concentrations in well 4W were at their lowest in August 2006, 15 months following the HRC injection. Since then concentrations have gradually increased to pre-injection levels. HRC typically has an effective longevity of about 12 to 18 months (Willett, 2004).

Ecology continues to monitor the site groundwater because PCE concentrations in well 4W continue to exceed MTCA cleanup level of 5 ug/L.

Hydrogeology

Site well logs indicate the Shelton Laundry and Cleaners site is covered by a thin layer of fill and 2 to 6 feet of silty sand. These surficial deposits are underlain by an undetermined thickness of gravely sand with minor sand interbeds. The construction log for well 4W, the location where PCE is primarily detected, shows the upper silty-sand layer grading to silty-fine gravel with some fine-to-coarse sand from 6 to 14 feet bgs (GeoEngineers, 1998). Soils from split spoon samples collected in June 2005 near well 4W indicate the presence of a silt layer at approximately 4 feet below the ground surface. Elevated concentrations of PCE were detected in soil samples collected at this depth.

The gravely sands in which all eight monitoring wells are screened are interpreted as Vashon recessional outwash deposits, which underlay the western outwash plain between the town of Shelton and the Skokomish Valley to the north. The site wells do not reach the base of this unit, but well logs for deeper production wells near the site indicate the recessional deposits can exceed 100 feet in thickness in the Oakland Bay area.

Depth to the water table beneath the project site ranged from approximately 3 to 6 feet during the 1997 - 2011 study period. Groundwater flow patterns determined from site water levels are southward. It is likely that the direction of groundwater flow is influenced by Shelton Creek, located about 300 feet north of the site. The local flow direction in the area of well 4W, the primary location of the PCE contamination, is toward the southeast and Oakland Bay (approximately 2000 feet away).

Methods

Groundwater Monitoring

Ecology collected groundwater samples in October 2010 and June 2011 from three shallow and two deep monitoring wells (Figure 2). Samples were submitted for analysis of volatile organic compounds (VOCs) to determine PCE concentrations in the vicinity of well 4W.

The three shallow wells installed in 1998 (1W, 4W, and 7W) are constructed of 1-inch diameter PVC to a depth of about 15 feet, with 10-foot screens. The two deep wells installed in 2002 (MW-5 and MW-6) are constructed of 2-inch diameter PVC to a depth of about 45 feet, with the screened interval from 35-45 feet bgs.

Ecology measured static water levels in all wells, prior to well purging and sampling, using a water level meter with a ¼-inch diameter probe. Measurements were made in accordance with Ecology's standard operating procedures (SOP) EAP052 (Marti, 2009).

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

Because of their small diameter (1 inch), wells 1W, 4W, and 7W were purged and sampled with a stainless steel mechanical bladder pump at a rate of 0.1 to 0.5-liter/minute. The wells were purged through a continuous flow cell until field parameter (temperature, pH, dissolved oxygen, and specific conductivity) readings stabilized. At the completion of purging, the flow cell was disconnected and the samples were collected directly from the monitoring well's dedicated pump discharge tubing into laboratory-supplied containers.

Monitoring wells MW-5 and MW-6 were purged and sampled using a stainless steel submersible pump, at a rate of ≤1-liter/minute. These wells were purged through a continuous flow cell until field parameter readings stabilized. At the completion of purging, the flow cell was disconnected and the samples were collected directly from the well's dedicated pump discharge tubing into the sample containers.

VOC samples were collected free of headspace in three 40-mL glass vials with Teflon-lined septa lids. Samples were field preserved with 1:1 hydrochloric acid. After labeling, all samples were stored in an ice-filled cooler while being transported to Ecology's Operation Center (OC) in Lacey, Washington. Samples were kept in the walk-in cooler at the OC until picked up by the courier and transported to the Ecology/EPA Manchester Environmental Laboratory in Manchester, Washington. Chain-of-custody procedures were followed per Manchester Laboratory protocols (Ecology, 2008).

The sampling pumps were decontaminated between uses by circulating a solution of laboratory-grade detergent and water through the pump, followed by a clean water rinse. Purge water from all the wells was collected and stored on-site in a 55-gallon drum. The purge water was transported and disposed of in accordance with Washington State Dangerous Waste Regulations (Chapter 173-303 WAC).

Analysis

Analytes, analytical methods, and reporting limits for both field and laboratory parameters are listed in Table 1. Manchester Laboratory analyzed all groundwater samples for VOCs.

Table 1. 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 Method 150.1 (EPA, 2001a)	±0.2 standard units
Temperature	YSI ProPlus with Quatro Cable	EPA Method 150.1	±0.2 ºC
Dissolved Oxygen	YSI ProPlus with Quatro Cable	EPA Method 360.1 (EPA, 2002)	±0.2 mg/L
Specific Conductance	YSI ProPlus with Quatro Cable	EPA Method 120.1 (EPA, 2001b)	±10 umhos/cm
Laboratory Analytes	Method	Reference	Reporting Limit
VOCs	EPA SW-846 Method 8260B	EPA 1996	1-5 ug/L

EAP: Ecology's Environmental Assessment Program.

Results

Data Quality Assessment

Field quality control samples consisted of blind field duplicates from well 4W. Ecology collected field duplicates by splitting the pump discharge between two sets of sample bottles, which 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 2 shows the results of the duplicate samples and the relative percent difference (RPD). RPD is calculated as the difference between sample results, divided by the mean and expressed as a percent.

Table 2. Relative Percent Difference (RPD) of Duplicate Sample Results (ug/L), October 2010 and June 2011.

Well Sample ID	Tetrachloroethene (PCE)		Trichloroethene (TCE)		Cis-1,2-Dichloroethene (cis-DCE)	
	10/10	6/11	10/10	6/11	10/10	6/11
4W	24	35 J	3.1	4.2	0.92 J	1.2
4W-A	25	42 J	3.2	5.1	0.94 J	1.4
RPD[1] (%)	4%	--	3%	19%	--	15%

MW-4A is the duplicate sample identification.
[1] RPD target ±15%.
J: Analyte was positively identified. The associated numerical result is an estimate.

In October 2010 and June 2011, the RPD for duplicate results from monitoring well 4W ranged from 3% to 19%. The June TCE duplicate data from well 4W was slightly above the data quality objectives established in the Quality Assurance Project Plan (Marti, 2002). The goal for total precision (analytical and sampling) for duplicate volatile organic samples is 15% RPD. However, the concentrations are within the range of previous results detected in this well. Therefore, the data is considered usable and has been "J" qualified as estimated.

A review of the laboratory data quality control and quality assurance results indicates that the overall analytical performance was good. The reviews include descriptions of analytical methods, holding times, instrument calibration checks, blank results, matrix spikes, surrogate recoveries, and laboratory control samples. In June the percent recovery for tetrachloroethene was high in the laboratory control sample, therefore the results have been "J" qualified. As a result the June PCE data for well 4W may be biased high. No other 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 Environmental Information Management (EIM) database: www.ecy.wa.gov/eim/index.htm at study ID: PMART001.

Field Results

Ecology measured depth-to-water in each monitoring well prior to purging. End-of-purge pH, temperature, dissolved oxygen, and specific conductance readings are listed in Table 3.

Table 3. Summary of Field Parameter Results, October 2010 and June 2011.

Well Sample ID	Total Depth (feet)[1]	Depth-to-Water Below Ground Surface (feet)		Water Table Elevation (feet)[2]		pH (standard units)		Temperature (°C)		Dissolved Oxygen (mg/L)		Specific Conductance (umhos/cm)	
		10/10	6/11	10/10	6/11	10/10	6/11	10/10	6/11	10/10	6/11	10/10	6/11
Shallow													
1W	14.56	5.49	5.18	9.61	9.92	7.3	7.1	12.0	11.9	5.0	5.1	203	204
4W	13.77	4.96	4.68	9.71	9.99	7.2	7.1	13.0	11.9	3.7	4.7	204	201
7W	14.83	4.51	4.24	9.59	9.86	7.3	7.1	12.0	11.7	4.2	5.4	204	202
Deep													
MW-5	45.5	4.94	4.67	9.72	9.99	7.2	7.1	12.7	11.3	4.4	5.2	203	201
MW-6	45.3	4.59	4.31	9.66	9.94	7.2	7.1	11.7	10.9	--	5.3	211	208

[1] Measured from top of PVC casing.
[2] Vertical Datum NGVD29.
-- Not measured.

Completion depths for the five monitoring wells range from 13.77 to 14.83 feet for the shallow wells and 45.3 to 45.5 feet for the deep wells. Depth-to-water below the ground surface was measured in all eight wells and ranged from 4.51 to 5.49 feet in October 2010 and 4.24 to 5.18 feet in June 2011.

Hydrographs showing water-level elevations for each well, along with monthly precipitation values from May 2002 to June 2011, are shown in Figure 3. Hydrograph data are presented in Appendix A. The hydrographs indicate that, overall, the seasonal fluctuation is small throughout the year (about 1-2 feet), and the horizontal groundwater gradient is fairly flat. Water level elevations in September and November 2007 were lower than normal; this may be attributed to dewatering during sewer and other construction work conducted in the area during this period. Water level data also indicates that vertical gradients at paired wells are small and overall appears to be upward.

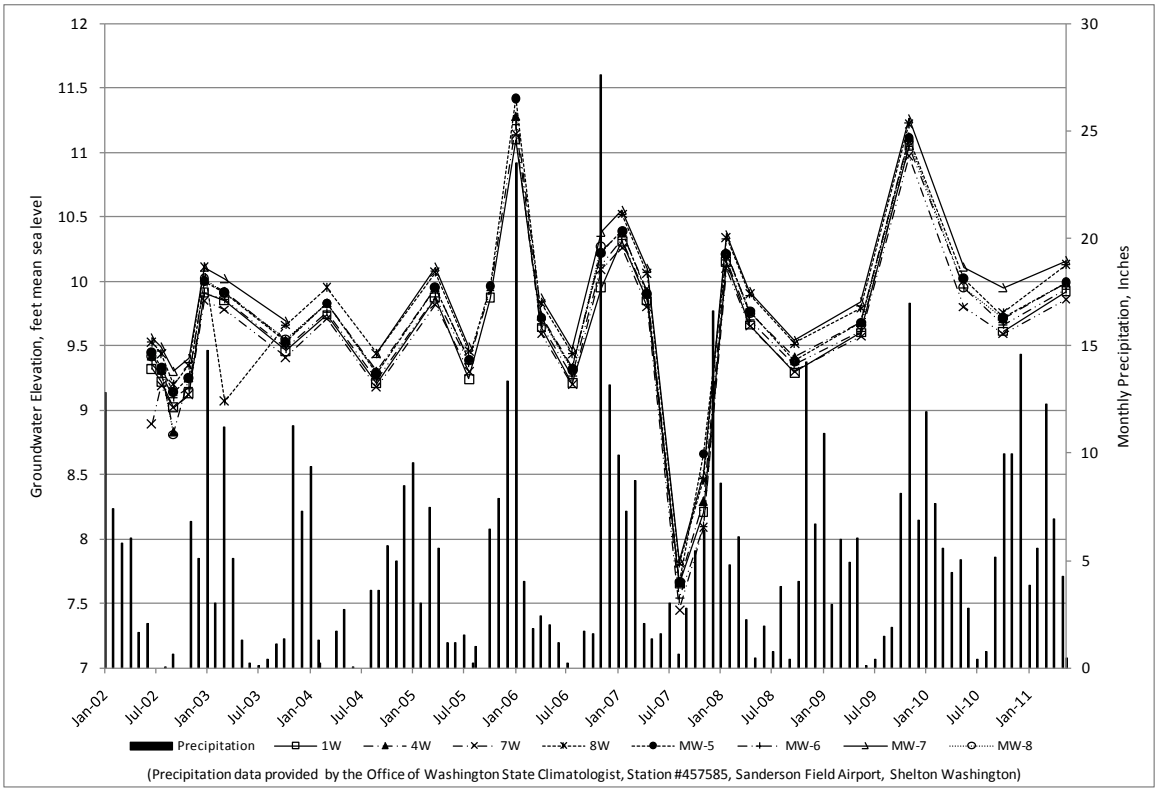

Figure 3. Shelton Laundry and Cleaners – Hydrographs, May 2002 through June 2011.

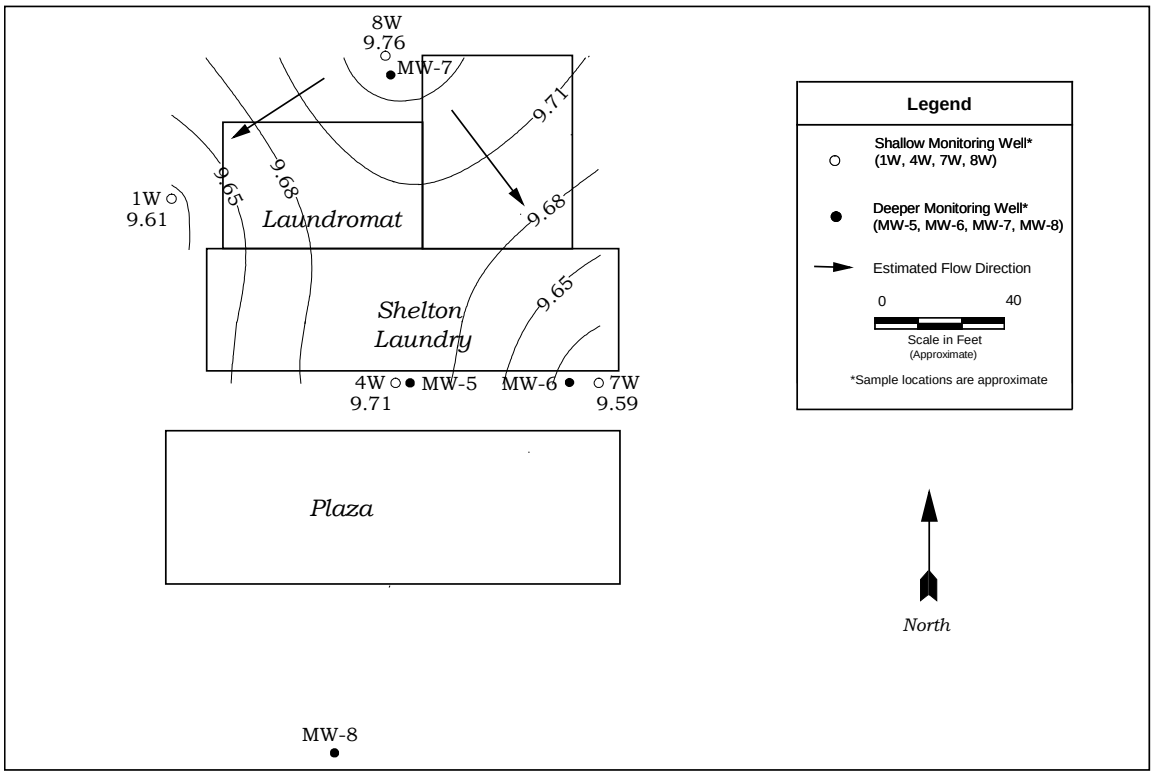

Figure 4. Shelton Laundry and Cleaners – Water Table Elevation (ft, NGVD29), October 2010.

A typical groundwater flow pattern based on water levels measured from the shallow wells in October 2010 is shown in Figure 4. The groundwater flow direction is approximately perpendicular to the contours. The shallow flow direction appears to be southward. Water levels measured from the deep wells indicate that the groundwater flow is to the southeast, in the direction of Oakland Bay.

Field parameter results for October 2010 and June 2011 were consistent between sample locations and within expected ranges. During the monitoring period, pH of the groundwater averaged 7.2. Groundwater temperatures ranged from 10.9º to 12.7 ºC. Water temperature is subject to change during sampling due to ambient air conditions and therefore may not be representative of in-situ groundwater conditions. Dissolved oxygen measurements ranged from 3.7 to 5.4 mg/L. Specific conductance measurements averaged 204 umhos/cm.

Analytical Results

Analytical results for the contaminants of concern are summarized in Table 4. A summary of historical data is presented in Appendix B. PCE, TCE, and cis-DCE were the only volatile organics detected.

Table 4. Summary of Analytical Results (ug/L), October 2010 and June 2011.

Well ID	Tetrachloroethene (PCE)		Trichloroethene (TCE)		Cis-1,2-Dichloroethene (cis-DCE)	
	10/10	6/11	10/10	6/11	10/10	6/11
Shallow						
1W	1 U	2 U	1 U	1 U	1 U	1 U
4W	**24**	**35 J**	**3.1**	**4.2 J**	**0.92 J**	**1.2**
7W	1 U	2 U	1 U	1 U	1 U	1 U
Deep						
MW-5	1 U	2 U	1 U	1 U	1 U	1 U
MW-6	1 U	2 U	1 U	1 U	1 U	1 U

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.

PCE and TCE were detected in well 4W during both the October 2010 and June 2011 sampling. PCE concentrations in this well ranged from approximately 24 to 35 J ug/L. Due to a quality control issue at the lab, the June PCE result may be biased high and is therefore qualified as an estimate. TCE and cis-DCE concentrations in well 4W were near the practical quantitation limit of 1 ug/L.

PCE, TCE, and cis-DCE were not detected in shallow wells 1W and 7W. These contaminants have not been detected in well 1W since monitoring began in 1998. PCE was last detected in well 7W in February 2006 at a concentration of 0.53 ug/L.

Volatile organics have not been detected in the deep wells since the wells were installed in July 2002.

Discussion

PCE, TCE, and cis-DCE concentrations in well 4W have fluctuated since the injection of the HRC in June 2005 (Figure 5, Table B2). Prior to injection, the average PCE and TCE concentrations in this well were 15 ug/L and 1.6 ug/L, respectively. Five months following the HRC injection (November 2005), PCE and TCE concentrations decreased to 6.8 ug/L and 0.52 ug/L respectively, while cis-DCE concentrations increased from a pre-HRC average of 0.62 ug/L to 1.8 ug/L. The decrease in PCE and TCE concentrations, combined with the increase in cis-DCE concentrations, a breakdown product, suggests a period of enhanced degradation due to the HRC injection.

PCE concentrations increased to an estimated 18 ug/L in February 2006 and a high of 324 ug/L in May 2006. Concentrations of TCE and cis-DCE also increased to a high of 13 ug/L and 16 ug/L, respectively, in May 2006. Hansen et al. (2000) noted that there can be temporary increases in aqueous contaminant concentrations in an HRC treatment area. This is because biosurfactants (microbial surface active agents) produced by stimulating microbial growth in the subsurface can solubilize volatile organics adsorbed to the aquifer media.

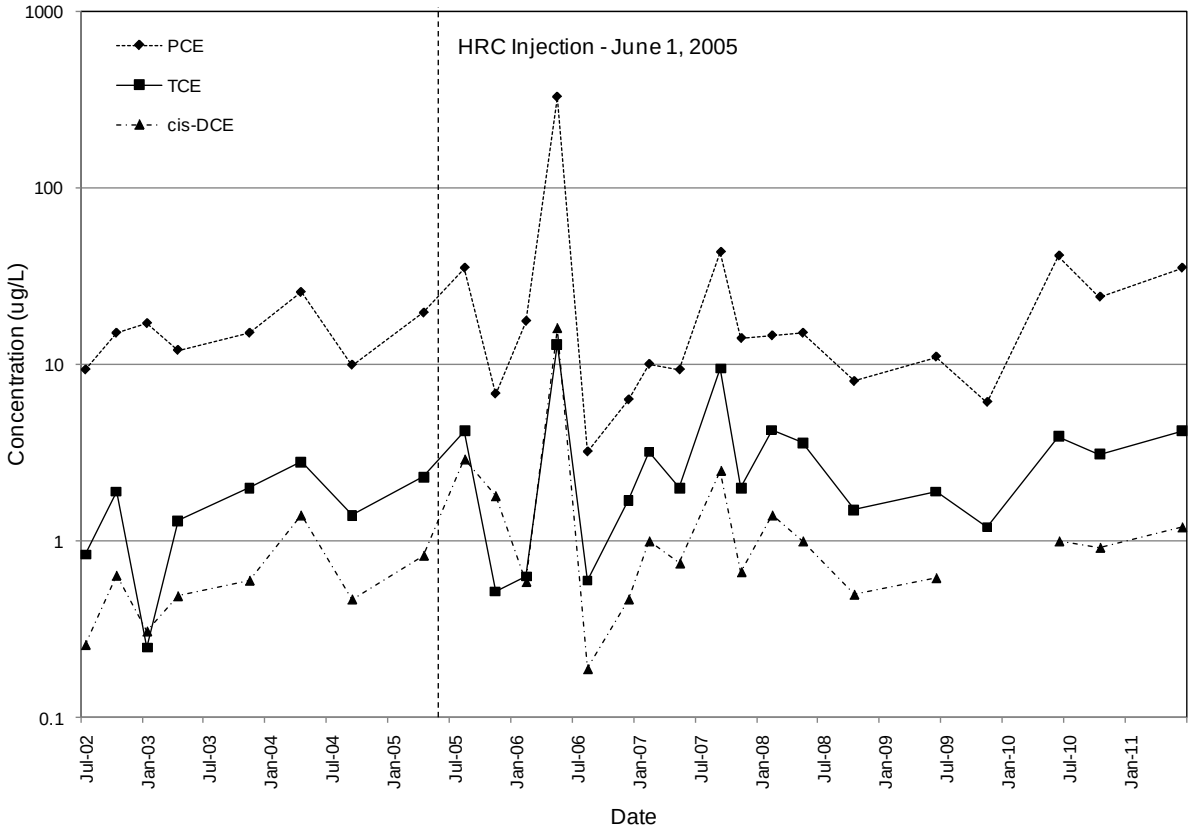

Figure 5: PCE, TCE, and cis-DCE Concentrations (ug/L – log scale) in well 4W, July 2002 through June 2011.

In August 2006, PCE (3.2 ug/L), TCE (0.6 ug/L), and cis-DCE (0.19 ug/L) had decreased to some of the lowest concentrations observed. This was the first occurrence of PCE concentrations below the MTCA Method A cleanup level of 5 ug/L since monitoring began in 2002. However, since August 2006, PCE, TCE, and cis-DCE concentrations have gradually increased, returning to their pre-HRC injection concentrations (Figure 5). The average PCE concentration in well 4W for data collected from 2007 through 2011 is 19 ug/L.

The increase of PCE, TCE, and cis-DCE concentrations suggest that the HRC is past its effectiveness. In a review of HRC case histories, Willett et al. (2004) found that the effective longevity of HRC is about 12 to 18 months. Data from the Shelton site corresponds to the predicted HRC effective longevity.

Shallow groundwater underlying the Shelton Laundry and Cleaners site continues to be contaminated in the area of well 4W. PCE continues to be detected in this well above the cleanup level of 5 ug/L. The only other occurrence of PCE has been in well 7W which was last detected in 2006 at a concentration below 1 ug/L. The remaining shallow and deep wells have never shown detectable levels of contamination.

Conclusions and Recommendations

Conclusions

During the monitoring periods of October 2010 and June 2011, PCE concentrations in shallow well 4W continue to exceed the MTCA Method A cleanup level of 5 ug/L. PCE concentrations ranged from approximately 24 to 35 J ug/L.

TCE and cis-DCE, associated with the breakdown of PCE, were also detected in well 4W but below their respective cleanup levels of 5 ug/L and 70 ug/L. TCE concentrations ranged from approximately 3.1 to 4.2 ug/L, and cis-DCE concentrations ranged from 0.92 to 1.2 ug/L.

Shallow groundwater underlying the Shelton Laundry and Cleaners site continues to be contaminated in the area of well 4W, even after injection of the hydrogen release compound (HRC®) in June 2005.

PCE, TCE, and cis-DCE results following the HRC injection suggest that enhanced degradation was occurring. Despite a spike in contaminant concentrations in May 2006, PCE and TCE concentrations decreased while cis-DCE concentrations increased following the injection.

The lowest contaminant concentrations were observed in August 2006, 15 months following the HRC injection. However, concentrations have gradually increased the past five years, returning to their pre-HRC injection concentrations. The increase in PCE, TCE, and cis-DCE concentrations suggests the HRC is no longer effective in reducing contaminant concentrations.

The deeper wells continue to show no detectable contamination.

Recommendations

Groundwater monitoring should continue in the three shallow wells (1W, 4W, and 7W) on an annual basis for the next year since PCE concentrations in monitoring well 4W continue to exceed the MTCA Method A cleanup level of 5 ug/L.

Because contaminants have never been detected in deep wells MW-5 and MW-6, it is recommended that the sampling frequency for these wells be reduced to every other year.

The Shelton Laundry and Cleaners site is in need of a better placed downgradient well. Groundwater flow direction from the source area consistently appears to be to the southeast. It is recommended that a more appropriate downgradient well either be installed or an existing well located that may be used in the monitoring program.

Elevated PCE concentrations were detected in shallow soil samples (4-8 feet) near well 4W in June 2005. Since groundwater concentrations continue to exceed MTCA Method A cleanup levels at 4W after the HRC injection treatment, evaluation of additional soil remediation is recommended.

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References

Balaraju, P., 2005. Certified Letter to Mr. William Fox of Shelton Laundry and Cleaners. Attached proposal for Insitu Groundwater Treatment by Hydrogen Release Compound (HRC).

Biondolillo, J., 2006. Regenesis, Technical Manager, West Region. Personal communication. May 2006. Email: jbiondolillo@regenesis.com.

Building Analytics, 1997. Phase II Subsurface Investigation of Wells Fargo Bank Property, Shelton, Washington. File No. 197415. Building Analytics, Glendale, CA. June 1997.

Ecology, 2008. Manchester Environmental Laboratory, Lab Users Manual. Ninth edition. 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.

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.

GeoEngineers, 1998. Subsurface Investigation, Shelton Cleaners and Laundry, Shelton, Washington. File No. 6539-001-00. August 10, 1998.

GeoEngineers, 2000. Ground Water Monitoring, Shelton Cleaners and Laundry, Shelton, Washington. File No. 6539-002-00/100200. October 2, 2000.

Hansen, M.A., J. Burdick, F.C. Lenzo, and S. Suthersan, 2000. Enhanced Reductive Dechlorination: Lessons Learned at over Twenty Sites. p. 263–270 *In:* Bioremediation and Phytoremediation of Chlorinated and Recalcitrant Compounds. G.B. Wickramanayake et al. (eds.). Columbus, OH: Battelle Press.

Marti, P., 2002. Quality Assurance Project Plan: Shelton Cleaners and Laundry. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-078. www.ecy.wa.gov/biblio/0203078.html.

Marti, P., 2003. Shelton Laundry and Cleaners, July 2002 through April 2003 Groundwater Monitoring Results. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-038. www.ecy.wa.gov/biblio/0303038.html.

Marti, P., 2009. Standard operating procedure for manual well-depth and depth-to-water measurements. Washington State Department of Ecology, Environmental Assessment Program, EAP052, Version 1.0.

Marti, P., 2011. Standard operating procedure for purging and sampling monitoring wells. Washington State Department of Ecology, Environmental Assessment Program, EAP078, Version 1.0.

Willett, A., J. Tseng, R. Gillespie, and S. Koenigsberg, Ph.D., 2004. Hydrogen Release Compound (HRC®): A Review of Published Papers and Case Histories 1999-2003. Regenesis, San Clemente, CA. Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents. August 2004.

Previous Studies at the Shelton Laundry and Cleaners Site

Marti, P., 2003. Shelton Laundry and Cleaners, July 2002 through April 2003 Groundwater Monitoring Results. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-038. www.ecy.wa.gov/biblio/0303038.html.

Marti, P., 2004. Shelton Laundry and Cleaners, November 2003 through April 2004 Groundwater Monitoring Results. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-029. www.ecy.wa.gov/biblio/0403029.html.

Marti, P., 2005. Shelton Laundry and Cleaners, September 2004 through April 2005 Groundwater Monitoring Results. Washington State Department of Ecology, Olympia, WA. Publication No. 05-03-019. www.ecy.wa.gov/biblio/0503019.html.

Marti, P., 2006. Shelton Laundry and Cleaners, August 2005 through May 2006 Groundwater Monitoring Results. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-029. www.ecy.wa.gov/biblio/0603029.html.

Marti, P., 2007. Shelton Laundry and Cleaners, August 2006 through May 2007 Groundwater Monitoring Results. Washington State Department of Ecology, Olympia, WA. Publication No. 07-03-045. www.ecy.wa.gov/biblio/0703045.html.

Marti, P., 2008. Shelton Laundry and Cleaners, September 2007 through May 2008 Groundwater Monitoring Results. Washington State Department of Ecology, Olympia, WA. Publication No. 08-03-033. www.ecy.wa.gov/biblio/0803033.html.

Marti, P., 2010. Shelton Laundry and Cleaners, October 2008 and June 2009 Groundwater Monitoring Results. Washington State Department of Ecology, Olympia, WA. Publication No. 10-03-002. www.ecy.wa.gov/biblio/1003002.html.

Marti, P., 2010. Shelton Laundry and Cleaners, November 2009 and June 2010 Groundwater Monitoring Results. Washington State Department of Ecology, Olympia, WA. Publication No. 10-03-060. www.ecy.wa.gov/biblio/1003060.html.

Appendices

Appendix A. Hydrograph Data

Table A-1. Groundwater Elevations (feet, NGVD29), May 2002 through June 2010.

Well ID:	1W	4W	7W	8W	MW-5	MW-6	MW-7	MW-8
5/13/02	9.51	9.61	9.49	9.74	9.64	9.57	9.77	--
7/16/02	9.32	9.42	8.89	9.53	9.45	9.35	9.56	9.42
8/20/02	9.22	9.31	9.19	9.44	9.33	9.28	9.49	9.31
10/2/02	9.02	8.83	9.02	9.20	9.14	9.10	9.30	8.81
11/26/02	9.13	9.25	9.12	9.35	9.25	9.18	9.50	--
1/21/03	9.91	10.01	9.85	10.11	10.00	9.91	10.11	10.02
4/2/03	9.85	9.92	9.78	9.07	9.91	9.86	10.02	9.91
11/5/03	9.46	9.54	9.41	9.66	9.53	9.48	9.69	9.55
4/1/04	9.74	9.83	9.71	9.95	9.83	9.76	--	9.83
9/23/04	9.21	9.30	9.18	9.44	9.28	9.23	9.44	9.29
4/20/05	9.87	9.95	9.82	10.07	9.95	9.88	10.11	--
8/19/05	9.24	9.39	9.30	9.46	9.39	9.37	9.49	--
11/3/05	9.87	--	--	--	9.96	9.93	--	--
2/1/06	11.10	11.28	11.14	--	11.42	11.21	--	--
5/3/06	9.64	9.73	9.59	9.83	9.72	9.66	9.87	9.71
8/22/06	9.21	9.33	9.20	9.44	9.32	9.26	9.47	9.31
12/1/06	9.95	10.23	10.09	--	10.22	10.13	10.38	10.27
2/15/07	10.31	10.38	10.26	10.52	10.39	10.32	10.55	--
5/14/07	9.85	9.92	9.80	10.06	9.90	9.87	10.10	--
9/7/07	7.65	7.66	7.45	7.81	7.66	7.54	7.83	7.67
11/30/07	8.21	8.29	8.09	8.46	8.66	8.10	8.50	--
2/19/08	10.15	10.22	10.10	10.34	10.21	10.17	10.36	10.21
5/14/08	9.66	9.76	9.65	9.90	9.77	9.70	9.92	9.75
10/20/08	9.29	9.41	9.30	9.52	9.38	9.35	9.54	--
6/12/09	9.60	9.68	9.57	9.79	9.68	9.61	9.84	9.66
11/20/09	11.05	11.12	10.97	11.22	11.11	11.05	11.26	11.09
6/10/2010	--	--	9.8	--	10.02	9.95	10.11	9.95
10/15/2010	9.61	9.71	9.59	9.76	9.72	9.66	9.95	9.71
6/10/2011	9.92	9.99	9.86	10.13	9.99	9.94	10.16	--

-- Not measured.
Vertical Datum NGVD29.

Appendix B. Historical Data

Table B-1. PCE, TCE, and DCE Groundwater Results (ug/L), May 1997 through September 2000.

Well ID	Building Analytics	AA Enviro Assessment	GeoEngineers			
	5/21/97	3/3/98	7/24/98	11/18/98	7/12/99	9/6/00
1W						
PCE	--	--	<1.0	<1.0	<1.0	NS
TCE	--	--	<1.0	<1.0	<1.0	NS
4W						
PCE	**130**[1]	**1510**[2]	**280**	**130**	**39**	**25**
TCE	NR	NR	**4.7**	<1.0	<1.0	<1.0
DCE	NR	NR	**33**	<1.0	<1.0	<1.0
7W						
PCE	--	--	**4.3**	**3**	<1.0	**1.2**
TCE	--	--	<1.0	<1.0	<1.0	<1.0
DCE	--	--	**6.4**	<1.0	<1.0	<1.0
8W						
PCE	--	--	<1.0	<1.0	<1.0	NS
TCE	--	--	<1.0	<1.0	<1.0	NS
MW-5 PCE TCE	This deep monitoring well was installed in 2002.					
MW-6 PCE TCE	This deep monitoring well was installed in 2002.					
MW-7 PCE TCE	This deep monitoring well was installed in 2002.					
MW-8 PCE TCE	This deep monitoring well was installed in 2002.					

Bold = Analyte was detected.
NS – Not Sampled.
NR – Not Reported.
<1.0 – Analyte was not detected at a concentration above the value shown.
[1] Concentration reported by Building Analytics from a temporary boring located in vicinity of well 4W.
[2] Concentration reported by AA Enviro Assessment from a temporary boring located in vicinity of well 4W.

Table B-2. PCE, TCE, and DCE Groundwater Results (ug/L), July 2002 through June 2011.

Well ID	Ecology															
	7/17/02	10/3/02	1/22/03	4/3/03	11/5/03	4/1/04	9/23/04	4/20/05	8/19/05	11/3/05	2/1/06	5/3/06	8/22/06	12/1/06	2/15/07	5/14/07
1W																
PCE	1 U	1 U	1 U	1 U	--	--	--	--	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
TCE	1 U	2 U	1 U	1 U	--	--	--	--	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
4W																
PCE	**9.3**	**15**	**17**	**12**	**15**	**26**[a]	**9.9**	**20**[a]	**35**[a]	**6.8**	**18**[a]	**324**	**3.2 J**	**6.3**	**10**	**9.3**
TCE	**0.84 J**	**1.9 J**	**0.25 J**	**1.3**	**2**	**2.8**[a]	**1.4**	**2.3**	**4.2**[a]	**0.52 J**	**0.63 J**	**13**	**0.60 J**	**1.7**	**3.2**	**2**
DCE	**0.26 J**	**0.64 J**	**0.31 J**	**0.49 J**	**0.60 J**	**1.4**	**0.47 J**	**0.83 J**	**2.9**[a]	**1.8**	**0.59 J**	**16**	**0.19 J**	**0.47 J**	**1**	**0.75 J**
7W																
PCE	1 U	**0.19 J**	1 U	1 U	1 U	**1.7**	**0.47 J**	**0.15 J**	**0.38 J**	1 U	**0.53 J**	1 U	1 U	1 U	1 U	1 U
TCE	1 U	2 U	1 U	1 U	1 U	1 U	**0.26 J**	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
DCE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
8W																
PCE	1 U	1 U	1 U	1 U	--	--	--	--	--	--	--	--	--	--	--	--
TCE	1 U	2 U	1 U	1 U	--	--	--	--	--	--	--	--	--	--	--	--
MW-5																
PCE	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U
TCE	1 U	2 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
MW-6																
PCE	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U
TCE	1 U	2 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
MW-7																
PCE	1 U	1 U	1 U	1 U	--	--	--	--	--	--	--	--	--	--	--	--
TCE	1 U	2 U	1 U	1 U	--	--	--	--	--	--	--	--	--	--	--	--
MW-8																
PCE	1 U	1 U	1 U	1 U	--	--	--	--	--	--	--	--	--	--	--	--
TCE	1 U	2 U	1 U	1 U	--	--	--	--	--	--	--	--	--	--	--	--

Bold = Analyte was detected.

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

UJ - Analyte was not detected at or above the reported estimated result.

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

[a] Average concentration of duplicate samples.

Table B-2 (continued). PCE, TCE, and DCE Groundwater Results (ug/L), July 2002 through June 2011.

Well ID	Ecology									
	9/7/07	11/30/07	2/19/08	5/14/08	10/20/09	6/12/09	11/20/09	6/10/10	10/15/10	6/10/11
1W										
PCE	2 U	2 U	1 U	2 U	1 U	1 U	1 U	1 U	1 U	2 U
TCE	2 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
4W										
PCE	**43**	**14**	**15 J[a]**	**15 J**	**8**	**11**	**6.1 J[a]**	**41 J[a]**	**24**	**35 J**
TCE	**9.5**	**2**	**4.3 J[a]**	**3.6**	**1.5**	**1.9**	**1.2**	**3.9 J[a]**	**3.1**	**4.2 J**
DCE	**2.5**	**0.67 J**	**1.4 J**	**1**	**0.5 J**	**0.62 J**	1 U	**1**	**0.92 J**	**1.2**
7W										
PCE	2 U	2 U	1 U	2 U	1 U	1 U	1 U	1 U	1 U	2 U
TCE	2 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
8W										
PCE	--	--	--	--	--	--	--	--	--	--
TCE	--	--	--	--	--	--	--	--	--	--
MW-5										
PCE	2 U	2 U	1 U	2 U	1 U	1 U	1 U	1 U	1 U	2 U
TCE	2 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
MW-6										
PCE	2 U	2 U	1 U	2 U	1 U	1 U	1 U	1 U	1 U	2 U
TCE	2 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
MW-7										
PCE	--	--	--	--	--	--	--	--	--	--
TCE	--	--	--	--	--	--	--	--	--	--
MW-8										
PCE	--	--	--	--	--	--	--	--	--	--
TCE	--	--	--	--	--	--	--	--	--	--

Bold = Analyte was detected.

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

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

[a] Average concentration of duplicate samples.

Appendix C. Glossary, Acronyms, and Abbreviations

Glossary

Depth-to-water: A measure of the depth to water (i.e., water level) in a well.

Groundwater: Water in the subsurface that saturates the rocks and sediment in which it occurs. The upper surface of groundwater saturation is called the water table.

Hydrograph: A graph of the water levels observed in a well over time.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Specific conductance: A measure of water's ability to conduct an electrical current. Specific conductance is related to the concentration and charge of dissolved ions in water.

Acronyms and Abbreviations

Cis-DCE	Cis-1,2-dichloroethene
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HRC®	Hydrogen release compound
MTCA	Model Toxic Control Act
PCE	Tetrachloroethene
PVC	Polyvinyl chloride
RPD	Relative percent difference
TCE	Trichloroethene
VOC	Volatile organic compound
WAC	Washington Administrative Code

Units of Measurement

°C	degrees centigrade
ug/L	micrograms per liter (parts per billion)
ug/Kg	micrograms per kilogram (parts per billion)
umhos/cm	micromhos per centimeter