A Department of Ecology Report

Palermo Wellfield Superfund Site Subdrain System and Treatment Lagoon, Status Report, November 2006 and June 2007

Abstract

In the late 1980s, groundwater contaminated with trichloroethene (TCE) and tetrachloroethene (PCE) migrated from an upland commercial area to the City of Tumwater's Palermo Wellfield in the Deschutes River valley. The contaminated groundwater also surfaced at the base of Palermo bluff and ponded in the yards and crawlspaces of area homes. In 2000, the U.S. Environmental Protection Agency (EPA) constructed a subdrain system to lower the groundwater table and reduce the human health risk from the contaminated water.

In December 2002, the Department of Ecology assumed the lead for monitoring the subdrain system. The monitoring goal was to collect water-level and PCE/TCE data to determine if the subdrain system is operating within the remediation goals set for the project.

The most recent monitoring was conducted in November 2006 and June 2007. Groundwater levels were three to five feet below ground surface near the northern and central homes; this meets the remediation goals. As in the past, groundwater levels were less than three feet near the two southern homes.

Total depths measured in the subdrain cleanouts were close to the 2001 original depths. Total depths measured in CO-4, CO-5, and CO-8 indicate some sediment is present in these cleanouts located in the central and southern end of the perforated pipe. It does not appear that sediment deposition or scouring is occurring in the catch basins and lagoon.

PCE and TCE concentrations continue to be highest in water samples from the southern and central portion of the perforated pipe, with average concentrations of 22 µg/L for PCE and 22 µg/L for TCE. PCE and TCE concentrations from station 364 (treated water discharge to the Deschutes River) were below the remediation goals of 0.8 µg/L for PCE and 2.7 µg/L for TCE.

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Background

In the late 1980s, the City of Tumwater, Washington, discovered trichloroethene (TCE) contamination in some of the water supply wells at their Palermo Wellfield. Groundwater contaminated with TCE and tetrachloroethene (PCE) migrated from an upland commercial area to the Deschutes River valley where the Palermo Wellfield is located (Figure 1). The contaminant sources are a dry cleaners and a materials testing laboratory (US EPA, 1999). In the spring of 1999, the U.S. Environmental Protection Agency (EPA) began operating an air-stripping treatment system at the Palermo Wellfield Superfund Site to remove TCE contamination from the water supply.

In addition to the wellfield, contaminated groundwater was found to surface at the base of the Palermo bluff where it ponded in the yards and crawlspaces of area homes. This ponded water posed an inhalation risk to human health since PCE and TCE can volatilize from the water into the homes. To alleviate this situation, the EPA constructed a subdrain system and treatment lagoon in 2000 to lower the local groundwater table at the base of the bluff and remove the contaminants from the collected water.

The subdrain system includes a subgrade perforated piping network installed around seven houses along Rainier Avenue (Figure 2). The main perforated pipe or "trunk drain" is aligned through the backyards of the houses. Water collected by the perforated pipes is routed to an unperforated "tightline" pipe beneath Rainier Avenue and M Street. The tightline drains to a treatment lagoon located at the City of Tumwater Municipal Golf Course. PCE and TCE are removed from the water by surface aeration before it is discharged to the Deschutes River by way of an existing water course. The volatilized PCE and TCE disperse to the air and degrade naturally.

The remediation goals for this project are (1) to lower the static groundwater elevation beneath the homes along the west side of Rainier Avenue to at least three feet below ground surface, and (2) for contaminant concentrations of the treated water that discharges to the Deschutes River to be below 0.8 µg/L for PCE and 2.7 µg/L for TCE (Appendix A).

The Washington State Department of Ecology (Ecology) assumed the lead for monitoring the subdrain system from the EPA in December 2002 (Marti, 2003b). Results since December 2002 indicate that groundwater elevations have been lowered three or more feet below the ground surface for the homes in the central and northern portion of the trunk drain. However, the performance criteria do not appear to have been met for the two homes at the southern end of the trunk drain. Total depths measured in the cleanouts indicated that sediment was accumulating in the perforated portion of the drain system. In the fall of 2006, the City of Tumwater removed sediment from several of the cleanouts. Total depths measured in the catch basins and lagoon have not been significantly different from the original depths. PCE and TCE concentrations in the treated surface water samples have been below the remediation goals.

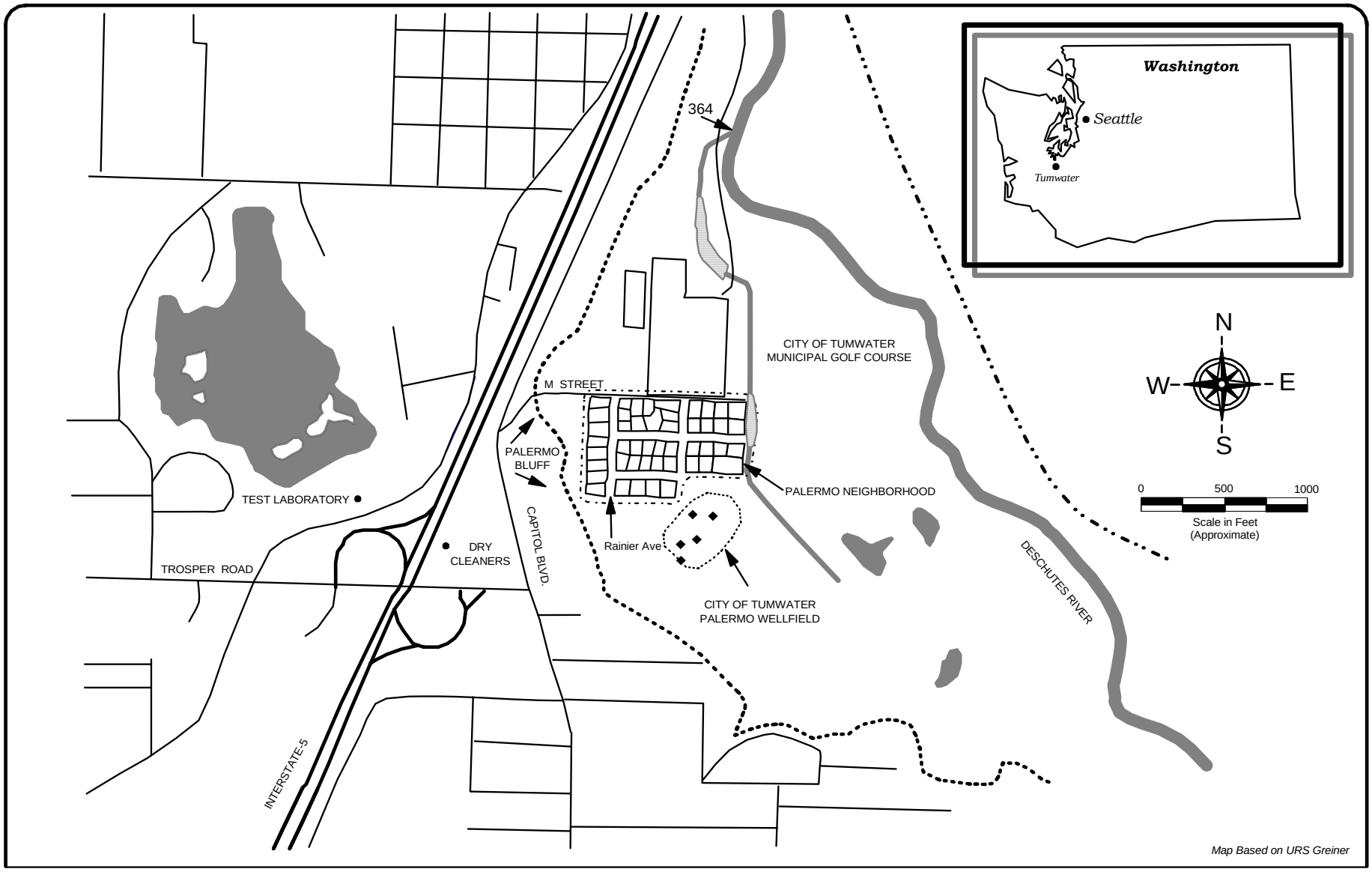


Figure 1	Palermo Wellfield and Neighborhood Site Location

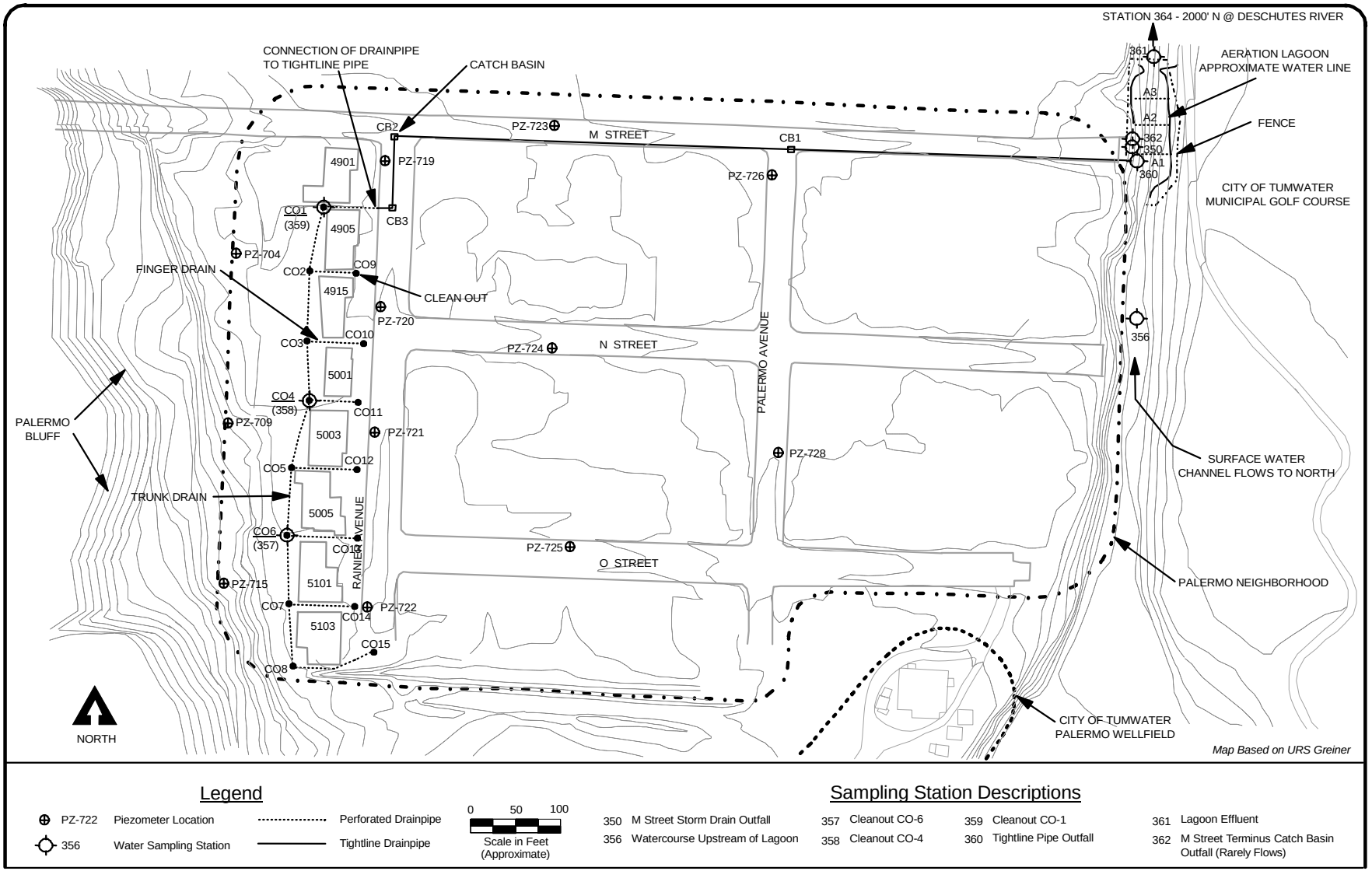


Figure 2	Palermo Wellfield Subdrain System and Treatment Lagoon Monitoring Stations

Methods

The goal of this project is to provide Ecology's Toxics Cleanup Program with water level data and PCE/TCE concentrations on a semi-annual basis to determine if the subdrain system and treatment lagoon are operating within the remediation goals. Monitoring and sampling of the system (Figure 2) were conducted by Ecology's Environmental Assessment Program on November 28-29, 2006 and June 19-20, 2007, and included the following activities:

- Measure depth-to-groundwater in 12 piezometers (PZ-704 through PZ-728) and eight trunk drain cleanouts (CO-1 through CO-8) to determine if the subdrain system has lowered the static groundwater elevation beneath the homes at the base of Palermo bluff to at least three feet below the ground surface.
- Measure total depth in CO-1 through CO-8 and three catch basins (CB-1, CB-2, CB-3) to determine if sedimentation has occurred in the trunk drain or tightline pipe. Measure total depth of the treatment lagoon along three cross-sections (A1, A2, A3) to determine if sedimentation or scouring has occurred in the lagoon.
- Measure flow rates and collect water samples for chemical analysis from three drain cleanouts (357, 358, 359), three outfalls to the treatment lagoon (360, 350, 362), and three surface water stations (356, 361, 364) to assess the contaminant removal performance of the system and compliance with remediation goals. Station 364, where the lagoon watercourse discharges to the Deschutes River, was added to the monitoring program in October 2003 to allow better comparison of contaminant concentrations to the remediation goals. Locations of the sample stations as well as the sample identification numbers are described in Table 1 and shown in Figures 1 and 2.

Table 1: Sample Station Identification and Descriptions, Palermo Subdrain System.

Sample Identification	Sample Station Description
Flow in Subdrain System – South to North	
357	Cleanout CO-6 (southernmost station within trunk drain)
358	Cleanout CO-4 (central station within trunk drain)
359	Cleanout CO-1 (northernmost station within trunk drain)
360	Tightline pipe outfall (influent from subdrain system to treatment lagoon)
361	Lagoon effluent
364	Lagoon watercourse discharge to Deschutes River
Inflows to Treatment Lagoon Other Than the Subdrain System	
350	M Street storm drain outfall
356	Watercourse flow upstream of the treatment lagoon
362	M Street terminus catch basin outfall (rarely flows)

Depth-to-Groundwater

Static water levels were measured in the piezometers (PZ-704 through PZ-728) using a ¼-inch diameter Solinst water level meter. Depth-to-groundwater was also measured in the trunk drain cleanouts (CO-1 through CO-8). Measurements were recorded to 0.01 feet and are accurate to ±0.03 feet. Measurements were made from a surveyed mark at the top of the piezometer casing or cleanout frame. The water level probe was rinsed with deionized water and wiped clean between measurements.

In November and June, the static water levels were not measured in piezometers PZ-704 and PZ-715. These piezometers are located on the wooded Palermo bluff and are becoming more difficult to locate because of the thick vegetation.

Total Depth

The total depth of the trunk drain cleanouts (CO-1 through CO-8) and catch basins (CB-1 through CB-3) were measured from a surveyed mark near the top of the structure. These measurements were taken using a weighted tape measure marked in increments of 0.01 foot, and measurements were accurate to ±0.03 feet. The tape measure was rinsed with deionized water and wiped clean between measurements.

Depth of the aeration lagoon was measured along three cross-sections (A3-north, A2-central, and A1-south). A 100-foot measuring tape was secured between survey hubs located near the mooring posts for the three lagoon aerators. Depth was measured from the east bank to the west bank at two-foot increments from a reference elevation with a survey rod. Depth of the aeration lagoon was not measured in November 2006 because of unseasonably cold weather conditions.

Water Flow Rate

In November and June, depth and velocity of water flow were measured from six of the nine stations within the subdrain system (357, 358, 359, 360, 361, and 350). Water velocity was measured with a Marsh-McBirney velocity meter. Depending on the station, flow depth was measured using either a flow wading rod (for lagoon effluent) or a graduated steel tape (for pipe outfalls). For stations within the trunk drain pipe, flow depth was calculated from depth-to-water measurements collected with a water level meter (northerly rim elevation – depth-to-water = groundwater elevation – pipe invert elevation = flow depth). Flow in open channels was measured in accordance with the standard area-velocity method of measuring streamflows as described in the Operation and Maintenance Plan (US EPA, 2000).

As in previous monitoring rounds, flow rates at station 356 were not measured. Since the installation of the lagoon, the watercourse at this point has become wide and slow, which makes an accurate flow measurement difficult. No flow was observed from station 362 (M St. terminus catch basin) during either monitoring round. Flow rates were not measured at station 364 (Figure 1) because of the difficulty of reaching either end of the culvert through which the lagoon watercourse flows before discharging to the Deschutes River.

Water Sampling

Water samples were collected from eight of the nine sample stations (357, 358, 359, 360, 361, 350, 356, and 364) using pre-cleaned glass beakers. No sample was collected at station 362 (M St. terminus catch basin) during either monitoring round because there was no flowing water.

The glass beakers were pre-cleaned with a Liquinox® wash and sequential rinses of hot tap water, deionized water, and pesticide-grade acetone. After cleaning, the beakers were air-dried and wrapped in aluminum foil.

Samples were transferred from the beaker into three 40-mL glass vials with Teflon-lined septa lids for volatile organic analysis. Samples were free of headspace and preserved with 1:1 hydrochloric acid. After sample collection and proper labeling, all samples were stored in an ice-filled cooler. Samples were transported to Ecology's Operation Center in Lacey. Samples were kept in the walk-in cooler until picked up by the courier to the Ecology/EPA Manchester Environmental Laboratory in Manchester. Chain-of-custody procedures were followed according to Manchester Environmental Laboratory protocol (Ecology, 2005).

Laboratory

Analytes, methods, and reporting limits for both field and laboratory parameters are listed in Table 2. All water samples were analyzed for volatile organics, including the target analytes of PCE, TCE, and cis-dichloroethene (cis-DCE).

Table 2: Field and Laboratory Measurements for November 2006 and June 2007 Samples.

Parameter	Method	Reference	Reporting Limit
Field			
Water Level	Solinst Water Level Meter	NA	±0.03 feet
Total Depth	Weighted Tape Measure	NA	±0.03 feet
	Survey Rod	NA	±0.01 feet
Flow Velocity	Marsh-McBirney Current Meter	NA	0.05 feet/second
Laboratory			
VOAs	EPA SW-846 Method 8260B	U.S. EPA 1996	0.5-5 µg/L

VOAs - volatile organics analysis

Data Quality

Field quality control samples consisted of blind field duplicates obtained from the tightline pipe outfall (station 360). Field duplicates were collected by splitting the water collected in a pre-cleaned glass beaker between two sets of sample bottles. This 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 are also influenced by the natural variability of the concentrations in the media being sampled.

Table 3 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 3. Relative Percent Difference (RPD) of PCE and TCE Duplicate Sample Results (ug/L) for November 2006 and June 2007.

Well Sample ID	November 2006		June 2007	
	PCE	TCE	PCE	TCE
360	12	22	9.5	17
360D	12	22	9.3	17
RPD (%)	0%	0%	2%	0%

In November 2006 and June 2007, the RPD for duplicate samples from station 360 ranged from 0% to 2%. All data met the measurement quality objectives established in the Quality Assurance Project Plan (Marti, 2003b).

A review of the data quality control and quality assurance from laboratory case narratives indicates 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. No data were rejected, and all results were 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) data management system: www.ecy.wa.gov/eim/index.htm. Search study ID, PALERMO.

Results

Depth-to-Groundwater

Depth-to-groundwater data measured in the piezometers in the Palermo neighborhood are listed in Table 4, along with calculated groundwater elevations and depth below the ground surface (bgs). Groundwater elevations and depth below ground surface are also shown in Figure 3. Historical depth-to-groundwater data, including data collected prior to the drain installation, are presented in Appendix B.

Table 4: Depth-to-Groundwater, Groundwater Elevations, and Groundwater Depth Below Ground Surface in Piezometers for November 2006 and June 2007 (measured in feet).

Piezometer	Inner PVC Elevation	Concrete/ Ground Elevation	November 2006			June 2007		
			Measured Depth to Groundwater[1]	Groundwater Elevation	Groundwater Depth Below Ground Surface	Measured Depth to Groundwater[1]	Groundwater Elevation	Groundwater Depth Below Ground Surface
Piezometers Influenced by the Subdrain System								
PZ-704	110.61	108.43	--	--	--	--	--	--
PZ-709	114.27	112.01	3.31	110.96	**-1.05**	3.66	110.61	**-1.40**
PZ-715	117.79	115.51	--	--	--	--	--	--
PZ-720	107.75	108.22	3.39	104.36	-3.86	4.22	103.53	-4.69
PZ-721	108.32	108.57	2.88	105.44	-3.13	3.36	104.96	-3.61
PZ-722	108.82	109.21	-0.43	109.25	**0.04**	-0.46	109.28	**0.07**
Piezometers Beyond the Influence of the Subdrain System								
PZ-719	107.13	107.37	2.51	104.62	-2.75	2.85	104.28	-3.09
PZ-723	106.34	106.80	2.33	104.01	-2.79	3.04	103.30	-3.50
PZ-724	106.45	106.88	1.08	105.37	-1.51	2.27	104.18	-2.70
PZ-725	108.22	108.58	2.25	105.97	-2.61	3.27	104.95	-3.63
PZ-726	105.39	105.61	2.60	102.79	-2.82	3.82	101.57	-4.04
PZ-728	105.27	105.84	2.40	102.87	-2.97	3.68	101.59	-4.25

[1] = Measured from top of PVC -- = Not measured

Bold = Did not meet performance criteria of lowering the water table to 3 feet below the ground surface.

Depth-to-groundwater ranged from 1.05 to 3.86 feet bgs in November and 1.40 to 4.69 feet in June, fluctuating about one foot or less. PZ-722 is the exception; the water depth was at the ground surface. As in the past, lowering of the water table to three feet bgs was not achieved in wells PZ-709 and PZ-722 in November and June. In November, water levels in PZ-719, PZ-723, PZ-724, PZ-725, PZ-726, and PZ-728 were also high, but these piezometers are located beyond the influence of the subdrain system.

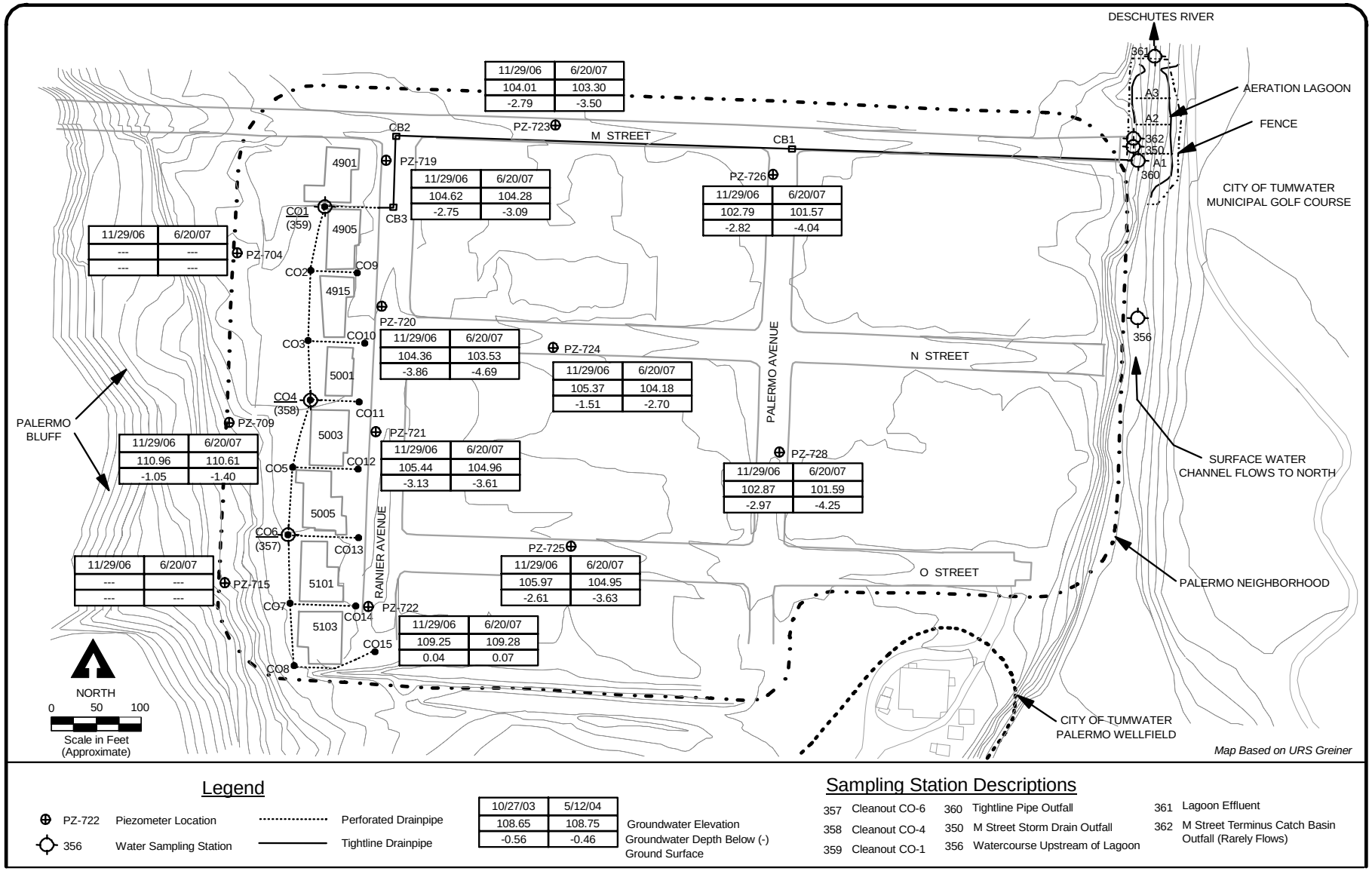


Figure 3	Palermo Wellfield Subdrain System and Treatment Lagoon Groundwater Depth

The remediation goal of reducing the groundwater elevation to three feet bgs for the residences along the west side of Rainier Avenue appears to have been met for the central and northern homes. Groundwater levels measured in piezometers near this portion of the subdrain ranged from three to about five feet bgs. In November and June, the water level was at ground surface in PZ-722, therefore it is assumed that the performance criterion was not met for the two most southern homes. Groundwater levels routinely continue to be the highest for these two homes.

Total Depth

In November 2006 and June 2007, total depth measurements were made in the cleanouts and catch basins. Depth measurements were recorded along three cross-sections of the treatment lagoon in June 2007. Total depths are measured to determine if sedimentation or erosion is occurring within the subdrain system. Previous total depth measurements for the cleanouts, catch basins, and lagoon are presented as tables and figures in Appendix C.

Table 5: Total Depth of Cleanouts and Catch Basins for November 2006 and June 2007 (feet).

Location	February 2001	November 2006		June 2007	
	Original Depth	Total Depth	Change from Original	Total Depth	Change from Original
CB-1	7.78	7.78	0.0	7.81	-0.03
CB-2	8.78	8.79	-0.01	8.78	0.0
CB-3	8.81	8.95	-0.14	8.95	-0.14
CO-1	7.82	7.83	-0.01	7.80	0.02
CO-2	7.1	7.12	-0.02	7.10	0.0
CO-3	6.84	6.83	0.01	6.83	0.01
CO-4	7.84	7.44	0.40	7.38	0.46
CO-5	7.84	7.19	0.65	7.60	0.24
CO-6	7.7	7.72	-0.02	7.70	0.0
CO-7	7.89	7.79	0.10	7.72	0.17
CO-8	8.1	7.87	0.23	7.66	0.44

As shown in Table 5, the average depths for the catch basins and cleanouts in November and June ranged from 6.83 to 8.95 feet. In the three catch basins, the total depth measurements were not significantly different (less than ±0.14 feet) from the original depths measured in February 2001.

From September 2004 through June 2006, total depth measurements indicated that sediment had accumulated in cleanouts CO-3 through CO-8 (Appendix C). In the fall of 2006, the City of Tumwater removed the sediment buildup in this portion of the trunk drain. In November 2006 and June 2007, total depths of five of the cleanouts (CO-1, CO-2, CO-3, CO-6, and CO-7) were ±0.17 feet from the original depths. Total depths measured in CO-4, CO-5, and CO-8 indicate that sediment is still present in these cleanouts. The average change in depths for this monitoring period were +0.43 feet in CO-4, +0.45 feet in CO-5, and +0.34 feet in CO-8. Each cleanout has a sump below where the trunk drain enters the cleanout (pipe invert). The sump depths in these cleanouts are approximately 0.8 feet.

Since construction, cleanout CO-4 has consistently been about +0.4 feet less than the original depth. This may suggest that sediment is still present in the sump or that the original depth measurement was not correct.

Due to the freezing weather conditions in November 2006, depth measurements for the lagoon were not collected. In June 2007, the lagoon depths were similar to the original depth measurements (February 2001) with a margin of error of ±0.5 feet (Appendix C). Many factors affect depth measurements, such as how the measuring tape is secured to the survey hubs which can cause slight variations in the reference elevation. Small changes in the placement of the survey rod can also affect the measured depth due to the steepness of the lagoon walls, the presence of riprap at the lagoon edges, and occasional cobbles on the lagoon bottom. Vegetation along the lagoon banks also makes it difficult to measure near the bank edges. Overall, it appears that no measurable sediment deposition or scouring of the lagoon has occurred.

Water Flow Rate

Water flow depth and velocity data were used to calculate flow rates at each sample station, as shown in Table 6. Flow rates measured since February 2001 are presented in Appendix D.

Table 6: Flow Rates (gallons per minute) for November 2006 and June 2007.

Sample Station	Location	November 2006	June 2007
Flow in Subdrain System Through Discharge to Deschutes River			
357	Cleanout CO-6	50	56
358	Cleanout CO-4	66	97
359	Cleanout CO-1	193	214
360	Tightline pipe outfall	137	127
361	Lagoon effluent	926	295
364	Lagoon watercourse discharge to Deschutes River	--	--
Inflows to Treatment Lagoon Other Than the Subdrain System			
350	M Street storm drain outfall	16	10
356	Watercourse flow upstream of M Street catch basin outfall	--	--
362		No Flow	No Flow

-- Not measured.

Flow rates from the south end of the trunk drain (station 357) to the north end (station 359) represent the cumulative groundwater inflow to the perforated pipe. In November 2006 and June 2007, flow rates in these stations increased from an average of 53 gallons per minute (gpm) at station 357 to 204 gpm at station 359.

Flow rates at station 360 (tightline pipe outfall), which represent the total flow of the subdrain system, did not compare well with flow rates from station 359 (northern end of the perforated pipe). Flow rates at station 360 were consistently lower, with an average flow of 132 gpm, as compared to an average flow of 204 gpm at station 359. This is probably the result of inaccurate velocity measurements. There was some difficulty completely submerging the velocity probe head in the shallow flow that drains from the pipe.

Flow rates from station 350 (M St. storm drain outfall) were 16 gpm in November and 10 gpm in June. As mentioned previously, the flow rate was not measurable at station 356 (upstream of lagoon), and station 362 had no flow. Flow rates were not measured at station 364.

In November, the flow rate at station 361 (lagoon outfall) was 926 gpm, and in June it was 296 gpm. The lagoon outfall continues to be covered by a thick mat of grass. Riprap at the lagoon outfall also makes it difficult to collect accurate depth and flow velocity measurements.

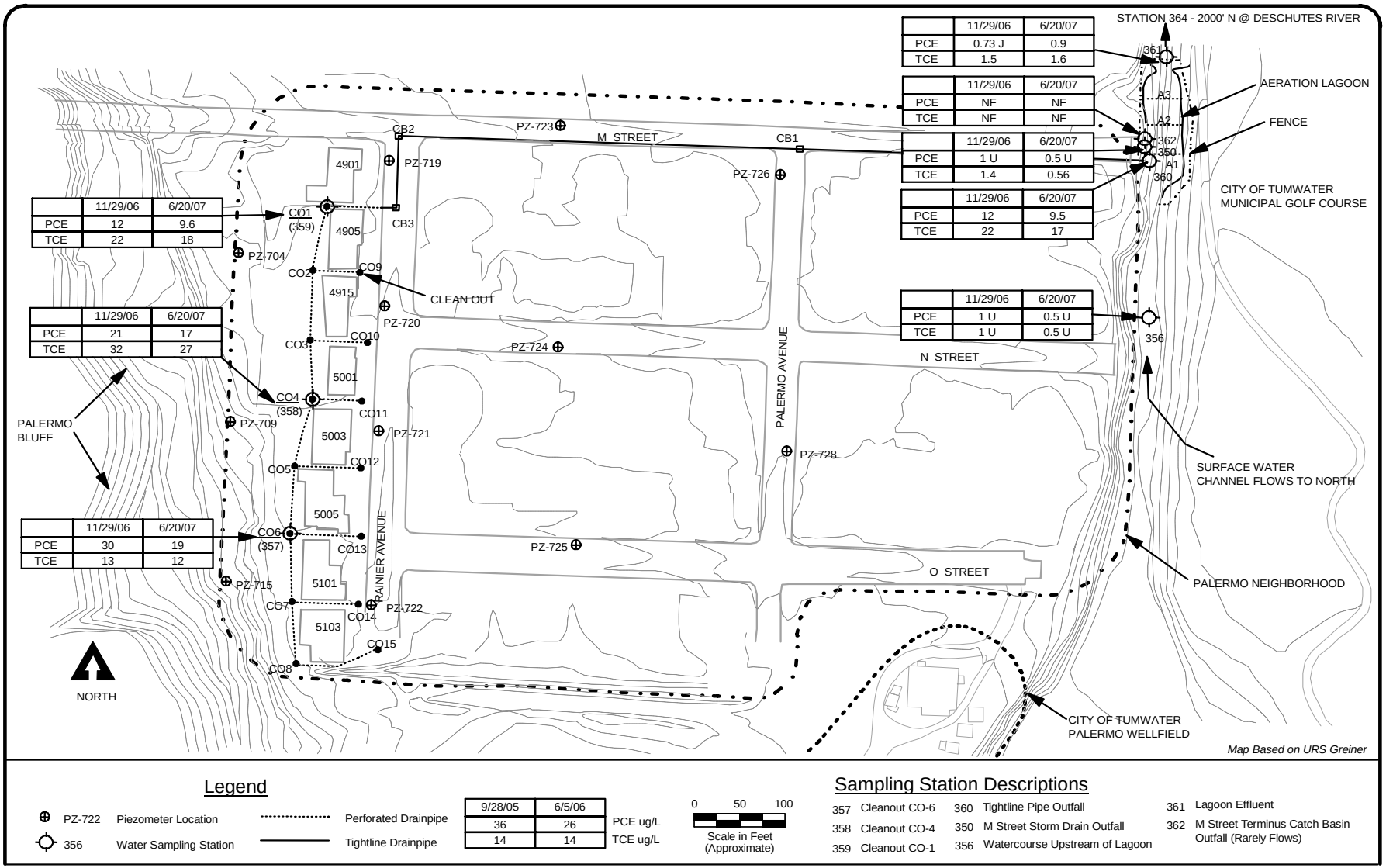
Water Quality

Analytical results for PCE, TCE, cis-1,2-DCE and vinyl chloride (VC) are summarized in Table 7. PCE and TCE results for November and June are shown in Figure 4. Figures 5 and 6 show PCE and TCE concentrations in samples collected from the subdrain system and the lagoon effluent since February 2001. PCE and TCE results for each station, as well as calculated flow rates, are presented in Appendix D.

Table 7: Summary of Target Analyte Results (µg/L) for November 2006 and June 2007.

Sample Station	November 2006				June 2007			
	PCE	TCE	Cis-1,2-DCE	VC	PCE	TCE	Cis-1,2-DCE	VC
Flow in Subdrain System – South to North								
357	30	13	1 U	1 U	19	12	1 U	1 U
358	21	32	1 U	1 U	17	27	1 U	1 U
359	12	22	1 U	1 U	9.6	18	1 U	1 U
360	12	22	1 U	1 U	9.5	17	1 U	1 U
361	0.73 J	1.5	1 U	1 U	0.9	1.6	1 U	1 U
Inflows to Treatment Lagoon Other Than the Subdrain System								
350	1 U	1.4	1 U	1 U	0.5 U	0.56	1 U	1 U
356	1 U	1 U	1 U	1 U	0.5 U	0.5 U	1 U	1 U
362	NF	NF	NF	NF	NF	NF	NF	NF
Lagoon Watercourse Discharge to Deschutes River								
364	0.59 J	1.2	1 U	1 U	0.46 J	0.62	1 U	1 U
Remediation Goals	0.8	2.7	--	--	0.8	2.7	--	--

U : Analyte was not detected at or above the reported value.
J : Analyte was positively identified. The associated numerical result is an estimate.
NF: No Flow.



	11/29/06	6/20/07
PCE	12	9.6
TCE	22	18

	11/29/06	6/20/07
PCE	21	17
TCE	32	27

	11/29/06	6/20/07
PCE	30	19
TCE	13	12

	11/29/06	6/20/07
PCE	0.73 J	0.9
TCE	1.5	1.6

	11/29/06	6/20/07
PCE	NF	NF
TCE	NF	NF

	11/29/06	6/20/07
PCE	1 U	0.5 U
TCE	1.4	0.56

	11/29/06	6/20/07
PCE	12	9.5
TCE	22	17

	11/29/06	6/20/07
PCE	1 U	0.5 U
TCE	1 U	0.5 U

Legend

PZ-722 Piezometer Location

356 Water Sampling Station

Perforated Drainpipe

Tightline Drainpipe

9/28/05	6/5/06	
36	26	PCE ug/L
14	14	TCE ug/L

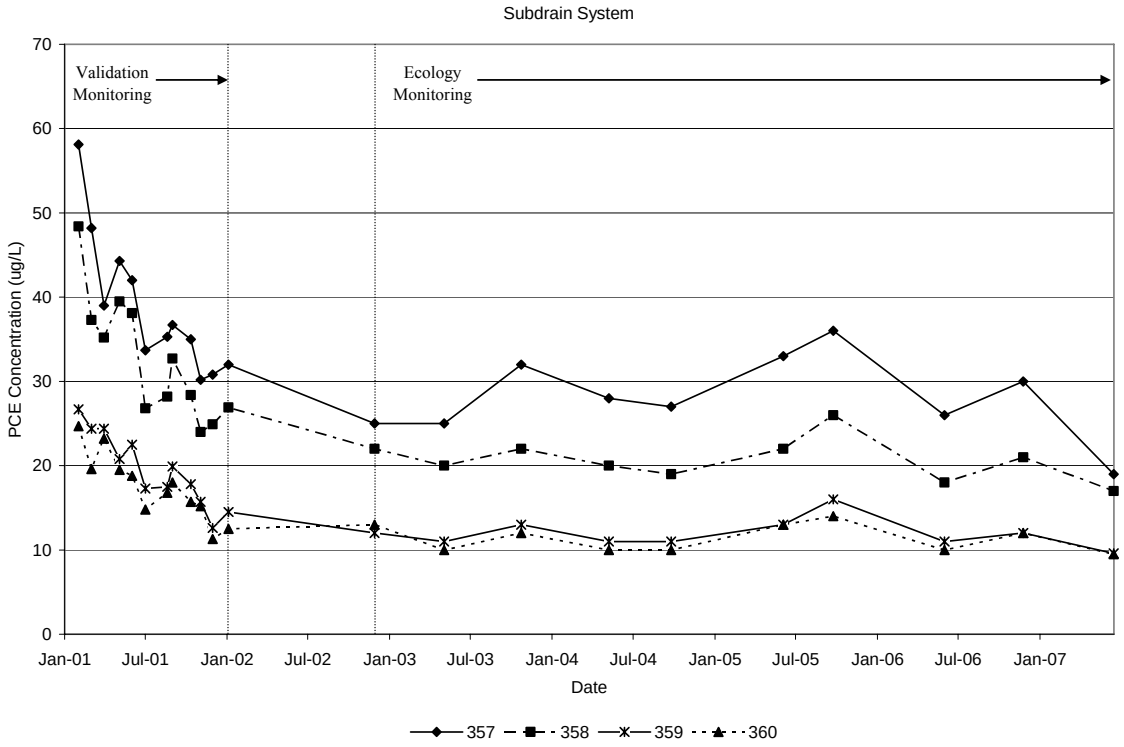
0 50 100

Scale in Feet (Approximate)

Sampling Station Descriptions

357 Cleanout CO-6
358 Cleanout CO-4
359 Cleanout CO-1
360 Tightline Pipe Outfall
350 M Street Storm Drain Outfall
356 Watercourse Upstream of Lagoon
361 Lagoon Effluent
362 M Street Terminus Catch Basin Outfall (Rarely Flows)

Figure 4 | Palermo Wellfield Subdrain System and Treatment Lagoon PCE/TCE Concentrations



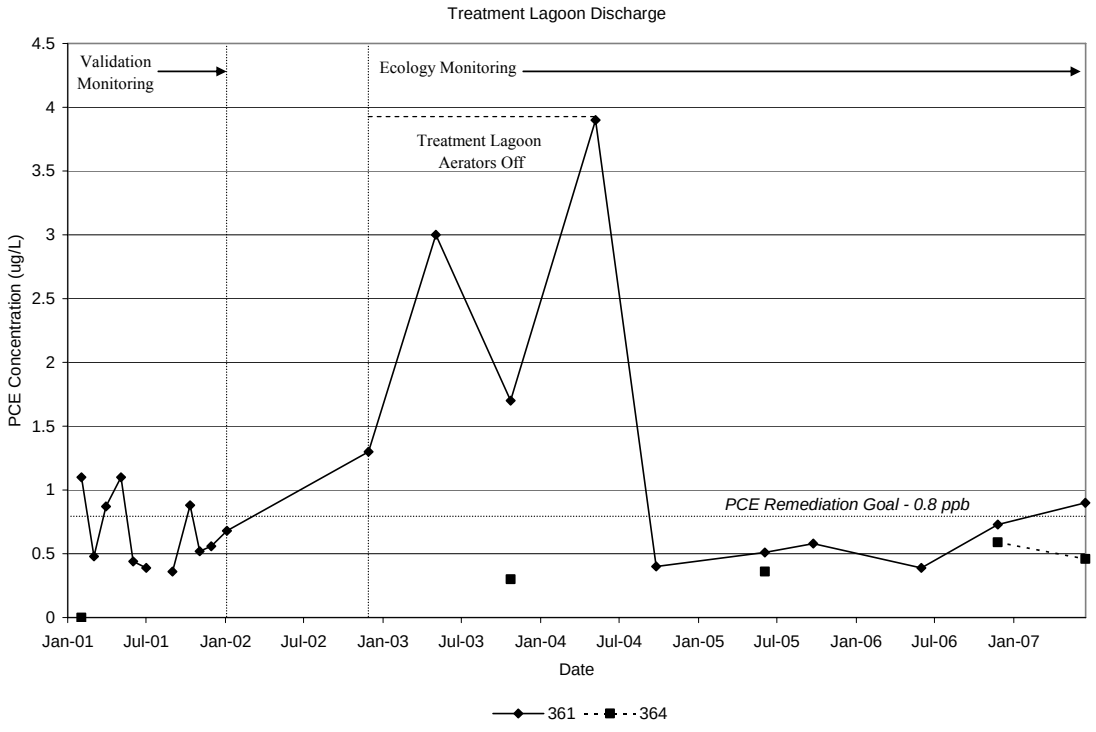


Figure 5: PCE Concentrations (µg/L) for Palermo Subdrain System and Treatment Lagoon, February 2001 through June 2007.

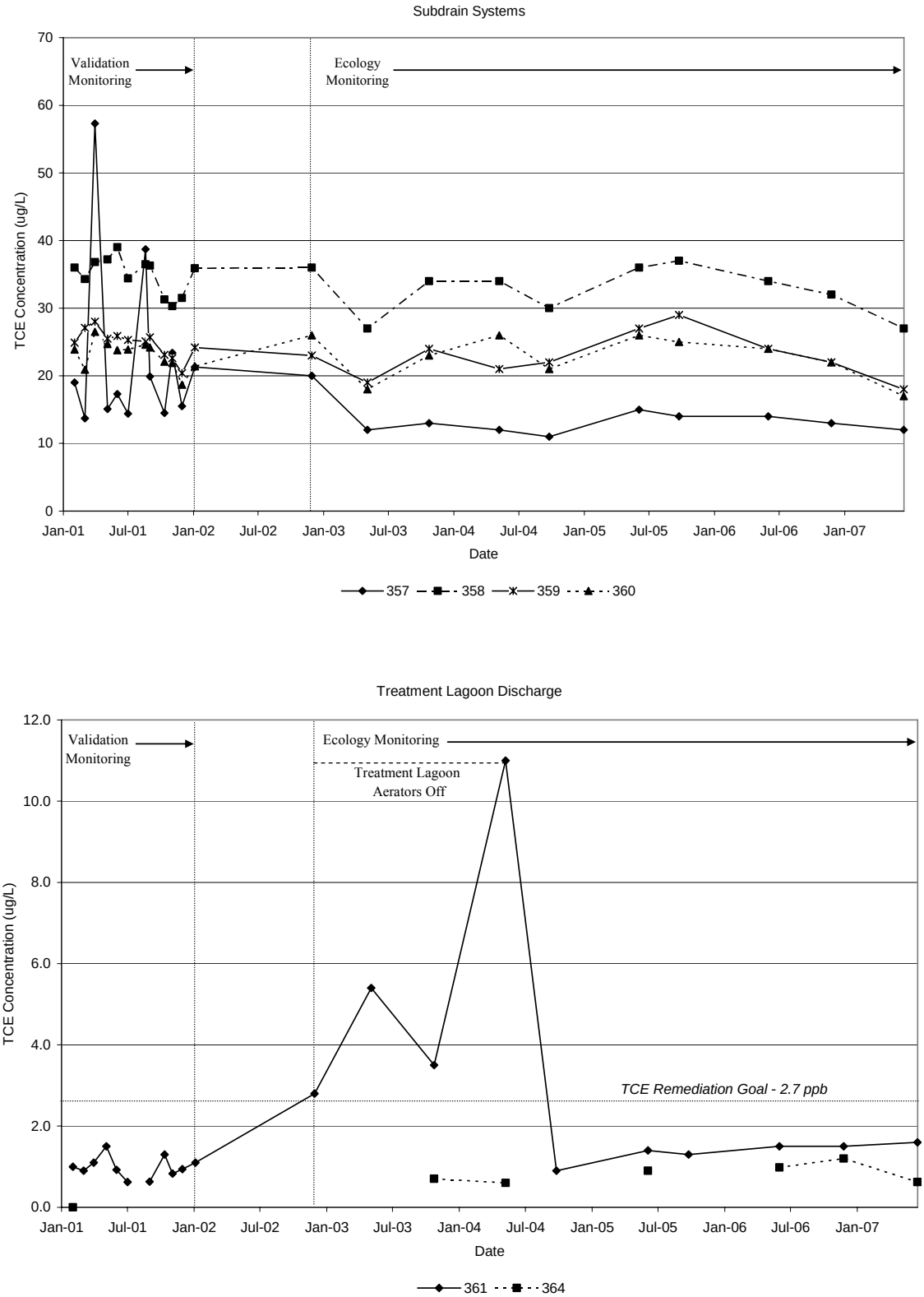


Figure 6: TCE Concentrations (µg/L) for Palermo Subdrain System and Treatment Lagoon, February 2001 through June 2007.

PCE and TCE concentrations continue to be highest in groundwater samples from stations 357 and 358, located in the mapped area of the shallow groundwater plume. Average PCE concentrations for November 2006 and June 2007 were 25 µg/L at station 357 and 19 µg/L at station 358. TCE concentrations varied more during the same two monitoring periods, with average concentrations of 13 µg/L at station 357, increasing to an average concentration of 30 µg/L at station 358. TCE concentrations continue to be higher in samples from station 358, at the center of the trunk drain. PCE and TCE concentrations decreased at station 359 as less contaminated groundwater was collected at the northern end of the perforated pipe, with average concentrations of 11 µg/L and 20 µg/L, respectively.

PCE and TCE concentrations at stations 359 (CO-1) and 360 (tightline pipe outfall) were similar, with average concentrations for both stations during this 2006-07 monitoring period of 11 µg/L for PCE and 20 µg/L for TCE. The similar concentration implies that little contaminant loss or degradation occurs within the tightline pipe, and that there is no substantial loss or gain of water between the connection with the drain pipe and the outfall.

Two of the three remaining stations that contribute flow to the treatment lagoon were sampled during November 2006 and June 2007. PCE and TCE were not detected at station 356, upstream of the lagoon. TCE was detected at station 350 (M St. storm drain outfall) at concentrations near the practical quantitation limits of 1 µg/L in November and 0.5 µg/L in June. Station 362 (M St. terminus catch basin outfall) was not sampled because there was no flowing water.

PCE and TCE concentrations in samples from station 361 (lagoon effluent) during November 2006 and June 2007 averaged 0.82 µg/L for PCE and 1.6 µg/L for TCE. Concentrations at the lagoon outfall were near the remediation goal of 0.8 µg/L for PCE and below the remediation goal of 2.7 µg/L for TCE for water discharging to the Deschutes River. Samples from station 361 (lagoon effluent) collected between December 2002 and May 2004, as shown in Figures 5 and 6, were collected while the treatment lagoon aerators were turned off. PCE and TCE results for this period are higher than during the 2001-2002 validation monitoring.

Station 364 was added to the monitoring network in 2003 to allow a true comparison to the remediation goals. This station is located where the treated water discharges to the Deschutes River, approximately 2,000 feet downstream from the lagoon. PCE and TCE were detected at this station in November and June, with average concentrations of 0.53 J µg/L and 0.91 µg/L, respectively. PCE and TCE concentrations at station 364 were below the remediation goals.

Based on the lagoon effluent concentrations for PCE and TCE, the lagoon achieved a contaminant reduction of about 94% in November 2006 and 91% in June 2007, as shown in Appendix E. The calculated residence time of the water in the lagoon was about two hours in November and six hours in June.

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Conclusions

- Reduction of groundwater elevations to three feet below the ground surface was met for the central and northern homes along the west side of Rainier Avenue. Groundwater measured in piezometers near this portion of the trunk drain ranged from at least three to five feet below ground.
- Reduction of groundwater elevations to three feet below ground surface was not met for the two most southern homes along the west side of Rainier Avenue. In November 2006 and June 2007, the water levels in PZ-722 were at the ground surface. Groundwater levels routinely continue to be the highest at these two homes.
- Total depths measured in most of the cleanouts were close to the original depths measured in February 2001. Cleaning performed by the City of Tumwater in the fall of 2006 appears to have successfully removed most of the sediments accumulated in trunk drain cleanouts CO-3 through CO-8. Total depths measured in CO-4, CO-5, and CO-8 indicate that some sediment is still present in these cleanouts which are located at the central part and southern end of the perforated pipe.
- Total depths measured in the catch basins and lagoon were not significantly different from the original depths measured in February 2001.
- PCE and TCE were detected in samples collected from station 364, where the treatment lagoon watercourse enters the Deschutes River (approximately 2,000 feet downstream from the lagoon). PCE and TCE concentrations were below the remediation goals set for both PCE (0.8 µg/L) and TCE (2.7 µg/L) for surface water that discharges to the Deschutes River.
- Reduction in contaminant concentrations after the treatment lagoon was about 94% in November 2006 and 91% in June 2007.

Recommendations

- Access to piezometers PZ-704, PZ-709, and PZ-715, which are located on the wooded Palermo bluff, is becoming more difficult because of thick vegetation. Access needs to be reestablished if these piezometers are to be used in the future.
- Because of past sediment accumulation in the perforated pipe, total depths of cleanouts CO-3, CO-4, CO-5, CO-6, CO-7 and CO-8 should continue to be closely monitored to ensure that the subdrain system continues to operate within the parameters established during the 2001 validation monitoring.
- The west survey marker for cross-section A3 at the north end of the lagoon is gone. This needs to be replaced so that accurate depth measurements can be recorded.
- The central aerator has sunk to the bottom of the lagoon. The aerator needs to be recovered and put back into operation.

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Appendix A. Subdrain System Operating Parameters

Table A-1: System Operating Parameters as Established During Validation Monitoring, February 2001 to April 2002.

Parameter	Representative Value	Comments
Flow rate from drain to lagoon	110 to 215 gpm	Average of 158 gpm; some low seasonal variation.
Flow rate in watercourse through lagoon	130 to 1470 gpm	High seasonal variation.
Chemicals of concern in water from drain to lagoon	PCE: 11.3 to 24.7 µg/L TCE: 18.7 to 26.5 µg/L	Overall decrease over performance validation period.
Chemicals of concern in water leaving lagoon	PCE: 0.5U to 1.1 µg/L TCE: 0.5U to 1.5 µg/L	With at least two aerators running.
Influence of drain on groundwater	Predicted: 3 feet of drawdown 35 feet away. Actual: 0.5 to 5.5 feet of drawdown, influence at 150 to 250 feet.	"Influence" refers to downgradient of drain. Actual is greater than predicted; however, near southern end of drain, effect is small (less than 1 foot of drawdown).

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Appendix B. Groundwater Elevation Data

Table B-1: Groundwater Elevation Changes Over Time, December 1999 through June 2007.

Date	PZ-704			PZ-709			PZ-715		
	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year
12/20/99	107.15	--	--	111.60	--	--	114.79	--	--
1/31/00	107.49	0.34	--	111.83	0.23	--	114.70	-0.09	--
2/23/00	103.89	-3.60	--	111.75	-0.08	--	114.19	-0.51	--
3/28/00	107.20	3.31	--	111.82	0.07	--	114.54	0.35	--
5/9/00	107.38	0.18	--	111.77	-0.05	--	114.42	-0.12	--
5/26/00	107.07	-0.31	--	111.75	-0.02	--	114.44	0.02	--
6/22/00	106.81	-0.26	--	111.61	-0.14	--	113.90	-0.54	--
7/26/00	106.61	-0.20	--	111.30	-0.31	--	113.90	0.00	--
8/21/00	106.28	-0.33	--	111.02	-0.28	--	112.66	-1.24	--
10/2/00	106.21	-0.07	--	111.03	0.01	--	112.17	-0.49	--
11/21/00	102.61	-3.60	--	111.10	0.07	--	112.75	0.58	--
2/7/01	104.26	1.65	0.37	110.99	-0.11	-0.76	111.85	-0.90	-2.34
3/6/01	104.21	-0.05	-2.99	110.96	-0.03	-0.86	112.52	0.67	-2.02
4/3/01	104.30	0.09	-3.08	110.95	-0.01	-0.82	112.23	-0.29	-2.19
5/8/01	104.21	-0.09	-2.86	111.01	0.06	-0.74	112.01	-0.22	-2.43
6/6/01	104.11	-0.10	-2.70	110.33	-0.68	-1.28	111.82	-0.19	-2.08
7/5/01	103.86	-0.25	-2.75	110.23	-0.10	-1.07	111.40	-0.42	-2.50
8/24/01	103.92	0.06	-2.36	110.64	0.41	-0.38	111.07	-0.33	-1.59
9/4/01	103.73	-0.19	-2.48	110.24	-0.40	-0.79	110.58	-0.49	-1.59
10/17/01	103.86	0.13	-2.35	109.70	-0.54	-1.40	110.89	0.31	-1.28
11/6/01	103.56	-0.30	0.95	109.97	0.27	-1.13	110.95	0.06	-1.80
12/5/01	104.99	1.43	2.38	111.10	1.13	0.00	112.03	1.08	-0.72
1/8/02	105.44	0.45	1.18	111.00	-0.10	0.01	112.43	0.40	0.58
2/7/02	105.06	-0.38	0.80	111.05	0.05	0.06	112.18	-0.25	0.33
3/7/02	104.87	-0.19	0.66	111.04	-0.01	0.08	112.35	0.17	-0.17
4/1/02	104.97	0.10	0.67	111.07	0.03	0.12	112.28	-0.07	0.05
12/3/02	104.46	-0.51	-0.53	109.46	-1.61	-1.64	111.91	-0.37	-0.12
5/7/03	104.77	0.31	-0.20	109.87	0.41	-1.20	112.14	0.23	-0.14
10/27/03	104.74	-0.03	0.28	110.58	0.71	1.12	111.92	-0.22	0.01
5/12/04	104.93	0.19	0.16	NM	--	--	112.07	0.15	-0.07
9/29/04	104.54	-0.39	-0.20	109.87	--	-0.71	111.74	-0.33	-0.18
6/8/05	NM	--	--	NM	--	--	112.08	0.34	0.01
9/27/05	104.44	--	-0.10	NM	--	--	111.46	-0.62	-0.28
6/5/06	105.38	0.94	--	110.86	--	--	NM	--	--
11/29/06	NM	--	--	110.96	0.10	--	NM	--	--
6/20/07	NM	--	--	110.61	-0.35	-0.25	NM	--	--
Average:	105.07	0.65	--	110.88	0.28	--	112.50	0.38	--
Maximum:	107.49	--	--	111.83	--	--	114.79	--	--
3' BGS Elev.	105.43	--	--	109.01	--	--	112.51	--	--

Table B-1: Continued.

Date	PZ-719			PZ-720			PZ-721		
	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year
12/20/99	103.90	--	--	106.59	--	--	107.37	--	--
1/31/00	104.85	0.95	--	106.45	-0.14	--	107.36	-0.01	--
2/23/00	104.88	0.03	--	106.50	0.05	--	107.32	-0.04	--
3/28/00	104.92	0.04	--	106.49	-0.01	--	107.33	0.01	--
5/9/00	104.93	0.01	--	106.57	0.08	--	107.44	0.11	--
5/26/00	104.82	-0.11	--	106.48	-0.09	--	107.22	-0.22	--
6/22/00	104.57	-0.25	--	106.60	0.12	--	106.94	-0.28	--
7/26/00	104.31	-0.26	--	105.89	-0.71	--	106.83	-0.11	--
8/21/00	103.73	-0.58	--	105.38	-0.51	--	106.19	-0.64	--
10/2/00	103.33	-0.40	--	105.41	0.03	--	105.77	-0.42	--
11/21/00	<97	--	--	<97	--	--	NM	--	--
2/7/01	103.50	--	-1.38	103.73	--	-2.77	104.26	--	-3.06
3/6/01	103.19	-0.31	-1.73	102.65	-1.08	-3.84	103.94	-0.32	-3.39
4/3/01	103.48	0.29	-1.45	102.73	0.08	-3.84	104.32	0.38	-3.12
5/8/01	103.65	0.17	-1.17	102.91	0.18	-3.57	104.43	0.11	-2.79
6/6/01	103.58	-0.07	-0.99	102.81	-0.10	-3.79	104.05	-0.38	-2.89
7/5/01	102.78	-0.80	-1.53	102.42	-0.39	-3.47	103.61	-0.44	-3.22
8/24/01	103.47	0.69	-0.26	102.61	0.19	-2.77	103.80	0.19	-2.39
9/4/01	102.62	-0.85	-0.71	102.38	-0.23	-3.03	103.45	-0.35	-2.32
10/17/01	102.99	0.37	-0.34	102.52	0.14	-2.89	103.72	0.27	-2.05
11/6/01	103.49	0.50	--	102.68	0.16	--	104.15	0.43	--
12/5/01	104.65	1.16	1.32	103.24	0.56	-2.17	104.98	0.83	-0.79
1/8/02	105.02	0.37	1.52	103.85	0.61	0.12	105.44	0.46	1.18
2/7/02	104.32	-0.70	0.82	103.12	-0.73	-0.61	104.92	-0.52	0.66
3/7/02	104.12	-0.20	0.93	103.07	-0.05	0.42	104.74	-0.18	0.80
4/1/02	104.21	0.09	0.73	103.12	0.05	0.39	104.85	0.11	0.53
12/3/02	103.76	-0.45	-0.89	102.91	-0.21	-0.33	104.60	-0.25	-0.38
5/7/03	104.04	0.28	-0.17	103.05	0.14	-0.07	104.60	0.00	-0.25
10/27/03	104.19	0.15	0.43	103.19	0.14	0.28	104.72	0.12	0.12
5/12/04	104.28	0.09	0.24	103.26	0.07	0.21	104.67	-0.05	0.07
9/29/04	103.75	-0.53	-0.44	103.00	-0.26	-0.19	104.28	-0.39	-0.44
6/8/05	104.23	0.48	-0.05	--	--	--	104.59	0.31	-0.08
9/27/05	103.59	-0.64	-0.16	102.95	--	-0.05	104.17	-0.42	-0.11
6/5/06	104.42	0.83	0.19	--	--	--	105.04	0.87	0.45
11/29/06	104.62	0.20	1.03	104.36	--	1.41	105.44	0.40	1.27
6/20/07	104.28	-0.34	-0.14	103.53	-0.83	--	104.96	-0.48	-0.08
Average:	104.01	0.40	--	104.01	0.27	--	105.19	0.31	--
Maximum:	105.02	--	--	106.60	--	--	107.44	--	--
3' BGS Elev.	104.37	--	--	105.22	--	--	105.57	--	--

Table B-1: Continued.

Date	PZ-722			PZ-723			PZ-724		
	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year
12/20/99	109.91	--	--	99.47	--	--		--	--
1/31/00	109.87	-0.04	--	103.57	4.10	--	104.89	--	--
2/23/00	110.06	0.19	--	103.71	0.14	--	104.85	-0.04	--
3/28/00	110.08	0.02	--	103.65	-0.06	--	105.01	0.16	--
5/9/00	110.10	0.02	--	103.89	0.24	--	105.01	0.00	--
5/26/00	109.97	-0.13	--	104.52	0.63	--	104.73	-0.28	--
6/22/00	109.88	-0.09	--	103.36	-1.16	--	104.50	-0.23	--
7/26/00	109.65	-0.23	--	103.01	-0.35	--	104.02	-0.48	--
8/21/00	109.43	-0.22	--	101.82	-1.19	--	102.63	-1.39	--
10/2/00	108.42	-1.01	--	100.85	-0.97	--	101.66	-0.97	--
11/21/00	109.47	1.05	--	102.85	2.00	--	104.06	2.40	--
2/7/01	108.42	-1.05	-1.64	102.89	0.04	-0.82	103.31	-0.75	-1.54
3/6/01	108.12	-0.30	-1.96	102.62	-0.27	-1.03	103.17	-0.14	-1.84
4/3/01	108.47	0.35	-1.63	102.91	0.29	-0.98	103.46	0.29	-1.55
5/8/01	107.88	-0.59	-2.09	102.91	0.00	-1.61	103.57	0.11	-1.16
6/6/01	108.52	0.64	-1.36	102.42	-0.49	-0.94	103.10	-0.47	-1.40
7/5/01	108.73	0.21	-0.92	101.60	-0.82	-1.41	102.14	-0.96	-1.88
8/24/01	107.65	-1.08	-1.78	102.70	1.10	0.88	102.36	0.22	-0.27
9/4/01	107.24	-0.41	-1.18	101.69	-1.01	0.84	NM	--	--
10/17/01	107.64	0.40	-0.78	101.97	0.28	1.12	NM	--	--
11/6/01	108.18	0.54	-1.29	102.68	0.71	-0.17	NM	--	--
12/5/01	109.00	0.82	-0.47	104.26	1.58	1.41	NM	--	--
1/8/02	109.49	0.49	1.07	105.24	0.98	2.35	105.97	--	2.66
2/7/02	109.14	-0.35	0.72	103.71	-1.53	0.82	104.43	-1.54	1.12
3/7/02	109.03	-0.11	0.91	103.36	-0.35	0.74	104.20	-0.23	1.03
4/1/02	109.32	0.29	0.85	103.44	0.08	0.53	104.31	0.11	0.85
12/3/02	108.67	-0.65	-0.33	102.84	-0.60	-1.42	104.07	-0.24	--
5/7/03	108.67	0.00	-0.65	103.02	0.18	-0.42	103.77	-0.30	-0.54
10/27/03	108.65	-0.02	-0.02	103.48	0.46	0.64	104.53	0.76	0.46
5/12/04	108.75	0.10	0.08	103.38	-0.10	0.36	104.21	-0.32	0.44
9/29/04	108.48	-0.27	-0.17	99.72	-3.66	-3.76	103.37	-0.84	-1.16
6/8/05	108.76	0.28	0.01	99.71	-0.01	-3.67	104.17	0.80	-0.04
9/27/05	108.61	-0.15	0.13	102.52	2.81	2.80	103.27	-0.90	-0.10
6/5/06	108.80	0.19	0.04	99.98	-2.54	0.27	104.44	1.17	0.27
11/29/06	109.25	0.45	0.64	104.01	4.03	1.49	105.37	0.93	2.10
6/20/07	109.28	0.03	0.48	103.30	-0.71	3.32	104.18	-1.19	-0.26
Average:	108.93	0.36	--	102.70	1.01	--	103.96	0.63	--
Maximum:	110.10	--	--	105.24	--	--	105.97	--	--
3' BGS Elev.	106.21	--	--	103.8	--	--	103.88	--	--

Table B-1: Continued.

Date	PZ-725			PZ-726			PZ-728		
	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year
12/20/99	105.79	--	--	98.30	--	--	98.49	--	--
1/31/00	105.45	-0.34	--	101.59	3.29	--	101.72	3.23	--
2/23/00	100.99	-4.46	--	101.52	-0.07	--	98.56	-3.16	--
3/28/00	105.56	4.57	--	101.79	0.27	--	101.86	3.30	--
5/9/00	105.32	-0.24	--	101.64	-0.15	--	101.49	-0.37	--
5/26/00	105.20	-0.12	--	101.47	-0.17	--	101.96	0.47	--
6/22/00	105.00	-0.20	--	101.35	-0.12	--	101.14	-0.82	--
7/26/00	--	--	--	100.83	-0.52	--	100.54	-0.60	--
8/21/00	103.17	-1.83	--	100.76	-0.07	--	97.68	-2.86	--
10/2/00	102.81	-0.36	--	98.35	-2.41	--	97.23	-0.45	--
11/21/00	105.30	2.49	--	100.99	2.64	--	101.63	4.40	--
2/7/01	104.22	-1.08	3.23	100.74	-0.25	-0.78	100.26	-1.37	1.70
3/6/01	104.08	-0.14	-1.48	100.55	-0.19	-1.24	100.00	-0.26	-1.86
4/3/01	NM	--	--	100.85	0.30	-0.79	100.74	0.74	-0.75
5/8/01	104.68	--	-0.52	100.88	0.03	-0.59	100.87	0.13	-1.09
6/6/01	104.34	-0.34	-0.66	100.03	-0.85	-1.32	100.31	-0.56	-0.83
7/5/01	103.26	-1.08	--	97.76	-2.27	-3.07	98.90	-1.41	-1.64
8/24/01	103.19	-0.07	0.02	100.07	2.31	-0.69	98.49	-0.41	0.81
9/4/01	102.68	-0.51	-0.13	98.64	-1.43	0.29	97.89	-0.60	0.66
10/17/01	103.44	0.76	0.63	100.81	2.17	2.46	99.10	1.21	1.87
11/6/01	104.13	0.69	-1.17	100.34	-0.47	-0.65	100.19	1.09	-1.44
12/5/01	106.13	2.00	0.83	102.72	2.38	1.73	102.84	2.65	1.21
1/8/02	106.36	0.23	2.14	103.33	0.61	2.59	103.04	0.20	2.78
2/7/02	105.31	-1.05	1.09	101.88	-1.45	1.14	101.49	-1.55	1.23
3/7/02	105.03	-0.28	0.95	101.37	-0.51	0.81	101.18	-0.31	1.18
4/1/02	105.19	0.16	0.97	101.52	0.15	0.67	101.49	0.31	0.75
12/3/02	105.47	0.28	-0.66	100.94	-0.58	-1.78	102.05	0.56	-0.79
5/7/03	104.72	-0.75	-0.47	100.70	-0.24	-0.81	100.52	-1.53	-0.97
10/27/03	105.31	0.59	-0.16	102.12	1.42	1.18	102.03	1.51	-0.02
5/12/04	NM	--	--	101.62	-0.50	0.92	101.60	-0.43	1.08
9/29/04	104.23	--	-1.08	100.70	-0.92	-1.42	100.66	-0.94	-1.37
6/8/05	104.89	0.66	--	100.53	-0.17	-1.09	101.42	0.76	-0.18
9/27/05	103.94	-0.95	-0.29	100.50	-0.03	-0.20	100.27	-1.15	-0.39
6/5/06	105.12	1.18	--	101.89	1.39	1.36	101.68	1.41	0.26
11/29/06	105.97	0.85	2.03	102.79	0.90	2.29	102.87	1.19	2.60
6/20/07	104.95	-1.02	-0.17	101.57	-1.22	-0.32	101.59	-1.28	-0.09
Average:	104.58	0.98	--	100.93	0.93	--	100.66	1.23	--
Maximum:	106.36	--	--	103.33	--	--	103.04	--	--
3' BGS Elev.	105.58	--	--	102.61	--	--	102.84	--	--

Notes for Table B-1:

2/7/2001 – Subdrain system completed, beginning of validation monitoring.
Average – Arithmetic mean of data in column for both groundwater elevation and change in elevation for piezometer.
Maximum – Maximum groundwater elevation recorded for each piezometer (shaded).
3' BGS Elev. – Elevation for groundwater to be 3 feet below ground surface to meet performance criterion.
GW Elev. – Elevation of groundwater in piezometer on date shown in feet above mean sea level.
Delta Month – Change in groundwater elevation since the last measurement (typically the previous month)
Delta Year – Change in groundwater elevation since the last measurement taken the same month the previous year.
NM – Depth-to-groundwater not measured at this location on this date.
-- No data available to perform calculation for this cell.
<97 – groundwater elevation was lower than the total depth of the well on this date (the well was dry).
The numerical value is the approximate elevation of the bottom of the well.

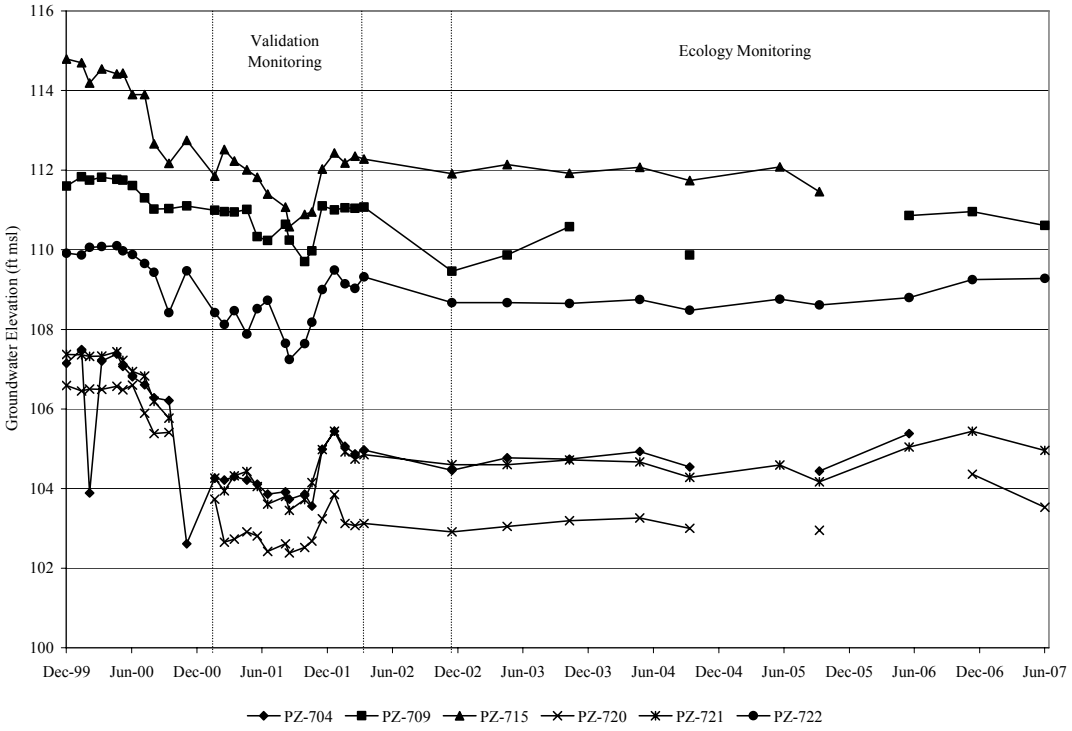


Figure B-1. Groundwater Elevations for Piezometers Influenced by the Subdrain System, December 1999 through June 2007.

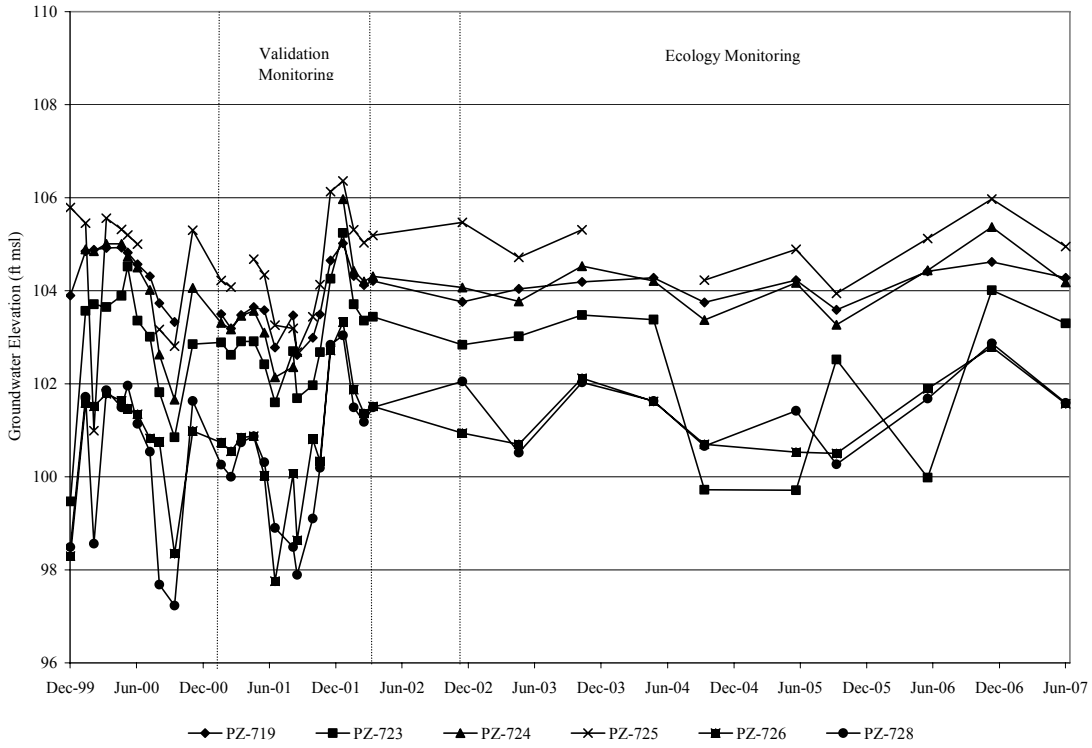


Figure B-2. Groundwater Elevations for Piezometers Beyond the Influence of the Subdrain System, December 1999 through June 2007.

Table B-2: Depth-to-Water and Water Elevations (feet) in Cleanouts from December 2002 through June 2007.

Cleanout	North Rim Elevation	Depth to Water	Water Elevation	Depth to Water	Water Elevation
		December 2002		May 2003	
CO-1	108.39	6.38	102.01	6.38	102.01
CO-2	108.04	--	--	5.95	102.09
CO-3	107.96	--	--	5.72	102.24
CO-4	108.73	6.42	102.31	6.22	102.51
CO-5	109.32	--	--	6.69	102.63
CO-6	109.78	6.59	103.19	6.58	103.20
CO-7	110.73	--	--	6.72	104.01
CO-8	110.96	--	--	6.85	104.11
		October 2003		May 2004	
CO-1	108.39	6.36	102.03	6.35	102.04
CO-2	108.04	5.91	102.13	5.91	102.13
CO-3	107.96	5.71	102.25	5.72	102.24
CO-4	108.73	6.22	102.51	6.21	102.52
CO-5	109.32	6.68	102.64	--	--
CO-6	109.78	6.55	103.23	6.58	103.20
CO-7	110.73	--	--	--	--
CO-8	110.96	6.85	104.11	6.85	104.11
		September 2004		June 2005	
CO-1	108.39	6.37	102.02	6.30	102.09
CO-2	108.04	5.95	102.09	5.90	102.14
CO-3	107.96	5.72	102.24	5.72	102.24
CO-4	108.73	6.22	102.51	6.19	102.54
CO-5	109.32	6.68	102.64	--	--
CO-6	109.78	6.59	103.19	6.58	103.20
CO-7	110.73	6.71	104.02	6.69	104.04
CO-8	110.96	--	--	6.76	104.20
		September 2005		June 2006	
CO-1	108.39	6.36	102.03	6.22	102.17
CO-2	108.04	5.94	102.10	5.75	102.29
CO-3	107.96	5.75	102.21	5.64	102.32
CO-4	108.73	6.21	102.52	6.23	102.50
CO-5	109.32	6.69	102.63	6.68	102.64
CO-6	109.78	6.60	103.18	6.62	103.16
CO-7	110.73	6.71	104.02	6.73	104.00
CO-8	110.96	6.77	104.19	6.76	104.20

-- not measured.

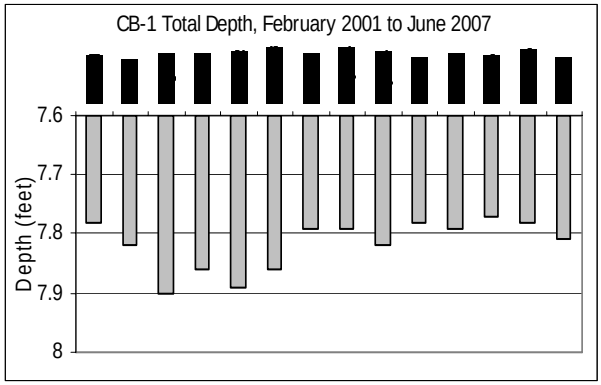
Table B-2 (continued): Depth-to-Water and Water Elevations (feet) in Cleanouts from December 2002 through June 2007.

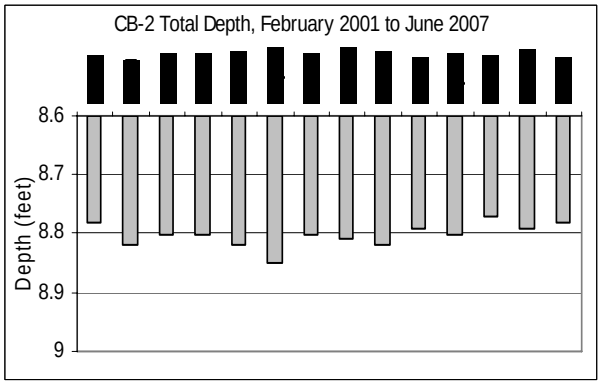
Cleanout	North Rim Elevation	Depth to Water	Water Elevation	Depth to Water	Water Elevation
		November 2006		June 2007	
CO-1	108.39	6.25	102.14	6.20	102.19
CO-2	108.04	5.76	102.28	5.71	102.33
CO-3	107.96	5.58	102.38	5.47	102.49
CO-4	108.73	6.22	102.51	6.18	102.55
CO-5	109.32	6.63	102.69	6.66	102.66
CO-6	109.78	6.65	103.13	6.60	103.18
CO-7	110.73	6.72	104.01	6.70	104.03
CO-8	110.96	6.75	104.21	6.71	104.25

Appendix C. Total Depth Data for Cleanouts, Catch Basins, and Treatment Lagoon

Table C-1: Total Depth (feet) of Catch Basins, February 2001 through June 2007.

Date	CB-1		CB-2		CB-3	
	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original
2/6/01	7.78	--	8.78	--	8.81	--
6/6/01	7.82	-0.04	8.82	-0.04	8.92	-0.11
8/24/01	7.9	-0.12	8.8	-0.02	8.96	-0.15
11/6/01	7.86	-0.08	8.8	-0.02	8.41	0.4
12/2/02	7.89	-0.11	8.82	-0.04	8.95	-0.14
5/7/03	7.86	-0.08	8.85	-0.07	8.93	-0.12
10/27/03	7.79	-0.01	8.80	-0.02	8.93	-0.12
5/12/04	7.79	-0.01	8.81	-0.03	8.93	-0.12
9/29/04	7.82	-0.04	8.82	-0.04	8.91	-0.1
6/8/05	7.78	0.0	8.79	-0.01	8.92	-0.11
9/28/05	7.79	-0.01	8.80	-0.02	8.91	-0.1
6/5/06	7.77	0.01	8.77	0.01	8.93	-0.12
11/29/06	7.78	0.0	8.79	-0.01	8.95	-0.14
6/20/07	7.81	-0.03	8.78	0.0	8.95	-0.14





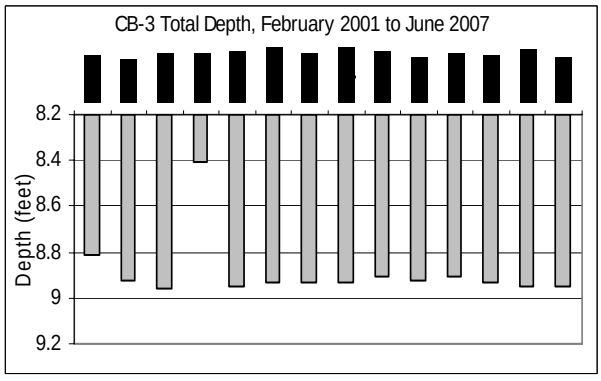


Figure C-1: Total Depth of Catch Basins, February 2001 through June 2007.

Table C-2: Total Depth (feet) of Cleanouts CO-1 to CO-4, February 2001 through June 2007.

Date	CO-1		CO-2		CO-3		CO-4	
	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original
2/6/01	7.82	--	7.1	--	6.84	--	7.84	--
6/6/01	7.82	0.00	7.24	-0.14	6.84	0.00	7.44	0.4
8/24/01	7.78	0.04	7.2	-0.1	6.6	0.24	7.41	0.43
11/6/01	7.79	0.03	7.19	-0.09	6.82	0.02	7.43	0.41
12/2/02	7.79	0.03	7.19	-0.09	6.84	0.00	7.42	0.42
5/7/03	7.87	-0.05	7.23	-0.13	6.82	0.02	7.46	0.38
10/27/03	7.81	0.01	7.21	-0.11	6.84	0	7.42	0.42
5/12/04	7.81	0.01	7.21	-0.11	6.82	0.02	7.43	0.41
9/29/04	7.79	0.03	7.20	-0.1	6.81	0.03	7.39	0.45
6/8/05	7.79	0.03	7.19	-0.09	6.83	0.01	7.37	0.47
9/28/05	7.81	0.01	7.21	-0.11	6.81	0.03	7.38	0.46
6/5/06	7.81	0.01	7.17	-0.07	6.14	0.7	6.71	1.13
11/29/06	7.83	-0.01	7.12	-0.02	6.83	0.01	7.44	0.40
6/20/07	7.8	0.02	7.1	0.0	6.83	0.01	7.38	0.46

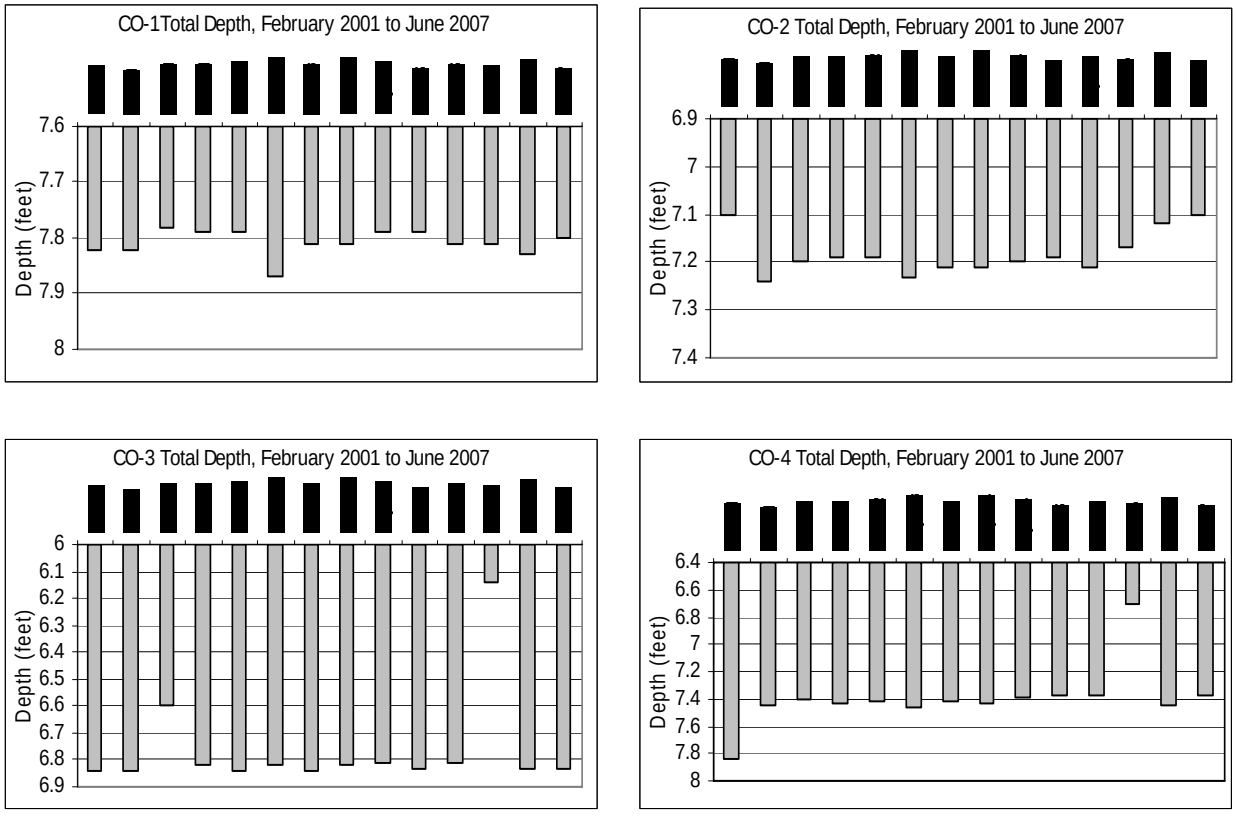


Figure C-2: Total Depth of Cleanouts CO-1 to CO-4, February 2001 through June 2007.

Table C-3: Total Depth (feet) of Cleanouts CO-5 to CO-8, February 2001 through June 2007.

Date	CO-5		CO-6		CO-7		CO-8	
	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original
2/6/01	7.84	--	7.7	--	7.89	--	8.1	--
6/6/01	7.84	0.00	7.72	-0.02	7.86	0.03	8.12	-0.02
8/24/01	7.83	0.01	7.65	0.05	7.82	0.07	8.0	0.1
11/6/01	7.81	0.03	7.65	0.05	7.76	0.13	7.99	0.11
12/2/02	7.83	0.01	7.69	0.01	7.76	0.13	8.0	0.1
5/7/03	7.85	-0.01	7.68	0.02	7.8	0.09	7.97	0.13
10/27/03	7.83	0.01	7.67	0.03	--	--	7.98	0.12
5/12/04	--	--	7.68	0.02	--	--	8.02	0.08
9/29/04	7.81	0.03	7.67	0.03	7.22	0.67	6.85	1.25
6/8/05	--	--	7.61	0.09	7.04	0.85	6.86	1.24
9/28/05	7.71	0.13	7.64	0.06	7.02	0.87	6.92	1.18
6/5/06	7.04	0.8	7.12	0.58	7.07	0.82	6.88	1.22
11/29/06	7.19	0.65	7.72	-0.02	7.79	0.10	7.87	0.23
6/20/07	7.6	0.24	7.7	0.0	7.72	0.17	7.66	0.44

-- not measured.

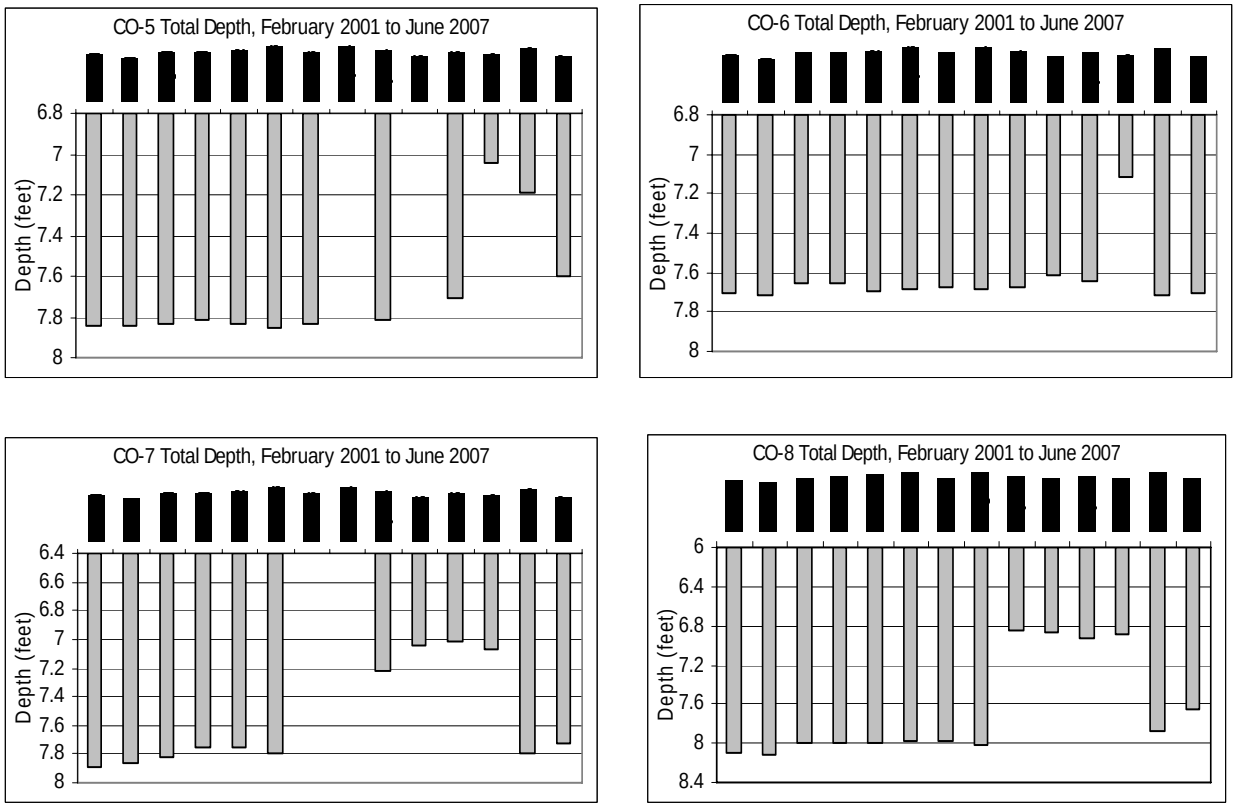
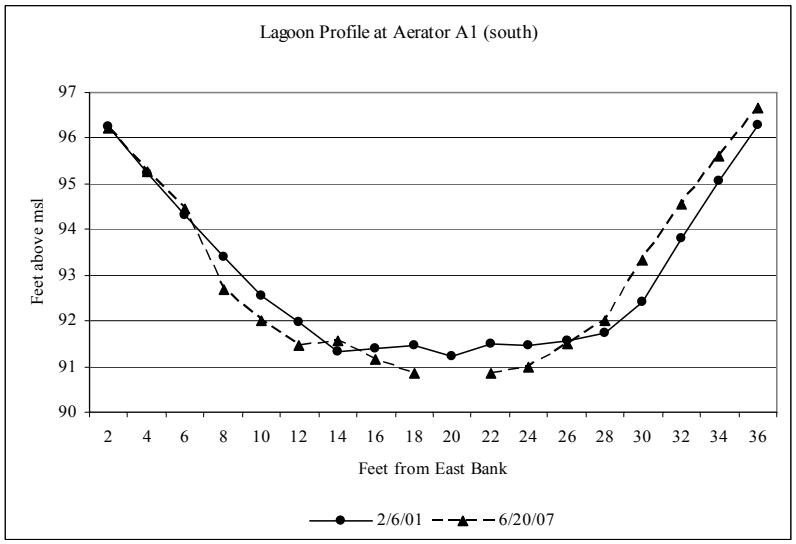


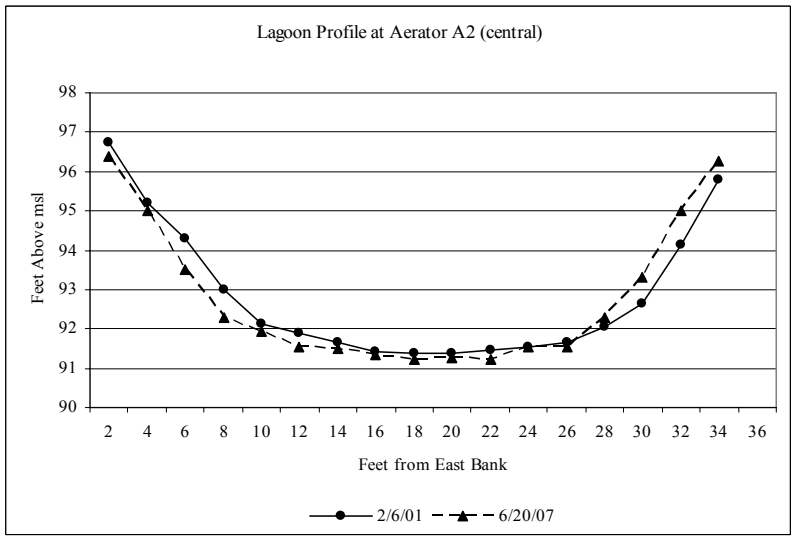
Figure C-3: Total Depth of Cleanouts CO-5 to CO-8, February 2001 through June 2007.

Table C-4: Treatment Lagoon Total Depth (feet), June 2007.

Feet From East Bank	Aerator A1 (south)			Aerator A2 (central)			Aerator A3 (north)		
	Depth Below Survey Elev.	Elev. Above Datum	Change from Original	Depth Below Survey Elev.	Elev. Above Datum	Change from Original	Depth Below Survey Elev.	Elev. Above Datum	Change from Original
2	2.78	96.22	-0.04	2.63	96.37	-0.37	2.72	96.28	0.02
4	3.73	95.27	0.05	3.98	95.02	-0.18	3.53	95.47	0.27
6	4.55	94.45	0.15	5.5	93.5	-0.8	5.15	93.85	0.37
8	6.32	92.68	-0.72	6.72	92.28	-0.7	6.78	92.22	0.08
10	7.0	92.0	-0.54	7.05	91.95	-0.17	7.84	91.16	-0.39
12	7.54	91.46	-0.52	7.47	91.53	-0.35	7.9	91.1	-0.28
14	7.42	91.58	0.24	7.51	91.49	-0.17	7.98	91.02	-0.36
16	7.85	91.15	-0.23	7.66	91.34	-0.06	--	--	--
18	8.14	90.86	-0.6	7.76	91.24	-0.14	8.27	90.73	-0.69
20	--	--	--	7.75	91.25	-0.11	7.6	91.4	-0.34
22	8.15	90.85	-0.63	7.78	91.22	-0.24	7.12	91.88	-0.16
24	8.02	90.98	-0.48	7.46	91.54	0.02	6.54	92.46	-0.52
26	7.5	91.5	-0.08	7.45	91.55	-0.11	4.6	94.4	-0.24
28	6.98	92.02	0.28	6.73	92.27	0.23	3.58	95.42	-0.36
30	5.66	93.34	0.94	5.68	93.32	0.68	2.85	96.15	
32	4.45	94.55	0.73	3.99	95.01	0.89			
34	3.4	95.6	0.52	2.74	96.26	0.46			
36	2.35	96.65	0.37						

-- not measured.





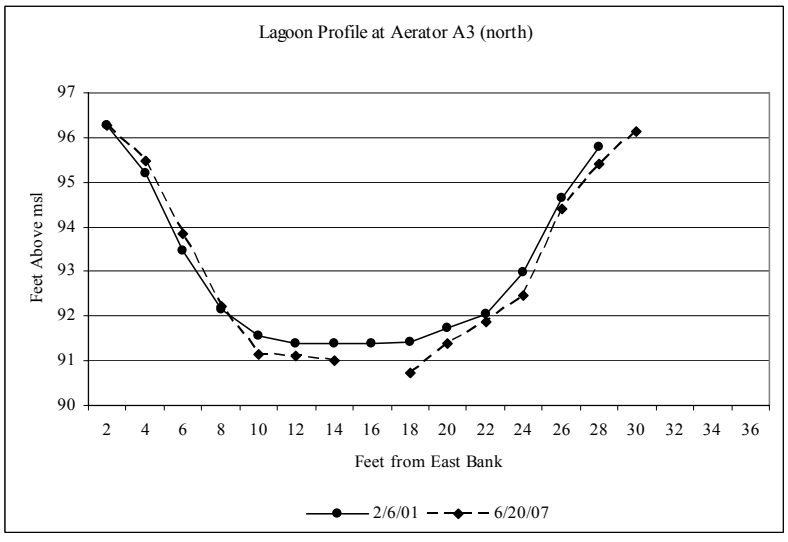


Figure C-4: Treatment Lagoon Total Depth for June 2007, Compared to Original Depth of February 2001. (msl = mean sea level.)

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Appendix D. PCE and TCE Concentrations with Flow Rates from February 2001 through June 2007

Table D-1. PCE and TCE Concentrations with Flow Rates from February 2001 to June 2007.

Sample		Sampling Month													
Station	COC	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02	Dec-02	May-03
350	PCE (ppb)	1.0 U	0.5 U	0.5 U	0.5 U	NF	NF	0.5 U	NF	NF	0.5 U	0.5 U	0.5 U	1 U	1 U
(M St. SD)	TCE (ppb)	1.0 U	0.5 U	0.5 U	0.5 U	NF	NF	0.5 U	NF	NF	0.5 U	1.5	1.7	0.76 J	0.44 NJ
	Flow (gpm)	2.6	1.3	1.6	0.04	0	0	126	0	0	Trace	39	72	5	11
356	PCE (ppb)	1.0 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.50 U	0.5 U	0.5 U	0.5 U	0.5 U	1 U	1 U
(Ustrm)	TCE (ppb)	1.0 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.38 J	0.5 U	0.5 U	0.5 U	0.5 U	2 U	1 U
	Flow (gpm)	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU
357	PCE (ppb)	58.1	48.2	39.0	44.3	42.0	33.7	35.3	36.7	35	30.2	30.8	32.0	25	25
(CO-6)	TCE (ppb)	19.0	13.7	57.3	15.1	17.3	14.4	38.7	19.9	14.5	23.4	15.5	21.3	20	12
	Flow (gpm)	91	38	58	61	71	52	112	46	86	71	72	71	75	76
358	PCE (ppb)	48.4	37.3	35.2	39.5	38.1	26.8	28.2	32.7	28.4	24.0	24.9	26.9	22	20
(CO-4)	TCE (ppb)	36	34.3	36.8	37.2	39.0	34.4	36.5	36.3	31.3	30.3	31.5	25.9	36	27
	Flow (gpm)	81	94	77	88	88	69	59	80	75	78	101	120	16	55
359	PCE (ppb)	26.7	24.4	24.4	20.8	22.5	17.3	17.5	19.9	17.8	15.7	12.6	14.5	12	11
(CO-1)	TCE (ppb)	24.9	27.1	28.0	25.5	25.9	25.3	25.1	25.7	23.1	22.6	20.4	24.2	23	19
	Flow (gpm)	157	118	135	150	135	114	121	111	137	111	169	118	176	170
360	PCE (ppb)	24.7	19.6	23.2	19.5	18.8	14.8	16.8	18	15.7	15.2	11.3	12.5	13	10
(TPO)	TCE (ppb)	23.9	20.9	26.5	24.7	23.8	23.9	24.6	24.2	22.1	21.9	18.7	21.4	26	18
	Flow (gpm)	142	154	154	154	109	129	166	195	161	161	160	213	81	101
361	PCE (ppb)	1.1	0.48	0.87	1.1	0.44	0.39 J	0.5 U	0.4	0.88	0.52	0.56	0.68	1.3	3
(LE)	TCE (ppb)	1.0	0.90	1.1	1.5	0.92	0.62	0.5 U	0.6	1.3	0.83	0.94	1.1	2.8	5.4
	Flow (gpm)[a]	0 (137)	505	0 (540)	159 (524)	FU	FU	FU (178)	FU (128)	FU (372)	FU (337)	859 (1,465)	668 (846)	364	166
362	PCE (ppb)	NF	NF	NF	NF	NF	NF	0.5 U	NF	NF	NF	0.5 U	NF	NF	NF
(MSt.CBO)	TCE (ppb)	NF	NF	NF	NF	NF	NF	0.5 U	NF	NF	NF	0.5 U	NF	NF	NF
	Flow (gpm)	NF	NF	NF	NF	NF	NF	Trace	0	0	NF	Trace	NF	NF	NF
364	PCE (ppb)														
Deschutes	TCE (ppb)														
	Flow (gpm)														

Table D-1 Continued.

Sample Station		Sampling Month							
	COC	Oct-03	May-04	Sep-04	Jun-05	Sep-05	Jun-06	Nov-06	Jun-07
350	PCE (ppb)	0.5 U	0.5 U	1 UJ	1 U	1 U	2 U	1 U	0.5 U
(M St. SD)	TCE (ppb)	0.61 NJ	0.78 NJ	1 UJ	0.63 J	1 U	0.97 J	1.4	0.56
	Flow (gpm)	28	32	4	20	NM	19	16	10
356	PCE (ppb)	0.5 U	0.5 U	1 UJ	1 U	1 U	2 U	1 U	0.5 U
(Ustrm)	TCE (ppb)	0.5 U	0.5 U	1 UJ	1 U	1 U	2 U	1 U	0.5 U
	Flow (gpm)	FU	FU	FU	FU	FU	FU	FU	FU
357	PCE (ppb)	32	28	27	33	36	26	30	19
(CO-6)	TCE (ppb)	13	12	11	15	14	14	13	12
	Flow (gpm)	81	71	60	30	72	39	50	56
358	PCE (ppb)	22	20	19	22	26	18	21	17
(CO-4)	TCE (ppb)	34	34	30	36	37	34	32	27
	Flow (gpm)	76	79	44	63	73	69	66	97
359	PCE (ppb)	13	11	11	13	16	11	12	9.6
(CO-1)	TCE (ppb)	24	21	22	27	29	24	22	18
	Flow (gpm)	197	201	161	189	164	166	193	214
360	PCE (ppb)	12	10	10 J	13	14	10	12	9.5
(TPO)	TCE (ppb)	23	26	21 J	26	25	24	22	17
	Flow (gpm)	111	121	78	87	97	107	137	127
361	PCE (ppb)	1.7	3.9	0.4 J	0.51 J	0.58 J	0.39 J	0.73 J	0.9
(LE)	TCE (ppb)	3.5	11	0.9 J	1.4	1.3	1.5 J	1.5	1.6
	Flow (gpm)[a]	755	52	225	77	347	234	926	295
362	PCE (ppb)	NF	NF	NF	NF	NF	NF	NF	NF
(MSt.CBO)	TCE (ppb)	NF	NF	NF	NF	NF	NF	NF	NF
	Flow (gpm)	NF	NF	NF	NF	NF	NF	NF	NF
364	PCE (ppb)	0.30 J	0.5 U	1 UJ	0.36 J	1 U	2 U	0.59 J	0.46 J
Deschutes	TCE (ppb)	0.70 J	0.61 NJ	1 UJ	0.90 J	1 U	0.98 J	1.2	0.62
	Flow (gpm)	NM	NM	NM	NM	NM	NM	NM	NM

[a] - Flow for Station 361; the water flow was difficult or impossible to measure using the stream cross section technique. Numbers in parentheses are flow rate measurements at a pair of parallel culverts downstream of station 361 and considered to be representative of flow at station 361.
FU - Water flow rate was unmeasurable with the available instrument.
NF - No water flow at this station on this date.
NM - Flow at this station was not measured.
5 - Flow seems low for station; could be the result of inaccurate measurement.
U - The analyte was not detected at or above the reported result.
J - The analyte was positively identified. The associated numerical result is an estimate.
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.

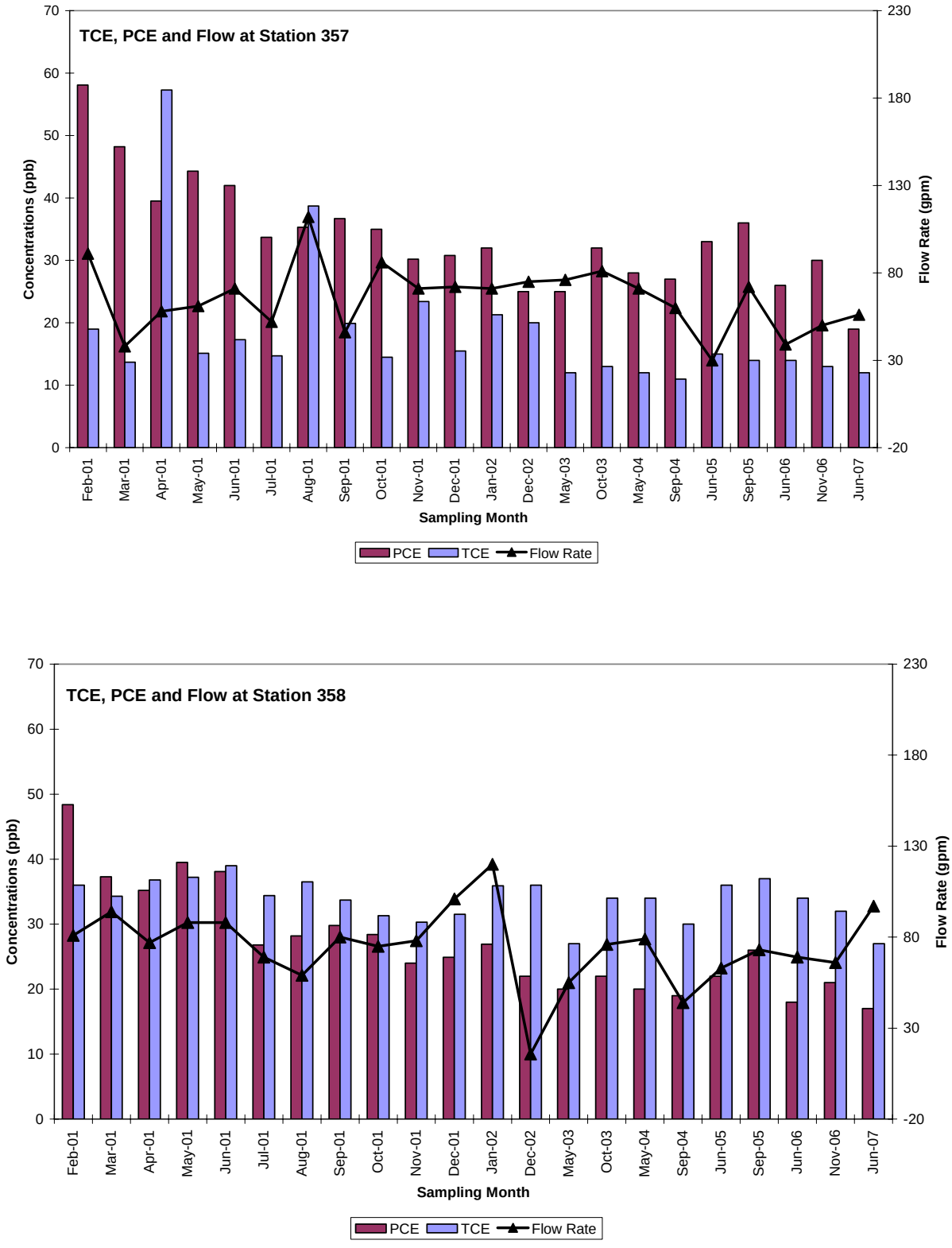
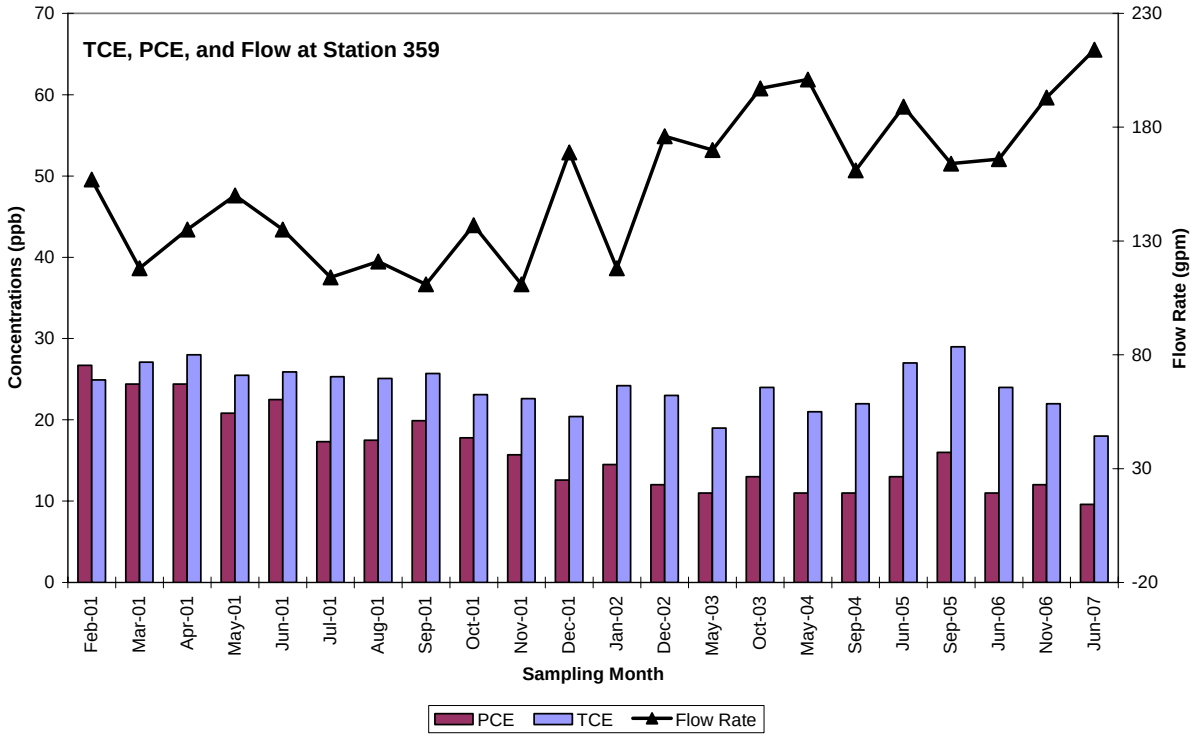


Figure D-1. PCE and TCE Concentrations with Flow Rates from February 2001 through June 2007.



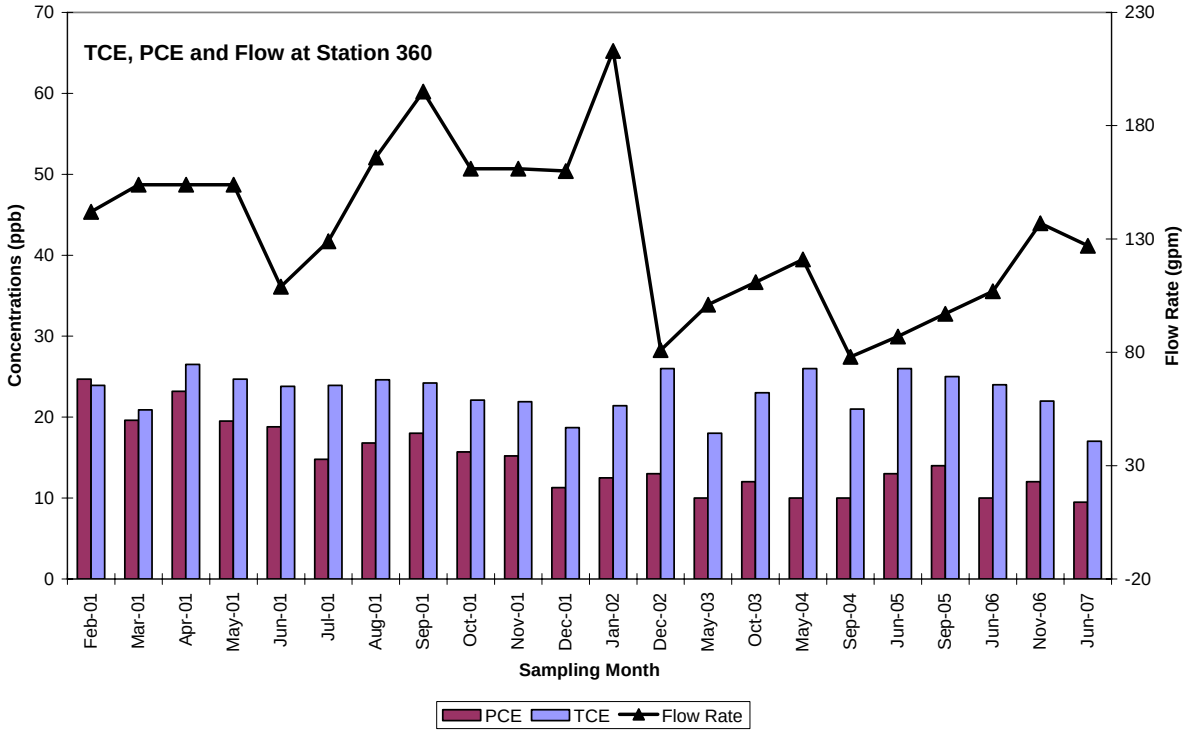


Figure D-1 (continued).

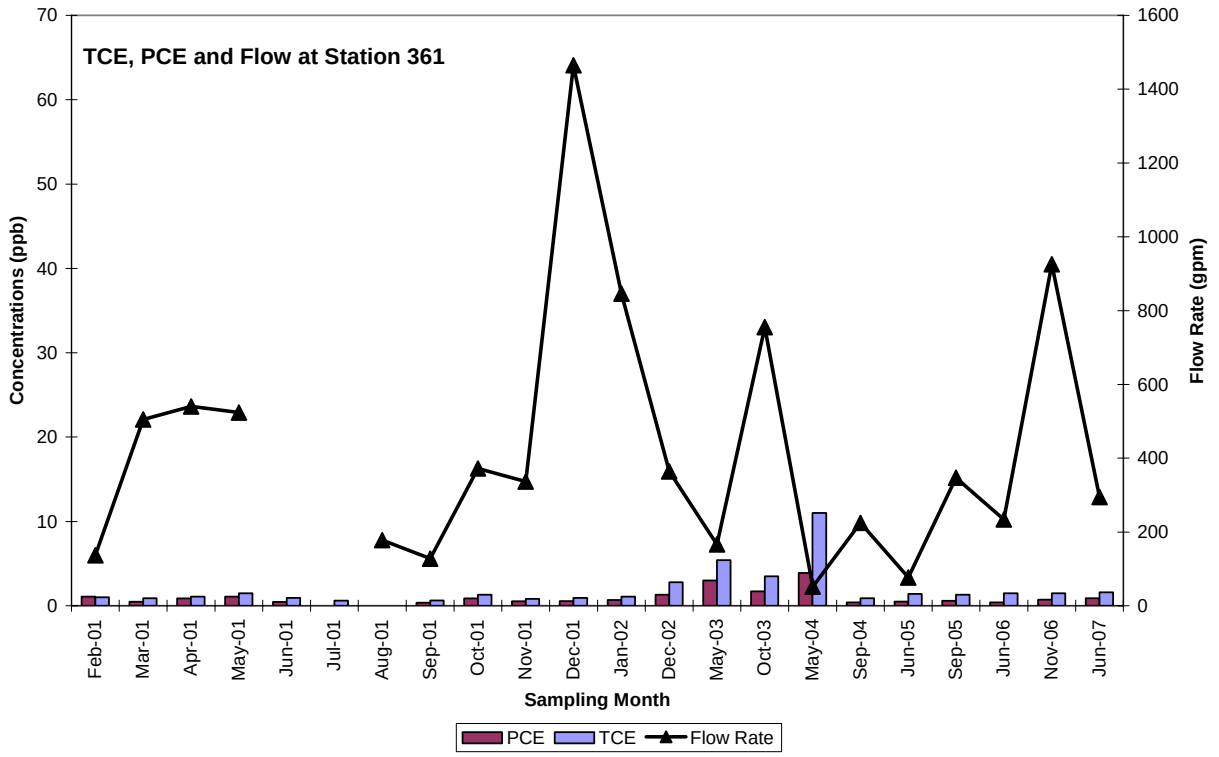


Figure D-1 (continued).

Appendix E. Lagoon Performance Calculations

Percent Contaminant Reduction by Lagoon for November 29, 2006

Measured Parameters

Lagoon influent		
PCE	12	µg/L
TCE	22	µg/L
Flow	137	gpm
Lagoon effluent		
PCE	0.73	µg/L
TCE	1.5	µg/L
Flow	926	gpm

Overall Percent Reduction

$$\frac{\text{Influent Concentration - Effluent Concentration}}{\text{Influent Concentration}} \times 100 = \text{Percent Reduction}$$

PCE: 94%
TCE: 93%

Residence Time

Lagoon volume = 556.3 cubic yards

Convert to gallons = 112,350 gallons

Calculate residence time:

$$\frac{112{,}350 \text{ gal}}{926 \text{ gal/min}}$$

Residence time = 121 minutes or 2 hours

Percent Contaminant Reduction by Lagoon for June 20, 2007

Measured Parameters

Lagoon influent		
PCE	9.5	µg/L
TCE	17	µg/L
Flow	127	gpm
Lagoon effluent		
PCE	0.9	µg/L
TCE	1.6	µg/L
Flow	295	gpm

* Flow rate is too low

Overall Percent Reduction

$$\frac{\text{Influent Concentration - Effluent Concentration}}{\text{Influent Concentration}} \times 100 = \text{Percent Reduction}$$

PCE: 91%
TCE: 91%

Residence Time

Lagoon volume = 556.3 cubic yards

Convert to gallons = 112,350 gallons

Calculate residence time:

$$\frac{112{,}350 \text{ gal}}{295 \text{ gal/min}}$$

Residence time = 381 minutes or 6.3 hours