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For more information contact:

Publications Coordinator
Environmental Assessment Program
P.O. Box 47600, Olympia, WA 98504-7600
Phone: (360) 407-6764

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

Headquarters, Olympia	(360) 407-6000
Northwest Regional Office, Bellevue	(425) 649-7000
Southwest Regional Office, Olympia	(360) 407-6300
Central Regional Office, Yakima	(509) 575-2490
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American Plating
Post-Interim-Action
Groundwater Monitoring Results

April and October, 2010

by

Pamela B. Marti, Licensed Hydrogeologist

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

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Abstract

This report is one in a series that describes groundwater monitoring results at the former American Plating site located on the Thea Foss Waterway in Tacoma, Washington.

During April and October 2010, The Washington State Department of Ecology (Ecology) collected groundwater samples from four site monitoring wells. The samples provide groundwater data on dissolved metals (cadmium, chromium, hexavalent chromium, copper, and nickel) and weak acid dissociable (WAD) cyanide.

Due to the proximity of the site to the waterway, Ecology developed the groundwater cleanup levels based on protection of human contact with surface water (MTCA Method B surface water levels) and on protection of marine organisms (WAC 173-201A). The point of compliance for the groundwater cleanup levels is along the banks of the waterway where groundwater discharges to the surface water.

Results for 2010 were below cleanup levels for dissolved cadmium (9.3 ug/L), copper (3.1 ug/L), and nickel (8.2 ug/L). Dissolved chromium concentrations were below the state marine water quality standard for protection of aquatic organisms for acute exposure to hexavalent chromium of 50 ug/L. WAD cyanide was detected once in one well just above the reporting limit of 5 ug/L. WAD cyanide was not detected in any of the other samples. The reporting limit for WAD cyanide is above the cleanup level of 1 ug/L established for this site.

A further reduction in measured concentrations may occur due to natural processes such as sorption and tidal dispersion as groundwater flows toward the point of compliance.

The Foss Waterway Development Authority plans to eventually develop this area as a public park.

Introduction

Background

The American Plating Company operated a metal electroplating facility adjacent to the Thea Foss Waterway in Tacoma, Washington (Figure 1) beginning in 1976. The site had been occupied by plating companies since 1955. American Plating ceased production at the site in 1986 due to violations of Washington State's dangerous waste regulations[1].

In 1986 the U.S. Environmental Protection Agency (EPA) conducted a preliminary site assessment and concluded that high concentrations of plating waste and contaminated materials were present throughout the site. Based on these and previous findings by the Washington State Department of Ecology (Ecology), formal removal of waste materials and site cleanup activities began in June 1987. Additional soil and groundwater investigations were conducted between 1988 and 1994. In 1997, the site was ranked on Ecology's Hazardous Site List as a "2" (rank of 1 is highest priority relative to other statewide sites; 5 is lowest).

In 2003 Ecology initiated an interim action cleanup of the site. This was done to reduce (1) the potential human health risk from contact with contaminated soils and (2) the potential ecological risk to aquatic organisms in the waterway from the discharge of contaminated groundwater. Contaminants of concern at the site included cadmium, chromium, copper, nickel, cyanide, and volatile organic compounds (VOCs). The cleanup included the removal of site buildings, a concrete pad, sumps, an underground storage tank, and soils designated as dangerous waste (Figure 2). Clean fill and topsoil were added to excavated areas (SAIC, 2003). A metals-contaminated, concrete rubble pile, remaining on-site after the interim cleanup, was removed in June 2007.

Remediation of any remaining contaminated site soils will be performed under a final cleanup action plan when the Foss Waterway Development Authority develops the site as a public park.

Ecology is currently monitoring the site groundwater until the final cleanup action is developed. Data provided from this monitoring will help determine the final cleanup remedy.

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[1] The Department of Ecology conducted several site inspections between 1980 and 1985. These inspections showed that discharges, leaks, and spills of brass, cadmium, chromium, copper, nickel, and zinc plating materials had occurred at the site during operations by American Plating and prior site operators.

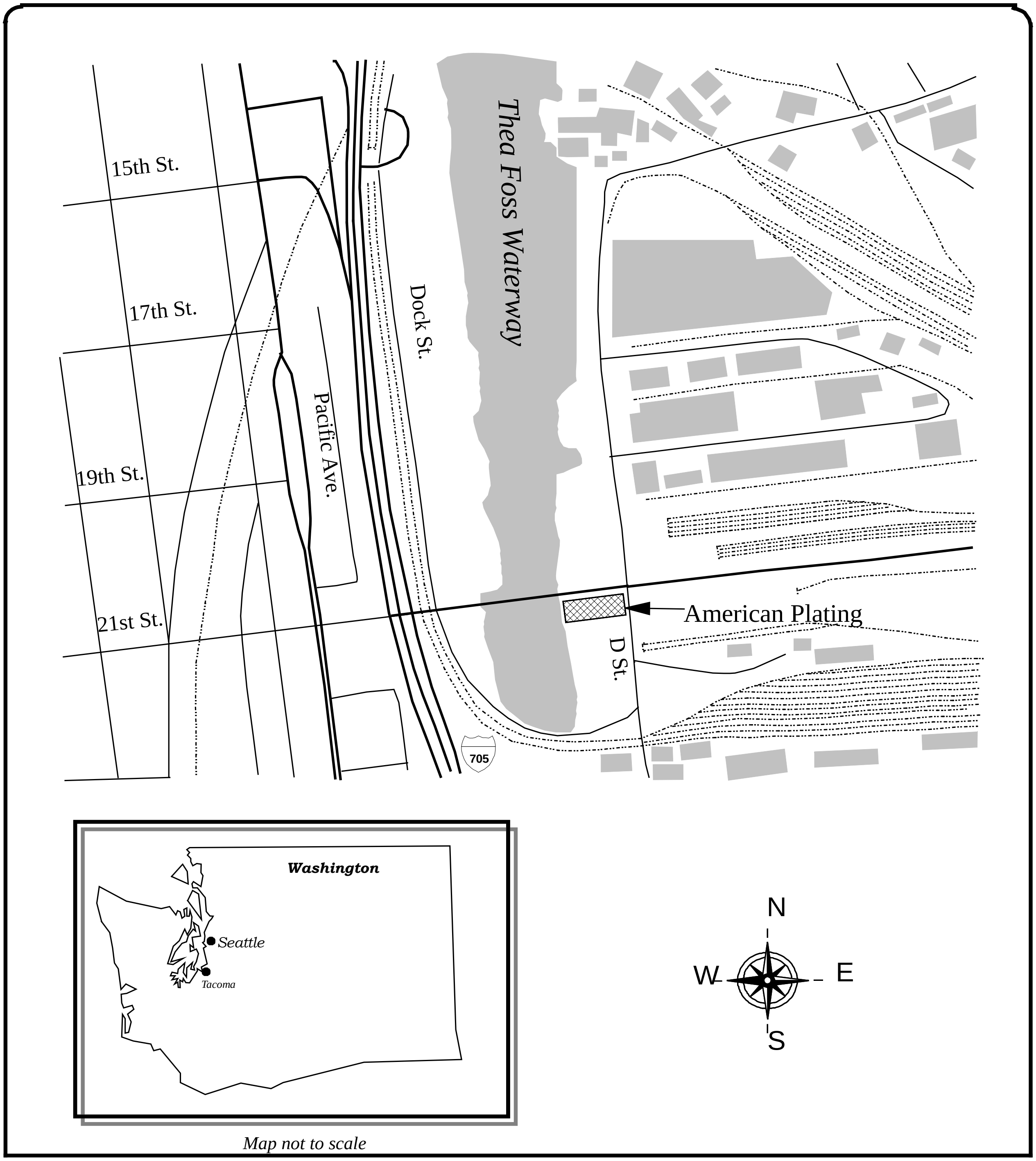


Figure 1. American Plating Site Location in Tacoma, Washington.

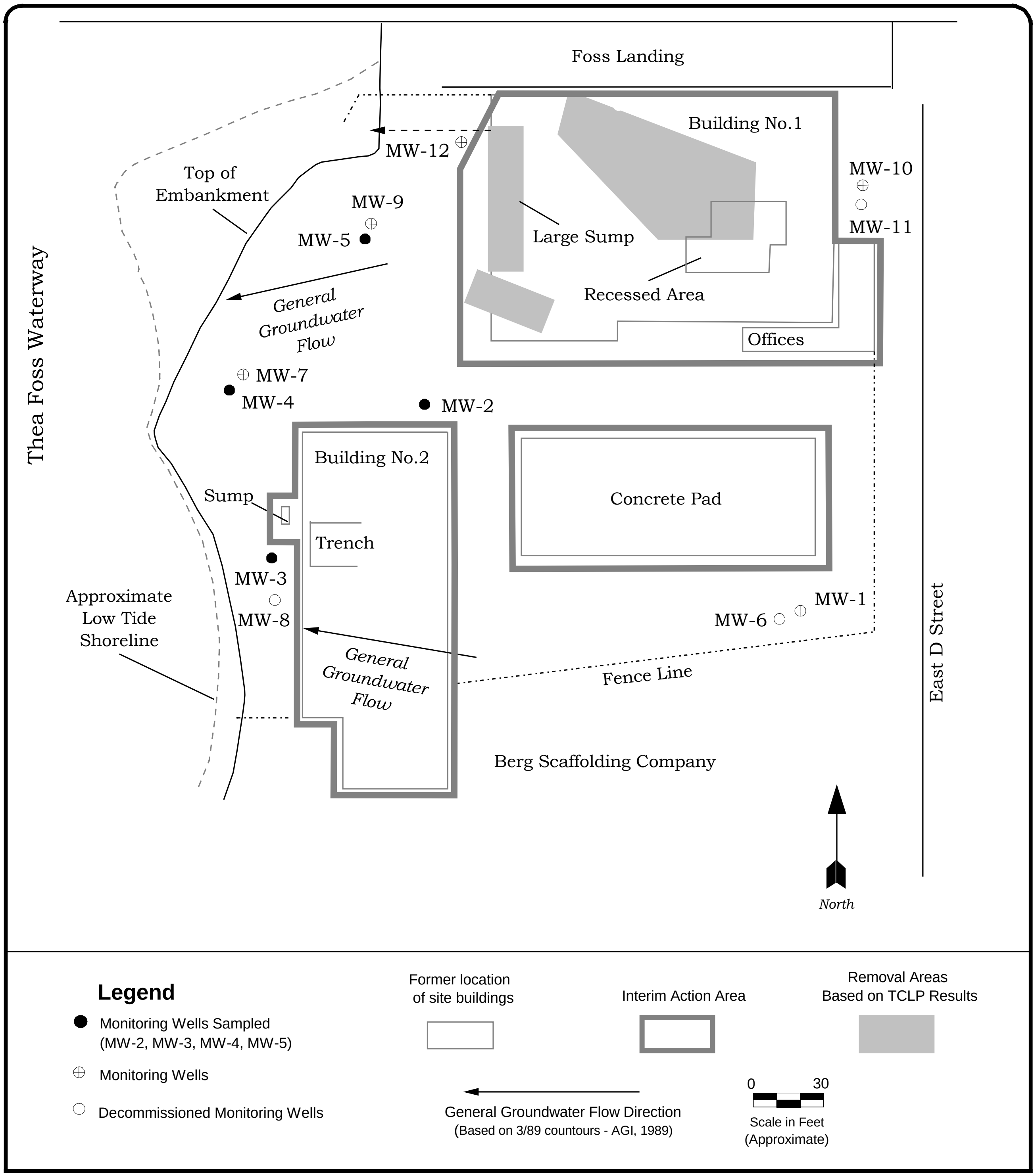


Figure 2. American Plating Sampling Site Locations.

Hydrogeology

Site geology was described during initial site characterization efforts and includes, from the surface down: fill materials, undifferentiated fill and marsh deposits, deltaic deposits, and glacial till.

Prior to site excavation, the fill materials were heterogeneous, consisting of gravels, silty sand, and wood debris to a depth of 5 to 18 feet below the surface. The undifferentiated fill and marsh deposits consist of very soft, sandy silts to clayey silts. These silts were generally encountered around 3 to 12 feet below the surface, and ranged up to 15 feet thick (SAIC, 1994; PRC, 1995).

The deltaic deposits contain medium-dense, silty sand and silty gravel about 5 feet thick, encountered at a depth of about 18 feet. These deposits appear to be relatively continuous beneath the site and seem to thicken to the northwest across the site.

Till is generally encountered at depths of about 23 to 29 feet, with an unknown thickness, and consists of slightly consolidated, very dense, silty sand to silty gravel.

Aquifers exist in both the unconfined fill/marsh deposits and the deltaic deposits. The deltaic deposits contain a semi-confined sand aquifer. The two aquifers are interconnected and tidally influenced. The relationship between the two aquifers and the waterway is complex. High salinity has been measured in much of the site groundwater (SAIC, 2003). Vertical flow components between the two aquifers are difficult to establish because of the complicated stratigraphy and tidal influence at the site.

The unconfined water table in the fill/marsh aquifer ranges from approximately 5 to 9 feet below ground surface. Groundwater flow is interpreted to be in a general westerly direction towards the Thea Foss Waterway. However, the hydraulic gradient in the unconfined aquifer may reverse at high tide phases, at least beneath the western portion of the site.

Methods

Groundwater Monitoring

Ecology collected groundwater samples from four monitoring wells in April and October 2010 (Figure 2). Previous investigations showed no contamination in the lower semi-confined aquifer; therefore, Ecology samples taken since 2004 have been limited to wells screened in the upper unconfined aquifer. The goal of the sampling is to continue to monitor post-interim-action groundwater concentrations of dissolved metals (cadmium, chromium, hexavalent chromium, copper, and nickel) and WAD cyanide.

The four wells sampled (MW-2, MW-3, MW-4, and MW-5) were completed in the upper fill/marsh deposits aquifer at depths of about 14.5 to 17 feet. The wells have 5-foot screened intervals at the base.

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

The monitoring wells were purged and sampled using a peristaltic pump with dedicated tubing for each well. The tubing intake was placed at the middle of the screened interval. Wells were purged at a rate of 0.5-liter/minute or less through a continuous flow cell until pH, temperature, and specific conductance readings stabilized and turbidity readings decreased. Dissolved oxygen (DO) was measured at the end of purging using a field test kit. Purge water from the wells was collected and stored on site in a 55-gallon drum. Purge water waste transport and disposal procedures followed Washington State regulations (Chapter 173-303-400 WAC).

At the completion of purging, Ecology collected samples directly from the discharge tubing into laboratory-supplied containers. Non-dedicated tubing in the pump head was replaced between wells.

Metal samples were field-filtered, with a clean, high-capacity, in-line 0.45 micron membrane filter, into a 1/2-liter, high-density polyethylene container and preserved with nitric acid to a pH < 2. Hexavalent chromium samples were field-filtered into a 125-mL polyethylene bottle and preserved with sodium hydroxide to a pH of 9. WAD cyanide samples were collected in a 250-mL amber polyethylene bottle and preserved with sodium hydroxide to a pH of 12.

After collection and labeling, samples were stored in an ice-filled cooler. To meet the analytical method holding time of 24 hours, the hexavalent chromium samples were delivered to the contract laboratory directly following sampling. The remaining samples were transported to Ecology's Operation Center in Lacey, where they were kept in the walk-in cooler until transported by courier to the Ecology/EPA Manchester Environmental Laboratory in Manchester, Washington. Chain-of-custody procedures were followed (Ecology, 2008).

Analysis

Analytes, analytical methods, and reporting limits for both field and laboratory parameters are listed in Table 1. Groundwater samples were analyzed for selected dissolved metals (cadmium, chromium, hexavalent chromium, copper, and nickel), WAD cyanide, and 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 150.1 (EPA, 2001a)	±0.2 std. units
Temperature	YSI ProPlus with Quatro Cable	EPA 150.1	±0.2 ºC
Specific Conductance	YSI ProPlus with Quatro Cable	EPA 120.1 (EPA, 2001b)	±10 µmhos/cm
Turbidity	HF Scientific DRT-15C Meter	EPA 180.1 (EPA, 1994b)	±2 NTU
Dissolved Oxygen	Chemetrics Colormetric Kit	Rhodazine D	RL: 0-1 mg/L
Laboratory Analytes	Reference	Method	Reporting Limit
Dissolved Metals	EPA 1996	EPA Method 200.8	0.02-1.0 ug/L
Dissolved Hexavalent Chromium	APHA 1992	SM 3500-Cr D	5 ug/L
WAD Cyanide	APHA 1998	SM 4500CN-I	5 ug/L

EAP: Environmental Assessment Program.

RL: Reporting Limit.

Results

Data Quality Assessment

Quality control samples collected in the field consisted of blind duplicate samples, which were obtained from well MW-3 during both rounds of sampling. Field duplicates were collected 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. The numeric comparison of duplicate results is expressed as the relative percent difference (RPD). The RPD is calculated as the difference between sample results, divided by the mean and expressed as a percent. Table 2 shows the results of the duplicate samples and the RPD for samples collected from well MW-3.

Table 2. Relative Percent Difference (RPD) of Duplicate Sample Results (µg/L) for April and October 2010.

Well Sample ID	Dissolved Cadmium		Dissolved Chromium		Dissolved Hexavalent Chromium		Dissolved Copper		Dissolved Nickel		WAD Cyanide	
	4/10	10/10	4/10	10/10	4/10	10/10	4/10	10/10	4/10	10/10	4/10	10/10
MW-3	0.2 U	0.2 U	10.8 J	9.99 J	5 U	10 U	2.33	1.55	1 U	4.89	5 U	5.1
MW-3A	0.2 U	0.2 U	9.74 J	6.28 J	5 U	10 U	2.69	2.00	1 U	5.79	5 U	8.4
RPD (%)	--	--	--	--	--	--	14%	25%	--	17%	--	49%

MW-3A: The duplicate sample identification.

The RPDs in April and October 2010 ranged from 14% to 25%, with the exception of WAD cyanide in October with a RPD of 49%. The October RPD for WAD cyanide data was more than double the data quality objective of 20% (Marti, 2004a). However, WAD cyanide has been detected in this well once before at a concentration of 7 ug/L; therefore, the data will be reported as estimated. The October RPD for copper was also slightly above the data quality object of 20% for metals; therefore, the copper data has also been “J” qualified as estimated.

A review of the data quality control and quality assurance from laboratory case narratives indicates that, overall, laboratory analytical performance was acceptable. The reviews include descriptions of analytical methods, holding times, instrument calibration checks, blank results, surrogate recoveries, and laboratory control samples. The dissolved chromium data have been qualified as estimates because routine calibration verification checks were slightly outside the acceptance limit. The lab did not encounter any other difficulties during analysis; all other checks, as well as the calibration correlation coefficients, were acceptable.

The October hexavalent chromium samples were diluted prior to analysis due to high turbidity which increased the reporting limit.

The quality of the remaining data is acceptable and usable as qualified. Quality assurance case narratives and laboratory reporting sheets are available from the author upon request.

All field measurements and analytical results are available in electronic format from Ecology's Environmental Information Management (EIM) System database: www.ecy.wa.gov/eim/index.htm at study ID, AMERPLAT.

Field Results

Table 3 displays depth-to-water measurements in each sampled well prior to purging. Table 3 also presents pH, dissolved oxygen, specific conductance, and turbidity readings measured at the time of sampling. Temperature was measured but, because readings are from water moving through a flow cell which is influenced by ambient conditions, the values provide a comparative measurement useful to indicate well stabilization, but not true groundwater conditions. Therefore temperature measurements are not presented.

Table 3. Summary of Field Parameter Results for April and October 2010.

Monitoring Well	Total Depth (feet)[1]	Depth-to-Water (feet)[1]				pH (standard units)		Dissolved Oxygen (mg/L)		Specific Conductance (umhos/cm)		Turbidity (NTU)	
		Time	4/10	Time	10/10	4/10	10/10	4/10	10/10	4/10	10/10	4/10	10/10
MW-2	16.65	09:09	5.38	13:28	6.53	6.5	6.8	0.2	0.25	2,570	2,470	13	2.5
MW-3	14.67	09:13	2.92	09:00	4.30	6.6	6.6	0.4	0.2	21,610	20,240	0.8	0.2
MW-4	16.89	08:58	4.86	10:42	6.50	7.0	6.9	0.15	--	8,990	17,700	0.2	0.4
MW-5	16.84	09:02	5.98	12:15	7.21	7.2	7.4	0.4	0.35	21,670	21,660	0.4	0.7

[1] Measured from top of PVC casing.

Figure 3 shows the tidal phase when water levels were measured and samples were collected. The April monitoring occurred during a low tide and the October monitoring occurred during a rising tide. Samples collected at or near low tide are assumed to be more representative of groundwater conditions flowing toward the waterway. Depth-to-groundwater ranged from 2.92 to 5.98 feet below the measuring points in April, and 4.30 to 7.21 feet in October. Groundwater elevations ranged from about 9 to 12 feet above mean sea level during the two sample rounds.

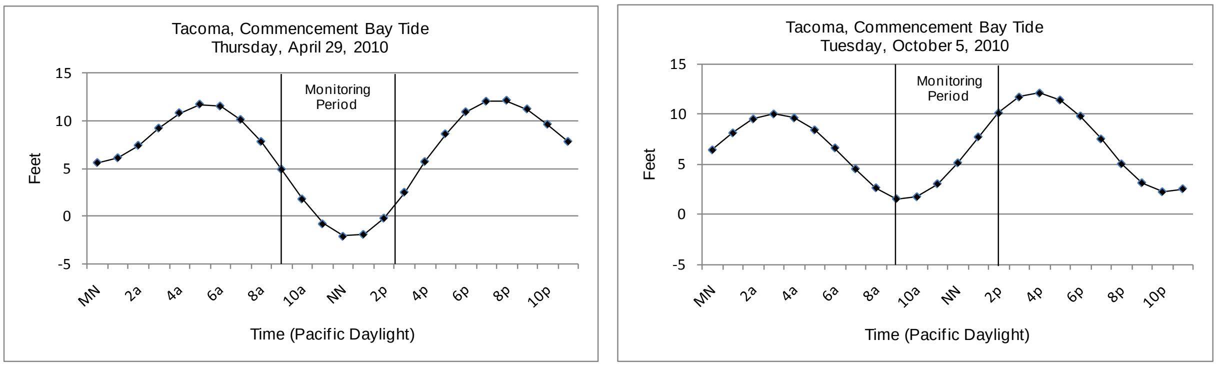


Figure 3. Tide Phase for April 29 and October 5, 2010.

Screened in the soft sandy silt, silt, and clayey silt of the fill/marsh deposits, the four sampled wells are low yielding. While purging at the lowest flow possible, water levels dropped in all wells an average of one to six feet in April and October. Purge volumes ranged from 3.5 to 4 gallons during the two sample events.

During the monitoring period, groundwater pH ranged from 6.5 to 7.4. Dissolved oxygen measurements were low, ranging from 0.15 to 0.4 mg/L, indicative of anaerobic or reducing conditions. Specific conductance measurements ranged from 2,470 to 21,670 umhos/cm. Specific conductance values for wells closer to the Thea Foss Waterway were higher, consistent with the close proximity to salt water. Specific conductance of the Waterway has been reported between 15,000 and 35,000 umhos/cm (SAIC, 1994.) Turbidity measurements ranged from 0.2 to 13 NTUs. Groundwater temperatures measured in the flow cell ranged from 11.2 to 12.7 ºC in April and 14.3 to 16.0 ºC in October.

Analytical Results

Analytical results for dissolved metals and WAD cyanide are summarized in Table 4 and presented in Figure 4. A summary of historical data for this project is presented in tables and graphs in Appendix A.

Table 4. Summary of Analytical Results (ug/L) for April and October 2010.

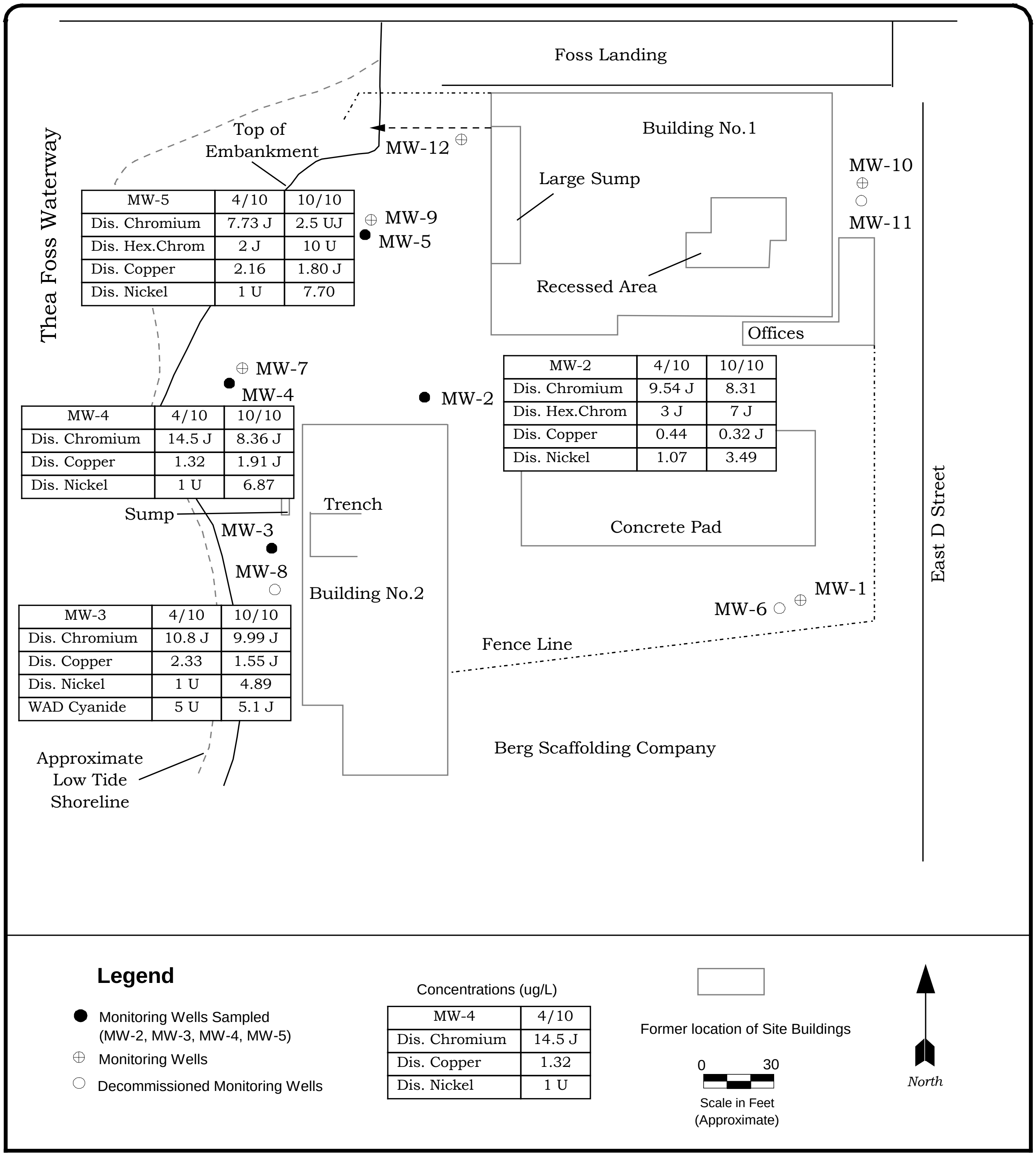
Well	Dissolved Cadmium		Dissolved Chromium		Dissolved Hexavalent Chromium		Dissolved Copper		Dissolved Nickel		WAD Cyanide	
	4/10	10/10	4/10	10/10	4/10	10/10	4/10	10/10	4/10	10/10	4/10	10/10
MW-2	0.02 U	0.2 U	**9.54 J**	**8.31**	**3 J**	**7 J**	**0.44**	**0.32 J**	**1.07**	**3.49**	5 U	5 U
MW-3	0.2 U	0.2 U	**10.8 J**	**9.99 J**	5 U	10 U	**2.33**	**1.55 J**	1 U	**4.89**	5 U	**5.1 J**
MW-4	0.2 U	0.2 U	**14.5 J**	**8.36 J**	5 U	10 U	**1.32**	**1.91 J**	1 U	**6.87**	5 U	5 U
MW-5	0.2 U	0.2 U	**7.73 J**	2.5 UJ	**2 J**	10 U	**2.16**	**1.80 J**	1 U	**7.70**	5 U	5 U

U: Analyte was not detected at, or above, the reported value.
J: Analytical result is an estimate.
Bold: Analyte was detected.

Dissolved chromium, copper, and nickel were detected at low concentrations in the groundwater samples.

Dissolved hexavalent chromium was detected in samples from wells MW-2 and MW-5 at an estimated concentration range of 2 to 7 ug/L. Hexavalent chromium was detected in these two wells in May 2008 at similar concentrations.

WAD cyanide was detected in the October sample from well MW-3 just above the reporting limit of 5 ug/L. Samples from wells MW-3 and MW-4 tested positive for sulfide during both sample rounds. The presence of sulfide can interfere with cyanide analysis and bias the results low. As in the past the April and October cyanide samples were preserved with sodium hydroxide to a pH of 12. Cyanide converts to thiocyanate in the presence of sulfide and high pH. Therefore, the results for samples from wells MW-3 and MW-4 may be under reported due to sulfide interference.



MW-5	4/10	10/10
Dis. Chromium	7.73 J	2.5 UJ
Dis. Hex.Chrom	2 J	10 U
Dis. Copper	2.16	1.80 J
Dis. Nickel	1 U	7.70

MW-4	4/10	10/10
Dis. Chromium	14.5 J	8.36 J
Dis. Copper	1.32	1.91 J
Dis. Nickel	1 U	6.87

MW-2	4/10	10/10
Dis. Chromium	9.54 J	8.31
Dis. Hex.Chrom	3 J	7 J
Dis. Copper	0.44	0.32 J
Dis. Nickel	1.07	3.49

MW-3	4/10	10/10
Dis. Chromium	10.8 J	9.99 J
Dis. Copper	2.33	1.55 J
Dis. Nickel	1 U	4.89
WAD Cyanide	5 U	5.1 J

MW-4	4/10
Dis. Chromium	14.5 J
Dis. Copper	1.32
Dis. Nickel	1 U

Figure 4. American Plating Summary of Analytical Results (ug/L).

Discussion

Low concentrations of the sampled metals continue to be detected in groundwater samples from the American Plating site. Table 5 shows a comparison of the 2010 analytical results to numerical cleanup levels established for the site.

Table 5. Comparison of 2010 Groundwater Results (ug/L) to Surface-Water Based Cleanup Levels.

Parameter	American Plating Cleanup Levels (ug/L)	Monitoring Wells			
		MW-2	MW-3	MW-4	MW-5
Dissolved Metals					
Cadmium	9.3	0.02 U - 0.2 U	0.2 U	0.2 U	0.2 U
Chromium	--	8.31 - 9.54 J	9.99 J - 10.8 J	8.36 J – 14.5 J	2.5 UJ - 7.73 J
Copper	3.1	0.32 J – 0.44	1.55 J - 2.33	1.32 - 1.91 J	1.80 J – 2.16
Hexavalent Chromium	--	3 J – 7 J	5 U – 10 U	5 U – 10 U	2 J – 10 U
Nickel	8.2	1.07 - 3.49	1 U – 4.89	1 U – 6.87	1 U - 7.70
WAD Cyanide	1	5 U	5 U – 5.1 J	5 U	5 U

U: Analyte was not detected at, or above, the reported value.
J: Analyte was positively identified. The associated numerical result is an estimate.

Due to the proximity of the site to the Thea Foss Waterway, the groundwater cleanup levels were developed based on protection of human health due to contact with surface water (MTCA Method B surface water levels) and on protection of marine organisms (WAC 173-201A) for the groundwater-to-surface-water pathway. The surface water cleanup level for cyanide (1 ug/L for acute exposure) is based on the WAD cyanide.

A summary of historical data for this project is presented in tables and graphs in Appendix A.

Sampling for WAD cyanide began in 2004 and was detected in well MW-4 from 2006 to 2008 and well MW-5 in 2007 and 2008. It was not detected in these wells in 2009 or 2010. WAD cyanide was detected in the October 2010 sample from well MW-3. Sulfide is consistently detected in wells MW-3 and MW-4, and to a lesser extent well MW-5. The presence of sulfide in samples collected from wells MW-3 and MW-4 may interfere with the cyanide analysis and bias the results low. Also the available reporting limit for WAD cyanide of 5 ug/L exceeds the cleanup level of 1 ug/L established for this site. Total cyanide was detected in wells MW-2, MW-3, MW-4, and MW-10 in samples collected from 1988 to 1994 as shown in Appendix A.

In 2004, dissolved chromium concentrations in wells MW-4 and MW-5 exceeded Washington State surface water quality standard for protection of aquatic organisms in marine waters for acute exposure to hexavalent chromium of 50 ug/L (WAC 173-201A). Since it was not possible to determine which form of chromium (trivalent or hexavalent) was present, samples have been collected and analyzed for hexavalent chromium since August 2005. Dissolved hexavalent chromium was not detected in any samples until May 2008. The 2008 samples were inadvertently analyzed using EPA methods 218.5 and 200.7 revision 4.4. The samples were reported to contain estimated concentrations of 1.6 to 8 ug/L hexavalent chromium, which is below the state surface water quality standard. Dissolved hexavalent chromium was again detected in the 2010 samples from wells MW-2 and MW-5 at an estimated concentration range of 2 to 7 ug/L.

Before removal of the metals-contaminated concrete rubble pile, dissolved chromium concentrations in samples collected between February 2004 and April 2007 from wells MW-2, MW-3, MW-4, and MW-5 had an average range of 25 to 150 ug/L. Since removal of the rubble pile in June 2007, concentrations have decreased significantly as seen in Figure A2 in the Appendix. Average concentrations from September 2007 to October 2010 ranged from 12 to 20 ug/L.

Summary of Results

Cleanup levels for the American Plating site were based on Washington State surface water quality standards with the point of compliance for groundwater being the areas where groundwater discharges to surface water along the bank of the Thea Foss Waterway. Groundwater concentrations measured in the site monitoring wells are considered the conditional point of compliance. With the exception of cyanide and an occasional nickel result, most groundwater concentrations meet (are below) the cleanup levels established for the point of compliance since Ecology began monitoring in 2004.

Sample results in 2010 were below cleanup levels for dissolved cadmium, copper, and nickel. Dissolved chromium results are below state surface water quality standards. WAD cyanide was detected in well MW-3 above the cleanup level, but results in the other wells were reported as non-detect. However, the available analytical reporting limit of 5 ug/L is above the cleanup level of 1 ug/L established for this site.

It is assumed that a further reduction in measured concentrations may occur due to natural processes of sorption and tidal dispersion as the groundwater flows toward the point of compliance (GeoEngineers, 2003).

Conclusions

Dissolved chromium, copper, and nickel continue to be detected at low concentrations in groundwater samples collected at the former American Plating site. With the exception of an occasional nickel and WAD cyanide result, most concentrations are below the regulatory site cleanup levels. However, a further reduction in measured concentrations may occur due to natural attenuation processes as groundwater flows toward the regulatory point of compliance along the banks of the waterway.

Recommendations

As a result of this study, the following recommendations are made.

1. The condition of monitoring wells MW-2 and MW-3 has declined. To prevent further damage, new concrete pads, bollards, or some other protective barrier should be installed at these wells and any of the wells located near planned construction activities.

2. Well MW-10 was part of the monitoring program from February 2004 until it was damaged in 2006. This well should be located and properly decommissioned.

3. Responsibility for compliance monitoring should be transferred to the Foss Waterway Development Authority once park development is underway.

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Appendices

Appendix A. Historical Data

Table A-1. Historical Dissolved Metals and Total Cyanide Results (ug/L) from April 1988 to September 1994.

Well ID	LR Jones				EPA	LR Jones		PRC
	5/88	8/88	11/88	2/89	2/89	3/89	12/93	9/94
MW-2								
Cadmium	4 U	--	--	--	5 U	--	0.5 U	2 U
Chromium	10 U	--	--	--	10 U	--	10 U	5 U
Copper	20 U	--	--	--	25 U	--	10 U	3 U
Nickel	20 U	--	--	--	17 U	--	10 U	**19 P**
Total Cyanide	10 U	**20**	**20**	**20**	5 U	**10**	**9**	**13**
MW-3								
Cadmium	4 U	--	--	--	5 U	--	0.2 U	--
Chromium	10 U	--	--	--	10 U	--	10 U	--
Copper	20 U	--	--	--	25 U	--	10 U	--
Nickel	**20**	--	--	--	17 U	--	10 U	--
Total Cyanide	10 U	10 U	10	10 U	5 U	**10**	**27**	--
MW-4								
Cadmium	4 U	--	--	--	5 U	--	0.5 U	10 U
Chromium	10 U	--	--	--	10 U	--	10 U	25 U
Copper	20 U	--	--	--	25 U	--	10 U	15 U
Nickel	20 U	--	--	--	17 U	--	10 U	50 U
Total Cyanide	10 U	**30**	**30**	**20**	5 U	**10**	**9**	**15**
MW-5								
Cadmium	4 U	--	--	--	5 U	--	0.4 U	--
Chromium	10 U	--	--	--	10 U	--	10 U	--
Copper	20 U	--	--	--	**41.9**	--	10 U	--
Nickel	20 U	--	--	--	17 U	--	**28**	--
Total Cyanide	10 U	10 U	10	10 U	5 U	10 U	5 U	--
MW-10								
Cadmium	--	--	--	--	--	--	0.5 U	--
Chromium	--	--	--	--	--	--	10 U	--
Copper	--	--	--	--	--	--	10 U	--
Nickel	--	--	--	--	--	--	**110**	--
Total Cyanide	--	--	--	--	--	**40**	**24**	--

--: Not sampled.
Bold: Analyte was detected.
U: Analyte was not detected at, or above, the reported value.
P: Analyte was detected but at a concentration between the instrument detection limit and the quantitation limit.
LR Jones: (PRC, 1995).
PRC: PRC Environmental Management.

Table A-2. Dissolved Metals and WAD Cyanide Results (ug/L) for Well MW-10, February 2004 to August 2005.

Well ID	Ecology			
	Feb-04	Aug-04	Mar-05	Aug-05
MW-10				
Cadmium	--	0.2 U	**0.32**	**0.026**
Chromium	--	**25.5**	2.5 U	**9.1 J**
Hexavalent Chromium	--	--	--	2 UJ
Copper	--	1 U	1 U	1 U
Nickel	--	**62.2**	**40.3**	**29**
WAD Cyanide	10 U	10 U	10 U	5 U

--: not sampled.
Bold: Analyte was detected.
U: Analyte was not detected at, or above, the reported value.
Shaded values are higher than Cleanup Levels established for the site.

Table A-3. Dissolved Metals and WAD Cyanide Results (ug/L) from February 2004 to October 2010.

Well ID	Ecology													
	Feb-04	Aug-04	Mar-05	Aug-05	May-06	Sep-06	Apr-07	Sep-07	May-08	Sep-08	May-09	Nov-09	April-10	Oct-10
MW-2														
Cadmium	0.2 U	0.2 U	0.2 U	0.2 U	0.02 U	**0.022**	0.2 U	0.02 U	0.02 U	**0.027**	0.2 U	0.2 U	0.02 U	0.2 U
Chromium	**8.2**	**30.2**	**18**	**21**	**49.9**	**16.1**	**28**	**28.4**	**11.2**	**6.9 J**	**15.3**	**7.24**	**9.54 J**	**8.31**
Hex Chromium	--	--	--	2 UJ	5 U	5 U	5 U	REJ	**8 J**	5 U	5 U	50 U	**3 J**	**7 J**
Copper	1 U	1 U	1 U	1 U	1 U	**0.39**	1 U	**0.48**	**1.1**	1 U	1 U	1 U	**0.44**	**0.32 J**
Nickel	**4.3**	**4.4**	**3.7**	**3.1**	**2.8**	**3.3**	**2.3**	**5.96**	**13.3**	**4 J**	**3.92**	**4.03**	**1.07**	**3.49**
WAD Cyanide	10 U	10 U	10 U	5 U	5 U	5 U	5 U	5 U	REJ	5 U	5 U	5 U	5 U	5 U
MW-3														
Cadmium	0.2 U	0.2 U	**0.48**	0.2 U	0.2 U	0.2 U	**0.26**	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Chromium	**12.2***	**24***	**16**	**28**	**30.6**	**25**	**180**	**33.2**	**7.6**	**9.6 J**	**9.78**	**10.9**	**10.8 J**	**9.99 J**
Hex Chromium	--	--	--	2 UJ	5 U	5 U	5 U	REJ	**3.2 J**	5 U	5 U	50 U	5 U	10 U
Copper	**1.4***	**2.7**	**2.5**	**3.6**	**2.5 J**	**2.8 J**	**1.35 J***	**2.5**	**2.1**	**2.9**	**1.26**	**2.43 J**	**2.33**	**1.55 J**
Nickel	**8.6***	**5.8**	**6.6**	**4.8**	**3.8**	1 U	1 U	**4.1**	**6**	**2.3 J**	**1.88**	**5.09**	1 U	**4.89**
WAD Cyanide	10 U	10 U	10 U	5 U	5 U	5 U	**7**	5 U	REJ	5 U	REJ	5 U	5 U	**5.1 J**
MW-4														
Cadmium	0.2 U	0.2 U	**0.35**	0.2 U	0.02 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Chromium	**20**	**54.9**	**51**	**76**	**66.2**	**35.8 J**	**750**	**63.8**	**11**	**9.4 J**	**23.5**	**15.4**	**14.5 J**	**8.36 J**
Hex Chromium	--	--	--	2 UJ	5 U	5 U	5 U	REJ	**4.7 J**	5 U	5 U	**600 J**	5 U	10 U
Copper	1 U	**2.1**	**1.3**	**2.4**	**1.9 J**	**1.6 J**	1 U	**1.1**	1 U	**2.2**	**1.18**	**1.75 J**	**1.32**	**1.91 J**
Nickel	**4.9**	**4.9**	**3.4**	**3.2**	**2.2**	1 U	1 U	**3.1**	**3.7**	1 U	**1.55**	**4.51**	1 U	**6.87**
WAD Cyanide	10 U	10 U	10 U	5 U	**5**	**8**	**11**	**13**	REJ	**6**	REJ	5 U	5 U	5 U
MW-5														
Cadmium	0.2 U	0.2 U	**0.37**	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Chromium	**30.9**	**71**	**37.7**	**88**	**104**	**40.7**	**170**	**84.1**	**6.2**	**2.8 J**	5 U	**5.74**	**7.73 J**	2.5 UJ
Hex Chromium	--	--	---	2 UJ	5 U	5 U	5 U	REJ	**1.6 J**	5 U	5 U	50 U	**2 J**	10 U
Copper	1 U	**1.5**	**2**	**2.8**	**1.4 J**	**2.4 J**	**1.2**	**1.4**	**1.8**	**3.0**	**2.26**	**2.22 J**	**2.16**	**1.80 J**
Nickel	**14.8**	**11.8**	**9.2**	**7.9**	**3.6**	**1**	1 U	**6.7**	**8.9**	**5 J**	**2.59**	**7.05**	1 U	**7.70**
WAD Cyanide	10 U	10 U	10 U	5 U	5 U	5 U	**6**	**7**	REJ	**3 J**	5 U	5 U	5 U	5 U

--: not sampled.
Bold: Analyte was detected.
*: Average concentration of duplicate samples.

U: Analyte was not detected at, or above, the reported value.
REJ: Results have been rejected.
Shaded values are higher than Cleanup Levels established for the site.

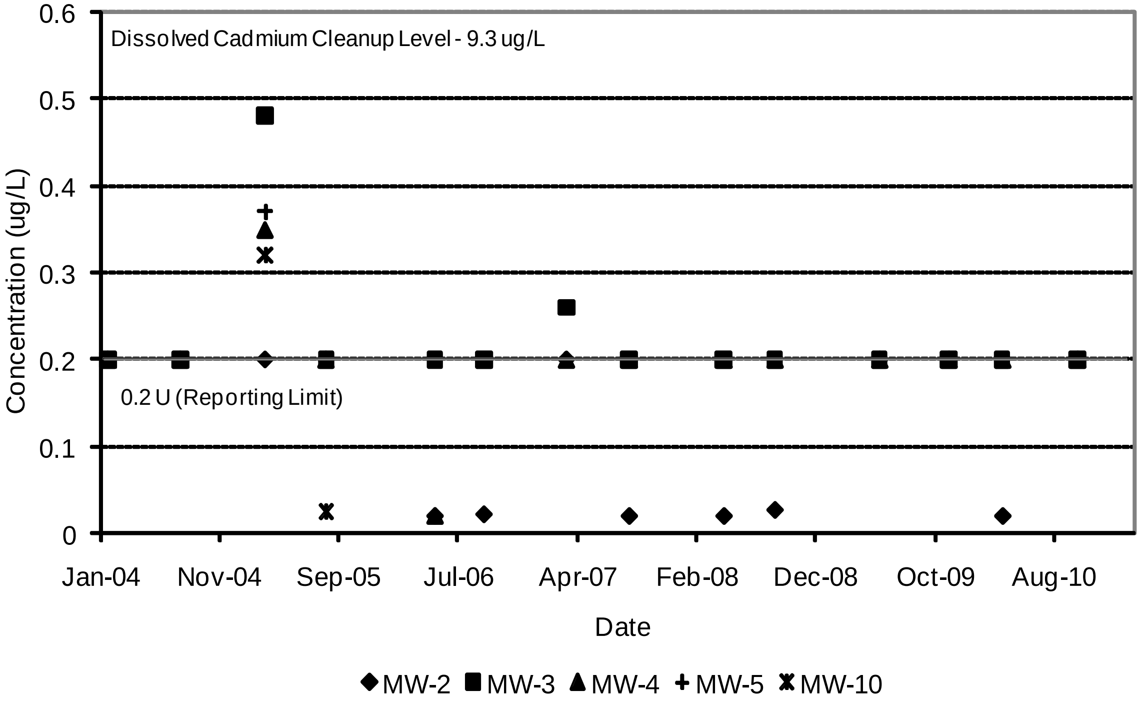

Figure A-1. Dissolved Cadmium Results (ug/L) from February 2004 to October 2010.

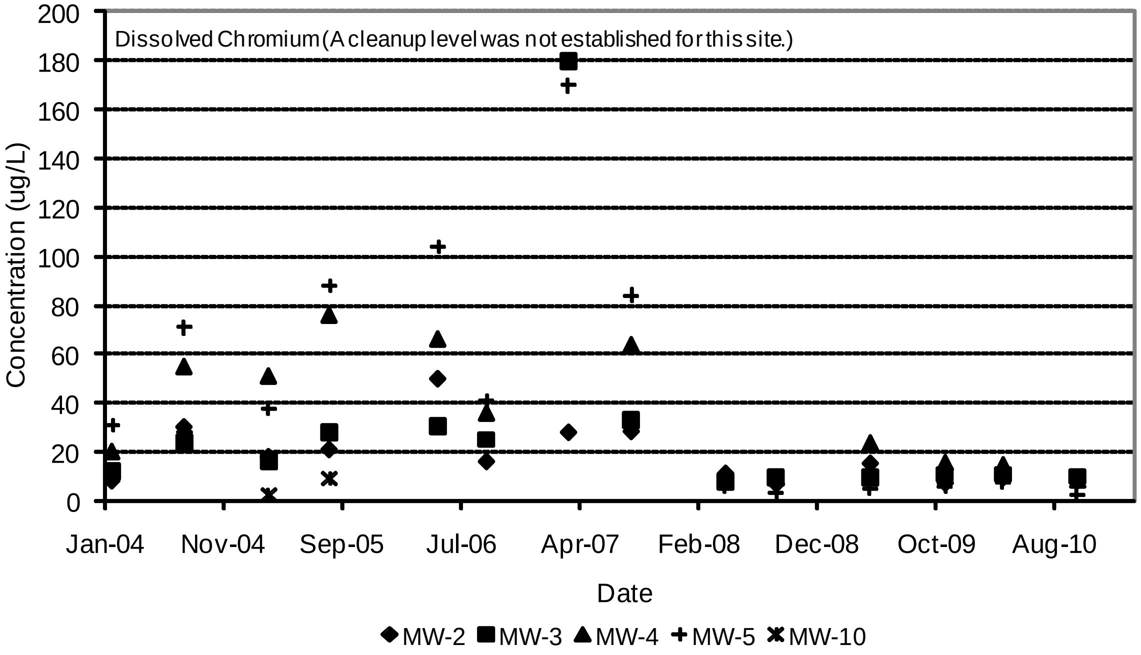

Figure A-2. Dissolved Chromium Results (ug/L) from February 2004 to October 2010.
NOTE: April 2007 MW-4 value of 750 ug/L is not plotted.

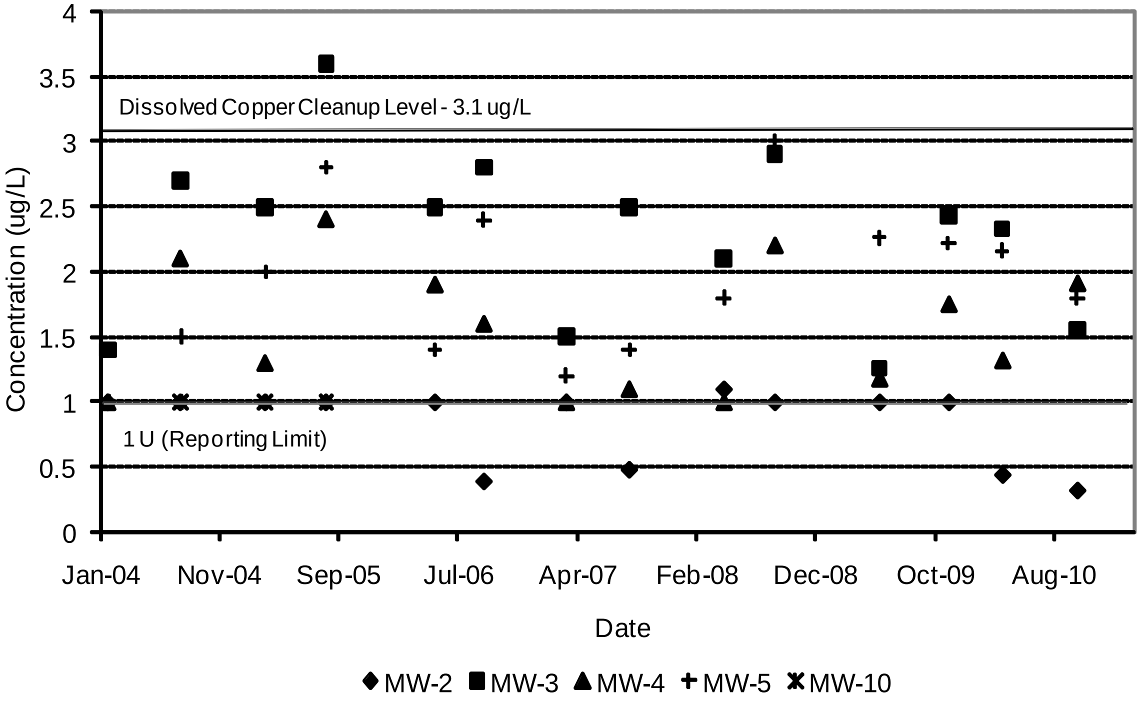

Figure A-3. Dissolved Copper Results (ug/L) from February 2004 to October 2010.

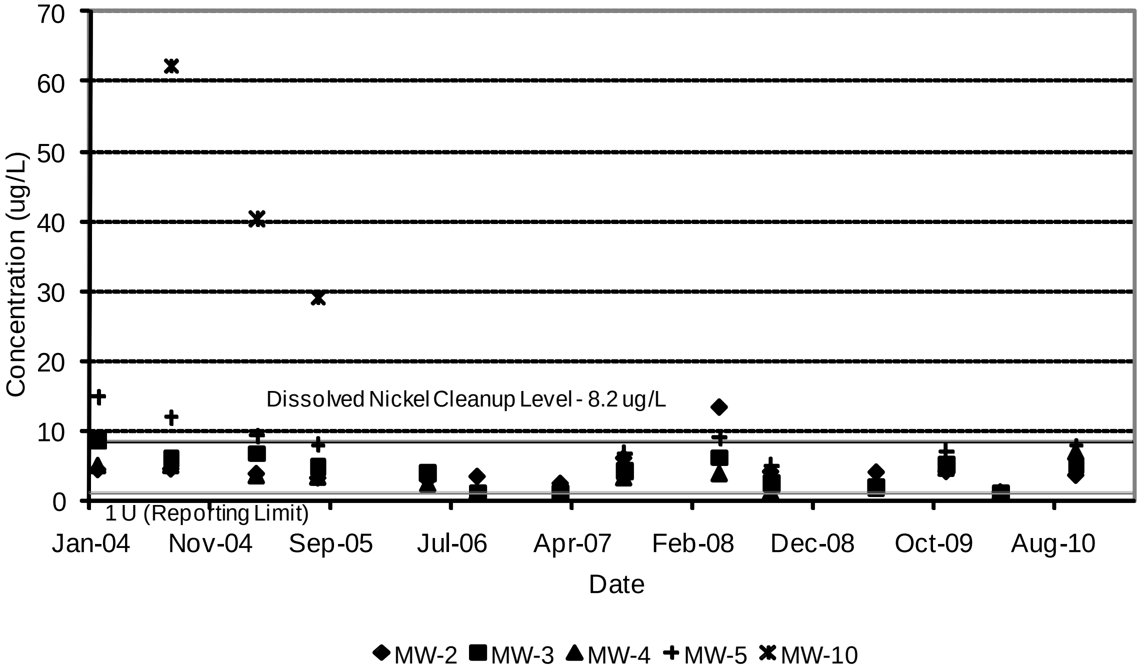

Figure A-4. Dissolved Nickel Results (ug/L) from February 2004 to October 2010.

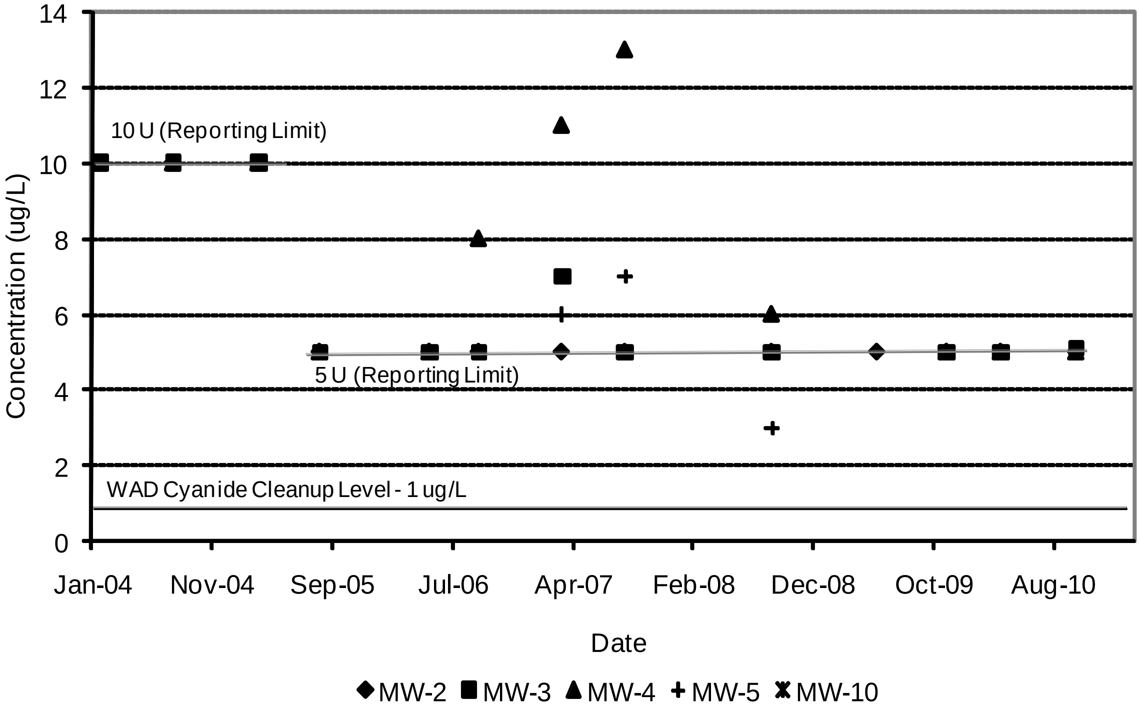

Figure A-5. WAD Cyanide Results (ug/L) from February 2004 to October 2010.

Appendix B. Glossary, Acronyms, and Abbreviations

Glossary

Ambient: Refers to the surrounding air temperature.

Analyte: Water quality constituent being measured (parameter).

Deltaic deposits: The accumulation of sediment at the mouth of a river (delta).

Depth-to-water: A measure of depth to the 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 commonly termed the water table.

Hydraulic gradient: The difference in hydraulic head between two measuring points, divided by the distance between the two points.

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

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Semi-confined aquifer: An aquifer partially confined by soil layers of low permeability through which recharge and discharge can still occur.

Sorption: The process in which one substance takes up (absorption) or holds another (adsorption).

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.

Stratigraphy: Refers to the natural divisions of rocks and their arrangement according to their composition, distribution, correlation, and mutual relationships.

Turbidity: A measure of the amount of suspended silt or organic matter in water.

Unconfined aquifer: An aquifer containing water that is not under pressure; the water level in a well is the same as the water table outside the well.

Acronyms and Abbreviations

Ecology	Washington State Department of Ecology
EIM	Environmental Information Management
EPA	U.S. Environmental Protection Agency
MTCA	Model Toxic Control Act
PVC	Polyvinyl Chloride
RPD	Relative Percent Difference
SOP	Standard Operating Procedure
TCLP	
VOC	Volatile Organics Compound
WAC	Washington Administrative Code
WAD	Weak Acid Dissociable

Units of Measurement

mL	milliliters
NTU	nephelometric turbidity units
ug/L	micrograms per liter (parts per billion)