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American Plating
Post-Interim-Action
Groundwater Monitoring Results

May and November, 2009

by

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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 May and November 2009, 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.

Dissolved chromium, copper, and nickel continue to be detected in groundwater samples collected at the site.

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 surface water cleanup level for cyanide (1 µg/L for acute exposure) is based on WAD cyanide. The point of compliance for the groundwater cleanup levels is along the banks of the waterway where groundwater discharges to the surface water.

Sample results for 2009 were below cleanup levels for dissolved cadmium, copper, and nickel. Most WAD cyanide results were reported as non-detect. However, the available analytical reporting limit of 5 µg/L is above the cleanup level of 1 µg/L established for this site.

It is assumed that 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" (1 being high priority relative to other statewide sites; 5 being low).

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 top soil were added to excavated areas (SAIC, 2003).

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.

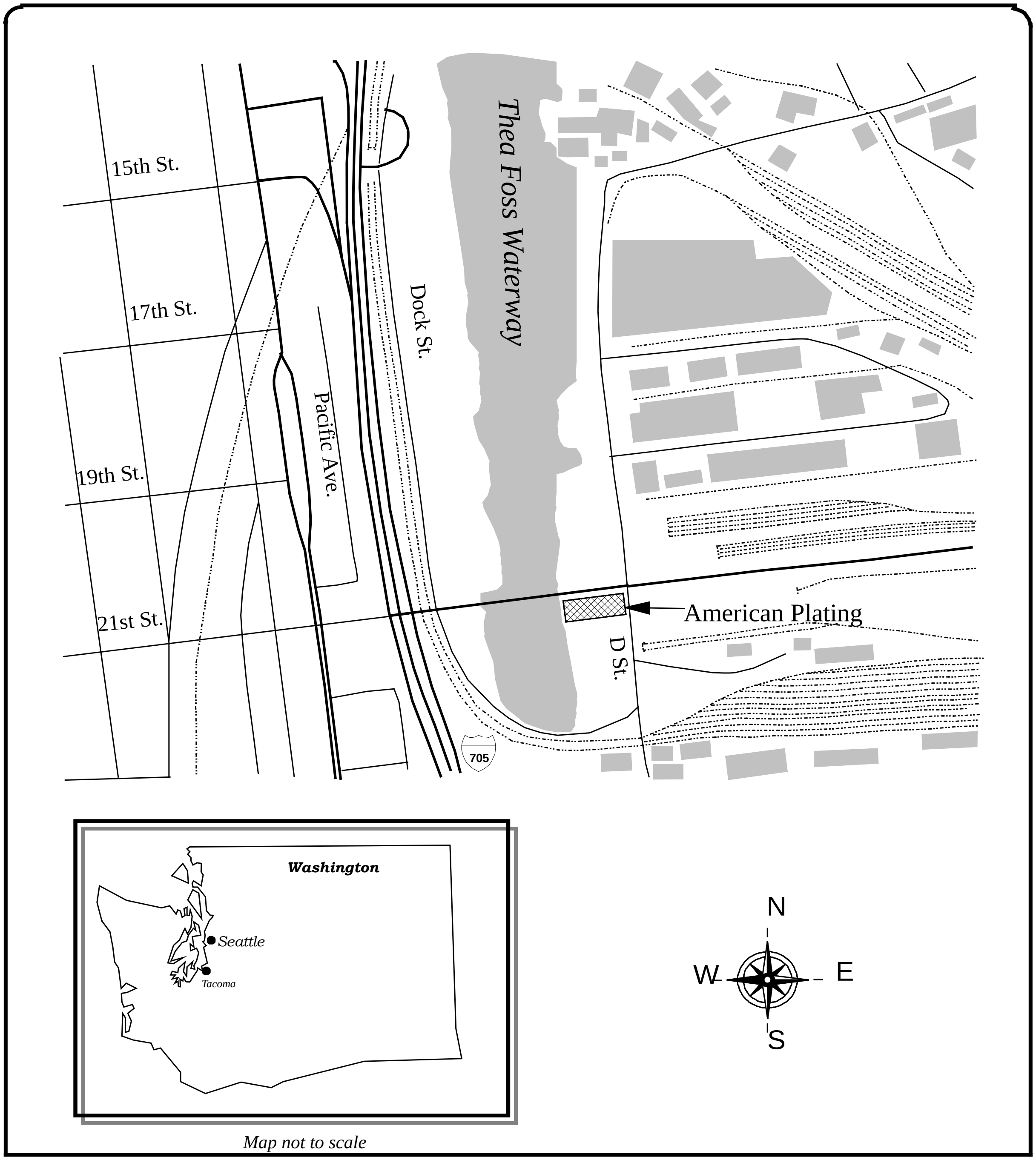


Figure 1. American Plating Site Location.

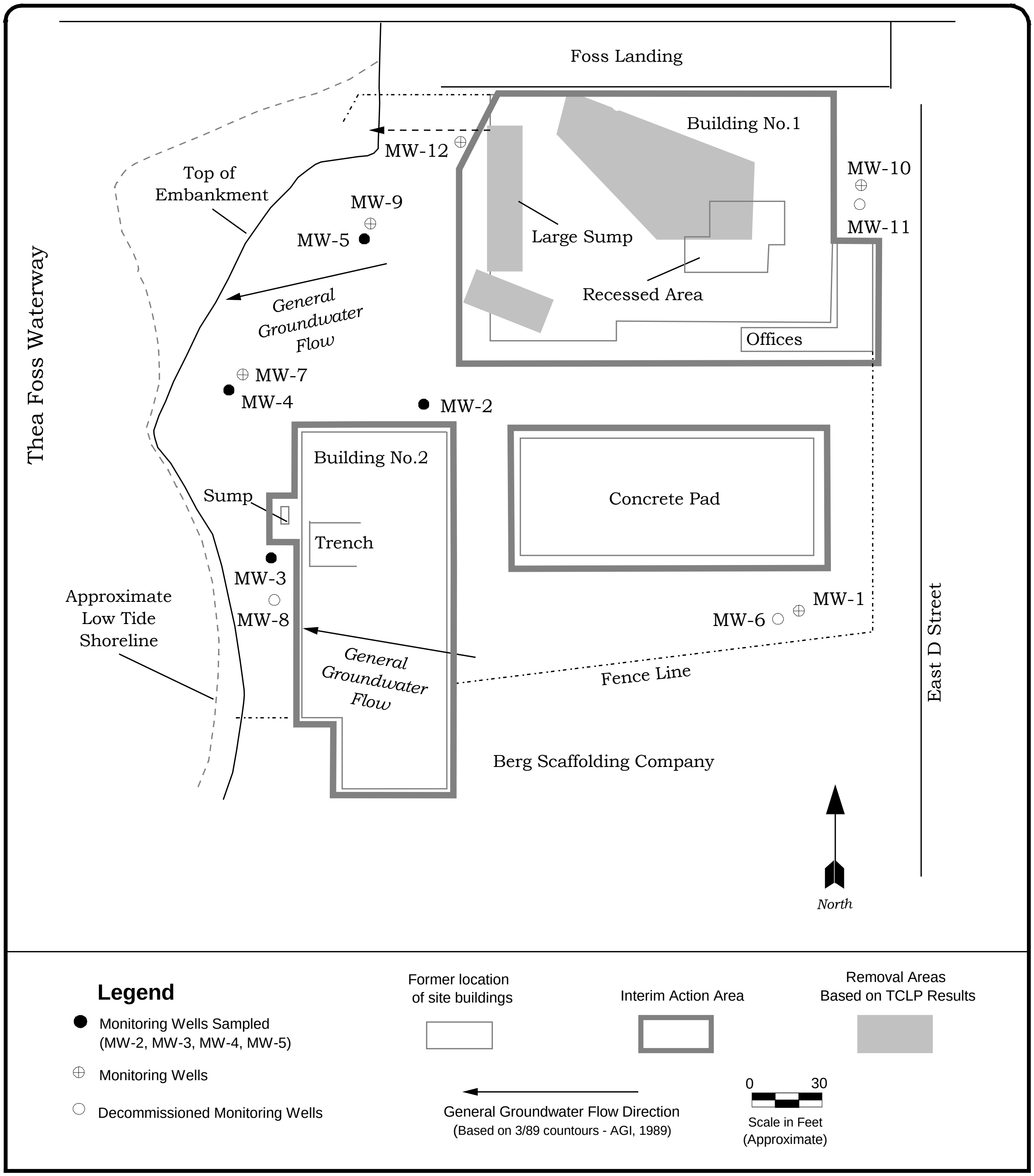


Figure 2. American Plating Sampling Site Locations.

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 which 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

Ecology collected groundwater samples from four monitoring wells in May and November 2009 (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 of the completion depth.

Static water levels were measured in all sampled wells using a Solinst water-level meter prior to well purging and sampling. Measurements were recorded to 0.01 foot and are accurate to 0.03 foot. The probe was rinsed with deionized water between measurements.

The monitoring wells were purged and sampled using a Grundfos Redi-Flo2 stainless steel submersible pump with dedicated tubing for each well. The pump intake was placed at the middle of the screened interval in each well and purged at a rate of 0.5-liter/minute or less. Wells were purged through a continuous flow cell until pH, temperature, and specific conductance readings stabilized and turbidity readings decreased. 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. The pump was decontaminated between wells by circulating laboratory-grade detergent/water through the pump followed by a clean water rinse, with each cycle lasting five minutes.

Metal samples were field filtered, with a clean, high-capacity 0.45 micron membrane filter, into a 1/2-liter, high-density polyethylene container and preserved with nitric acid to a $\text{pH} < 2$. 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. Two of the May cyanide samples were not properly preserved in the field; therefore, the data from these samples has been rejected. This is further discussed in the following section.

After collection and proper labeling, samples were stored in an ice-filled cooler. In order 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).

Results

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	Orion 25A Field Meter	EPA 150.1 (EPA, 2001a)	±0.1 std. units
Temperature	Orion 25A Field Meter	EPA 150.1	±0.1 ºC
Specific Conductance	YSI 3520 Conductivity Cell	EPA 120.1 (EPA, 2001b)	±10 µmhos/cm
Turbidity	HF Scientific DRT-15C Meter	EPA 180.1 (EPA, 1994b)	±2 NTU
Laboratory Analytes	**Reference**	**Method**	**Reporting Limit**
Dissolved Metals	EPA 1996	EPA Method 200.8	0.02-1.0 µg/L
Dissolved Hexavalent Chromium	APHA 1992	SM 3500-Cr D	5 µg/L
WAD Cyanide	APHA 1998	SM 4500CN-I	5 µg/L

EAP: Environmental Assessment Program.

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.

The RPDs in May and November 2009 ranged from 2% to 18% which meets the data quality objective of 20% for metals (Marti, 2004a).

The May WAD cyanide samples from wells MW-3 and MW-4 have been rejected due to incomplete sample preservation. These samples tested positive for sulfide. Because of an insufficient amount of lead acetate, the samples could not be properly neutralized prior to being preserved with sodium hydroxide. Sulfide and cyanide can form thiocyanate in the presence of lead sulfide, causing decreased cyanide recoveries. The lead sulfide precipitate also was not filtered from the sample before adding the sodium hydroxide.

Table 2. Relative Percent Difference (RPD) of Duplicate Sample Results (µg/L) for May and November 2009.

Well Sample ID	Dissolved Cadmium		Dissolved Chromium		Dissolved Hexavalent Chromium		Dissolved Copper		Dissolved Nickel		WAD Cyanide	
	5/09	11/09	5/09	11/09	5/09	11/09	5/09	11/09	5/09	11/09	5/09	11/09
MW-3	0.2 U	0.2 U	9.78	10.9	5 U	50 U	1.26	2.43 J	1.88	5.09	REJ	5 U
MW-3A	0.2 U	0.2 U	11.7	11.1	5 U	50 U	1.48	2.86 J	2.13	5.22	REJ	5 U
RPD (%)	--	--	18%	2%	--	--	16%	--	12%	3%	--	--

MW-3A: The duplicate sample identification.
REJ: Results have been rejected due to improper field preservation of the sample.

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 November dissolved copper data have been qualified as estimates because a routine calibration verification check was greater than 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.

In November the hexavalent chromium samples were diluted prior to analysis due to 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 result data 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 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. Because temperature measurements were recorded 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 May and November 2009.

Monitoring Well	Total Depth (feet)[1]	Depth-to-Water (feet)[1]				pH (standard units)		Dissolved Oxygen (mg/L)		Specific Conductance (µmhos/cm)		Turbidity (NTU)	
		Time	5/09	Time	11/09	5/09	11/09	5/09	11/09	5/09	11/09	5/09	11/09
MW-2	16.65	09:22	5.74	09:30	4.87	6.5	7.2	0.8	1.02	1,851	3,280	--	8.5
MW-3	14.67	09:40	4.10	09:34	2.12	6.6	6.9	1.04	0.16	14,880	27,300	--	0.7
MW-4	16.89	09:27	6.16	09:37	3.29	7.1	7.1	0.57	1.02	8,450	15,540	--	1.0
MW-5	16.84	09:33	5.29	09:41	5.63	7.2	7.7	0.97	0.98	21,600	18,060	--	3.0

[1] Measured from top of PVC casing.

Figure 3 shows the tidal phase when water levels were measured and samples were collected. Both monitoring sessions occurred during low tides. Samples collected at low tide are assumed to be more representative of groundwater conditions flowing toward the waterway. Depth-to-groundwater ranged from 4.10 to 6.16 feet below the measuring points in May, and 2.12 to 5.63 feet below the measuring points in November. Groundwater elevations ranged from about 10 to 13 feet during the two sample rounds.

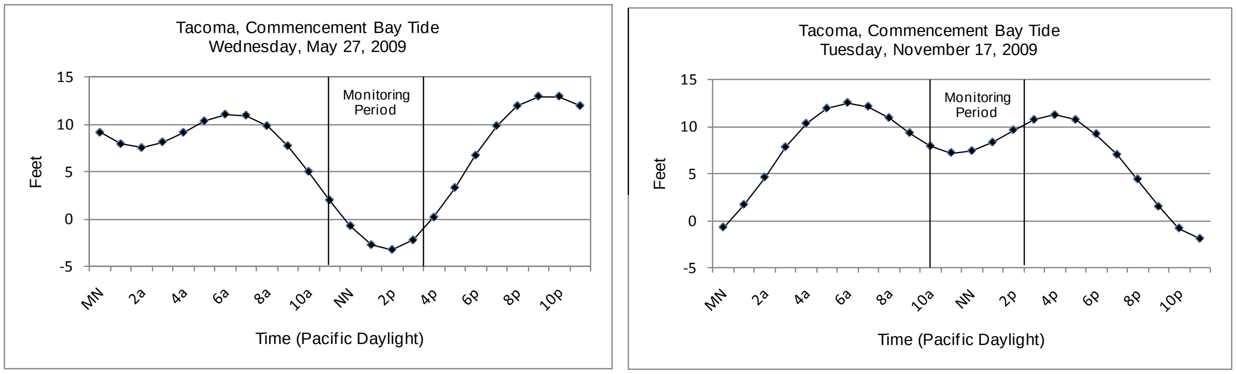


Figure 3. Tide Phase for May 27 and November 17, 2009.

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 in May and November. Purge volumes ranged from 3.5 to 5 gallons during the two sample events.

During the monitoring period, groundwater pH ranged from 6.5 to 7.7. Dissolved oxygen measurements were low, ranging from 0.16 to 1.04 mg/L, suggesting anaerobic or reducing conditions. Specific conductance measurements ranged from 1,851 to 27,300 µmhos/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 to 35,000 µmhos/cm (SAIC, 1994.) Turbidity measurements ranged from 0.7 to 8.5 NTUs in November. Groundwater temperatures measured in the flow cell ranged from 13.4 to 14.7 ºC in May and 13.9 to 15.6 ºC in November.

Analytical Results

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

Table 4. Summary of Analytical Results (µg/L) for May and November 2009.

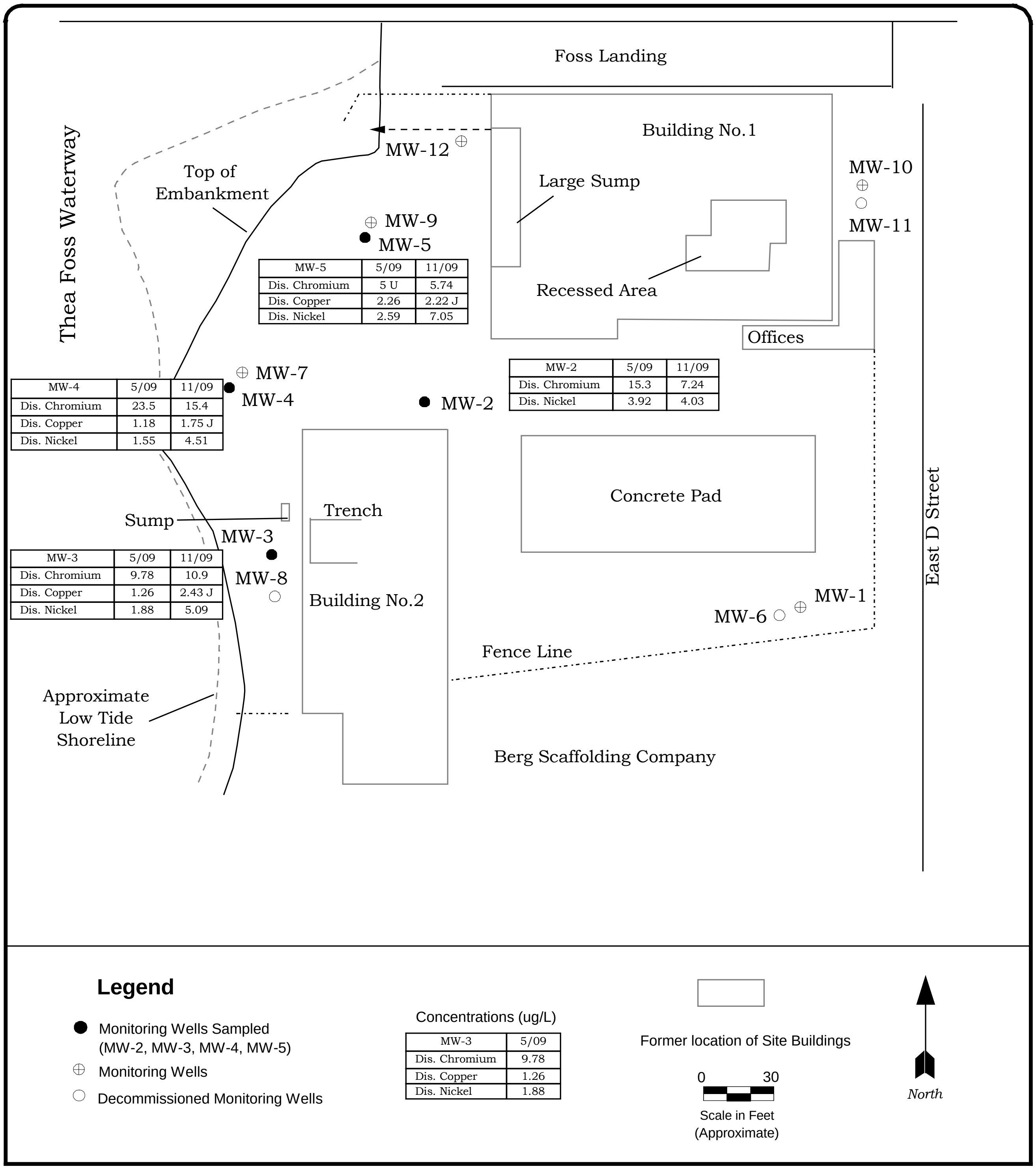
Well	Dissolved Cadmium		Dissolved Chromium		Dissolved Hexavalent Chromium		Dissolved Copper		Dissolved Nickel		WAD Cyanide	
	5/09	11/09	5/09	11/09	5/09	11/09	5/09	11/09	5/09	11/09	5/09	11/09
MW-2	0.2 U	0.2 U	**15.3**	**7.24**	5 U	50 U	1 U	1 U	**3.92**	**4.03**	5 U	5 U
MW-3	0.2 U	0.2 U	**9.78**	**10.9**	5 U	50 U	**1.26**	**2.43 J**	**1.88**	**5.09**	REJ	5 U
MW-4	0.2 U	0.2 U	**23.5**	**15.4**	5 U	**600** J	**1.18**	**1.75 J**	**1.55**	**4.51**	REJ	5 U
MW-5	0.2 U	0.2 U	5 U	**5.74**	5 U	50 U	**2.26**	**2.22 J**	**2.59**	**7.05**	5 U	5 U

U: Analyte was not detected at, or above, the reported value.
J: Analytical result is an estimate.
REJ: Results have been rejected due to improper field preservation of sample.
Bold: Analyte was detected.

Dissolved chromium, copper, and nickel were detected in groundwater at the former American Plating site in 2009.

Dissolved hexavalent chromium was not detected in the May samples. However, it was detected in the November sample from well MW-4 at a concentration of 600 µg/L. Hexavalent chromium has been detected only once before, in May 2008 when the samples were inadvertently analyzed using EPA methods 218.5 and 200.7 revision 4.4. The concentrations in May 2008 ranged from an estimated 1.6 to 8 µg/L. Since the dissolved chromium concentration for well MW-4 was 15.4 µg/L, which is similar to past concentrations, the hexavalent chromium concentration of 600 µg/L has been qualified as an estimate. The reason for the discrepancy in concentrations is unknown.

WAD cyanide was not detected in the May or November samples. However, 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. Since the May samples from these wells were not properly preserved in the field, the data have been rejected. As in the past the November samples were preserved with sodium hydroxide to a pH of 12. Cyanide will convert to thiocyanate in the presence of sulfide and a high pH. Therefore, the November results for samples from wells MW-3 and MW-4 may also be under reported due to sulfide interference.



MW-5	5/09	11/09
Dis. Chromium	5 U	5.74
Dis. Copper	2.26	2.22 J
Dis. Nickel	2.59	7.05

MW-2	5/09	11/09
Dis. Chromium	15.3	7.24
Dis. Nickel	3.92	4.03

MW-4	5/09	11/09
Dis. Chromium	23.5	15.4
Dis. Copper	1.18	1.75 J
Dis. Nickel	1.55	4.51

MW-3	5/09	11/09
Dis. Chromium	9.78	10.9
Dis. Copper	1.26	2.43 J
Dis. Nickel	1.88	5.09

MW-3	5/09
Dis. Chromium	9.78
Dis. Copper	1.26
Dis. Nickel	1.88

Figure 4. American Plating Summary of Analytical Results (μg/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 2009 analytical results to numerical cleanup levels established for the site.

Table 5. Comparison of 2009 Groundwater Results (µg/L) to Surface-Water Based Cleanup Levels.

Parameter	American Plating Cleanup Levels (µg/L)	Monitoring Wells			
		MW-2	MW-3	MW-4	MW-5
Dissolved Metals					
Cadmium	9.3	0.2 U	0.2 U	0.2 U	0.2 U
Chromium	--	7.24 - 15.3	9.78 - 10.9	15.4 – 23.5	5 U - 5.74
Copper	3.1	1 U	1.26- 2.43 J	1.18 - 1.75 J	2.26 – 2.22 J
Hexavalent Chromium	--	5 U – 50 U	5 U – 50 U	5 U – 600 J	5 U – 50 U
Nickel	8.2	3.92 - 4.03	1.88 – 5.09	1.55 – 4.51	2.59 - 7.05
WAD Cyanide	1 (WAD)	5 U	5 U	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 µg/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 had been consistently detected in well MW-4 since 2006 and well MW-5 since 2007. It was not detected in 2009. However, the presence of sulfide in samples collected from wells MW-3 and MW-4 may have interfered with the cyanide analysis and biased results low. Also the available reporting limit for WAD cyanide of 5 µg/L exceeds the cleanup level of 1 µg/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 did not meet (exceeded) Washington State surface water quality standards for protection of aquatic organisms in marine waters for acute exposure to hexavalent chromium of 50 µg/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 had not been detected in any of the samples until May 2008. As discussed previously, the May 2008 samples were analyzed using a different analytical method. The samples were reported to contain estimated concentrations from 1.6 to 8 µg/L, which is below the state surface water quality standards.

The reported hexavalent chromium concentration for the November 2009 sample from well MW-4 is 600 µg/L. The dissolved chromium concentration for this well is 15.4 µg/L. The reason for the discrepancy in concentrations is unknown. Since the hexavalent chromium concentration is outside the range of past dissolved chromium concentrations, it has been qualified as estimated.

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 for 2009 were below cleanup levels for dissolved cadmium, copper, and nickel. WAD cyanide results that were not rejected were reported as non-detect. However, the available analytical reporting limit of 5 µg/L is above the cleanup level of 1 µg/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 the occasional nickel and WAD cyanide result, most concentrations are below the regulatory site cleanup levels. However, it is assumed that 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. Sample analysis should be expanded to include iron because of the potential for iron to interfere with the accuracy of chromium analysis (Parks et al., 2004).

2. 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.

3. 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.

4. 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 (µg/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 (µg/L) from February 2004 to November 2009.

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
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
Chromium	**8.2**	**30.2**	**18**	**21**	**49.9**	**16.1**	**28**	**28.4**	**11.2**	**6.9 J**	**15.3**	**7.24**
Hexavalent Chromium	--	--	--	2 UJ	5 U	5 U	5 U	REJ	**8 J**	5 U	5 U	50 U
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
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**
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
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
Chromium	**12.2***	**24***	**16**	**28**	**30.6**	**25**	**180**	**33.2**	**7.6**	**9.6 J**	**9.78**	**10.9**
Hexavalent Chromium	--	--	--	2 UJ	5 U	5 U	5 U	REJ	**3.2 J**	5 U	5 U	50 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**
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**
WAD Cyanide	10 U	10 U	10 U	5 U	5 U	5 U	**7**	5 U	REJ	5 U	REJ	5 U
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
Chromium	**20**	**54.9**	**51**	**76**	**66.2**	**35.8 J**	**750**	**63.8**	**11**	**9.4 J**	**23.5**	**15.4**
Hexavalent Chromium	--	--	--	2 UJ	5 U	5 U	5 U	REJ	**4.7 J**	5 U	5 U	**600 J**
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**
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**
WAD Cyanide	10 U	10 U	10 U	5 U	**5**	**8**	**11**	**13**	REJ	**6**	REJ	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
Chromium	**30.9**	**71**	**37.7**	**88**	**104**	**40.7**	**170**	**84.1**	**6.2**	**2.8 J**	5 U	**5.74**
Hexavalent Chromium	--	--	---	2 UJ	5 U	5 U	5 U	REJ	**1.6 J**	5 U	5 U	50 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**
Nickel	**14.8**	**11.8**	**9.2**	**7.9**	**3.6**	**1**	1 U	**6.7**	**8.9**	**5 J**	**2.59**	**7.05**
WAD Cyanide	10 U	10 U	10 U	5 U	5 U	5 U	**6**	**7**	REJ	**3 J**	5 U	5 U
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.
*: 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.

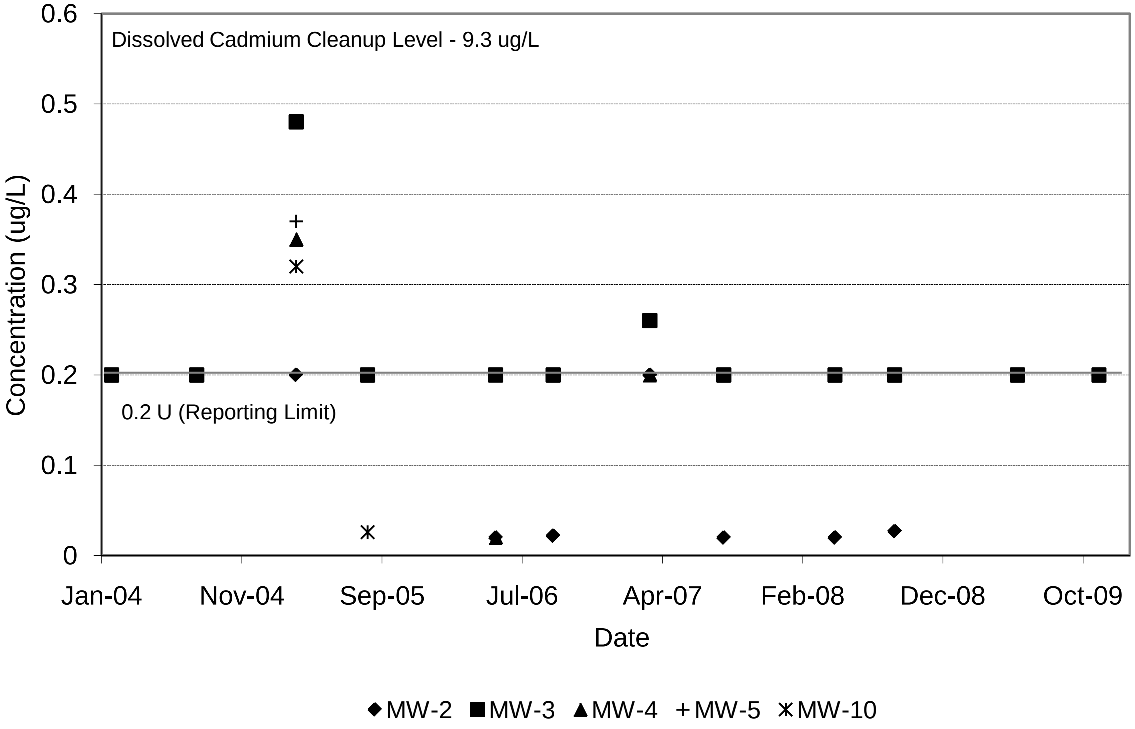

Figure A-1. Dissolved Cadmium Results (µg/L) from February 2004 to November 2009.

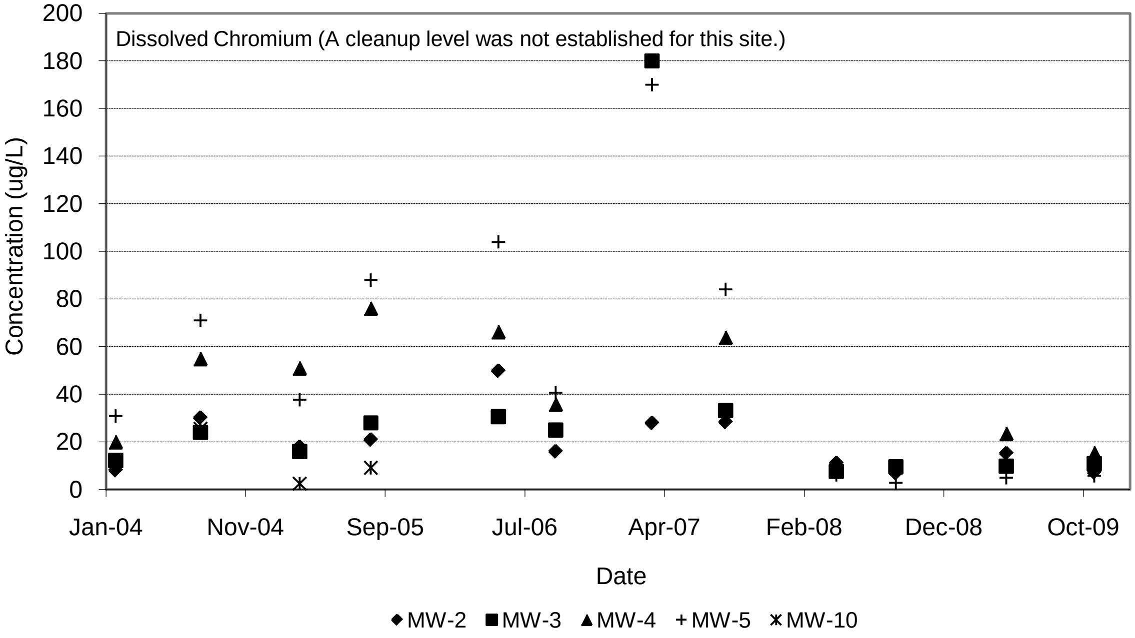

Figure A-2. Dissolved Chromium Results (µg/L) from February 2004 to November 2009.
NOTE: April 2007 MW-4 value of 750 µg/L is not plotted.

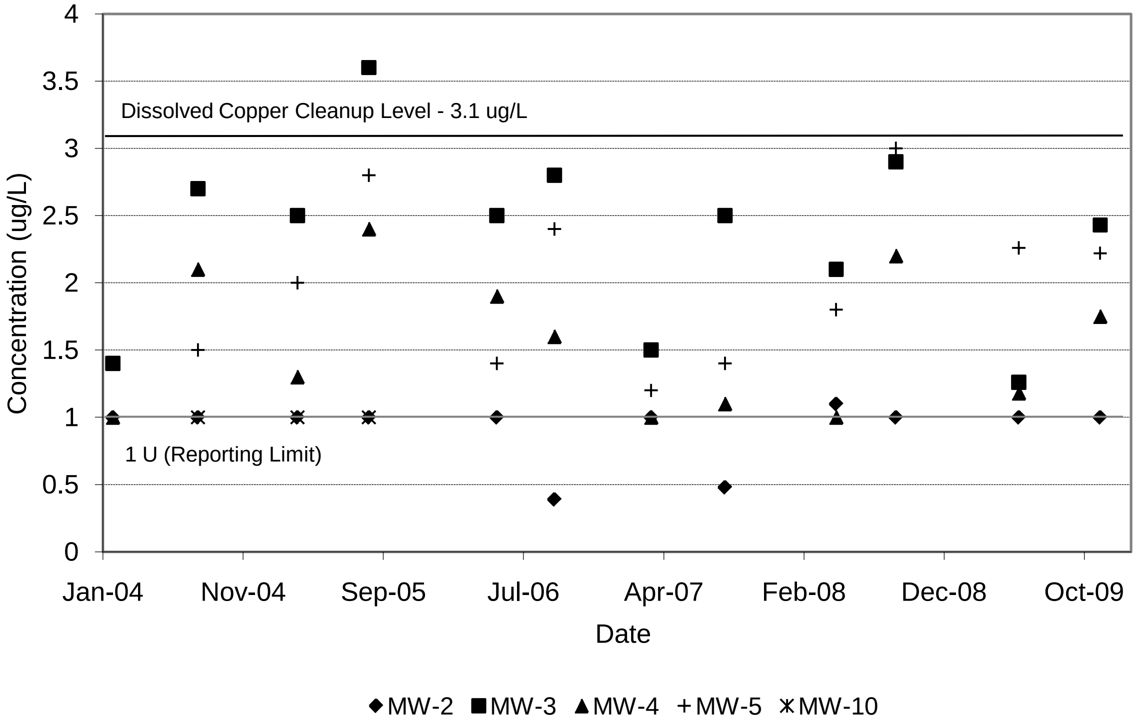

Figure A-3. Dissolved Copper Results (µg/L) from February 2004 to November 2009.

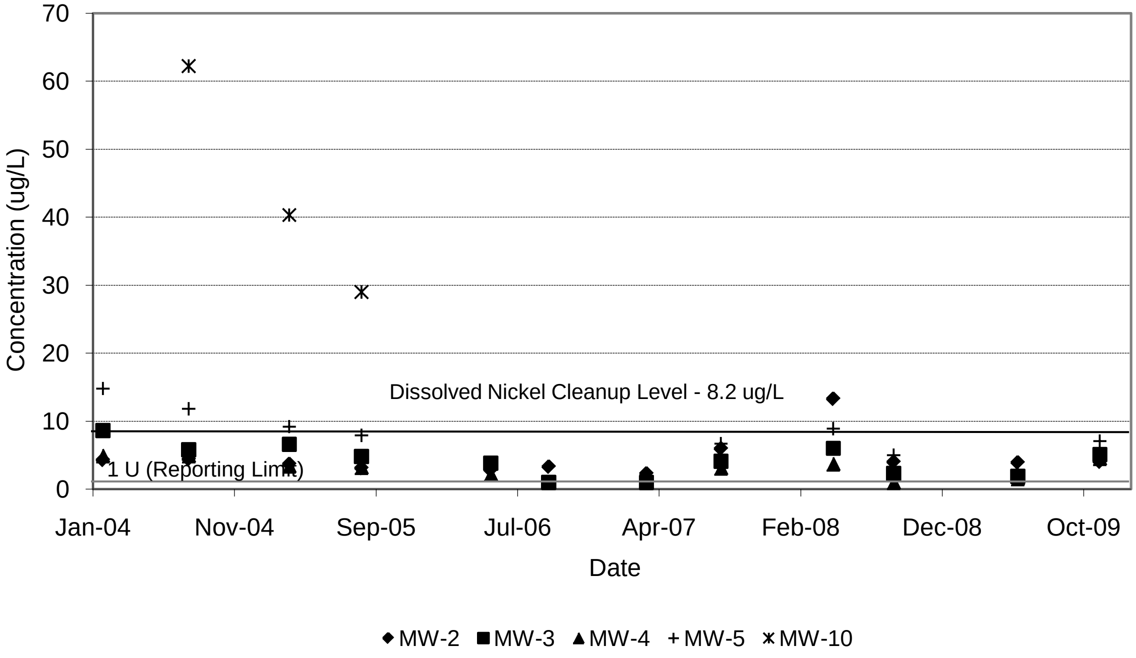

Figure A-4. Dissolved Nickel Results (µg/L) from February 2004 to November 2009.

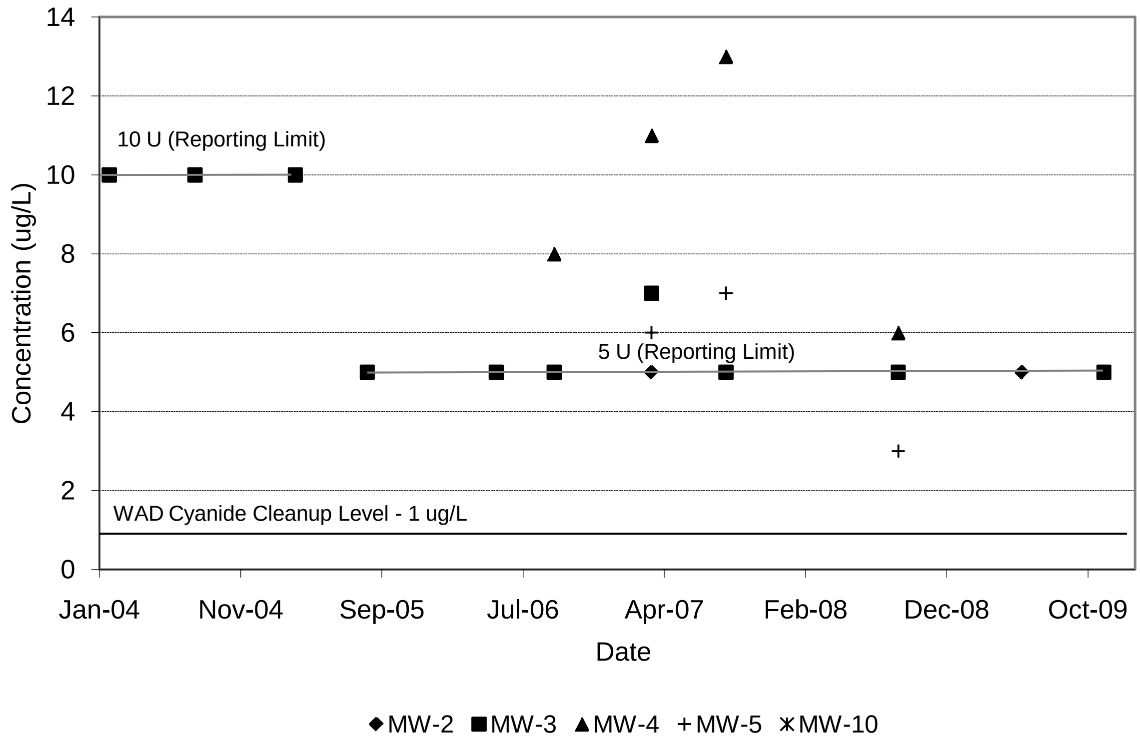

Figure A-5. WAD Cyanide Results (µg/L) from February 2004 to November 2009.

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
VOC	Volatile Organics Compound
WAC	Washington Administrative Code
WAD	Weak Acid Dissociable

Units of Measurement

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