2010 TO 2014 POST-CONSTRUCTION MONITORING REPORT
HOLLY STREET LANDFILL

Prepared for

City of Bellingham

Public Works Department

Bellingham, Washington

For Submittal to

Washington State Department of Ecology

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November 2014

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
ARI	Analytical Resources, Inc.
CAP	Cleanup Action Plan
cfs	cubic feet per second
City	City of Bellingham
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
L	liter
m^2	square meters
MLLW	mean lower low water
mm	millimeters
MTCA	Washington State Model Toxics Control Act
RI/FS	Remedial Investigation/Feasibility Study
SAP	Sampling and Analysis Plan
Site	Holly Street Landfill Site
USGS	U.S. Geological Survey
WAC	Washington Administrative Code

1 INTRODUCTION

The Holly Street Landfill site is a 13-acre historical municipal solid waste landfill located in the City of Bellingham's (City's) Old Town District. Municipal solid waste was historically placed on both sides of Whatcom Creek. The Holly Street Landfill Site (Site) on the northwest bank and Maritime Heritage Park on the southeast bank of Whatcom Creek are listed and ranked by the Washington State Department of Ecology (Ecology) as contaminated sites subject to the investigation and cleanup requirements of the Washington State Model Toxics Control Act (MTCA), administered under Chapter 173-340-360 Washington Administrative Code (WAC). Since this is essentially a single landfill site bisected by Whatcom Creek, Ecology combined the areas into the Site. The City currently owns 8.3 acres of the Site, including all landfill properties located along the Whatcom Creek shoreline. Various private property owners own land around the upland/inland perimeter of the landfill.

Design and construction of cleanup actions at the Site occurred under the legal framework of a 2003 Consent Decree between Ecology, the City, and other defendants. Ecology's final Cleanup Action Plan (CAP) for the Site, which was included as an appendix to the Consent Decree, included the following elements:

- Excavation and off-site disposal of shoreline solid waste
- Construction of shoreline capping systems to restrict tidal mixing with refuse
- Maintenance of soil caps throughout the upland/inland landfill area
- Implementation of institutional controls and deed restrictions
- Compliance monitoring

Cleanup actions are more fully described in final design documents approved by Ecology in April 2004 (Anchor and Aspect 2004). The City successfully constructed the cleanup actions from August 2004 to March 2005 (Anchor 2006a).

The Consent Decree and CAP also include detailed requirements for compliance monitoring to verify that the Site cleanup actions have achieved cleanup standards. The initial compliance monitoring event was performed in 2006, corresponding to Year 1 following completion of the remedial action (Anchor 2006a). The Year 1 monitoring confirmed the integrity and protectiveness of caps constructed at the Site, though marginally elevated metal concentrations were detected in a localized erosional area immediately adjacent to a stormwater outfall on the northwest shoreline. To ensure the long-term integrity of the cap, the City subsequently redirected a portion of the stormwater flow away from the Site into the larger C Street stormwater system.

This report presents the results of post-construction compliance monitoring activities performed from 2010 to 2014 (corresponding to Years 5 to 9 following completion of the remedial action), and outlines future management response actions to ensure the long-term effectiveness of the cleanup remedy.

1.1 Background

Beginning in approximately 1937 and continuing as late as 1959, municipal solid waste was placed on both sides of Whatcom Creek. A 2003 Remedial Investigation/Feasibility Study (RI/FS) characterized the nature and extent of contamination at the Site (Anchor and Aspect 2003). Based on the findings of the RI/FS, Ecology determined that controls were needed at the Site to prevent future human and environmental exposure to buried (subsurface) refuse and associated soil contaminants. Although contaminants were not detected in Site groundwater at levels of potential concern, metals in the landfill refuse, such as copper and zinc, were mobilized by tidal processes in the shoreline landfill zone, posing a potential risk to sensitive aquatic species in this area.

As set forth in the Consent Decree, Ecology's selected cleanup alternative for the Site included excavation and off-site disposal of shoreline refuse, construction of a cap along parts of the Whatcom Creek shoreline and upland areas, implementation of institutional controls and deed restrictions, and monitoring of localized surface water seeps. Based on a consideration of geochemical processes controlling copper and zinc mobility at the Site, the shoreline capping system was designed to restrict tidal mixing and associated oxygen transfer into nearshore refuse deposits of the northwest landfill lobe, controlling the release of dissolved copper and zinc into Whatcom Creek.

Consistent with the requirements of the Consent Decree, the cleanup option implemented by the City combined habitat restoration, public access, and land use elements into a single integrated cleanup and source control remedy. The integrated plan included the following:

- Excavating wedges of shoreline solid waste within and adjacent to the B Street right-of-way, and along limited oversteepened/bulkhead areas of the Maritime Heritage Park shoreline, and disposing of the excavated material off-site
- Constructing a rock berm to protect the northwest bank shoreline from peak shear stresses during high flow conditions in Whatcom Creek
- Backfilling the excavation areas with a minimum 2-foot-thick clean cap graded to relatively flat slopes, concurrently stabilizing the slope and restoring historically lost aquatic habitat in this important estuary
- Enhancing the existing soil cap in portions of the Maritime Heritage Center to be consistent with other landfill areas already capped to ensure that humans and the environment are protected from buried solid waste
- Incorporating public access into the overall project design to address existing community open space goals and planning objectives

The habitat restoration component of the integrated action included conversion of approximately 0.3 acres of uplands to aquatic habitat via excavation of refuse and subsequent capping, restoring critical estuarine riparian buffer, marsh, and mudflat banks that historically existed in this area of Bellingham Bay. This action also provided a park-like setting in the Site area. Incorporating public access design with cleanup and habitat restoration helped meet community open space goals and planning objectives, leveraged additional community support and funding for the project, and provided an opportunity to educate the public about critical estuarine environments. The City's future plans are consistent with maintaining long-term habitat restoration and public access benefits at the Site.

1.2 Overview of Sampling and Analysis Activities

Detailed requirements for compliance monitoring and adaptive management at the Site are provided in Exhibit E of the Consent Decree (Anchor 2002), which describes the required environmental monitoring at the Site, including the duration and frequency of monitoring, triggers for contingency response actions along the shoreline, and the rationale for terminating monitoring. The overall objective of compliance monitoring activities is to confirm that cleanup standards have been achieved and to verify the long-term effectiveness of cleanup actions at the Site. Three types of compliance monitoring are described in Exhibit E (Anchor 2002):

- Protection monitoring to confirm that human health and the environment are adequately protected during the construction period of the cleanup action
- Performance monitoring to confirm that the cleanup action achieves cleanup standards and other performance standards
- Confirmation monitoring to confirm the long-term effectiveness of the cleanup action once performance standards have been attained

Protection monitoring elements of Exhibit E were completed in March 2005, coinciding with the completion of remedial construction. Year 1 performance and confirmation monitoring activities were completed in 2006 (Anchor 2006a). This report presents the results of Year 5 to Year 9 performance and confirmation monitoring activities performed in 2010, 2011, 2012 and 2014, including the following:

- Detailed bathymetric surveys of the shoreline remedial action area and the adjacent Whatcom Creek channel
- Collection and analysis of wellpoint seepage samples from the shoreline action area
- Collection and analysis of representative samples of epibenthic and benthic infauna from the shoreline action area (2010 only)
- Observation of juvenile salmonid utilization within the shoreline action area (2010 only)
- Proposed future management activities at the Site

The Ecology-approved Sampling and Analysis Plan (SAP; Anchor 2000) and SAP Addendum No. 3 (Anchor 2006b) describe the supplemental investigation tasks required to complete performance and confirmation monitoring at the Site. Sampling locations are depicted on Figures 1 through 4. No substantive deviations to the approved procedures occurred during the 2010, 2011, 2012, and 2014 monitoring, with the exception that, due to insufficient water volume, field duplicate samples could not be collected during the 2011 and 2012 monitoring events, and water samples could not be collected at two sample locations during the 2014 monitoring event.

2 BATHYMETRIC MONITORING

As discussed in the 2006 post-construction monitoring and project completion report (Anchor 2006a), record drawing information was combined with earlier bathymetric surveys to produce a single "as-built" plan sheet of post-construction Site conditions in June 2005. A Year 1 bathymetric survey of the Site was again performed in May 2006 by Pacific Surveying and Engineering to provide a synoptic post-construction survey of the in-water remedial action area. The Year 1 survey confirmed the integrity of the shoreline cap and also verified that the required capping thicknesses were still maintained throughout the Site.

A follow-on Year 5 bathymetric survey was again performed by Pacific Surveying and Engineering in May 2010, initially using the same survey methods utilized for the earlier 2005 and 2006 surveys (i.e., upland-based survey transects on 25-foot centers performed during low tide conditions, consistent with the SAP Addendum [Anchor 2006b]). However, during the Year 5 survey, it was apparent that much of the offshore Whatcom Creek channel bed adjacent to the shoreline cap had eroded more than 3 feet relative to both the "as-built" and Year 1 surveys, precluding upland-based surveys throughout much of the creek channel due to water depth. Accordingly, a more detailed supplemental vessel-based bathymetric survey of the Whatcom Creek channel in the Site area was completed by Pacific Surveying and Engineering in June 2010, overlapping with the upland-based survey transects to ensure survey accuracy. Follow-on Year 6, 7, and 9 bathymetric surveys of the cap and adjacent channel area were again performed in August 2011, 2012, and 2014, respectively.

Comparison of the Year 5 (May/June 2010) bathymetric survey with the 2005 "as-built" survey is presented in Figure 1. A follow-on comparison of the Year 9 (August 2014) versus Year 5 survey is presented in Figure 2. To summarize net changes in bathymetry since completion of remedial actions, the most recent Year 9 survey is compared to the 2005 as-built survey in Figure 3, and a representative cross-section (A-A') through the shoreline cap and the adjacent Whatcom Creek channel depicting all surveys is presented in Figure 4. Some of the more significant changes in bathymetry that have occurred over the 9-year post-construction period are discussed below.

Within upstream areas of the Whatcom Creek channel in the vicinity of the rock berm constructed to protect the adjacent northwest bank shoreline (within the area of the historical Colony Dock piling), more than 2 feet of sand accreted on the surface of the rock by Year 5, subsequently eroded in Year 6, and remained stable through Year 9, suggesting that finer grained surface sediments in this upstream channel area are in dynamic equilibrium (alternating deposition and erosion). Similarly dynamic conditions were observed in other parts of the Whatcom Creek channel adjacent to the sediment cap.

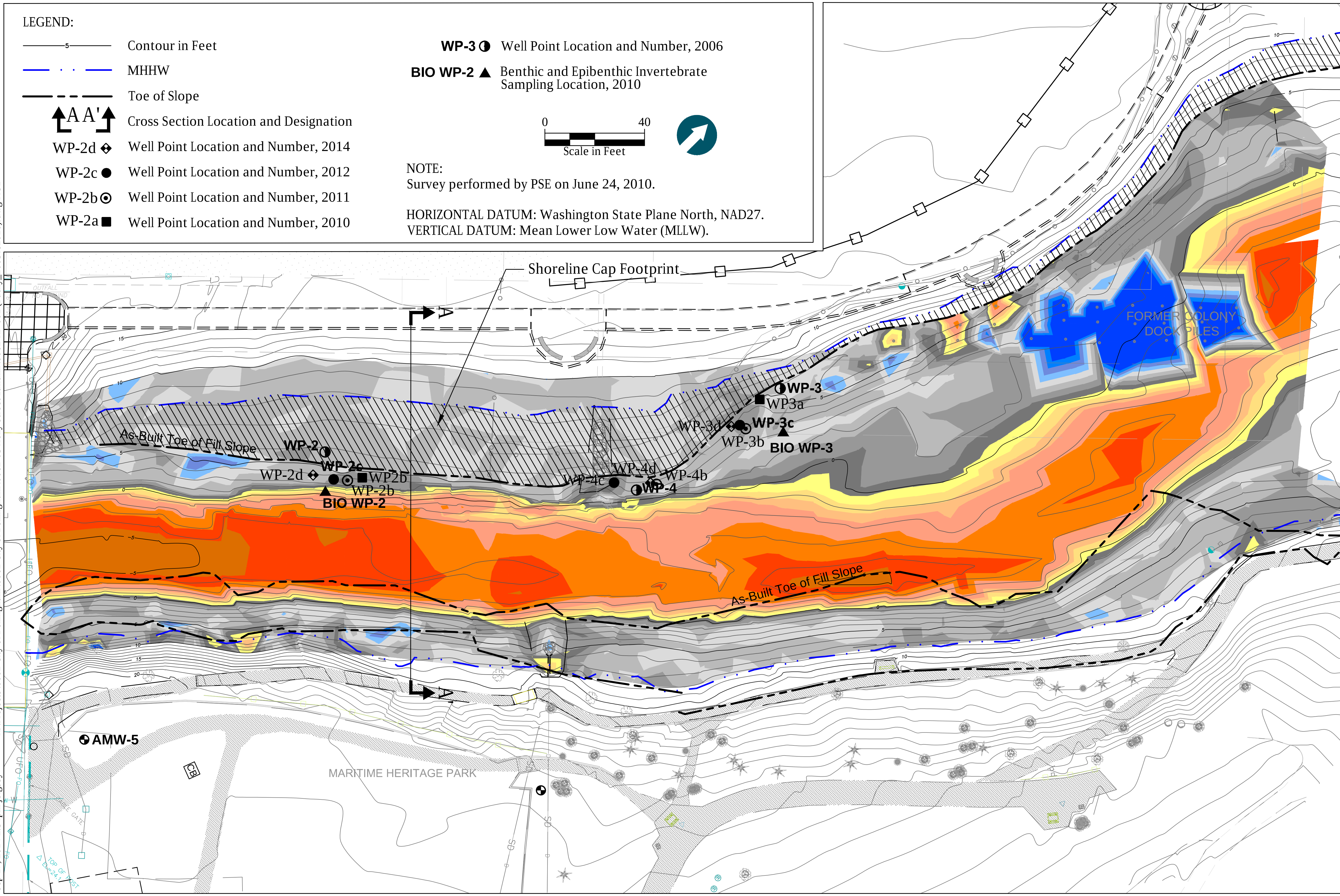
Between Year 1 and Year 5, net erosion of more than 3 feet of silty sand sediments occurred throughout most of the Whatcom Creek channel offshore of the landfill cap (Figure 1). Over the next 4 years, this same channel area subsequently accreted 1 to 3 feet of silty sand (Figure 2), though some areas of the channel remain below post-construction elevations (Figure 3). Significantly, all of the post-construction surveys have confirmed only minor fluctuations of the shoreline cap surface elevation (±6 inches relative to the 2005 as-built survey), which is within the precision of the differential bathymetric surveys. Thus, similarly to the Year 1 monitoring, the Year 5 to 9 bathymetric surveys all confirmed the integrity of the shoreline cap throughout the Site, which continued to exceed the required capping thickness specified in the CAP.

At the time of the Site RI/FS and remedial design, only historical (1945 to 1969) Whatcom Creek discharge data were available from the U.S. Geological Survey (USGS) gage #12203500 located immediately upstream of the Site. The peak stream flow measured by USGS during this period was 1,350 cubic feet per second (cfs), which occurred in 1950. Historical data from this gage were used by the Federal Emergency Management Agency (FEMA) to estimate the 100-year flood in Whatcom Creek of 1,429 cfs (FEMA 1982). The FEMA 100-year discharge was used to develop armor requirements for the shoreline cap and rock berm design, also incorporating appropriate factors of safety into the armor design to ensure long-term cap integrity (Anchor and Aspect 2004).

Beginning in April 2002, the City Public Works Department reactivated the Whatcom Creek gage. Daily average discharge data recorded by the City from 2002 to 2014 are presented in Figure 5, which also depicts the timeline of the remedial action and post-construction monitoring events at the Site. Significantly, a peak creek discharge event of approximately

1,459 cfs occurred on January 10, 2009 (the average daily discharge was 1,310 cfs, very close to the estimated 100-year recurrence interval event). As discussed in the final design report (Anchor and Aspect 2004), flows of this magnitude are capable of eroding sand-sized particles from the channel bed and transporting these sediments downstream. Thus, the erosion of bed sediments in the Whatcom Creek channel, as observed in the Year 5 (May/June 2010) survey, is likely attributable to the very high (roughly 100-year) creek discharge event that occurred in early 2009. Current flow management protocols in Whatcom Creek to reduce peak discharges are discussed in more detail in Section 5.1.

While the erosion of bed sediments in Whatcom Creek that likely occurred during early 2009 did not adversely affect the integrity of the shoreline cap, the dynamic equilibrium of the adjacent creek channel bed may have affected the performance of the shoreline capping system. That is, erosion of silty sand bed sediments adjacent to the shoreline cap could have promoted greater tidal-induced groundwater mixing and associated oxygen transfer into nearshore refuse deposits of the northwest landfill lobe, which in turn could affect the release of metals into Whatcom Creek. The effectiveness of water quality controls was directly assessed through collection of wellpoint seepage samples from the shoreline action area, as discussed in Section 3.



Isopach Thickness in Feet

Color	Range Beg.	Range End
	-11.87	-7.00
	-7.00	-6.00
	-6.00	-5.00
	-5.00	-4.00
	-4.00	-3.00
	-3.00	-2.50
	-2.50	-2.00
	-2.00	-1.50
	-1.50	-1.00
	-1.00	-0.50
	-0.50	0.00
	0.00	0.50
	0.50	1.00
	1.00	1.50
	1.50	2.00
	2.00	9.25

ANCHOR QEA

Figure 1
Comparison of June 2010 Survey vs. May/June 2005 As-built Bathymetry
Holly Street Landfill/Whatcom Creek Restoration

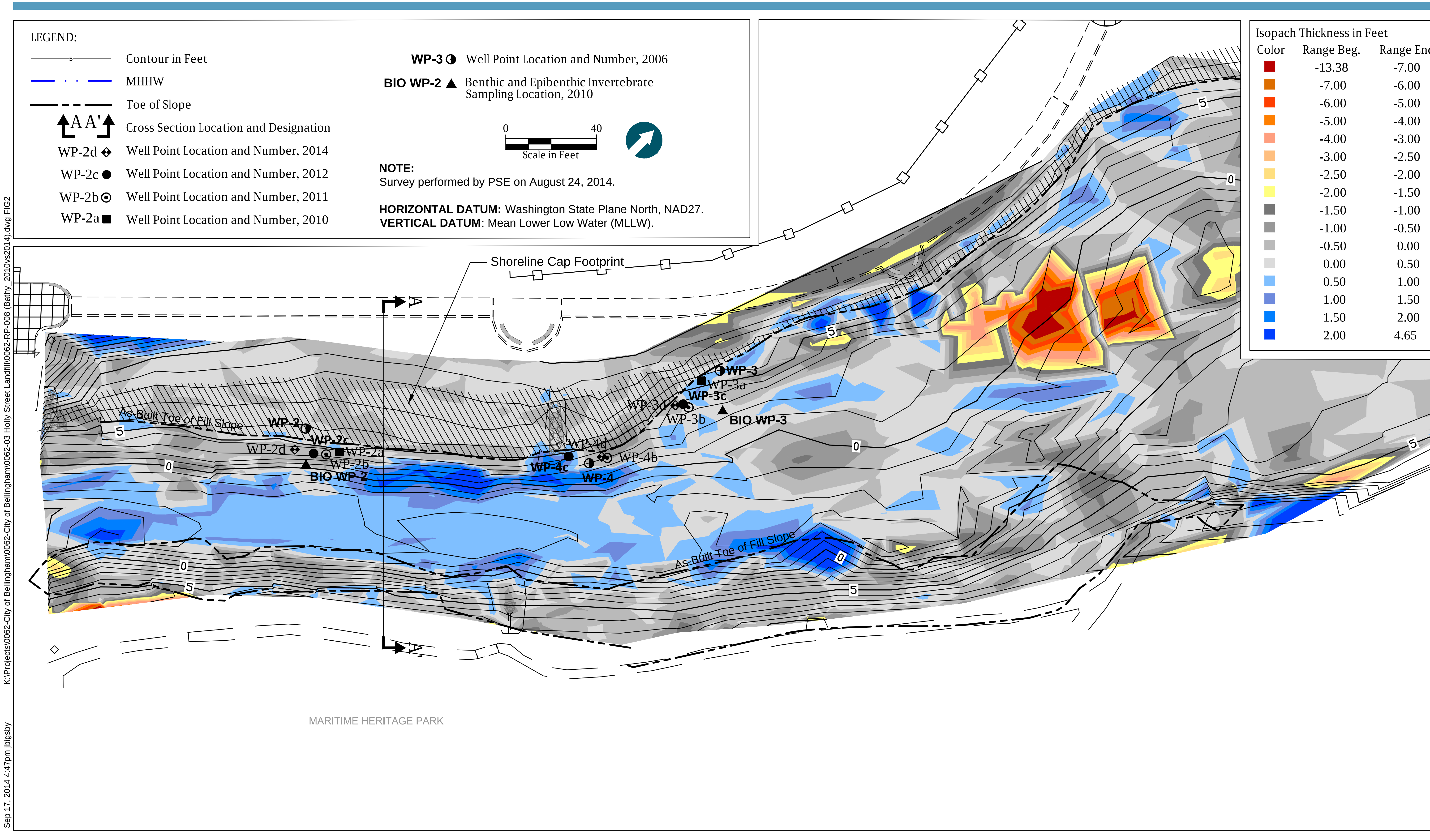


Figure 2
Comparison of August 2014 Survey vs June 2010 Bathymetry
Holly Street Landfill/Whatcom Creek Restoration

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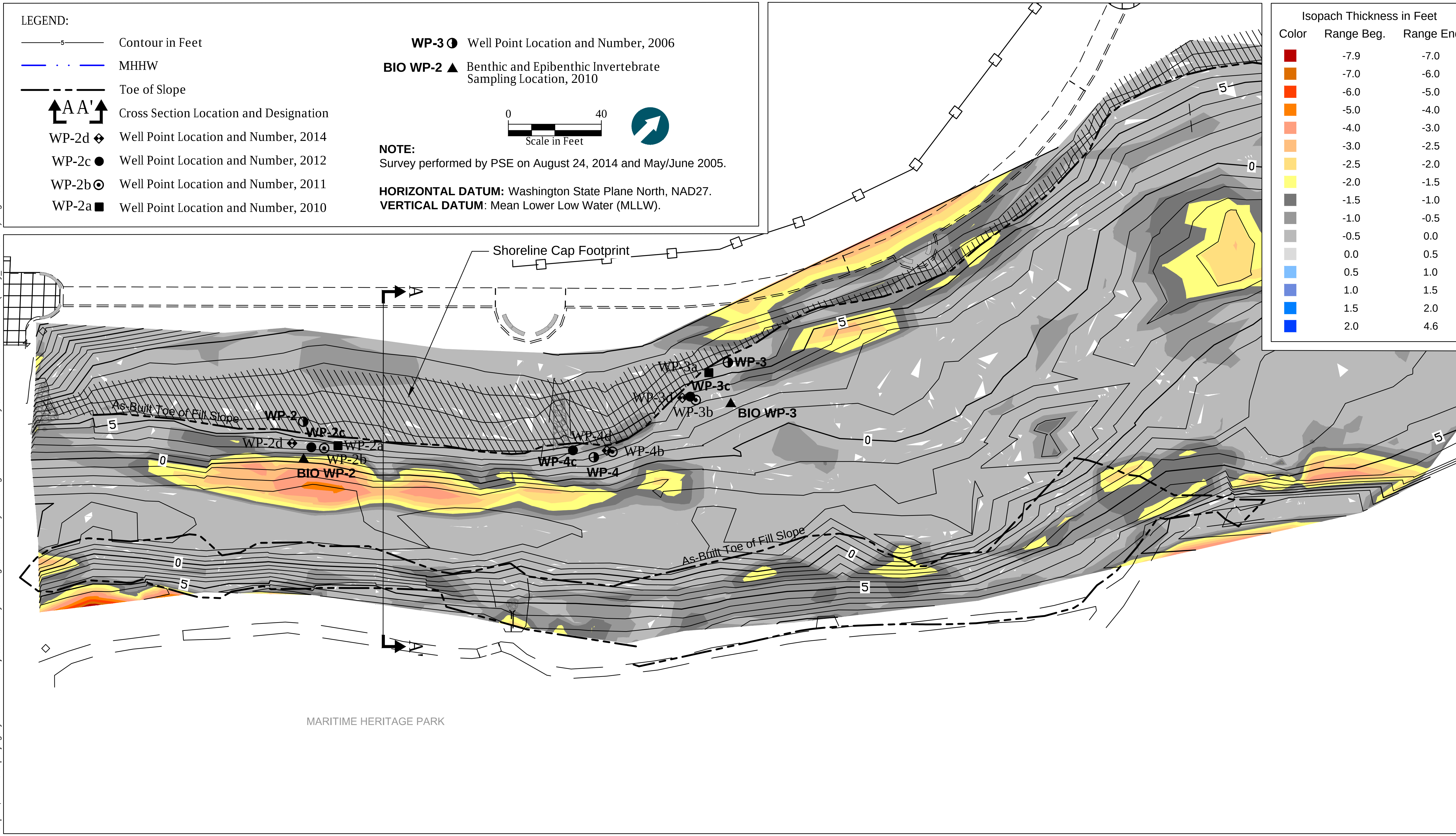

K:\Projects\0062-City of Bellingham\0062-03 Holly Street Landfill\0062-RP-005 (Bathy_2005vs2014).dwg FIG3

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Figure 3
Comparison of August 2014 Survey vs May/June 2005 As-built Bathymetry
Holly Street Landfill/Whatcom Creek Restoration

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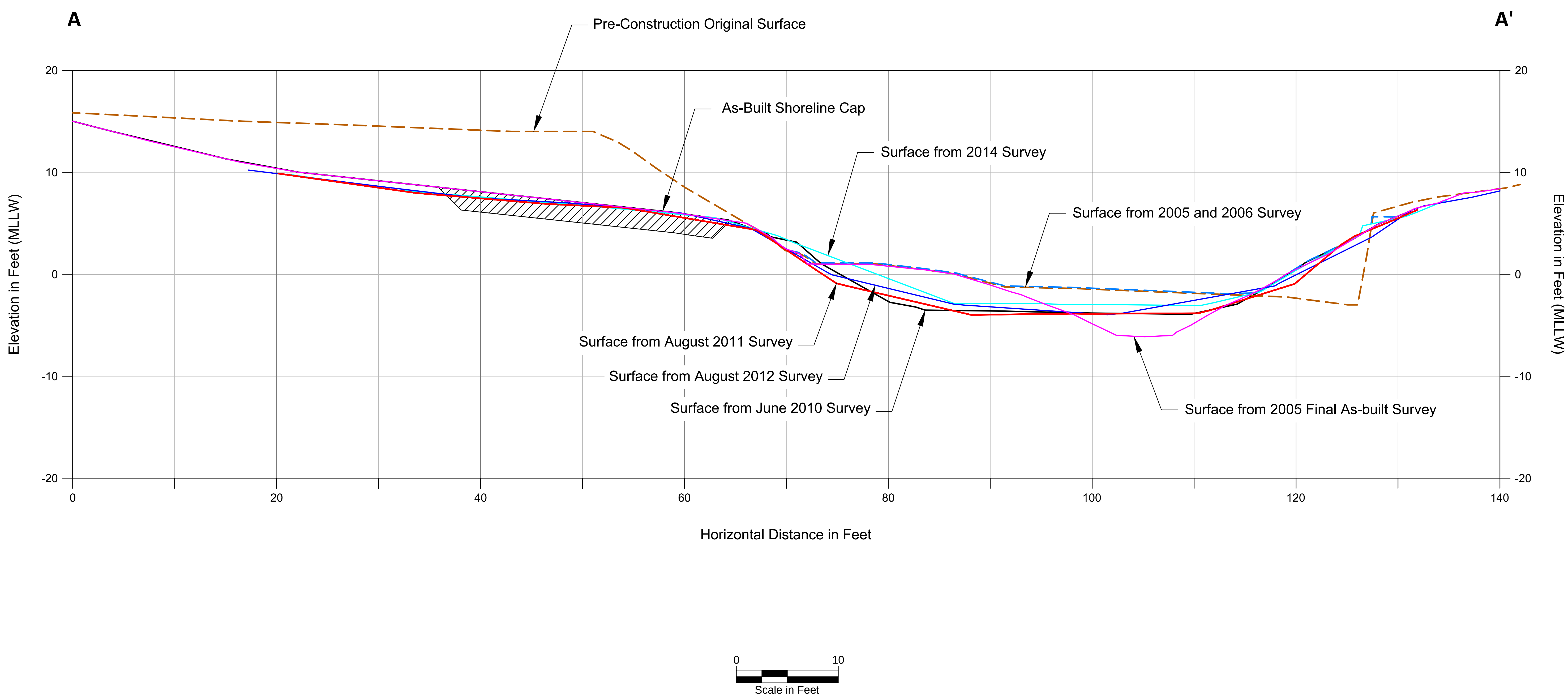

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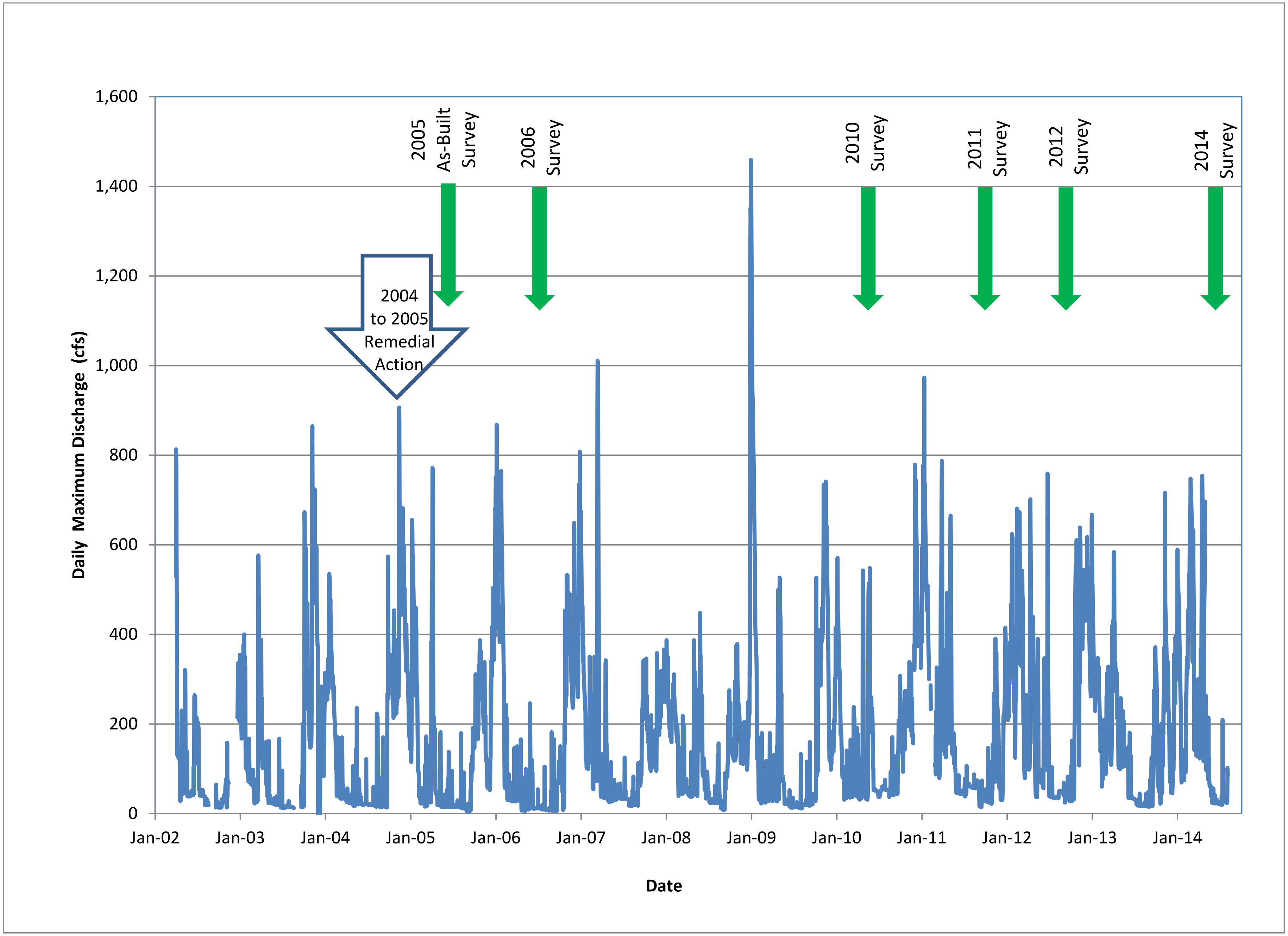
Figure 4
Cross Section A-A'
Holly Street Landfill/Whatcom Creek Estuary Restoration



2005 As-Built Survey
2006 Survey
2010 Survey
2011 Survey
2012 Survey
2014 Survey
2004 to 2005 Remedial Action
Daily Maximum Discharge (cfs)
1,600
1,400
1,200
1,000
800
600
400
200
0
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Date

3 WELLPOINT MONITORING

Post-construction water quality performance monitoring was performed at the Site in Year 1 (May 2006) and again in Year 5 (May 2010), Year 6 (August 2011), Year 7 (August 2012), and Year 9 (August 2014) to verify compliance of seepage discharges with cleanup levels. Primary seepage pathways to the Whatcom Creek shoreline were previously identified and sampled during the RI/FS using temporary wellpoints (Anchor and Aspect 2003). As stated in Exhibit E of the Consent Decree, post-construction monitoring focused on two representative wellpoint locations (WP-2 and WP-3; see Figures 1 to 3), completed within the intertidal landfill cap seepage pathway.

During the Year 1 sampling, metal concentrations measured in the primary Site compliance monitoring wellpoints WP-2 and WP-3 were below surface water cleanup levels (Table 1), confirming the protectiveness of the shoreline cap. However, a wellpoint sample collected in a localized erosional area immediately adjacent to a stormwater outfall along the northwest shoreline (WP-4; see Figures 1 to 3) contained a dissolved copper concentration of 4.7 micrograms per liter (μg/L), which marginally exceeded the cleanup level of 3.1 μg/L. Copper at this location appeared to have been mobilized by tidal mixing processes in the localized outfall erosional area. To ensure the long-term integrity of the cleanup action and reduce the potential for future localized erosion, in 2006 the City redirected a portion of the stormwater flow away from the Site into the C Street stormwater system.

Temporary wellpoints advanced at the WP-2 and WP-3 locations were sampled in Year 5 (May 2010) during low tide conditions. However, even after repeated attempts, an insufficient sample volume was recovered from WP-4; thus, no sample was collected from this location during Year 5 monitoring. The initial Year 5 installation at WP-2 also did not produce porewater in sufficient volume to provide an adequate sample for chemical analysis. However, this wellpoint was subsequently reinserted at a slightly lower elevation along the shoreline beyond the downslope edge of the cap to obtain sufficient sample volume.

Temporary wellpoints advanced at the WP-2, WP-3, and WP-4 locations were sampled in Year 6 (August 2011) and Year 7 (August 2012) during low tide conditions, and sufficient volume for chemical analysis was obtained from all three wellpoints. Temporary wellpoints were again advanced at the WP-2, WP-3, and WP-4 locations in Year 9 (August 2014) during low tide conditions. However, only at the WP-3 location was there sufficient volume for chemical analysis, even after several attempts to relocate wellpoints at WP-2 and WP-4.

Wellpoint samples were obtained using low-flow, low-turbidity sampling techniques to minimize the suspension of sediment into samples. Water samples were obtained from wellpoints using a peristaltic pump and disposable polyethylene tubing, pumping at a rate of approximately 0.5 liter per minute through tubing placed within the screened interval. During the Year 5 (May 2010) sampling, water quality monitoring was performed during purging, and water samples at each wellpoint were obtained after ambient groundwater conditions were achieved (i.e., electrical conductivity, pH, and temperature varied by less than 10 percent for two consecutive casing volume measurements). However, during Years 6 and 7 (August 2011 and 2012 sampling, respectively), relatively low sample volumes during sampling precluded detailed water quality monitoring. During the Year 9 (August 2014) sampling, sufficient volumes were available during sampling to allow for purging prior to collection of sampling at only one sampling location (WP-3). Ambient groundwater conditions were measured following the collection of the water samples.

All samples designated for dissolved metals analysis were filtered in the field through a 0.45-micron membrane in-line filter prior to nitric acid preservation. Wellpoint samples were submitted to Analytical Resources, Inc. (ARI; an Ecology-approved analytical laboratory) for analysis of dissolved metals (arsenic, cadmium, copper, lead, and zinc), salinity, and total suspended solids. As discussed in the SAP Addendum (Anchor 2006b), data quality objectives for these wellpoint samples were equivalent to those used during the RI/FS. Initial Year 5 analyses of dissolved metals at ARI met the data quality objectives, with the exception of the cadmium and lead analyses, which initially had reporting limits above data quality objectives. Accordingly, Year 5 wellpoint samples were subsequently reanalyzed for cadmium and lead at the Applied Speciation and Consulting, LLC laboratory in Bothell, Washington to meet the data quality objectives. All the Years 5, 6, 7, and 9 analyses met data quality objectives. However, during the Years 6 and 7 monitoring events, dissolved copper was detected in the rinseate blanks at only slightly lower concentrations (0.9 and 2.0 μg/L, respectively) than the wellpoint samples. Both blank-corrected and uncorrected values are discussed below.

The Year 5 (May 2010), Year 6 (August 2011), Year 7 (August 2012), and Year 9 (August 2014) wellpoint water quality monitoring data are summarized in Table 1, along with pre-construction (April and August 2000; Anchor and Aspect 2003) and Year 1 (May 2006; Anchor 2006a) data. Similar to the Year 1 data, the Years 5 to 9 sampling data demonstrate substantial reductions in seepage concentrations relative to pre-construction conditions, particularly for zinc and lead. The data also verify a significant decline in the overall risk posed by the seepage discharges (based on the cumulative ratio of measured concentrations to cleanup levels).

While post-construction wellpoint concentrations have remained well below pre-construction levels, dissolved copper concentrations in wellpoint samples collected in Year 5 from WP-2 and WP-3 (10 and 11 µg/L, respectively) nevertheless exceeded the cleanup level of 3.1 µg/L (Table 1 and Figure 6). The elevated Year 5 copper concentrations are likely attributable to erosion of bed sediments in the adjacent creek channel as a result of high flows occurring in January 2009. As discussed previously, erosion of silty sand bed sediments adjacent to the shoreline cap likely promoted greater tidal-induced groundwater/surface water mixing and associated oxygen transfer into nearshore refuse deposits contained below the shoreline cap, which in turn led to release of copper from these materials. Relative to the other metals present in landfill materials (e.g., lead and zinc), copper is generally more mobile under oxidizing groundwater conditions, and most frequently exceeds surface water criteria at other similar estuarine landfill sites (EPA 2007a).

During both the Years 6 and 7 monitoring events, dissolved copper concentrations in all three wellpoints (i.e., WP-2, WP-3, and WP-4) returned to levels similar to or lower than those observed in Year 1, and were marginally above or below the cleanup level of 3.1 µg/L, depending on whether uncorrected or blank-corrected values are used for comparison (Table 1 and Figure 6; blank-corrected values may be more appropriate in this case). During the Year 9 (August 2014) monitoring event, dissolved copper concentrations in wellpoint WP-3 (including duplicate analysis) ranged from 1 to 2 µg/L, substantially below the cleanup level. The improvement of water quality conditions is consistent with accretion of approximately 1 to 3 feet of silty sand within the adjacent channel between Years 5 and 9 (see Section 2), which has likely reduced tidal-induced groundwater/surface water mixing into the capped area.

During the Years 6 to 9 monitoring events, further evaluation of the potential risks posed by relatively low concentrations of dissolved copper in wellpoint samples was performed using the recently developed U.S. Environmental Protection Agency (EPA) biotic ligand model of copper bioavailability and toxicity (EPA 2007b). While the biotic ligand model is not used by Ecology under its water quality or cleanup programs, it can nevertheless provide an additional independent line of evidence to evaluate site-specific differences in the availability and toxicity of copper that can result from different water chemistry characteristics controlling copper bioavailability and toxicity (i.e., site-specific pH, dissolved organic carbon, cation, anion, alkalinity, and sulfide concentrations, all of which were measured during the Years 6 to 9 sampling). Because water chemistry characteristics associated with landfill seepage are substantially different from "typical" surface water, use of the biotic ligand model may be particularly relevant in this Site application. Again, these further evaluations of potential risks using the biotic ligand model do not alter the Site cleanup level, which is based on the total dissolved copper concentration.

As discussed in EPA's Copper Biotic Ligand Module (EPA 2007b), the biotic ligand model is used by EPA to develop national acute and chronic water quality criteria, and model results are often expressed as the calculated bioavailable copper concentration. In all wellpoint samples collected in Years 6 to 9, the bioavailable copper concentrations were well below 0.1 μg/L (Table 1), more than 10 times below the national water quality criterion. Relatively low bioavailability in this situation is primarily attributable to elevated concentrations of dissolved organic carbon (approximately 10 milligrams per liter) in Site seepage, which reduces the activity (and toxicity) of the copper ion. Elevated dissolved organic carbon levels are typical of landfill leachate. Thus, the biotic ligand model results provide an additional line of evidence suggesting that the relatively low (and declining) copper concentrations in seepage discharges at the Site may pose relatively little risk to the environment.

Table 1
Holly Street Landfill Wellpoint Monitoring Data Summary

Analyte	Cleanup Level	WP-2					WP-3						WP-4				
		Pre-Const. (Apr/Aug 2000)	**Year 1 (May 2006)**	**Year 5 (May 2010)**	**Year 6 (Aug 2011)**	**Year 7 (Aug 2012)**	**Pre-Const. (Apr/Aug 2000)**	**Year 1 (May 2006)**	**Year 5 (May 2010)**	**Year 6 (Aug 2011)**	**Year 7 (Aug 2012)**	**Year 9 (Aug 2014)**	**Pre-Const. (Apr/Aug 2000)**	**Year 1 (May 2006)**	**Year 5 (May 2010)**	**Year 6 (Aug 2011)**	**Year 7 (Aug 2012)**
Conventionals (units):																	
Temperature (°C)		13.6 - 18.0	17.2	12.1	--	--	11.4 - 18.0	16.4	12.4	--	--	--	--	16.2	--	--	--
pH		6.0 - 6.5	6.1	7.3	7.6	--	6.3 - 6.9	6.2	6.9	--	--	6.9	--	7.0	--	--	--
Dissolved Oxygen (mg/L)		2.6 - 4.3	5.5	8.9	--	--	3.4 - 4.3	5.1	9.0	--	--	3.3	--	8.0	--	--	--
Salinity (ppt)		3.5 - 9.4	4.0	7.3	7.6	--	3.5 - 8.2	4.3	4.2	--	11.3	4.2	--	9.5	--	--	--
Total Suspended Solids (mg/L)		4 - 9	57	64	487	--	5 - 11	116	14	--	205.0	23.8	--	19	--	--	--
Dissolved Metals in µg/L																	
Arsenic	36	1 U - **1.2**	**2.6**	**8.0**	**5.0**	**4.0**	**1.1 - 4.0**	**3.0**	5 U	**2.0**	2 U	1 U	--	**6.1**	--	2 U	**2.0**
Cadmium	9.3	**0.3** - 1 U	0.2 U	0.1 U	0.2 U	0.1 U	**0.2** - 1 U	0.2 U	0.1 U	**0.3**	0.5 U	0.2 U	--	0.5 U	--	0.5 U	0.2 U
Copper	3.1	**20 - 46**	**1.7**	**10.0**	**1.1 - 2.0 B**	**2.8 - 4.8 B**	**15 - 17**	**2.4**	**11.0**	**3.1 - 4.0 B**	**2.0 - 4.0 B**	**1.0 - 2.0**	--	**4.7**	--	**2.1 - 3.0 B**	**1.0 - 3.0 B**
*Bioavailable Copper (BLM)**	*3.1*				*<0.1*	*<0.1*				*<0.1*	*<0.1*	*<0.1*				*<0.1*	*<0.1*
Lead	8.1	**5 - 8**	1 U	0.1 J	**0.4**	**0.3**	**3** - 5 U	1 U	0.1 J	**0.4**	0.5 U	**1.4**	--	1 U	--	0.5 U	0.2 U
Zinc	81	**101 - 316**	**9**	10 U	10 U	4 U	**103 - 268**	**10**	**10**	**10**	**20**	**40**	**--**	**13**	**--**	20 U	**20**

Notes:

U denotes that the analyte was undetected at the indicated reporting limit.

J denotes that the analyte was detected between the minimum detection limit and reporting limit; value is estimated.

B denotes that the analyte was also detected in the rinseate blanks; the range of blank-corrected and uncorrected values is shown.

Bolded values represent detected analytes.

-- denotes that samples were not collected (e.g., WP-4 was not sampled in May 2010 due to insufficient sample volume recovered from this wellpoint).

Highlighted value denotes that the sample concentration exceeds the chronic (4-day-avg) surface water quality criterion.

* Bioavailable copper concentrations calculated with site-specific data using the EPA Copper BLM (EPA 2007); see text.

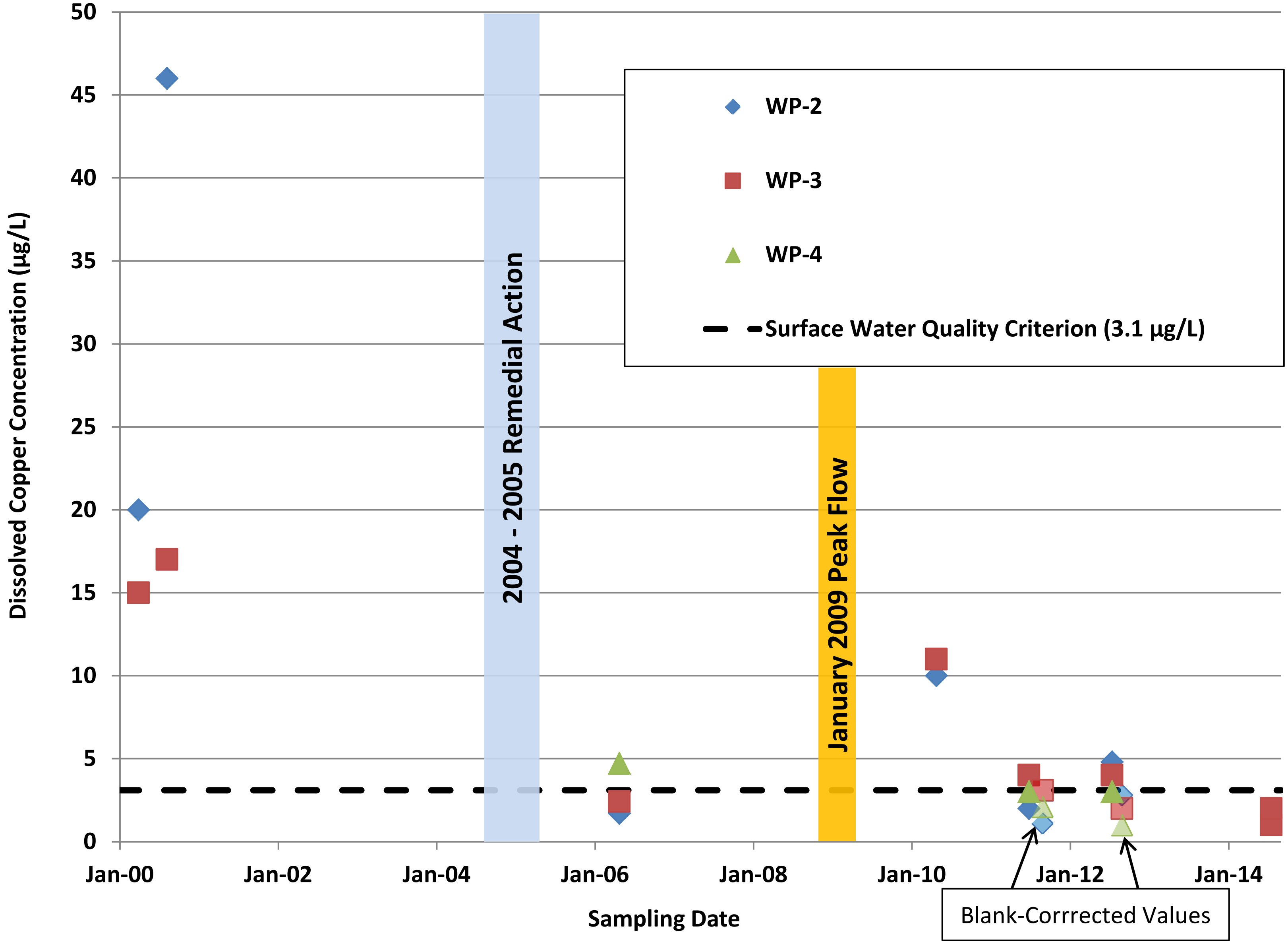
°C = degrees Centigrade

µg/L = micrograms per liter

BLM = Biotic Ligand Module

mg/L = milligrams per liter

ppt = parts per thousand



Dissolved Copper Concentration (µg/L)
50
45
40
35
30
25
20
15
10
5
0
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Sampling Date
2004 - 2005 Remedial Action
January 2009 Peak Flow
WP-2
WP-3
WP-4
Surface Water Quality Criterion (3.1 µg/L)
Blank-Corrrected Values

4 BIOLOGICAL MONITORING

The overall biological monitoring objective for the integrated habitat restoration and cleanup remedy implemented by the City is to verify that more productive biological communities become established in the project area. This objective was addressed by documenting recolonization of epibenthic and benthic macroinvertebrates in the area (relative to 2002 pre-construction baseline conditions), and documenting general utilization of the Site area by juvenile salmonids. An overview of the macroinvertebrate and juvenile salmonid sampling procedures is provided in Exhibit E of the Consent Decree (Anchor 2002). Primary habitat monitoring stations are labeled as BIO WP-2 and BIO WP-3 on Figures 1 to 3.

Post-construction epibenthic and benthic macroinvertebrate sampling was conducted in Year 1 (July 2006) and Year 5 (July 2010). Triplicate epibenthic and benthic macroinvertebrate samples were collected at BIO WP-2 and BIO WP-3. Species lists and enumeration results were recorded for each sample. Dr. Brian Bingham of Western Washington University oversaw all epibenthic and benthic macroinvertebrate sampling and enumeration.

To ensure that data collected in Year 5 would be comparable to the pre-construction baseline and Year 1 data, epibenthos collection methods were matched as closely as possible (Bingham 2002). An epibenthic suction pump (Simenstad et al. 1991) was used to collect three replicate samples of the epibenthos at each station. The pump covered a 0.033-square-meter (m^2) area of the bottom and enclosed a volume of 7.1 liters (L). To ensure that all invertebrates were removed from the pump, three volumes of water (21.3 L) were flushed through the system. The pump had 0.13-millimeter (mm) screened ports that retained the macroinvertebrates but allowed water to pass through and flush the system. The collected material was then washed through a 0.25-mm mesh sieve, and the sample was preserved in 10 percent buffered formalin. The samples were later transferred to 70 percent ethanol. In the laboratory, all invertebrates were picked from the samples, sorted, and identified to the lowest possible taxonomic level.

The Year 5 benthic invertebrate collection methods were also equivalent to those employed the pre-construction baseline and Year 1 surveys. However, during the pre-construction baseline sampling, accumulated rocks, glass, plastic, and other debris prevented collection of typical ponar grab samples (Bingham 2002), requiring sampling of the Site at low tide and collection of equivalent benthic sediment volumes with a shovel. During the Year 5 event, sampling was first attempted from a boat using a 0.023 m^2 petite ponar grab sampler (PSEP 1997); however, a relatively high density of cobbles and rocks on the bottom prevented effective sampling. To obtain a suitable benthic sample, the Year 5 sampling was performed at a low tide of approximately -2.5 feet mean lower low water (MLLW). Benthic invertebrate samples were collected using a shovel, mimicking the dimensions, depth, and volume of a ponar grab. The collected samples were washed through a 0.5-mm brass sieve and fixed with 10 percent buffered formalin. The samples were later transferred to 70 percent ethanol, sorted, and identified to the lowest possible taxonomic group.

Juvenile salmonid utilization of the restored habitat at the Site was monitored by conducting shoreline-based observations, using similar methods to those used in prior monitoring events. A trained Anchor QEA biologist used binoculars and polarized glasses to observe fish distributions in the project area. Observations were made during the spring juvenile salmonid outmigration period, and were conducted during two 15-minute periods to provide fish observation data during different portions of the tidal cycle (e.g., flood, ebb, slack). Observations were made from five sampling locations in the project area along the north and south banks of the estuary from the Whatcom Creek Fish Hatchery (also known as the Maritime Heritage Park Fish Hatchery) to the Holly Street Bridge.

4.1 Epibenthos Monitoring Results

A substantially greater number of epibenthic species were reported in Years 1 and 5 than during the baseline year. In Year 5, epibenthos were dominated by oligochaetes and small crustaceans (see Appendix A), similar to results from the Year 1 monitoring event. Notable differences in Year 5 results included an increase in the abundance of the arthropod *Tisbe* (sp. Tisbe) and calanoid copepods. A significant freshwater influence was also evident, with the observation of several insects and a single minnow. Relative to pre-construction baseline conditions, the post-construction epibenthic invertebrate taxonomic metrics (e.g., significantly increased species diversity and evenness) document that more productive and stable epibenthic communities have now become established in the Site area (Table 2).

Table 2
Summary of Epibenthic and Benthic Invertebrate Taxonomic Metrics

Year	Average Number of Species	Average Number of Individuals	Diversity Index	Pielou's Evenness
Epibenthos				
2002	9 (6–13)	194 (62–491)	0.47 (0.37–0.56)	1.00 (0.78–1.26)
2006	14 (13–19)	163 (98–213)	0.70 (0.67–0.75)	1.86 (1.72–2.06)
2010	16 (12–21)	258 (95–677)	0.72 (0.63–0.84)	2.01 (1.74–2.24)
P value	0.001	0.59	< 0.001	< 0.001
	2010 = 2006 > 2002		2010 = 2006 > 2002	2010 = 2006 > 2002
Benthos				
2002	7.8 (6–9)	472 (327–700)	0.41 (0.16–0.66)	0.82 (0.36–1.29)
2006	8.0 (7–10)	164 (65–244)	0.58 (0.52–0.64)	1.21 (1.03–1.41)
2010	5.7 (3–8)	15 (7–28)	0.88 (0.77–0.97)	1.45 (1.0–1.84)
P value	0.052	< 0.001	< 0.001	0.015
	--	2002 > 2006 > 2010	2010 > 2006 = 2002	2010 > 2002

4.2 Benthos Monitoring Results

As in the earlier monitoring, the benthic community in the Site area during the Years 5 monitoring was dominated by a few large polychaetes (*Neanthes limnicola* and *Nereis virens*; see Appendix A). These polychaetes accounted for most of the biomass in the benthic samples. As was the case in the prior sampling events, there were no mollusks in the benthic samples. Relative to pre-construction baseline conditions, the post-construction benthic invertebrate taxonomic metrics (e.g., significantly increased species diversity and evenness) document that more stable and productive benthic communities have now become established in the Site area (Table 2). While the average number of individual benthic organisms steadily declined from Years 1 to 5, the relationship between cumulative abundance and biomass in the Site area indicates the establishment of a more stable, productive benthic community over the post-construction monitoring period. In stable benthic communities with few disturbances, succession leads to communities dominated by larger long-lived organisms with higher biomass (Clarke and Warwick 2001), which has occurred in the Site area.

4.3 Juvenile Salmonid Monitoring Results

During the Year 5 fish monitoring (May 2010 survey), a total of approximately ten adult salmonids (trout) measuring approximately 220 to 270 mm in total length were observed feeding on the north side of the creek in the project area. In addition, one juvenile cutthroat approximately 30 to 60 mm in total length was observed feeding near the anchored woody debris, and an additional four juvenile salmonids measuring approximately 30 to 90 mm in total length were observed adjacent to the anchored woody debris. The Year 5 fish observations are summarized in Table 3.

The Year 5 observations are similar to the Year 1 monitoring results, when an estimated 50 to 65 juvenile salmonids measuring approximately 30 to 90 mm in total length were observed on the north bank in the project area (Anchor 2006a). In addition, a total of five juvenile salmonids were observed in Year 1 (May 2006 survey) near habitat restoration features, including anchored woody debris. Together, the Year 1 and 5 fish monitoring data document that juvenile salmonids are successfully utilizing the Site area for feeding and rearing.

Table 3
Summary of 2010 Juvenile Salmonid Observations

Observation	May 24, 2010		May 28, 2010	
	Morning	Afternoon	Morning	Afternoon
Tide Stage	Low Slack Tide, +0.0 Feet MLLW	High Tide, +6.5 Feet MLLW	Mid Ebb Tide, +4.0 feet MLLW	Mid Flood Tide, +4.0 Feet MLLW
Time	0930 to 0945	1600 to 1615	0800 to 0815	1600 to 1615
Weather	Partly Sunny	Partly Sunny	Overcast, Light Rain	Overcast, Light Rain
Location				
A	None	None	None	None
B	One juvenile cutthroat between 30 and 60 mm total length	Three juvenile salmonids between 60 and 90 mm total length; feeding near habitat logs	None	None
C	Approximately 50 shiner perch between 100 and 150 mm total length and approximately 10 trout between 220 and 270 mm total length; all appeared to be feeding	None	Observed fish surface feeding; assumed to be juvenile salmonids though the size and species of fish were not determined	None
D	None	None	None	None
E	None	None	None	None

Notes:
MLLW = mean lower low water
mm = millimeters

5 FUTURE MANAGEMENT AND MONITORING

This section describes current flow management protocols to control peak flows in Whatcom Creek, along with future monitoring to ensure the integrity of the Holly Street Landfill Site remedy.

5.1 Whatcom Creek Flow Management

Whatcom Creek is the outlet of the City's drinking water reservoir, Lake Whatcom. Several parameters control the flow of Whatcom Creek, including precipitation in the Lake Whatcom watershed (including Whatcom Creek), diversions from the middle fork of the Nooksack River, municipal water withdrawals, and outlet flows controlled by adjusting gates at the dam.

Currently, there are relatively limited opportunities to manage outflows from the dam by storing peak runoff in the lake, as Lake Whatcom lake management protocols do not allow water surface elevations to exceed the maximum lake level set by court order. However, the City's current protocols attempt to better optimize peak flows and lake levels. Another opportunity to control peak flows in Whatcom Creek, and thus minimize the potential for erosion of silty sand sediments in the channel adjacent to the Site, is to divert peak flows into the former Georgia-Pacific large capacity industrial supply pipeline that discharges into Bellingham Bay downstream of the Site.

5.2 Future Monitoring

As discussed in Section 2, post-construction bathymetric monitoring has confirmed the integrity of the shoreline cap constructed at the Site, and the cap thickness continues to exceed the requirements specified in the CAP. Moreover, epibenthic, benthic, and fisheries utilization data summarized in Section 4 indicate that more productive and stable biological communities have now become established in the project area.

As summarized in Section 3, the wellpoint water quality monitoring data have demonstrated substantial reductions in seepage concentrations of metals relative to pre-construction conditions, and also a significant decline in the overall risk posed by the seepage discharges. While temporary increases in dissolved copper concentrations above the cleanup level were observed following the January 2009 peak discharge event (estimated 100-year recurrence interval), during more recent Years 6 to 9 monitoring events, dissolved copper concentrations in all wellpoints returned to levels similar to or lower than those observed in Year 1. Based on the most recent data, dissolved copper concentrations in Site seepage discharges are now below the cleanup level of 3.1 µg/L (Figure 6). The improvement of water quality conditions is consistent with accretion of approximately 1 to 3 feet of silty sand within the adjacent channel over the past 4 years (see Section 2), which has likely reduced tidal-induced groundwater/surface water mixing into the capped area, further sequestering copper and other metals.

Because monitoring data collected to date confirm that more productive and stable biological communities have now become established in the project area, no further biological monitoring is necessary at the Site to confirm the effectiveness of the habitat restoration actions. Moreover, bathymetry surveys and wellpoint sampling suggest that dissolved copper concentrations in Site seepage discharges will continue to remain below cleanup levels as long as peak flows are controlled. In order to further confirm the protectiveness of the remedy, follow-on bathymetric surveys and wellpoint sampling will be performed by the City within 1 year following peak flows in Whatcom Creek (DuPont Street gage #1380) in excess of the approximate 30-year flood event of 1,200 cfs.

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APPENDIX A
2010 BENTHOS AND EPIBENTHOS MONITORING REPORT

2010 Benthos and Epibenthos Monitoring Report

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Materials and Methods

Quantitative sampling of the epibenthos

To ensure that data collected in Year 5 would be comparable to those collected in the baseline year, we matched collection methods as closely as possible (Bingham, 2002). We again used an epibenthic suction pump (Simenstad et al., 1991) to take three replicate samples of the epibenthos at each of 2 fixed stations (WP-2 and WP-3). The pump covered a 0.033 m^2 area of the bottom and enclosed a volume of 7.1 liters. To ensure that all invertebrates were removed from the pump, we flushed three volumes of water (21.3 l) through the system. The pump had 0.130-mm screened ports that retained the macroinvertebrates but allowed water to pass through and flush the system. We washed the collected material through a 0.253-mm mesh sieve and preserved the sample in 10% buffered formalin. The samples were later transferred to 70% ethanol. In the laboratory, all invertebrates were picked from the samples, sorted and identified to the lowest possible taxonomic level. This sampling was done on July 14, 2006 during an outgoing tide.

To determine biomass composition of each sample, we separated the invertebrates into broad taxonomic groups (i.e., annelids, mollusks, crustaceans and other). These grouped samples were oven dried at 60° C for 24 hours then weighed.

Quantitative sampling of benthic invertebrates

On July 14, 2006, we also took three 0.023 m^2 petite ponar grab samples (PSEP 1997a) from Site WP-2 and WP-3. The collection method differed slightly from the baseline year. In the baseline year, accumulated rocks, glass, plastic and other debris prevented us from taking typical ponar grab samples. Instead, we had to visit the site at low tide and collect equivalent benthic sediment volumes with a shovel. In the current year sampling, the benthic habitat was much sandier and cleaner, allowing us to collect the ponar samples from a small boat at high tide. The collected samples were washed through a 0.5-mm brass sieve and fixed with 10% buffered formalin. They were later transferred to 70% ethanol, sorted and identified to the lowest possible taxonomic group. After we had sorted and counted all the invertebrates, we grouped them into taxonomic groups, oven dried them at 60° C for 24 hours then weighed them to get a dry biomass measurement.

Results

Epibenthic samples were composed largely of oligochaetes and harpacticoid copepods. There were, however, many other species present in smaller numbers. We found more species in this sampling than we did in the baseline year (31 species vs. 21 species). Many of the new species were mollusks (which were completely absent in the baseline year samples).

As in the baseline year, benthic samples were dominated by large numbers of the nereid polychaete *Neanthes limnicola*. These polychaetes accounted for most of the biomass in the benthic samples. In the baseline year, we found insects in most of the epibenthic and benthic samples. These were nearly absent from the year 5 samples.

Appendix I.

Species Checklist for invertebrates collected in the Whatcom Waterway near the Holly Street bridge (Sites WP-2 and WP-3).

Phylum Sarcomastigophora
- Class Granuloreticulosea
  - Order Foraminiferida
    - Family Elphidiidae
      - *Elphidium excavatum* (Terquem)

Phylum Nematoda
- Unidentified nematodes

Phylum Annelida
- Class Polychaeta
  - Order Oweniida
    - Family Owenidae
      - *Owenia fusiformis* (Chiaje, 1841)
  - Order Phyllodocida
    - Family Nereidae
      - *Neanthes limnicola* (Johnson, 1903)
    - Family Phyllodocidae
      - *Eteone spetsbergensis* (Malmgren, 1865)
  - Order Sabellida
    - Family Sabellidae
      - Subfamily Fabricinae
        - unidentified (new?) species
  - Order Spionida
    - Family Spionidae
      - *Polydora* sp.
      - *Pseudopolydora bassarginensis* Zachs 1933
  - Order Terebellida
    - Family Ampharetidae
      - *Hobsonia florida* (Hartman, 1951)
- Class Oligochaeta
  - Unidentified species

Phylum Mollusca
- Class Gastropoda
  - Subclass Prosobranchia
    - Order Patellogastropoda
      - Family Lottidae
        - *Acmaea* sp.
    - Unidentified veliger larvae
- Class Bivalvia
  - Order Mytiloida
    - Family Mytilidae
      - *Modiolus modiolus* (Linnaeus, 1758)
    - Family Tellinidae

Macoma inquinata (DeShayes, 1854)
Order Veneroida
Family Montacutidae
Rochefortia tumida (Carpenter, 1864)
Family Veneridae
Transennella tantilla (Gould, 1852)

Phylum Arthropoda
Subphylum Crustacea
Class Copepoda
Order Callanoida
Unidentified species
Order Harpacticoida
Harpacticus sp.
Nannopus palustris (Brady, 1880)
Orthopsyllus illgi (Chappuis, 1958)
Tisbe sp.
Class Cirripedia
Balanus sp.
Class Malacostraca
Subclass Peracarida
Order Cumacea
Family Leuconiidae
Nippoleucon hinumensis (Gamo, 1967)
Family Nannastacidae
Cumella vulgaris (Hart, 1930)
Order Tanaidacea
Family Paratanaidae
Leptochelia savignyi (Kroyer, 1842)
Family Tanaidae
Pancolus californiensis Richardson, 1905
Order Amphipoda
Superfamily Gammaroidea
Family Anisogammaridae
Eogammarus sp.
Superfamily Corophioidea
Family Corophiidae
Corophium spinicorne Stimpson, 1857
Order Decapoda
Infraorder Brachyura
Unidentified zoea larvae
Class Ostracoda
Suborder Podocopida
Unidentified ostracod species 1
Unidentified ostracod species 2
Unidentified ostracod species 3
Unidentified ostracod species 4

Subphylum Uniramia

Class Insecta
- Order Coleoptera
  - Unidentified Eliminidae
- Order Diptera
  - Unidentified Chironomidae

Appendix II. Organisms collected in epibenthic samples from Whatcom Waterway (Sites WP-2 and WP-3)

Annelida

	Station					
	WP-2			WP-3		
	1	2	3	1	2	3
Neanthes limnicola	1					
Owenia fusiformis		3				
Polydora cornuta	1					
Unidentified oligochaete	39	24	51	12	16	39

Mollusca

	Station					
	WP-2			WP-3		
	1	2	3	1	2	3
Acmaea sp.				1		
Modiolus modiolus			1		2	1
Rochefortia tumida			2			
Transenella tantilla			3		1	1
Littorine egg case	1	3	3	28	1	6
Unidentified gastropod egg case		2	2	1	1	
Unidentified veliger	1	1	4			

Arthropoda

	Station					
	WP-2			WP-3		
	1	2	3	1	2	3
Corophium spinicorne		2	1		23	31
Cumella vulgaris		1				
Eogammarus sp.				15	1	
Harpacticus sp.	72	48	39	43	34	66
Leptochelia savignyi					1	
Nannopsis palustris	57	43	40	9	11	31
Nippoleucon hinumensis			5			
Orthopsyllis illgi			1	1		
Tisbe sp.					1	
Unidentified ostracod 1	3	1	4			1
Unidentified ostracod 2			3	1		
Unidentified ostracod 3				1		1

Unidentified ostracod 4	21	29	13	5	3	4
Unidentified copepod nauplius		1	1			
Unidentified calanoid copepod	4	2	5	3	1	2
Unidentified brachyuran zoea	1			1		
Unidentified chironomid			1			
Unidentified Elimidae						1

Miscellaneous	**Station**					
	WP-2			WP-3		
	1	2	3	1	2	3
Unidentified nematodes	8	3		8	3	12
Elphidium excavatum (Foraminifera)	4	1	1			

Appendix III. Organisms collected in benthic samples from Whatcom Waterway (Sites WP-2 and WP-3)

Annelida

	Station					
	WP-2			WP-3		
	1	2	3	1	2	3
Eteone spetsbergensis			3	2	5	
Hobsonia florida	5	6	10			
Neanthes limnicola	69	71	117	16	32	40
Pseudopolydora bassarginensis	16	7	4	4	2	2
Unidentified sabellid	10	2	2	3	1	4
Unidentified oligochaete	112	84	107	115	19	25

Mollusca

	Station					
	WP-2			WP-3		
	1	2	3	1	2	3
Macoma inquinata		1				

Arthropoda

	Station					
	WP-2			WP-3		
	1	2	3	1	2	3
Balanus sp.				1		
Corophium spinicorne	1				1	1
Nannopsis palustris	10	2	1	57	3	
Nippoleucon hinumensis					1	
Pancolus californiensis	2			3	1	2
Unidentified calanoid copepod				1		

Miscellaneous

	Station					
	WP2			WP3		
	1	2	3	1	2	3
Unidentified Nematodes						3

Appendix IV. Dry weight biomass of organisms collected in epibenthic samples from Whatcom Waterway (Sites WP-2 and WP-3). Values are in mg • 0.033 m^2 (the circular surface area covered by the epibenthic suction pump). BD (below detection) indicates that dry weight was too low to be accurately measured.

	Station					
	WP-2			WP-3		
	1	2	3	1	2	3
Annelida	0.2164	0.5094	0.1391	0.0327	0.0436	0.1163
Mollusca	BD	BD	0.1469	0.5009	0.0774	0.0489
Arthropoda	1.3874	1.3396	1.3454	0.5427	0.6620	1.1431
Other (Nematoda, Foraminifera)	0.1043	0.0352	0.0073	0.0734	0.0295	0.1101

Appendix V. Dry weight biomass of organisms collected in benthic samples from Whatcom Waterway (Sites WP-2 and WP-3). Values are in mg • 0.023 m^2 (the cross-sectional surface area sampled by the petit ponar grab). BD (below detection) indicates that dry weight was too low to be accurately measured.

	Station					
	WP-2			WP-3		
	1	2	3	1	2	3
Annelida	7.250	6.613	10.619	1.730	2.968	3.501
Mollusca		0.402				
Arthropoda	0.069	0.008	0.003	10.062	0.063	0.0255
Other (Nematoda, Foraminifera)						BD

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