LNAPL REMOVAL WORK PLAN

Crownhill Elementary School Site

Prepared for: Bremerton School District

Project No. 100094-003-02 • November 19, 2015

Aspect CONSULTING

earth + water

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1 Introduction

1.1 General

Historical landfill activities at the Bremerton School District (BSD) Crownhill Elementary School Site (Site) have resulted in the presence of light non-aqueous-phase liquid (LNAPL) floating on the water table. As described in the Site's *Cleanup Action Plan* (CAP; Ecology, 2014), periodic removal and offsite recycling/disposal of LNAPL from existing monitoring wells is required to help ensure the continued protectiveness of the selected cleanup action for the Site. This LNAPL Removal Work Plan (Work Plan) completed by Aspect Consulting, LLC, (Aspect) addresses removal procedures, removal frequency, recycling/disposal of recovered liquids, and reporting requirements.

The selected cleanup action also includes periodic monitoring of groundwater quality and LNAPL layer thickness. Those activities are prescribed in the *Groundwater/LNAPL Monitoring and Contingency Plan* (Aspect, 2015b), a companion document to this Plan. BSD is responsible for implementing this Plan and the *Groundwater/LNAPL Monitoring and Contingency Plan* in accordance with Agreed Order (AO) No. DE11107 between the Washington Department of Ecology (Ecology) and BSD.

1.2 Project Background

Crownhill Elementary School is located at 1500 Rocky Point in Bremerton, Washington (Figure 1). The Site was used for sand and gravel mining up to the 1930s, and the mined area was backfilled with municipal and industrial wastes in the 1930s and 1940s. The original school building was constructed in 1956, and partially burned down in 1993. A series of environmental investigations were conducted during the period between that fire and construction of the current school building, which was completed in 1996. Additional investigations were conducted beginning in 2009, culminating in the preparation of a *Remedial Investigation* (RI) report (Aspect, 2014a).

The purpose of the RI was to collect data necessary to adequately characterize the nature and extent of Site contamination. Using multiple lines of evidence (e.g., historical photographs, site assessment activity, construction observations), the RI identified two generalized areas of landfill accumulation, designated the 'north' and 'south' landfill areas. Figure 2 shows the interpreted boundaries of these two areas. Landfilled materials were found at up to 40-foot depth in the north landfill area, and at up to 20-foot depth in the south landfill area. Three monitoring wells (MW-1 through MW-3) were installed at the Site in December 1994/January 1995, and another 13 (MW-4 through MW-16) during the RI (between March 2011 and October 2012). This network of 2-inch-diameter wells was used to periodically monitor groundwater, which is encountered beneath the Site at roughly 110-foot depth, for a wide range of contaminants. Periodic monitoring identified the following constituents of concern (COCs) dissolved in groundwater in the northern portion of the Site:

- Total petroleum hydrocarbon (TPH) in the diesel and motor oil ranges;

- Trichloroethene (TCE);
- Arsenic; and
- Lead.

In addition to dissolved contaminants, separate-phase oil was found floating on the groundwater table (as LNAPL) in Well MW-8, installed in the north landfill area. The primary reason for installing the last five RI monitoring wells (MW-12 through MW-16) was to investigate the areal extent and thickness of the LNAPL accumulation.

Site cleanup alternatives were developed and comparatively evaluated with respect to criteria specified in the Washington Model Toxics Control Act (MTCA; Chapter 173-340 WAC) in the *Feasibility Study* (FS; Aspect, 2014b). Based on the FS evaluation, a cleanup action that includes periodic removal of LNAPL from existing monitoring wells was selected for implementation. Refer to the CAP (Ecology, 2014) for a full description of the selected cleanup action for the Site.

Following completion of the CAP, a draft of this Plan (Aspect, 2015a) was developed and submitted for Ecology review. In their comment letter (Ecology, 2015), Ecology recommended the installation of a larger-diameter LNAPL extraction well near MW-13 and MW-16, to supplement the monitoring well network. Well EW-17, a 4-inch-diameter well, was installed in October 2015 in response to Ecology's recommendation. In addition to having a larger diameter than the Site monitoring wells, EW-17 includes the following features to enhance entry of LNAPL into the well:

- Coarser sand (8-12 mesh size) used for the screen interval filter pack;
- Larger screen slot size (0.040-inch); and
- Vee-wrap screen construction, which has a higher open area for a given slot size compared to standard screen construction.

Well construction diagrams are provided in Appendix B of the *Groundwater/LNAPL Monitoring and Contingency Plan* (Aspect, 2015b). Because of its larger diameter and special design features, EW-17 is expected to be the most productive well with respect to LNAPL removal.

As noted on Figure 2, LNAPL has been observed to date in five wells in the north landfill area (MW-8, MW-13, MW-14, MW-16, and EW-17). Appendix B presents physical and chemical characteristics of LNAPL, based on analysis of a sample collected from Well MW-13 in November 2012 during the RI.

2 LNAPL Removal

2.1 General Requirements, Expectations, and Goals

The LNAPL removal program has been developed based on the following general requirements and expectations:

- Periodic LNAPL removal from existing wells addresses the remedial action objective (RAO) developed in the FS to remediate LNAPL to the maximum extent practicable. Periodic removal also reduces the likelihood that the LNAPL plume will spread laterally on the water table.

- Well MW-15 is the conditional point of compliance (CPOC) for LNAPL migration[1]. If LNAPL is detected in MW-15, more aggressive measures than the removal methods specified in this Work Plan will be considered/implemented to prevent further LNAPL migration. (Refer to the *Groundwater/LNAPL Monitoring and Contingency Plan* [Aspect, 2015b])

2.2 Removal Procedure

LNAPL removal events will typically be coordinated with the periodic groundwater quality monitoring specified in the *Groundwater/LNAPL Monitoring and Contingency Plan* (Aspect, 2015b). An electronic oil/water interface probe graduated to 0.01 foot will always be used to measure depth-to-LNAPL and depth-to-groundwater prior to initiating LNAPL removal. The interface probe produces three distinct tones depending on whether its tip is in contact with air, petroleum hydrocarbon product, or water. Due to the viscous, sticky nature of the LNAPL, probe response may be problematic. Multiple readings will be taken in order to improve the accuracy of this measurement technique.

Removal will be attempted from all wells containing at least 0.3 foot of LNAPL. Bottom-filling bailers will be used. While the bailing technique will attempt to minimize coincident water removal, water removal is unavoidable. Volumetric recovery of LNAPL and water will be tracked separately by emptying the bailer contents into a graduated cylinder and recording the water and total fluid volumes (the LNAPL volume being determined by difference). LNAPL removal will continue until a bailer retrieves a relatively large volume of water with little or no LNAPL. Based on LNAPL bailing tests conducted during the RI, this is generally expected to result in a residual LNAPL layer thickness of less than 0.1 foot.

Field measurements and observations will be recorded on the LNAPL Thickness Monitoring and Removal Record form provided in this Work Plan.

2.3 Removal Frequency

LNAPL removal events will be conducted semiannually (coincident with groundwater monitoring rounds), with the following exception: If an LNAPL layer thickness of 4 feet or greater is measured in any well (prior to LNAPL removal), then a follow-up removal event will be conducted approximately 3 months later. Layer thicknesses will be measured in all LNAPL wells during each removal event, and removal will be attempted from all wells containing at least 0.3 foot of LNAPL.

[1] The CAP specifies that MW-6 will be the CPOC for LNAPL migration. However, in their comment letter on the draft Work Plan (Ecology, 2015) Ecology stated that, in order for the CPOC for LNAPL migration to be as close as practicable to the source of hazardous substances [per WAC 173-340-720(8)(c)], it should be changed to MW-15.

2.4 Modifications to Removal Procedures and Frequency

As is evident from Table A-1 (Appendix A), there is currently very little data on the relationship between measured LNAPL thickness and the ability to recover LNAPL from a well. In addition, the data generated to date suggest that the relationship between thickness measurements and recoverability may not be straightforward. In Well MW-13, for example, the initial attempt at LNAPL removal proved to be quite productive (0.9 liter removed), whereas the subsequent removal attempts were much less productive even though larger LNAPL thicknesses were measured. As experience is gained and data are generated during LNAPL removal events, it is expected that modifications will be needed to optimize the removal process. The annual reports and 5-year review summaries described in Section 3 will provide opportunities for BSD to propose modifications to LNAPL removal procedures and/or frequency. Proposed modifications must be approved by Ecology prior to implementation.

2.5 Temporary Storage of Recovered Liquids

LNAPL and incidental groundwater bailed from the monitoring wells will be temporarily stored in 55-gallon drums at a secure site provided by BSD prior to offsite recycling or disposal.

3 Reporting Requirements

BSD will keep a running tally of LNAPL removal volumes on a well-by-well basis and report results to Ecology. Reporting formats will include the following:

- **Informal Reporting** – When an LNAPL removal event is conducted at the same time as a groundwater monitoring event, BSD will informally transmit (e.g., via e-mail) the combined results to Ecology within 3 weeks of receiving analytical laboratory reports. When LNAPL removal is conducted as a separate event, results will be informally transmitted to Ecology within 2 weeks.

- **Annual Reports** – BSD will prepare more formal reports on an annual basis. Annual reports will be comprehensive in nature, addressing all remedy implementation activities associated with the Site. (For example, cover system inspection and maintenance [I&M] will be documented in the same report.) They will also provide the opportunity for BSD to propose modifications to the LNAPL removal procedures and frequency specified in this Work Plan. Each report will cover activities completed on a calendar-year basis, and will be submitted to Ecology by January 31st of the following year.

- **Five-Year Review** – Ecology and BSD will meet at least every 5 years after initiation of the cleanup remedy to discuss the Site and the need, if any, for further remedial action. As specified in Section VIII.R of the AO, BSD will submit a summary report to Ecology at least 90 days prior to each 5-year review. The report will document whether human health and the environment are being protected based on the factors set forth in WAC 173-340-420(4). It will also

provide the opportunity for BSD to propose modifications to the LNAPL removal procedures and frequency specified in this plan.

References

Aspect Consulting, LLC (Aspect), 2014a, Remedial Investigation, Crownhill Elementary School, Prepared for Bremerton School District, dated November 2014.

Aspect, 2014b, Feasibility Study, Crownhill Elementary School, Prepared for Bremerton School District, dated November 24, 2014.

Aspect, 2015a, LNAPL Removal Work Plan, Crownhill Elementary School Site, Prepared for Bremerton School District, dated January 22, 2015 (Agency Review Draft).

Aspect, 2015b, Groundwater/LNAPL Monitoring and Contingency Plan, Crownhill Elementary School Site, Prepared for Bremerton School District, dated November 19, 2015.

Washington State Department of Ecology (Ecology), 2014, Cleanup Action Plan, Bremerton School District, Crownhill Elementary School Site, Washington State Department of Ecology, dated December 10, 2014.

Ecology, 2015, Letter to Bremerton School District (R. Carpenter) Re: Ecology Comments on Crownhill Elementary School LNAPL Removal Work Plan and Groundwater/LNAPL Monitoring and Contingency Plan (January 22, 2015, Review Drafts), dated August 4, 2015.

Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Bremerton School District for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

LNAPL Thickness Monitoring and Removal Record Form

Project Name: **Crownhill Elementary School**

Date:_____ **Well ID:**_____

Project No.:_____ Personnel:_____

LNAPL THICKNESS MONITORING AND REMOVAL RECORD

Initial Thickness

Time	Depth BTOC in feet		LNAPL Thickness in feet*	Observations/Notes
	LNAPL	Water		

Initial LNAPL Thickness in feet (est.): _____

Removal

Time	Bailer No.	Volume Removed in milliliters		Observations/Notes
		LNAPL	Water	
	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	Totals			

Final Thickness

Time	Depth BTOC in feet		LNAPL Thickness in feet*	Observations/Notes
	LNAPL	Water		

Final LNAPL Thickness in feet (est.): _____

* LNAPL thickness is calculated by difference

BTOC below top of well casing

LNAPL light non-aqueous-phase liquid

FIGURES

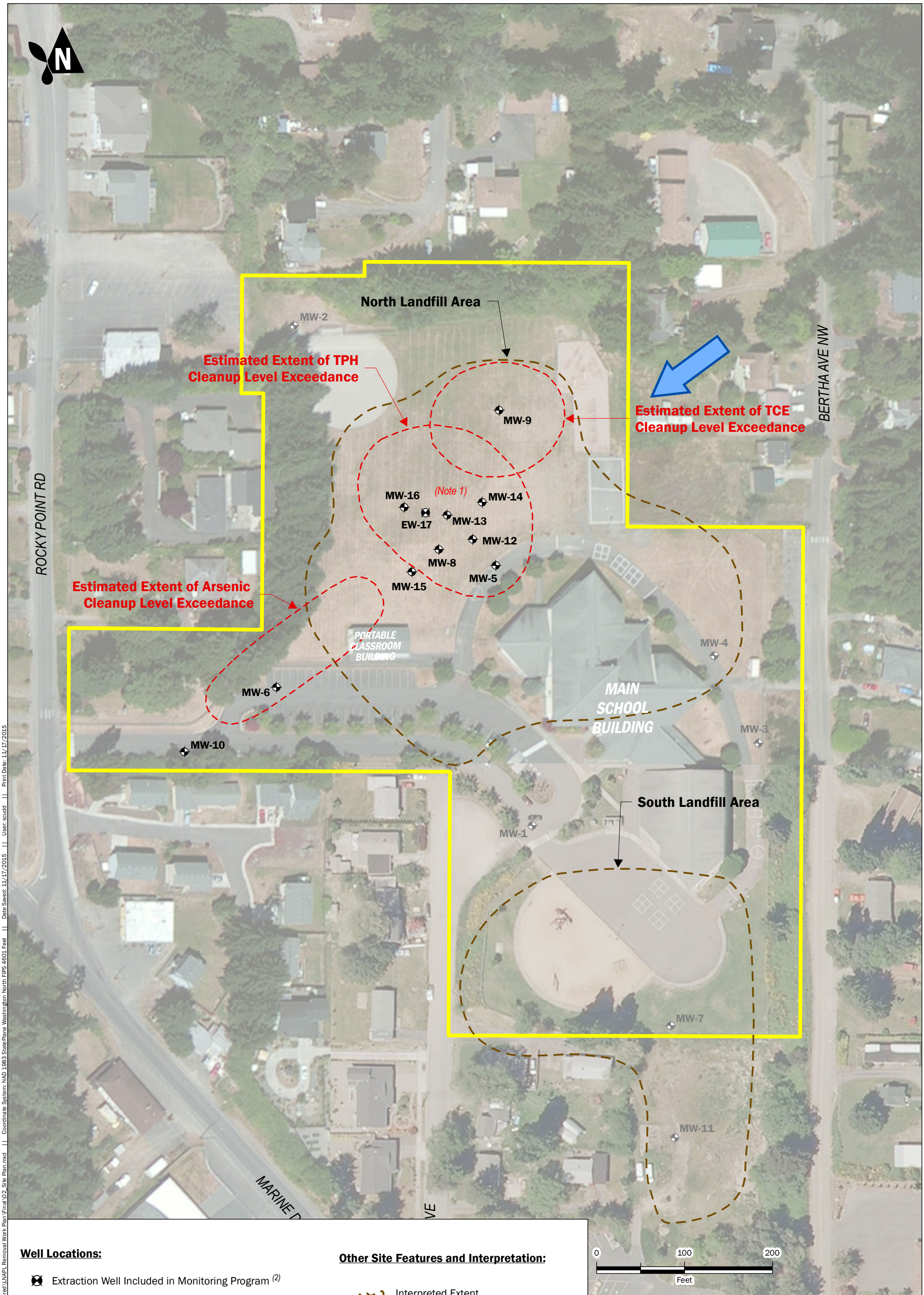
Vicinity Map

LNAPL Removal Work Plan
Crownhill Elementary, Bremerton, Washington

Aspect CONSULTING	NOV-2015	BY: PPW	FIGURE NO. 1
	PROJECT NO. 100094	REV BY: SCC	

Basemap Credits: Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

GIS Path: T:\projects_8\CrownHillElementary\Delivered\LNAPL Removal Work Plan\Final\01_VicinityMap.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 11/16/2015 || User: scudd || Print Date: 11/16/2015



Well Locations:

- Extraction Well Included in Monitoring Program (2)
- Monitoring Well Included in Monitoring Program (2)
- Monitoring Well Not Included in Monitoring Program (2)

Other Site Features and Interpretation:

- Interpreted Extent of Landfill Activity
- Bremerton School District Property Boundary
- Inferred Direction of Groundwater Flow

Note:

(1) LNAPL has been observed in Wells EW-17, MW-8, MW-13, MW-14, and MW-16.
(2) Refer to the Groundwater/LNAPL Monitoring and Contingency Plan (Aspect, 2015b).

Site Plan

LNAPL Removal Work Plan
Crownhill Elementary, Bremerton, Washington

Aspect CONSULTING	NOV-2015	BY: DLH / PPW	FIGURE NO. 2
	PROJECT NO. 100094	REV BY: SCC	

GIS Path: T:\projects_8\CrownHillElementary\Delivered\LNAPL Removal Work Plan\Final\02_Site Plan.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 11/17/2015 || User: scudd || Print Date: 11/17/2015

APPENDIX A

Summary of LNAPL Thickness Measurements and Removal Tracking through October 2015

Table A-1 - Summary of LNAPL Thickness Measurements and Removal Tracking through October 2015

Project No. 100094-003-02, Crownhill Elementary, Bremerton, Washington

Well ID	Date	Initial Thickness in ft[(1)]	LNAPL Removal in Liters	Notes
MW-8	10/26/12	0.20		Well installed on 12/20/11.
	11/21/12	nm		
	01/31/13	0.10		
	05/03/13	0.03		
	08/07/13	0.23		
	12/17/13	0.86		
	04/02/14	0.39	0.18	
	05/23/14	0.38	0.11	
	07/01/14	0.23		
	10/13/14	0.28		
	04/07/15	0.27		Not bailed because initial thickness was <0.3 feet.
	10/28/15	0.90	0.36	
	Cumulative LNAPL Removal		0.65	
MW-13	11/01/12	1.46		Well installed on 10/25/12.
	11/21/12	0.99	0.90	
	01/31/13	0.10		
	05/03/13	0.31		
	08/07/13	0.49		
	12/17/13	4.90		
	04/02/14	1.35	0.02	Water detected above LNAPL.
	05/23/14	2.08	0.18	Water detected above LNAPL.
	07/01/14	0.84		
	10/13/14	3.39		
	04/07/15	1.00	0.17	
	10/28/15	4.15	0.02	
	Cumulative LNAPL Removal		1.28	
MW-14	11/01/12	nd		Well installed on 10/26/12.
	01/31/13	nd		
	05/03/13	nd		
	08/07/13	0.12		
	12/17/13	0.10		
	04/02/14	0.08		Not bailed because initial thickness was <0.1 feet.
	05/23/14	0.09		Not bailed because initial thickness was <0.1 feet.
	07/01/14	0.46		
	10/13/14	0.71		
	04/07/15	0.23		Not bailed because initial thickness was <0.3 feet.
	10/28/15	1.48	0.35	
	Cumulative LNAPL Removal		0.35	
MW-16	11/01/12	nd		Well installed on 10/26/12.
	01/31/13	0.50		
	05/03/13	0.48		
	08/07/13	2.61		
	12/17/13	2.83		
	04/02/14	3.02	0.85	(Note 3)
	05/23/14	4.25	2.06	(Note 3)
	07/01/14	3.79		
	10/13/14	3.25		
	04/07/15	2.64	1.19	(Note 3)
	10/28/15	2.18	0.35	
	Cumulative LNAPL Removal		4.45	
EW-17	10/28/15	0.45	0.03	Well installed on 10/13/15.
	Cumulative LNAPL Removal		0.03	
	TOTAL LNAPL REMOVED		**6.76**	**(ALL WELLS)**

LNAPL light non-aqueous-phase liquid

nd no detectable LNAPL thickness

nm not measured

Notes

1) The viscous, sticky nature of the LNAPL results in inconsistent readings of the interface probe (used to measure depth-to-LNAPL and depth-to-water). Therefore, the reported LNAPL thicknesses can only be regarded as estimates.

2) The 2-inch ID wells have a unit volume of approx. 0.62 liter per vertical foot of well casing.

3) Bailing was stopped because bailer would no longer go down well due to LNAPL buildup on inside well casing.

APPENDIX B

Physical and Chemical Characteristics of LNAPL from Well MW-13

Table B-1 - Physical and Chemical Characteristics of LNAPL from Well MW-13

Project No. 100094-003-02, Crownhill Elementary, Bremerton, Washington

Monitoring Well ID:	**MW-13**
Sampling Date:	**11/21/2012**
TPH in mg/kg by Method NWTPH-Dx	
Diesel-range	370,000
Motor oil-range	350,000
Chlorinated VOCs in mg/kg by EPA Method 8260C	
Vinyl chloride	<100
Chloroethane	<100
1,1-Dichloroethene	<100
Methylene chloride	<500
trans-1,2-Dichloroethene	<100
1,1-Dichloroethane	<100
cis-1,2-Dichloroethene	<100
1,2-Dichloroethane(EDC)	<100
1,1,1-Trichloroethane	<100
Trichloroethene	<100
Tetrachloroethene	<100
Specific Gravity (@ 15.6°C)	0.89
Kinematic Viscosity in cSt (@ 20°C) by ASTM D-445	1,737
Flash Point in deg F (PMCC) by ASTM D-93	>210

cSt centistokes
PMCC Pensky-Marten closed cup (flash point test method)
TPH Total petroleum hydrocarbon
VOC Volatile organic compound

Notes

1) The LNAPL sample was obtained during the bailing test at Well MW-13. Refer to Section 4.2.3 of the RI (Aspect, 2014a).