PBS | Engineering + Environmental

March 3, 2014

Clark County, Washington
Attn: Mr. Jerry Barnett
23201 NE Pluss Road
Vancouver, Washington 98682

Re: Focused Groundwater Assessment for Perchlorate and Explosives
Lacamas Creek and Demolition Area 3 Wells
Camp Bonneville, Clark County, Washington
PBS Project No. 76151.005

Dear Mr. Barnett:

This letter report presents the results of supplemental groundwater monitoring activities conducted during the third and fourth quarters of 2013 at Camp Bonneville. A low-level detection of the explosive HMX occurred in groundwater from monitoring well LC-MW01D, which is included in the "Base Boundary" well grouping within the Lacamas Creek area. The sample collected from the well had a detection of HMX at 0.22 micrograms per liter (µg/L).

The remainder of the third quarter results for the Lacamas Creek wells was subsequently reviewed. Another well (LC-MW02D) had a detection of HMX between the method reporting limit (MRL) and the method detection limit (MDL). The MDL is defined as the minimum concentration that can be measured and reported with 99 percent confidence that the concentration is greater than zero, but the exact concentration cannot be reliably quantified.

The appearance of HMX at the downgradient Base Boundary location is anomalous, and it was decided that additional groundwater assessment was warranted in the area. Specifically, the following scope of work was agreed upon by Clark County (County) and the Washington Department of Ecology (Ecology) to occur:

- Obtain laboratory reports for the third and fourth quarter 2013 events that report the data to the MDLs for perchlorate, RDX, and HMX from the base boundary wells.
- Conduct groundwater monitoring at the five existing Demolition Area 3 wells. This Demolition Area is a potential source for the low level of contamination detected at the Base Boundary Wells. The Demolition Area 3 wells were removed from the active monitoring program in the third quarter of 2006.

This report provides the results of these activities.

PROJECT SETTING AND BACKGROUND

Camp Bonneville comprises approximately 3,820 acres and is located in southwestern Washington, approximately 10 miles northeast of Vancouver, Washington (Figure 1, Vicinity Map). The Department of the Army used Camp Bonneville for live fire of small arms, assault weapons, artillery, and field and

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air defense artillery between 1910 and 1995. Since 1947, Camp Bonneville has also provided training for a variety of military and non-military units, including National Guard, Army Reserves, U.S. Air Force, and federal, state, and local law enforcement agencies. Camp Bonneville includes approximately 820 acres of land leased from the State of Washington Department of Natural Resources (DNR).

Ordnance and explosive (OE) items have been found within Camp Bonneville's boundaries. Routine groundwater monitoring occurs in 19 wells located in two areas at the site: the landfill/Demolition Area (Landfill 4/Demo Area 1) and the Camp Bonneville base boundary at Lacamas Creek (Figure 2, Investigation Areas within Camp Bonneville). The Demolition Area 3 is also shown on Figure 2.

SITE GEOLOGY/HYDROGEOLOGY

The geology at Camp Bonneville can be divided into three general areas that correspond approximately to topographic divisions.[1] The area west of Lacamas Creek is comprised of a series of predominantly gravel and semi-consolidated conglomerate with scattered lenses and stringers of sand (Upper Troutdale Formation). Underlying the Troutdale Formation, and comprising the area to the north and east of Lacamas Creek, are basalt flows and flow breccia, with some pyroclastic and andesitic rocks, which are folded and faulted. The bottom land along Lacamas Creek is comprised of unconsolidated silt, sand, and gravel valley fill with some clay.

MONITORING WELL INFORMATION

Table 1 provides information for the Demolition Area 3 wells. This table includes total depth, screened interval, and top-of-casing elevation. Information for the Lacamas Creek/Base Boundary wells is provided in the routine quarterly monitoring reports.

For Demolition Area 3, wells LC-MW05S, LC-MW07S, and LC-MW08S have screens installed between 270 and 290 feet above mean sea level (AMSL) and therefore can be evaluated for groundwater flow direction. The screen for well LC-MW05D is installed much deeper, between 246 and 256 feet AMSL, and the screen for well LC-MW06S is installed shallower between 291 and 298 AMSL. Therefore, these wells cannot be included in a flow direction discussion. It should be noted that the boring logs for these wells indicate that the soil in the screened interval is expected to have low permeability.

WELL REDEVELOPMENT ACTIVITIES

Given that the Demolition Area 3 wells had not been sampled or monitored since 2006, it was determined that redevelopment would ensure high quality data. Well development activities for the five Demolition Area 3 wells occurred on December 19 and 20, 2013. PBS followed its standard operating procedure (SOP) for well development, provided as an attachment to this report, to redevelop the five monitoring wells. Wells were developed by using a Waterra Hydrolift-2 inertial pump, which has a removable surge block that surges approximately 2 feet of the screen at a time while also pumping water. Purge water from well development activities was captured and stored in 55-gallon drums.

The goal of redevelopment activities was to remove five borehole volumes per monitoring well. However, with the exception of well LC-MW06S, each of the monitoring wells exhibited slow recharge

1 Otak, Inc. (September 1998, 2nd Revision 15 November 2005). *Camp Bonneville Reuse Plan.* Prepared for The Camp Bonneville Local Redevelopment Authority (LRA).

and were pumped dry twice during redevelopment, so five volumes could not be removed. The following volumes were removed:

- Well LC-MW05S: ~ 39 gallons of water (4 borehole volumes); final turbidity reading of 39.6 Nephelometric Turbidity Units (NTUs).
- Well LC-MW05D: ~ 40 gallons of water (3 borehole volumes); final turbidity reading of 161 NTUs.
- Well LC-MW06S: ~ 19 gallons of water (10 borehole volumes); final turbidity reading of 560 NTUs.
- Well LC-MW07S: ~37 gallons of water (4 borehole volumes); final turbidity reading of 153 NTUs.
- Well LC-MW08S: ~ 35 gallons of water (3.5 borehole volumes); final turbidity reading of 29.8 NTUs.

GROUNDWATER MONITORING EVENT – JANUARY 2014

Field Activities

Groundwater samples were collected from one monitoring well pair (LC-MW05D and LC-MW05S) and three single wells (LC-MW06S, LC-MW07S and LC-MW08S) in Demolition Area 3 (Figure 3, Monitoring Well Locations) on January 2, 2014. This event was intended to represent fourth quarter 2013 monitoring activities. A field duplicate sample (labeled 04Q13LCMW150W) was collected from monitoring well LC-MW07S. Extra volume of groundwater was collected from monitoring well LC-MW05S for laboratory matrix spike/matrix spike duplicate (MS/MSD) samples.

Groundwater monitoring was performed in accordance with the site Health and Safety Plan[2] (HASP), revised on September 14, 2010, and the Draft Supplemental Groundwater Remedial Investigation Sampling and Analysis Plan and Quality Assurance Project Plan[3] (SAP/QAPP), revised in February 2012. Laboratory analytical services were provided by TestAmerica located in Portland, Oregon and Sacramento, California, under contract to PBS Engineering and Environmental Inc. (PBS).

Low-Flow Purging

A low-flow, minimal-drawdown technique was used for groundwater purging and sampling using the QED Sample Pro® portable bladder pump constructed of a stainless steel body and polyethylene disposable bladders. New one-quarter inch tubing was used at each monitoring well. The low-flow purging technique is described in detail in the SAP. Low-flow sampling minimizes disturbance to the aquifer and is designed to ensure that samples collected from the wells are representative of groundwater.

Groundwater Sample Collection

Groundwater samples were collected into new laboratory-supplied sample containers directly from the end of the disposable tubing discharge hose. The laboratory analytical method for perchlorate complies

[2] PBS Engineering + Environmental. (September 14, 2010). *Site Health and Safety Plan, Soil and Groundwater Sampling.*
[3] PBS Engineering + Environmental. (March 2012). *Supplemental Groundwater Remedial Investigation Sampling and Analysis Plan and Quality Assurance Project Plan - Remedial Action Units 2C and 3.*

with a Department of Defense recommendation for this chemical.[4] The method requires that sample collection include field filtering. The filtering is accomplished by using a laboratory-provided 60-milliliter (mL) graduated syringe and a 0.2 micrometer (µm) polyethersulfone (PES) filter. The filter is connected to the end of the syringe and approximately 120 mL of groundwater is filtered from the discharge hose through the syringe into a laboratory-provided, pre-sealed 250-mL polyethylene container using method guidelines. Additional sample volume is required for the MS/MSD sample. Samples are stored with headspace to minimize the possibility of anaerobic conditions developing that can lead to the breakdown of perchlorate in solution.

Quality Assurance/Quality Control Samples
One duplicate sample was collected and one MS/MSD sample was collected for analysis. An equipment blank was not included in this initial sample collection.

Deviations from SAP/QAPP

This section is intended to discuss deviations from established protocols as well as to note unusual conditions or equipment issues encountered. Unless noted otherwise, the issues did not affect the quality of the samples collected during this event.

- Samples were collected before the depth to water equilibrated for wells LC-MW05S, LC-MW05D, LC-MW07S, and LC-MW08S, as per the PBS SOP for low-flow sampling. As noted during well redevelopment, each monitoring well was pumped dry and was slow to recharge. The remaining field parameters (temperature, specific conductivity, dissolved oxygen [DO], pH, and oxidation reduction potential) were within an acceptable range. The deviation is not considered significant, and PBS considers the samples representative of aquifer conditions.

Investigation-Derived Waste

Gloves and other disposable field supplies were disposed of as solid waste. Purged groundwater was placed in 55-gallon drums that were sealed, labeled, and placed next to the wells.

DATA MANAGEMENT AND REVIEW

The laboratory data packages for the Base Boundary wells from the third and fourth quarter 2013 events were reprocessed by the laboratory and the results reported to the MDL. The data package analytical results from the January 2014 Demolition Area 3 sampling event were also reported to the MDL. All of the data packages were validated according to the procedures described in the QAPP. PBS reviewed all laboratory Quality Assurance/Quality Control (QA/QC) results and compared duplicate sample results.

Analytical results for all groundwater samples are presented in Table 2, Base Boundary Wells Analytical Results and Table 3, Demo Area 3 Analytical Results, and reported to the MDL. The MRLs are also noted on the Tables. Groundwater field parameters (i.e., pH, temperature, conductivity, oxidation reduction potential [ORP], DO, and turbidity) recorded at the time of sampling are presented in Table 4. The analytical reports and the Level III Data Package from the January 2014 Demolition Area 3 event are provided in the enclosed compact disk.

[4] Department of Defense Environmental Data Quality Workgroup. (August 2007). *DoD Perchlorate Handbook, Revision 1, Change 1*

Groundwater analytical results were compared to the State of Washington Model Toxics Control Act (MTCA) Method B cleanup levels. MTCA Method B cleanup levels and applicable, relevant, and appropriate state and federal groundwater screening values were obtained from the Ecology Cleanup Levels and Risk Calculations (CLARC)[5] database.

GROUNDWATER MONITORING RESULTS

Base Boundary Wells

Analytical results for the third and fourth quarters reported to the MRL are presented in quarterly monitoring reports.[6,7] Sample, field duplicate collection, and discussions of data quality are presented in these reports. There were no data quality issues in either sampling event that resulted in the flagging or rejection of any data.

There were three detections of target compounds above the MDL in the third quarter 2013 event. Perchlorate was detected in well LC-MW04S and HMX was detected in wells LC-MW01D and LC-MW02D. There were two detections of perchlorate in the fourth quarter 2013 event in wells LC-MW03D and LSMW04S. Detections in Base Boundary wells in the third and fourth quarter 2013 sampling events were above the MDL but below the MRL. Detections are summarized in Table 2.

Demolition Area 3 Wells

Groundwater elevations are provided in Table 4. Elevations in the wells ranged from 301.91 to 309.94 feet AMSL. For the three wells screened at the same interval (LC-MW05S, LC-MW07S, and LC-MW08S), groundwater flow direction appears to be to the southwest, roughly paralleling Lacamas Creek. For the nested wells (LC-MW05S and LC-MW05D), the vertical gradient is upward.

Please note that the highest measurement (309.94 feet AMSL) was from well LC-MW05D, which is an artesian well that often overflows the top of the PVC casing. Given the presence of low permeability soil noted previously in boring logs, it is apparent that this well is screened in a semi-confined or confined water-bearing unit. Accurate measurement of groundwater elevation in this well would require modification of the casing. If the Demolition Area 3 wells continue to be monitored, a modification (temporary during each field event) will be designed by PBS for County and Ecology approval.

There were no detections above the MDL of any analyzed compound in the Demolition Area 3 wells. Table 3 provides the MDLs and MRLs for the contaminants of concern.

DATA QUALITY OBJECTIVES SUMMARY

This evaluation was performed for the Base Boundary/Lacamas Creek wells in the quarterly reports prepared for the routine monitoring and is not repeated here. This section focuses on the supplemental monitoring that occurred in the Demolition Area 3 wells.

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[5] https://fortress.wa.gov/ecy/clarc/Reporting/CLARCReporting.aspx

[6] PBS Engineering and Environmental Inc. (January 2014). Third Quarter 2013 Groundwater Sampling and Analysis Report, Camp Bonneville, Vancouver, Washington.

[7] PBS Engineering and Environmental Inc. (February 2014). Fourth Quarter 2013 Groundwater Sampling and Analysis Report, Camp Bonneville, Vancouver, Washington.

The overall data quality objective is to provide data of known and sufficient quality to evaluate the physical extent and concentration ranges of the chemicals of potential concern from analysis of groundwater samples, and to assure compliance with environmental and health-related agencies. Data quality objectives for laboratory analysis are presented in the QAPP. Laboratory analytical data were evaluated with respect to quality assurance objectives for precision, accuracy, representativeness, comparability, and completeness parameters.

The project specifications were met for all analytes, indicating that the sampling and analysis procedures were reproducible. The TestAmerica laboratory report narratives, presented in the attachments, state that all quality control parameters that affect sample analysis were met.

Data Validation

All analytical data were validated at a Level II review standard. Level II validation and reporting include a brief narrative of the laboratory data along with presentation of the sample results and related QA/QC analyses. Additionally, 20 percent of the analytical data (1 of 5 samples) were validated at a Level III review standard. Level III validation adds the following to the reporting (not all of these method requirements are necessarily applicable to the analyses in this sampling event):

- Internal standards
- Blank association
- Serial dilution results
- Post-digestion spike results
- GC/MS tune table
- Initial calibration table
- Continuing calibration verifications
- Calibration blanks
- ICSA/AB, CRDL, MDL/IDL form
- Column confirmation
- Instrument run log

These data validation levels follow the criteria in the EPA's "Data Quality Objectives for Remedial Response Activities Development Process",[8] National Technical Information Service.

Presentation of Data

There was one sample submission on January 3, 2014. Samples were placed in two sample delivery groups (SDGs). One of the SDGs (250-16402-1) was processed at Level II and one (250-16401-1) at Level III. Laboratory reports and the Level III data package from the January 2014 Demolition Area 3 event are included on the enclosed compact disk.

Sample Handling and Control

The chain-of-custody forms indicate that samples were maintained under proper custody. Forms were signed upon release from the field and receipt at the laboratory. Samples were received by the

[8] Environmental Protection Agency (EPA). (1987b). *Data Quality Objectives for Remedial Response Activities-Development Process.* EPA/540/G-87/003, OSWER Directive 9355.07B, EPA, Washington, D.C. (PB88-131370).

laboratory at temperatures within acceptable limits and with proper preservation. All analyses from which results were reported were performed within applicable method-specified holding times.

Method Reporting Limits

All samples met laboratory-specified MRLs and, additionally, were reported to the lower MDLs for this supplemental evaluation.

Field Data Quality Assessment

There are no specific data quality objectives for the measurement of field parameters (e.g., temperature, pH, oxidation reduction potential [ORP], conductivity, DO, and turbidity). Specific conductance, temperature, ORP, DO, and pH were measured during purging. Turbidity is measured during sample collection. PBS' SOP on low-flow groundwater sampling describes the acceptable criteria for the measurement of field parameters. A copy of the SOP is provided in the SAP/QAPP.

Field Quality Control Sample Assessment

Duplicates

One duplicate sample was collected. The duplicate sample was analyzed for the same constituents as the source sample. The relative percent difference (RPD) was calculated as the difference between the values divided by the average of the values. For samples with results greater than five times the practical quantification limit (PQL), an RPD of less than 20 percent is considered good duplication. For samples with results less than five times the PQL, the difference between the sample and its duplicate must be less than the PQL in order to meet the quality assurance acceptance criteria. A significant difference between duplicate values for a few parameters indicates potential problems with the precision of specific analyses. A significant difference for many parameters indicates potential problems with the sample collection procedures.

Demolition Area 3 Duplicate

The field duplicate analysis for well LC-MW07S met all quality control requirements.

Laboratory Quality Control Assessment

The analytical data quality evaluations performed by TestAmerica are presented in the laboratory reports in the attachments. No analysis results required qualification. Case narratives describing sample receipt, identification, and general comments by laboratory personnel are included in each report.

Laboratory Quality Control Samples/Indicators

Blanks

There were no detections of target compounds in any blanks for any analyses.

Laboratory Control Spikes (LCS)

LCS samples had recoveries within specified control limits.

Matrix Spike/Matrix Spike Duplicates

MS and MSD recoveries and RPDs for MS/MSD pairs were within specified control limits.

Level III Data Review

The data package for SDG 250-16401-1 receiving Level III data reporting was reviewed for adherence to method criteria that exceeds Level II reporting. There were no deviations from method criteria.

CONCLUSION AND RECOMMENDATIONS

Perchlorate, RDX, and HMX were not detected above the MDL in the five wells from Demolition Area 3. Sampling will continue in these wells for an additional three quarters (March 2013, June 2013, and September 2013) to provide a full year of seasonal monitoring data.

For the Base Boundary Wells, perchlorate was detected between the MRL and MDL in well LC-M04S for both the third and fourth quarters 2013. Perchlorate was also detected in well LC-MW03D in the fourth quarter 2013 between the MRL and MDL. HMX was detected in wells LC-MW01D (above the MRL) and LC-MW02D (between the MRL and MDL) in the third quarter 2013, but not in the fourth quarter. The remaining compounds were below the MDL at the base boundary wells. MDL reports will continue to be evaluated for the Base Boundary wells in conjunction with the Demolition Area 3 well monitoring (three more quarterly events through September 2013).

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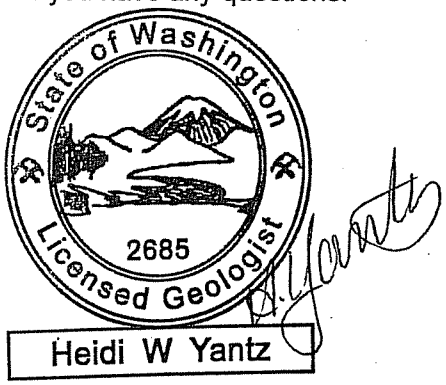
Please feel free to contact me at at 360.213.0461 if you have any questions.

Sincerely,
PBS Engineering and Environmental Inc.

Heidi Yantz, LG
Senior Hydrogeologist, Principal

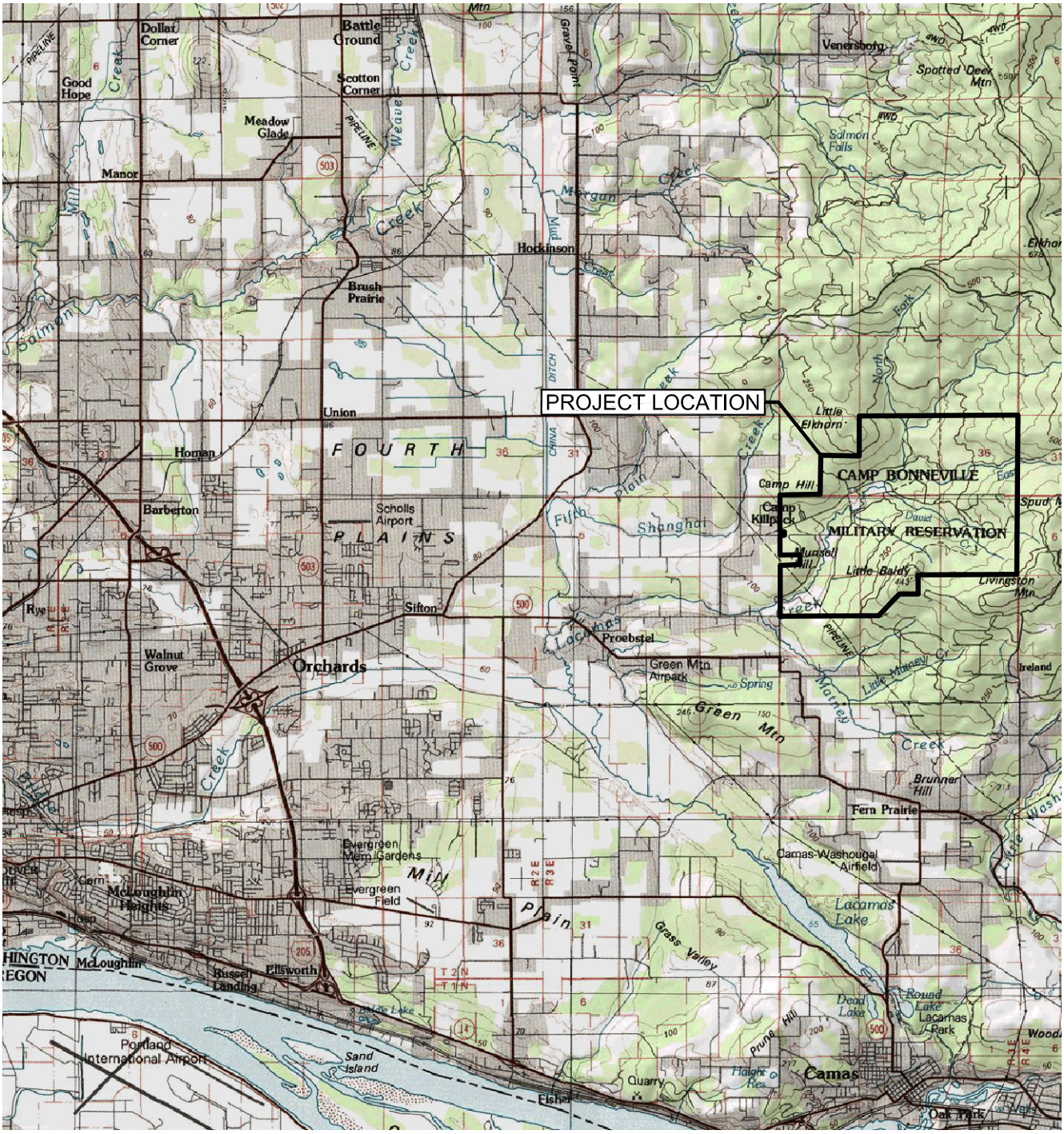
SB/HY/DB



Attachments:
Figure 1 – Vicinity Map
Figure 2 – Investigation Areas within Camp Bonneville
Figure 3 – Monitoring Well Locations near Demo Area 3
Table 1 – Demolition Area 3 Well Number and Construction Details
Table 2 – Base Boundary (Lacamas Creek) Wells Analytical Results
Table 3 – Demolition Area 3 Analytical Results
Table 4 – Demolition Area 3 Field Parameters for Groundwater Samples
Standard Operating Procedure – Development of a Groundwater Monitoring Well
Laboratory Reports and Sample Chain-of-Custody Forms

Enclosure: Analytical reports and Level III Data Package from the January 2014 Demolition Area 3 Event Compact Disk

Figures



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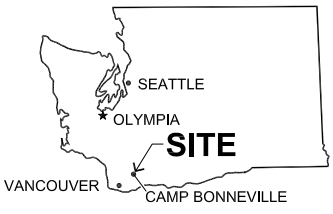

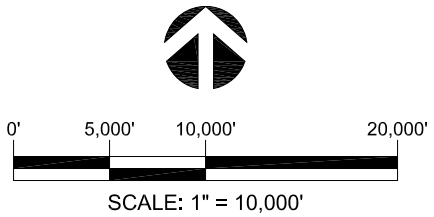

SCALE: 1" = 10,000'

PBS

PROJECT # 76151.005

DATE FEB 2014

VICINITY MAP

CAMP BONNEVILLE
CLARK COUNTY, WASHINGTON

FIGURE 1

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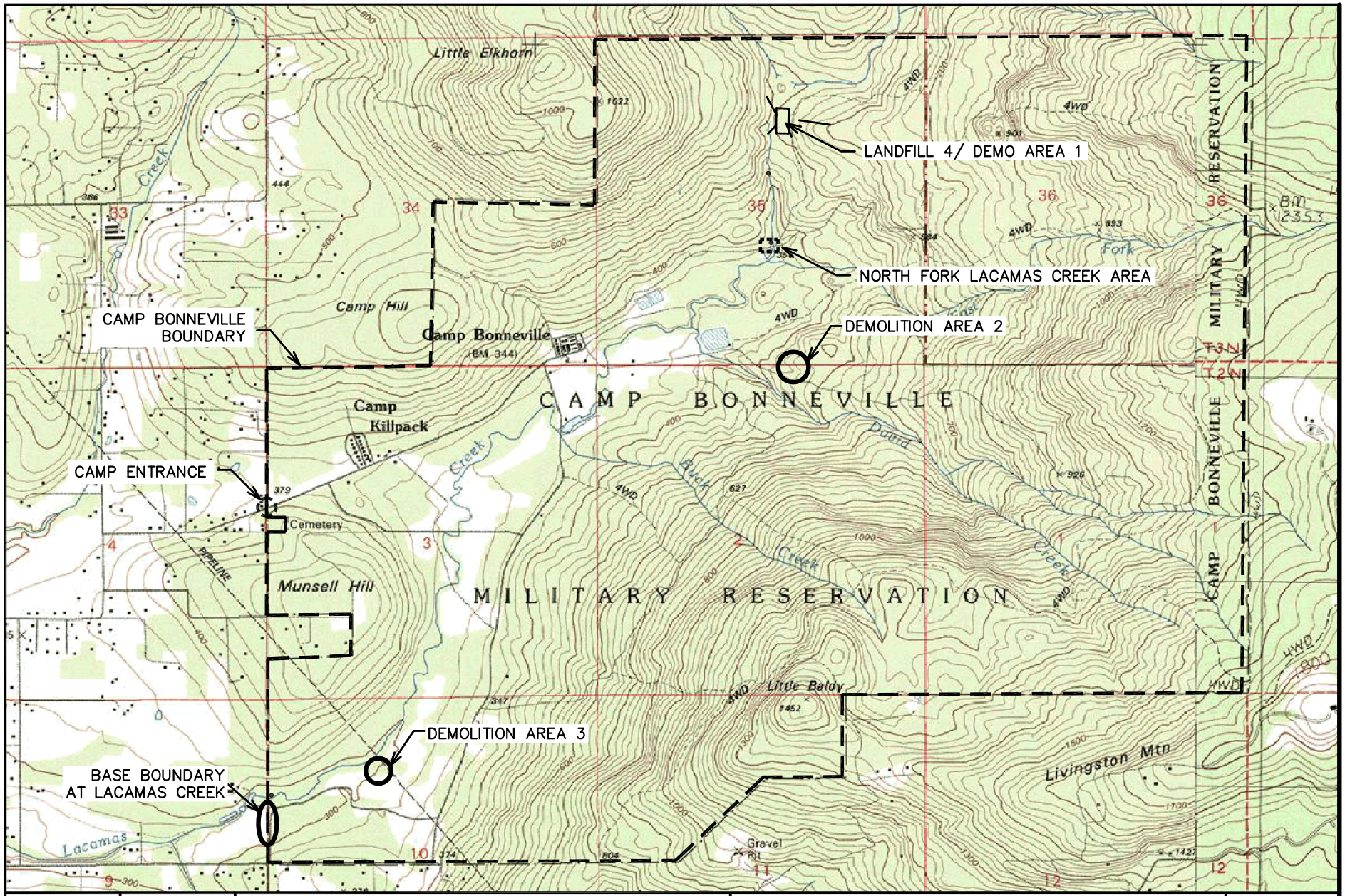

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PBS

Project #: 76151.005

Date: FEB 2014

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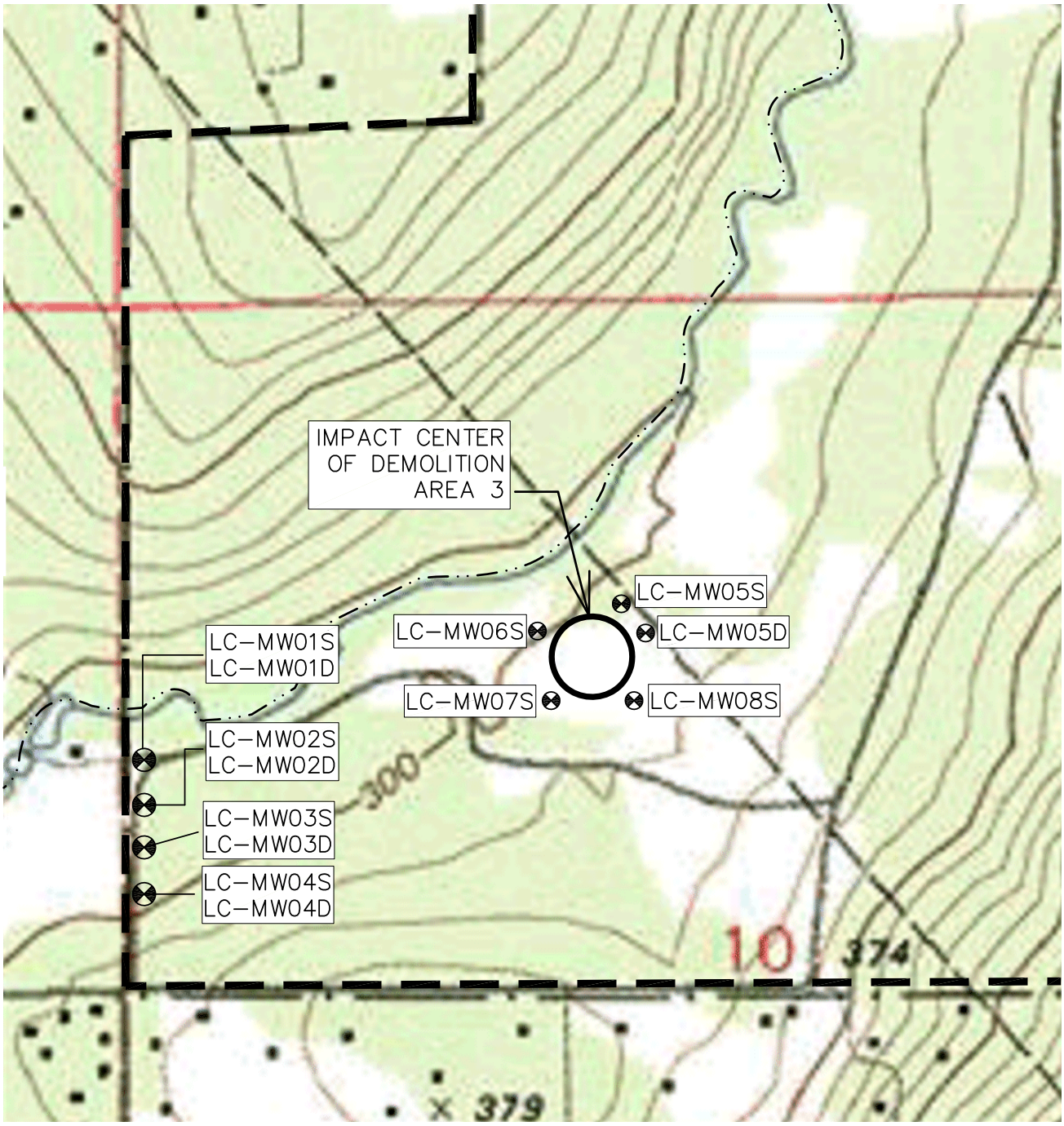
INVESTIGATION AREAS WITHIN CAMP BONNEVILLE BOUNDARY

CAMP BONNEVILLE
CLARK COUNTY, WASHINGTON

FIGURE 2



LEGEND

LC-MW01S / LC-MW01D — MONITORING WELL AND WELL NUMBER

LACAMAS CREEK

BASE BOUNDARY

0' 300' 600' 1,200'

SCALE: 1" = 600'

PBS

Project #: 76151.005

Date: FEB 2014

MONITORING WELL LOCATIONS NEAR DEMO AREA 3

CAMP BONNEVILLE
CLARK COUNTY, WASHINGTON

FIGURE 3

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Tables

Table 1: Demolition Area 3 Well Number and Construction Details
Camp Bonneville, Vancouver, Washington

Well No. in PBS Work Contract	Well Location	Well Log Total Depth (feet)*	Screened Interval (feet)**	Top of PVC Casing Elevation (feet amsl)
LC-MW05S	Demolition Area 3	37	22-37	310.10
LC-MW05D	Demolition Area 3	62	52-62	309.94
LC-MW06S	Demolition Area 3	15	8-15	308.27
LC-MW07S	Demolition Area 3	37	22-37	308.92
LC-MW08S	Demolition Area 3	37	22-37	309.78

Notes:

* = casing depth in feet recorded on well log

** = screened interval reported on well completion logs; feet below ground surface

amsl = above mean sea level

Table 2: Base Boundary (Lacamas Creek) Wells
Low-Level Analytical Results; Reported to MDL
3rd and 4th Quarters 2013
Camp Bonneville, Vancouver, Washington

Analyte	MTCA Method B Cleanup Values	LCMW01DW	LCMW01DW Duplicate	LCMW01SW	LCMW02DW	LCMW02SW	LCMW03DW	LCMW03SW	LCMW04DW	LCMW04DW Duplicate	LCMW04SW	MRL/range
		Third Quarter 2013										
Perchlorate	11	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082		**0.20 (0.082)**	0.5
HMX	4,000	**0.22 (0.028)**	< 0.028	< 0.028	**0.040 (0.029)**	< 0.027	< 0.028	< 0.028	< 0.028		< 0.028	0.10-0.11
RDX	0.8	< 0.068	< 0.066	< 0.067	< 0.069	< 0.066	< 0.067	< 0.066	< 0.067		< 0.067	0.10-0.11
		Fourth Quarter 2013										
Perchlorate	11	< 0.082		< 0.082	< 0.082	< 0.082	**0.082 (0.082)**	< 0.082	< 0.082	< 0.082	**0.21 (0.082)**	0.5
HMX	4,000	< 0.028		< 0.028	< 0.028	< 0.028	< 0.028	< 0.028	< 0.028	< 0.028	< 0.028	0.10-0.11
RDX	0.8	< 0.067		< 0.068	< 0.068	< 0.069	< 0.067	< 0.068	< 0.067	< 0.068	< 0.068	0.10-0.11

Notes:

MDL = method detection limit
MRL = Method Reporting Limit

All values in micrograms per liter (µg/L)

The most stringent MTCA Method B Standard value is used
Bold = detected value

0.22 (0.028) = detected value (MDL)

< 0.082 = not detected above the indicated MDL

Table 3: Demolition Area 3 Analytical Results
Low-Level Results Reported to MDL
Fourth Quarter 2013
Camp Bonneville, Vancouver, Washington

Analyte	MTCA Method B Std. Cleanup Values	LCMW05DW	LCMW05SW	LCMW06SW	LCMW07SW	LCMW07SW Duplicate	LCMW08SW	MRL/range
Perchlorate	11	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082	< 0.082	0.5
HMX	4,000	< 0.038	< 0.037	< 0.037	< 0.037	< 0.037	< 0.037	0.10-0.11
RDX	0.8	< 0.068	< 0.067	< 0.067	< 0.067	< 0.066	< 0.066	0.10-0.11

Notes:

MDL = method detection limit
MRL = Method Reporting Limit

All values in micrograms per liter (µg/L)

The most stringent MTCA Method B Standard value is used
Bold = detected value

0.22 (0.028) = detected value (MDL)

< 0.082 = not detected above the indicated MDL

Table 4: Demolition Area 3 Field Parameters for Groundwater Samples
4th Quarter 2013
Camp Bonneville, Vancouver, Washington

Sample ID	Date	Depth to Water	Water Elevation	Dissolved Oxygen	Oxidation Reduction Potential	pH	Specific Conductivity	Temperature	Turbidity
		feet below TOC*	feet amsl**	mg/L	millivolts	pH units	µS/cm	degrees Celsius	NTU
LC-MW05S	12/04/2013	6.21	303.89	9.51	150.1	6.89	151	10.60	3.56
LC-MW05D	12/04/2013	0.00	309.94 [1]	6.14	116.2	6.90	151	9.42	29.02
LC-MW06S	12/05/2013	6.36	301.91	4.68	118.1	5.92	95	10.47	27.16
LC-MW07S	12/05/2013	6.25	302.67	9.09	77.6	7.11	152	10.29	4.45
LC-MW08S	12/05/2013	6.40	303.38	9.51	88.7	7.09	154	10.90	4.49

Notes:
Depth to water measurements taken on January 2, 2014
[1] This is an artesian well. Determination of an accurate depth to water was not possible during this monitoring event. Water elevation may be higher than noted.
* depth in feet measured from top of well PVC casing
** water level in feet above mean sea level, relative to top of PVC casing elevation survey
Field parameters were measured using a YSI 556 and a flow-through cell, with the exception of turbidity, which was measured using a HF Scientific TPW Meter
TOC = top of casing
amsl = above mean sea level
mg/L = milligrams per liter
µS/cm = micro-siemens per centimeter
NTU = Nephelometric Turbidity Units

Standard Operating Procedure for Well Development

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STANDARD OPERATING PROCEDURE
DEVELOPMENT OF A GROUNDWATER MONITORING WELL

1.00 PURPOSE

The purpose of monitoring well development is to remove drilling fluids or other fluids introduced during drilling or well installation, stabilize the filter pack, and remove fine-grained sediment entering the well. This is typically done following groundwater monitoring well construction, no sooner than 24 hours following setting of a bentonite seal. If a dry granular bentonite seal is placed, you may begin development as soon as 12 hours (OAR 690-240-0485) following completion. U. S. EPA recommends waiting at least 48 hours, especially if vigorous surging methods are to be used during well construction.

2.00 EQUIPMENT LIST

1. Well lock keys
2. Field book
3. Electronic water level probe
4. Interface probe (if dense or light non-aqueous phase liquids are [DNAPL or LNAPL] is present)
5. Knife or scissors
6. Decontamination equipment
7. Site map and health and safety plan
8. Personal Protection Equipment (PPE) appropriate for the site
9. Submersible pump, air lift pump or other appropriate pump and associated equipment
10. Surge block
11. Polyvinyl Chloride (PVC) or stainless steel bailer (close in size to inside diameter of well)
12. Disposable tubing, if necessary
13. Field water quality monitoring equipment
14. Turbidity meter
15. Containers for purge water

3.00 PROCEDURE

The diameter of the well, the total depth of the well, and depth to water will determine the type of pump and equipment used for well development. Surging of the well can be done with a surge block tool or with a submersible pump if it is close in size to the inside diameter of the well. A PVC or stainless steel bailer may work if it is close in size to the inside diameter of the well. The purpose of surging is to suspend as much sediment as possible in the water column so it can be pumped out of the well. It also helps to get the filter pack and aquifer settled and cleaned of fine-grained sediment. The filter pack should have been surged during well construction, prior to placing the overlying seal in the well.

1. Note the general condition of the well. Check the well for damage or evidence of tampering and record pertinent observations. Note any maintenance tasks that should be completed, such as well cap or padlock replacement.

2. Open the well and wait a sufficient period of time for the atmospheric pressure to equalize, allowing the water levels to approach an equilibrium state before taking any measurements.
3. Measure the depth to water (DTW), (and DNAPL or LNAPL if present) relative to the marking on the well casing. If there is no mark, use the north side of the casing. Record the water level in the field book.
4. Measure and record the total depth of the well, making note if the bottom of the well is "soft" and compare it to the finished depth of the well from the well log. Also note the total screen length from the well log.
5. Subtract DTW from total depth for length of water column (WC).
6. Calculate one casing volume as follows:

CF x WC = Number of gallons in one casing volume

CF = conversion factor (dependent on well diameter listed in table below)
WC = length of water column in feet.

Well diameter (inches)	Conversion Factor (gallons/foot)
1	0.04
2	0.17
4	0.65

Annular space is calculated as follows:

$[(\text{Borehole diameter-casing diameter}/2)^2]$ H *N = Number of gallons in annular space

H = length of wetted filter pack in feet
N = porosity of filter pack (0.3 to 0.5)

7. Start by surging the well, moving a surge block tool or bailer up and down the length of the screened interval. Following surging (5 to 10 minutes), remove the surge block and install the pump. Place the pump in the bottom half of the screen and pump at a fairly high rate.
8. After the pump has been pumping for awhile, measure turbidity and record it. If water begins to clear, measure turbidity, again. Also, surge the well using the pump. If the water becomes more turbid, continue to pump. Record the time, amount pumped and turbidity in the field book.
9. The amount of water required to be pumped from the well is equal the amount of water put into the boring during well drilling and/or construction plus a minimum of 5 to 10 well bore volumes.

Bore hole volume = Number of gallons in annular space + casing volume

At least five well bore volumes need to be removed for monitoring wells set in silty, clayey sands, or silts. If there are coarse-grained soils in the screened interval such as sands and gravels, then 10 well bore volumes should be removed from the boring.

10. After the bottom portion of the water column clears, move the pump up in the well screen and continue to pump. As the water clears, surge using the pump.
11. An alternative to surge and pump would be to use a PVC or stainless steel bailer, close in size to the inside diameter of the well. The bailer could be used as a surge block, catching both sediment and removal of turbid water. It is particularly effective to bounce the bailer off the bottom of the well casing when there is sediment on the bottom of the well, in order to stir up the sediment and get it re-suspended so it can be removed. Sometimes a combination of both pumping and a bailer may be used.

12. Following development, record total depth of well and compare it to initial measurement and total depth at construction. Any sediment in the bottom of the well should be removed during well development, as much as possible. Also record the final water level and turbidity.
13. Decontaminate all pumps and equipment prior to moving to the next well.
14. All water should be stored in drums, tanks or other container, as appropriate.
15. Wells should be allowed to rest and recover at least 24 to 48 hours prior to sampling.

Resources consulted for this SOP include:

Oregon Department of Environmental Quality. (1992). *Groundwater Monitoring Well Drilling, Construction, and Decommissioning.* DEQ Guidance Document. August 24, 1992.

OAR 690-240 Construction, Maintenance, Alteration, Conversion and Abandonment of Monitoring Wells, Geotechnical holes and Other Holes in Oregon, (as of October 15, 2007).

U.S. Environmental Protection Agency. (2001). *Standard Operating Procedure 2044, Revision 0.1, Monitor Well Development.* October 23, 2001.

Laboratory Reports and Sample Chain-Of-Custody Forms
Level III Data Package

(Electronic files provided on enclosed CD)