TECHNICAL MEMORANDUM

LANDAU ASSOCIATES
ENVIRONMENTAL | GEOTECHNICAL | NATURAL RESOURCES

TO: Jing Liu, Washington State Department of Ecology

CC: Sonia Fernandez, Washington State Department of Ecology
Mike Stoner, Port of Bellingham

FROM: Jeremy Davis, P.E., C.H.M.M., and Larry Beard, P.E., L.G.

DATE: March 18, 2013

RE: REMEDIAL INVESTIGATION WORK PLAN ADDENDUM
BLAINE MARINA INC. SITE
BLAINE, WASHINGTON

INTRODUCTION

This work plan addendum describes the procedures for installing a light non-aqueous phase liquid (LNAPL) pilot recovery well and evaluating LNAPL recoverability as part of the ongoing remedial investigation (RI) for the Blaine Marina Inc. Site (Site) in Blaine, Washington (Figure 1). The Site is listed on the Washington State Department of Ecology (Ecology) Hazardous Sites List (FSID 2888) with a priority rank of 3 out of 5 for cleanup, with a ranking of 1 being the highest priority for cleanup. The Port of Bellingham (Port) is conducting the RI activities under Agreed Order No. DE 9000 between the Port and Ecology.

An RI work plan was prepared and approved by Ecology to guide the investigation. The RI work plan (Landau Associates 2012a) provides a detailed summary of the procedures for conducting the upland investigation at the Site, which was designed to be implemented in two phases. In October 2012, the Port conducted the first phase of the RI, which included evaluating soil quality and soil vapor quality, delineating the extent of significant contamination, and collecting groundwater grab samples from direct-push boring locations. The results of the first phase of the upland investigation were presented in a February 21, 2013 technical memorandum (Landau Associates 2013).

Based on the results of the first phase of the RI, seven groundwater monitoring wells will be installed to evaluate groundwater quality at the apparent limits of petroleum hydrocarbon contamination. Additionally, one well will be installed to evaluate whether sufficient free-phase LNAPL is present at the Site to warrant consideration of LNAPL recovery during development of the remedial alternatives that will be evaluated in the feasibility study (FS) for the Site. This work plan addendum describes the proposed construction procedures for the pilot LNAPL recovery well and the methods that will be used to evaluate the degree to which LNAPL is recoverable. This work plan addendum is intended to be implemented using the field methods and sampling procedures outlined in the RI work plan (Landau Associates 2012a).

PILOT LIGHT NON-AQUEOUS PHASE LIQUID RECOVERY WELL CONSTRUCTION

The pilot LNAPL recovery well will be constructed in accordance with Washington State Minimum Standards for Construction and Maintenance of Wells (WAC 173-160). The well will be drilled using conventional hollow-stem auger techniques with a minimum 6-inch inside diameter augers at the location indicated on Figure 2. Landau Associates field personnel familiar with environmental sampling and construction of resource protection wells will oversee the drilling and well installation activities, and maintain a detailed record of the well construction. While advancing the boring, if it becomes apparent that the subsurface conditions at this location are not suitable for LNAPL recovery due to the potential presence of a clay layer in this area, a second attempt will be made to install the well about 10 to 15 feet (ft) to the northwest. If a clay layer is also present at this location, an LNAPL pilot recovery well will not be installed, and the baildown test described later in this work plan addendum will be conducted at the existing groundwater monitoring well, MW-3.

The pilot LNAPL recovery well will be constructed using 4-inch-diameter, flush-threaded, Schedule 40 PVC pipe and a 10-ft screen. The screen will be constructed using 0.040-inch machine-slotted casings and the filter pack material will consist of pre-washed, pre-sized, number 8/12 silica sand to promote the entry of LNAPL into the well, if present.

The well screen will be placed from about 5 to 15 ft below ground surface to intersect the water table. The filter pack will be placed from the bottom of the well to approximately 1 ft above the top of the screen. Filter pack material will be placed slowly and carefully to avoid bridging of material. A bentonite seal will be placed above the filter pack material to within about 3 ft of the ground surface. Bentonite grout or chips will be used to backfill the boring to the subgrade for placement of the protective cover. A flush-mounted monument will be cemented in place at the ground surface.

Only limited well development will be conducted to avoid creating excessive drawdown and causing LNAPL to smear the deeper portion of the formation. The well will be developed by repeatedly surging the well with a surge block and purging the well with a drop tube installed at the bottom of the well. The LNAPL/water level will be monitored during well development and drawdown will not be allowed to exceed 3 ft from the static level. Well development will proceed until the purge water is largely free of suspended particulates, if practicable, and no less than five well casing volumes have been removed. During development, the purged groundwater will be monitored for the following field parameters:

- pH
- Conductivity
- Temperature
- Turbidity

- Oxidation reduction potential
- Dissolved oxygen.

Because the surrounding formation consists of silty sand, and the filter pack has been designed to facilitate the flow of LNAPL into the well instead of to reduce the flow of fine-grained particles, it is not expected that the water purged during development will decrease to the typical development goal of 5 nephelometric turbidity units (NTUs). After developing the well, the LNAPL accumulated in the well will be purged using a bailer.

LIGHT NON-AQUEOUS PHASE LIQUID RECOVERABILITY EVALUATION

In order to comply with the Washington State Model Toxics Control Act requirement to perform source control and remove LNAPL "to the maximum extent practicable" (WAC 173-340-370), a recoverability evaluation will be conducted to determine if it is practicable to recover LNAPL from the groundwater table. Recently, progress has been made in defining what constitutes "to the maximum extent practicable" by applying techniques such as determination of LNAPL transmissivity to the evaluation process. LNAPL transmissivity is a useful site-specific measure of potential LNAPL mobility, and is generally accepted as an effective metric for evaluating hydrocarbon recoverability (API 2012).

LNAPL transmissivity is a more useful metric than LNAPL thickness in that it accounts for different hydrogeologic conditions, soil types, and LNAPL characteristics, better represents changes in LNAPL mobility and saturation, and incorporates the formation thickness of LNAPL. For LNAPL recovery from a given well, the soil and LNAPL physical properties do not change significantly as LNAPL is removed. Instead, the LNAPL saturated thickness decreases, and transmissivity decreases in direct proportion to saturated thickness (AFCEE 2011) as LNAPL is removed. LNAPL recoverability is directly proportional to LNAPL transmissivity, and as a result, LNAPL transmissivity is considered a preferred metric to simply measuring LNAPL thickness.

One accepted approach to evaluating transmissivity is conducting a baildown test, which is similar to borehole slug test methods. This involves removing a volume of LNAPL from a well and observing the rate of fluid-level (water and LNAPL) recovery. The procedures described below are adapted from the method described by the American Petroleum Institute (API; 2012). The test will proceed only if a significant quantity of LNAPL is present in the well to effectively evaluate LNAPL transmissivity. An apparent LNAPL thickness of at least 6 inches is necessary to conduct the baildown test; if less than this thickness is observed, the test will not be conducted and LNAPL product recovery will be considered impracticable for the purposes of the FS.

The baildown test described below will be conducted at the pilot LNAPL recovery well at least 72 hours after it has been developed. The baildown test will be conducted at least twice, with at least 24 hours separating the two tests, to evaluate the reproducibility of the test. The baildown test procedures are as follows:

1. Measure and record depth to LNAPL and depth to water with an interface probe every 30 minutes over a 2-hour period to evaluate potential tidal influences.
2. Measure and mark purging tubing so that it can be lowered into the well until the inlet is set approximately 2 inches above the LNAPL/water interface. Use a peristaltic pump to remove LNAPL. LNAPL will be pumped from the well into a 5-gallon bucket with 1 liter graduations pre-marked on the side of the bucket. Field personnel will adjust the elevation of the tubing inlet based on observations during pumping, and will attempt to remove only LNAPL from the well. The results will not be nullified if water is also removed. Record the time pumping begins and ends, and the total volume of LNAPL removed.
3. Following removal of the LNAPL, the depth to LNAPL and depth to water will be measured until fluid level in the well returns to the approximate static level measured before purging LNAPL. Measurements will be collected and recorded at 1-minute intervals initially, because recovery could be fast. If recovery is noted to be slow, the time between measurements could be extended to provide a dataset that reasonable depicts the behavior of the fluid level recovery. A record of at least 20 measurements spread equally in terms of recovery volume will be the data objective. Nearly full recovery is important to develop an accurate conceptual model for recovery.

The baildown testing data will be input to a spreadsheet tool developed by API (the API LNAPL Transmissivity Workbook) which uses the Bouwer and Rise method (Bouwer 1989), to evaluate the data using the following equation:

$$T_n = \frac{r_e^{\,2} \ln\left(R/r_e\right) \ln\left(s_n(t_1)/s_n(t)\right)}{2(-J)(t-t_1)}$$

Where:

T_n = LNAPL transmissivity

r_e = Effective well radius (estimated within the spreadsheet tool using baildown test data)

R = Radius of influence (estimated within the spreadsheet tool using baildown test data)

s_n = LNAPL drawdown

t = Time

J = Kirkman J-ratio (slope of the linear relationship between LNAPL drawdown and LNAPL apparent thickness)

This approach uses a simple linear model to determine LNAPL transmissivity. Although other methods exist that may provide greater accuracy, the baildown test and Bouwer and Rise method of data analysis are simple to employ and provide a defensible and site-specific understanding of LNAPL behavior. Site LNAPL transmissivity data will be compared to values provided in the Interstate Technology & Regulatory Council (ITRC) LNAPL guidance document (ITRC 2009) or other available resources to provide a qualitative understanding of the feasibility of hydraulic recovery of LNAPL. For comparative purposes, ITRC indicates that hydraulic recovery systems can reduce transmissivity to between 0.1 and 0.8 square feet per day. As such, it would therefore appear feasible to recover LNAPL when transmissivity is greater than this range.

If hydraulic recovery is selected as a remedial technology for the Site, the LNAPL recovery rate could be predicted using modeling software or a pilot recovery test could be conducted at the pilot recovery well. These efforts are beyond what is necessary for this initial RI evaluation.

Details of the well installation, testing data, and the data analysis will be presented in the RI report.

JMD/LDB/ccy

References

API. 2012. *User Guide for API LNAPL Transmissivity Workbook: A Tool for Baildown Test Analysis*. American Petroleum Institute. June.

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Landau Associates. 2012a. *Remedial Investigation Work Plan, Blaine Marina Inc. Site, Blaine, Washington*. Prepared for the Port of Bellingham. October 4.

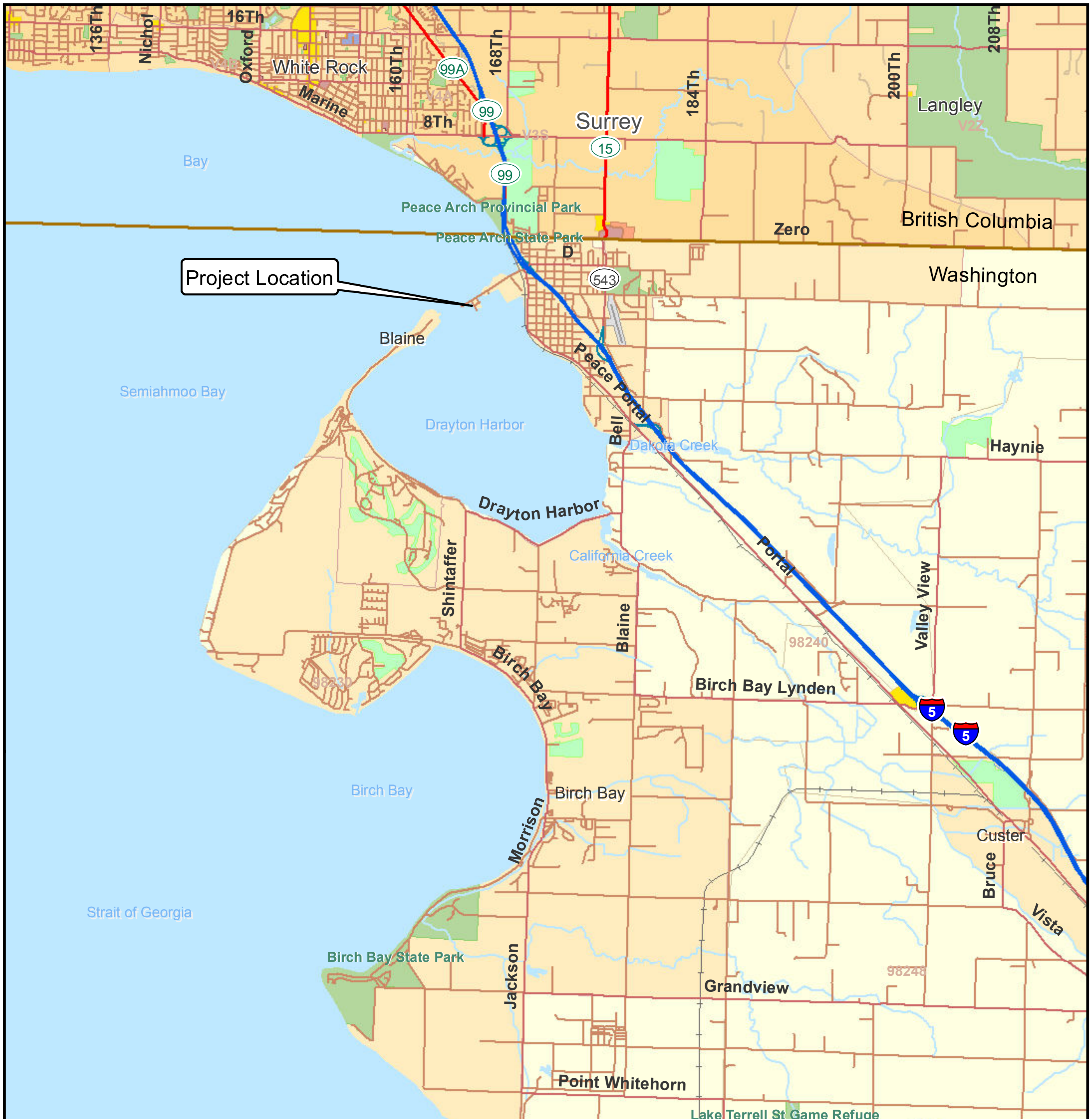
Landau Associates. 2012b. Report: *Geotechnical Engineering Services, Blaine Marina Fuel Pier Bulkhead Replacement, Bellingham, Washington*. Prepared for the Port of Bellingham. April 6.

RETEC. 1996. Letter Report: *Summary of Geoprobe Investigation at Blaine Marina*. From Grant Hainsworth to Mike Stoner, Port of Bellingham. August 28.

SEACOR. 1990. Letter Report: *Your Letter of May 8, 1990 on Blaine Marina*. From Lee Dorigan to Douglas L. Jones, Port of Bellingham. July 11.

Attachments

Figure 1: Vicinity Map
Figure 2: Proposed Monitoring Well and Pilot Light Non-Aqueous Phase Liquid Recovery Well Locations



0 1.5 3

Miles

N

Data Source: ESRI 2008

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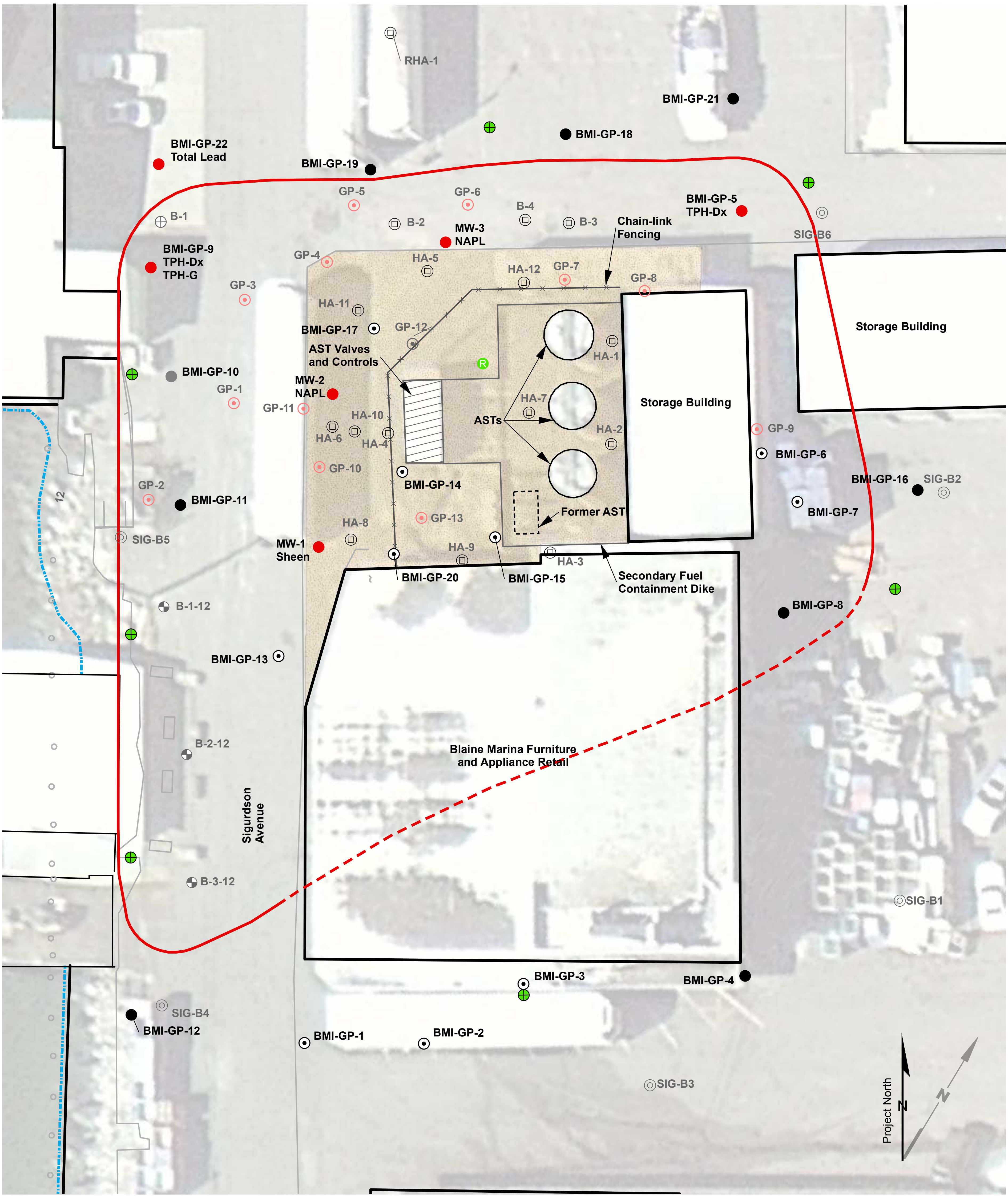
Blaine Marina Inc. Site Blaine Harbor Blaine, Washington	**Vicinity Map**	Figure 1



Legend

2012 Remedial Investigation
- Concentration in Groundwater Exceeds PSL
- Groundwater Sample with Detection
- Groundwater Sample without Detection
- Soil Sample Location (Groundwater not Sampled)
- Geotechnical Boring Location (Soil Sampling, Landau Associates 2012b)
- Proposed Groundwater Monitoring Well Location
- Proposed Pilot LNAPL Recovery Well

Historical Investigations
- Boring Location
- Groundwater Monitoring Well Location
- Hand Auger Location (Soil Sampling, SEACOR 1990)
- Geoprobe Location (Groundwater Sampling and Sheen Testing, RETEC 1996)
- Geoprobe Location (Soil Sampling, Farallon Consulting 2008)

- Approximate Site Boundary
- MHHW - 9.5 ft
- Gravel Area

0 20 40

Scale in Feet

Source: Wilson Engineering 2011, Port of Bellingham 2011, Walker and Associates, Inc.

Note

1. Explorations shown in red indicate concentrations exceed the PSL.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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Blaine Marina Inc. Site Blaine Harbor Blaine, Washington	**Proposed Monitoring Well and Pilot LNAPL Recovery Well Locations**	Figure 2