Annual Groundwater Quality Report
2019 Bioremediation Program
Blaine Marina, Inc. Cleanup Site
Blaine, Washington

March 13, 2020

Prepared for

Port of Bellingham
P.O. Box 1677
Bellingham, Washington

LANDAU ASSOCIATES

130 2nd Avenue South
Edmonds, WA 98020
(425) 778-0907

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This document was prepared by, or under the direct supervision of, the technical professionals noted below.

Document prepared by: _____ Jeremy Davis, PE, PMP
Primary Author

Document reviewed by: Stephanie Renando Stephanie Renando
Quality Reviewer

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Project Coordinator:	Christopher C. Young

LANDAU ASSOCIATES

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LIST OF ABBREVIATIONS AND ACRONYMS

AN	ammonium nitrate
CAP	cleanup action plan
Ecology	Washington State Department of Ecology
EDR	engineering design report
IHS	indicator hazardous substance
LAI	Landau Associates, Inc.
LNAPL	light non-aqueous phase liquid
mg/L	milligram per liter
OP	observation point
Port	Port of Bellingham
Site	Blaine Marina, Inc. cleanup site
TPH-D	diesel-range total petroleum hydrocarbons
TPH-G	gasoline-range total petroleum hydrocarbons
UIC	Underground Injection Control
Work Plan	Groundwater Bioremediation Work Plan

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1.0 INTRODUCTION

Landau Associates, Inc. (LAI) has prepared this annual groundwater quality report to provide details of the cleanup action currently in progress at the Blaine Marina, Inc. cleanup site (Site) in Blaine, Washington (Figure 1). This work is being conducted by the Port of Bellingham (Port), under a Consent Decree (No. 18-2-01266-37) between the Washington State Department of Ecology (Ecology) and the Port (Ecology 2018). Following source removal in 2018, the bioremediation program was implemented in 2019. This document summarizes the bioremediation program performance including injection and groundwater quality sampling activities conducted in 2019, and provides recommendations, when warranted, for proposed changes in the bioremediation approach.

1.1 Background

The Site is located in Blaine Harbor, at the north end of Drayton Harbor in Blaine, Washington, as shown on Figure 1. Blaine Marina, Inc. formerly operated a bulk fuel storage and transfer facility at the Site, from the 1950s until 2015, on land leased from the Port. Operations at the facility resulted in the release of petroleum hydrocarbons to soil and groundwater.

1.2 Cleanup Activities

The Port completed a majority of the required cleanup activities in 2018 that were described in the Cleanup Action Plan (CAP; Ecology 2017), and detailed in the Engineering Design Report (EDR; LAI 2018). The primary cleanup activities completed in 2018 include removing approximately 4,000 tons of soil contaminated with petroleum hydrocarbons, and removing light non-aqueous phase liquids (LNAPL). Additional demolition and Site restoration activities were required to accomplish the removal, since buildings were located above the source area where contamination levels were highest. The contaminated materials were removed from the Site and disposed of at an offsite Subtitle D landfill facility. Through soil excavation and LNAPL removal in the source area, an equivalent of approximately 16,000 gallons of petroleum hydrocarbons were removed (LAI 2019a). The ongoing cleanup activities discussed herein relate to addressing the residual contamination left in place outside of the source area.

1.3 Summary of Bioremediation Program

After completing the source removal activities described above, the Port is addressing the remaining residual contamination through bioremediation. If it is determined during the bioremediation program that additional nitrate solution is not required, a period of monitored natural attenuation may be conducted to continue tracking remedial progress and confirm cleanup levels are achieved and maintained. The final cleanup activities discussed herein were conducted in accordance with the Groundwater Bioremediation Work Plan (Work Plan; LAI 2019b), as approved by Ecology. The Work Plan provides details regarding implementation of enhanced, *in situ*, anaerobic bioremediation in groundwater, which primarily entails stimulating the naturally-occurring process, by infiltrating a

nitrate solution into the groundwater. The nitrate solution is introduced into the subsurface using equipment that was installed in 2018 during source removal efforts. The infiltration equipment allows large quantities of nitrate solution to infiltrate into the source area, where the contaminated soil was excavated and replaced with clean sand and gravel (selected to promote unrestricted groundwater flow) through infiltration trenches installed just outside of the boundary of the excavation.

The Port will continue implementing cleanup activities in cooperation with Ecology until concentrations of the indicator hazardous substances (IHSs) are reduced sufficiently to meet the cleanup requirements detailed in the CAP. The bioremediation program is anticipated to achieve cleanup levels within 4 years of the first injection, although additional data will be required to refine this assessment. These activities generally include continued *in situ* bioremediation, performance groundwater quality sampling, and preparing annual reports documenting cleanup progress. When it becomes evident that cleanup levels have been achieved, four additional consecutive quarters of groundwater monitoring will be conducted to confirm compliance is maintained throughout potential seasonal fluctuations. It is anticipated that less nitrate solution will be required over time, and as noted above, it may become evident during the latter portions of the bioremediation program that the naturally occurring contaminant degradation pathways do not require any supplemental nitrate solution. This determination would be made in coordination with Ecology if sufficient evidence indicates a reasonable restoration timeframe is expected without nitrate solution infiltration.

2.0 ANAEROBIC BIOREMEDIATION

As summarized above, nitrate solution is introduced into the groundwater to stimulate anaerobic bioremediation. Nitrate provides the terminal electron acceptor necessary for naturally-occurring aquifer bacteria to degrade petroleum hydrocarbons. The bacteria use petroleum hydrocarbons as electron donors in redox reactions to generate energy for growth and reproduction. The process is presented in detail in the Work Plan (LAI 2019b) and summarized below.

2.1 The Anaerobic Bioremediation Process

Biodegradation of petroleum hydrocarbons occurs through microbially-mediated redox reactions between electron donors (i.e., food) and electron acceptors (i.e., something to respire/breathe) (Cunningham et al. 2001; Wiedemeier et al. 1999). At this Site, petroleum hydrocarbons act as the electron donors while a number of compounds can serve as the electron acceptors (oxygen, nitrate, manganese [IV], ferric iron, sulfate, and/or carbon dioxide).

The electron acceptors occur naturally, but for this Site, they are supplemented to accelerate the cleanup process. And while oxygen is an excellent electron acceptor, nitrate is preferred at this Site for several reasons. Nitrate is much more soluble in groundwater than oxygen, which allows for a higher initial concentration of electron acceptor at the point of infiltration, more treatment longevity, and a larger downgradient extent of treatment. In addition, there is a lower demand for nitrate in the aquifer resulting in less of the electron acceptor being consumed by side-reactions, which allows for greater treatment longevity and a larger portion of the added electron acceptor used directly for contaminant reduction. This is particularly important in aquifers with naturally-reducing depositional environments, such as estuaries and tideflat deposits.

Multiple injection or infiltration events are typically required to complete a course of treatment to address petroleum hydrocarbons in groundwater and adsorbed to soil surfaces. Petroleum hydrocarbon concentrations in groundwater will likely fluctuate during treatment until the non-aqueous mass is depleted. Upon reduction of the aqueous-phase petroleum hydrocarbons and depletion of the nitrate, contaminants will desorb from soil surfaces and enter the groundwater, where petroleum hydrocarbon concentrations may rebound until more nitrate is added, or until the contaminant is depleted from the Site. Fluctuations in petroleum hydrocarbon concentration also occur as groundwater levels rise and fall due to seasonal changes in rainfall, or tidal influence causes the groundwater to contact additional contamination that may be adsorbed to soil surfaces in the vadose zone.

2.2 Implementation Details – 2019

At this Site, the nitrate solution is introduced into four pairs of infiltration ports. These are shown on Figure 2, and labeled as OP-1/OP-2; OP-3/OP-4; OP-5/OP-6; and OP-7/OP-8. The paired infiltration ports are connected in the subsurface by perforated piping installed horizontally near the

groundwater table. The perforations in the piping allow the injected solution to infiltrate throughout granular backfill material (sand and gravel) surrounding the perforated piping, then into the surrounding formation. Distribution of the solution throughout the Site is further enhanced by the hydraulic gradient created by the mounding of the groundwater table at the infiltration locations. Two of these pairs of infiltration ports (OP-3/OP-4 and OP-5/OP-6) were installed in the area excavated during the contaminant source removal. Since the entire excavation was backfilled with sand and gravel, the nitrate solution can move freely throughout the extent of the historical source area, and should infiltrate slowly out of the excavated area and into the surrounding aquifer through lenses of permeable soils. Outside of the source area, two additional pairs of infiltration ports (OP-1/OP-2 and OP-7/OP-8) were installed to target the highest levels of petroleum hydrocarbon contamination remaining on Site after the source-area excavation. Like the ports installed within the previous source area, these infiltration ports were constructed with gravel and perforated piping. However, since OP-1/OP-2 and OP-7/OP-8 were installed by trenching into areas composed of finer-grain soils (silt and clay), a smaller volume of nitrate solution is added to these areas.

The ammonium nitrate (AN) solution is partially prepared off site by Cascade Columbia Distribution Company, and delivered to the Site in highly concentrated batches. Tap water is used on site to dilute the AN solution to the desired concentrations in a 6,500-gallon mixing tank. Yeast extract is added to provide additional macro- and micro-nutrients for cellular growth and reproduction. Once the desired concentration is prepared and mixed with the yeast, the solution is pumped to one of the four pairs of infiltration ports described above.

Based on the desired distribution and estimated pore volumes, remediation at this Site is generally carried out by adding a total of approximately 40,000 gallons of nitrate solution at the Site during each infiltration event—approximately 36,000 gallons into OP-3/OP-4 and OP-5/OP-6, and another approximately 4,000 gallons into OP-1/OP-2 and OP-7/OP-8. Infiltration events currently occur twice per year. The frequency of the events, the volume of AN solution, and the concentration of nitrate or other nutrients in the solution are adjusted for each event based on a review of the performance results.

In 2019, two infiltration events were completed in accordance with requirements set forth in the CAP, the EDR, and the Washington State Underground Injection Control (UIC) permit per Chapter 173-218 of the Washington Administrative Code. One of these events was conducted in June 2019, and one in November 2019. Table 1 provides a summary of nitrate volumes and solution concentrations for each event.

Pumping flow rates are regulated by adjusting the throttle on the centrifugal pump used to transfer the solution from the mixing tank to the infiltration ports. Due to the large volume of relatively high hydraulic conductivity excavation backfill in the historical source area, flow rates in the infiltration galleries are much higher than in the infiltration trenches. AN solution is introduced simultaneously

into risers on either end of each infiltration gallery/trench for even distribution of solution within the gallery or trench.

The groundwater table is intentionally mounded during infiltration events, and appears to remain elevated as the solution infiltrates throughout the Site. During the infiltration events, LAI personnel monitor nearby groundwater monitoring wells, nearby utility corridors, catch basins, and surface water to observe for potential impacts to surface water and/or other utility corridors. During the first infiltration event in 2019, pressure transducers were installed in nearby groundwater monitoring wells to observe for mounding and dissipation.

Monitoring has confirmed nitrate solution is not entering utilities or flowing to the surface water during the infiltration events. During the first infiltration event, liquid was observed rising up through the pavement near infiltration port OP-8, which resulted in LAI personnel reducing the pumping flow rate, and during subsequent events, introducing smaller batches of nitrate solution at infiltration ports OP-7/OP-8, to prevent the nitrate solution from reaching ground surface. Additional monitoring is conducted to evaluate groundwater table elevation and groundwater quality to inform the cleanup, as discussed in the following section.

3.0 BIOREMEDIATION PERFORMANCE RESULTS

Bioremediation performance is primarily assessed through groundwater quality sampling. This provides the needed data to evaluate and document remedial progress and to provide information for tracking and potentially modifying the infiltration approach. Additionally, surface water samples are collected and analyzed for nitrate, to confirm that the nitrate solution is not negatively impacting surface water. When remedial progress indicates achievement of cleanup levels at the Site, monitoring efforts may be modified, in coordination with Ecology, to ensure sufficient data are generated to support a determination by Ecology that the requirements of the Consent Decree have been satisfactorily completed. Performance work currently includes measurements of the groundwater table elevation to understand groundwater flow, analysis of groundwater samples to assess groundwater quality in relation to the IHSs identified for this Site, and to confirm proper distribution of nitrate solution throughout the area where residual contamination persists. This section describes the overall approach to assessing bioremediation performance, and describes the results for groundwater quality sampling conducted in 2019.

3.1 Groundwater Quality

Groundwater quality is currently sampled on a quarterly basis from the 11 groundwater monitoring wells shown on Figure 2. The groundwater samples are analyzed for parameters that characterize the biological performance indicators, and IHS concentrations. The following bullets summarize the timeline of monitoring and nitrate solution infiltration events:

- November 2018: Baseline water quality event
- June 2019: Nitrate solution infiltration #1
- July 2019: 3rd Quarter water quality event
- October 2019: 4th Quarter water quality event
- November 2019: Nitrate solution infiltration #2.

3.1.1 Groundwater Elevations

During each groundwater sampling event, the distance is measured from the top of each well casing to the groundwater table at each monitoring well. Groundwater table elevations are then calculated using this measured distance and the known (surveyed) elevation at the top of the well casing. Measured groundwater elevations are provided in Table 2, and interpreted groundwater elevation contours for July and October 2019 are presented on Figures 3 and 4. As shown on these figures, a slight mounding of groundwater appears to be present in the central portion of the Site. As discussed in the EDR, this mounding is desired to promote lateral, outward flow of the nitrate solution away from the infiltration area, and toward the residual contamination.

An oil/water interface probe is used when measuring the depth to groundwater. If a measureable thickness of LNAPL is detected, groundwater samples are not collected for IHS analyses from that

location. This is based on the assumption that if LNAPL is present, IHS concentrations are assumed to be greater than the cleanup levels. In some instances, groundwater samples are collected from locations with LNAPL in order to analyze for nitrate and confirm that the infiltration solution is reaching the targeted areas.

During the baseline and 3rd quarter sampling events, where LNAPL was detected, it was removed. During the baseline monitoring event, LNAPL removal was conducted using a peristaltic pump. During the 3rd quarter monitoring event, a vacuum-truck was used to remove LNAPL and groundwater, effectively lowering the groundwater table in the immediate vicinity, to promote migration of LNAPL toward the well to improve capture.

3.1.2 Groundwater Sample Collection and Analysis

Groundwater samples are collected from the monitoring wells using the low-flow purging and collection techniques described in the Work Plan. This generally includes purging water from the wells while continually monitoring groundwater quality parameters for relative stabilization. When the parameters have stabilized, it is indicative that the groundwater being drawn from the well is representative of the surrounding formation, so samples are then collected into laboratory-supplied sample containers and preserved under chain-of-custody protocols. Table 3 presents the parameters analyzed in the field to confirm that purging is complete, and the analytical methods used by the Ecology-accredited laboratory.

3.1.3 Groundwater Quality Results

Groundwater quality laboratory analytical results are summarized in Table 4 with comparisons to the cleanup levels established in the CAP. Table 5 provides a compilation of the analytical data that are used for evaluating changes in IHS concentrations and other indicator parameters related to assessing bioremediation performance. Laboratory analytical reports are maintained on file and available upon request. The pertinent results for tracking bioremediation performance are presented in plan-view on Figures 5 through 9. The bullets below summarize Site groundwater quality with respect to the IHSs.

- **Gasoline-range total petroleum hydrocarbons** (TPH-G; Figure 5):
  - The cleanup level for TPH-G established in the CAP is 0.8 milligrams per liter (mg/L).
  - Based on the presence of LNAPL at MW-9 and MW-10, TPH-G concentrations at MW-9 and MW-10 were presumed to be above the cleanup level during the 2019 performance sampling events. However, LNAPL was not present at MW-9 in November 2019, so concentrations are likely decreasing. At MW-10, a slight increase in LNAPL thickness was observed in July and October (approximately 0.10 feet greater than baseline), but the thickness then decreased in November, apparently from LNAPL removal efforts and contaminant reductions from bioremediation.
  - TPH-G was detected at a concentration greater than the cleanup level at MW-7. The concentration decreased by 33 percent from baseline (November 2018), but remains above the cleanup level.

  - TPH-G was detected at MW-12 at a concentration greater than the cleanup level during the baseline event. However, the concentration was below the cleanup level during both subsequent monitoring events in 2019.
  - TPH-G concentrations are within compliance (less than cleanup levels) at all other monitoring wells (MW-4, MW-5, MW-6, MW-8, MW-11, MW-13, MW-14).

- **Diesel-range total petroleum hydrocarbons** (TPH-D; Figure 6):
  - The cleanup level for TPH-D established in the CAP is 0.5 mg/L.
  - As described above with respect to TPH-G, the TPH-D concentrations at MW-9 and MW-10 were presumed to be above the cleanup level during the 2019 monitoring events based on the presence of LNAPL. However, the LNAPL thickness decreased in November 2019 to zero at MW-9, and to a thickness less than baseline at MW-10—both are indications that conditions are improving at these locations, likely due to LNAPL removal efforts and contaminant reductions from bioremediation.
  - TPH-D was detected at a concentration greater than the cleanup level at MW-7, MW-8, MW-12, MW-13, and MW-14. Concentrations are fluctuating and have increased during bioremediation at two locations. As LAI has observed at other similar cleanup sites, the laboratory analytical method reports a range of organics and the results can be affected by breakdown products during the anaerobic degradation of other petroleum hydrocarbon contaminants. LAI has also observed increased TPH-D concentrations in early stages of bioremediation treatments at other sites due to desorption and/or mobilization of contaminants that were previously trapped within soil pore spaces. The existing data set is relatively small to speculate on trends. Continued performance sampling in 2020 and beyond will provide additional data to determine cleanup progress.

- **Benzene (Figure 7)**:
  - The cleanup level for benzene established in the CAP is 0.0024 mg/L.
  - As shown on Figure 7, benzene concentrations were detected above the cleanup level at only two wells: MW-13 and MW-14.
  - Concentrations appear to be decreasing at both locations, and are less than cleanup levels at all other locations.

- **Naphthalenes (Figure 8)**:
  - The cleanup level for total naphthalenes established in the CAP is 0.083 mg/L. This value is based on total naphthalenes, by adding the concentrations of detected naphthalene, 1-methyl naphthalene, and 2-methyl naphthalene. To evaluate compliance with the cleanup levels, analysis of total naphthalenes will be conducted during future performance sampling events. However, for the purpose of performance assessment, only naphthalene is analyzed as a cost-saving measure.
  - Naphthalene concentrations were less than the cleanup level at all locations.

- **Nitrate (Figure 9)**:
  - Nitrate is not a Site IHS, but is monitored during the quarterly events to evaluate distribution of nitrate solution from the infiltrations, and to evaluate the longevity of the nitrate as it is being consumed in the bioremediation process.
  - Nitrate was detected throughout the cleanup Site, indicating the injection program is successfully providing electron acceptor. Concentrations in 2019 ranged from 0.16 mg/L (MW-4) to 1,800 mg/L (MW-14), likely indicating that both distribution and nitrate consumption vary for groundwater outside and inside the infiltration area, respectively. At one location, MW-7, nitrate concentrations are low. This is likely due to the rapid nitrate consumption in the presence of higher levels of contamination. Continued evaluation will be conducted in order to inform future infiltrations, as additional efforts may be needed to improve nitrate distribution in this location.
  - Concentrations of nitrate decreased rapidly from what was observed at wells MW-12, MW-13, and MW-14 (approximately 35 to 40 feet from the shoreline) to wells MW-5, MW-6, and MW-7 (immediately adjacent to the shoreline). This reduction indicates that the nitrate is being used for bioremediation as desired, and not being lost to the surface water. It also indicates that the infiltration program is providing an appropriate quantity of nitrate to protect surface water from potential nitrate impacts.
  - Elevated concentrations of nitrate at MW-4, MW-9, and MW-10 provide additional evidence that the nitrate solution is being delivered to the areas of the Site that are considered to have the highest residual contaminant concentrations.

3.2 Surface Water Quality

As described in the Work Plan and required by the UIC permit, surface water samples are collected during the performance sampling events to confirm that nitrate concentrations are below acceptable limits. Although there are no marine surface water criteria for nitrate based on the Model Toxics Control Act cleanup levels, the primary concern for nitrate in marine surface water is that nitrate can act as a nutrient and exacerbate algal blooms that occur naturally during summer months.

During each quarterly event, two surface water samples are collected immediately adjacent to the shoreline (within 1 foot of the actual contact between the water and shoreline, which varies during tidal fluctuations), and at the base of the water column (within 2 inches of the sediment surface). Surface water quality results are summarized in Table 6. As indicated in the table, nitrate is typically non-detectable. The highest detected concentration of nitrate is greater than 10 times below the acceptable limit (25 mg/L nitrate + nitrite), indicating that the bioremediation program is being conducted in a manner protective of surface water quality.

4.0 UPCOMING SCHEDULE AND RESTORATION TIMEFRAME

Based on the results presented above, LAI anticipates that the bioremediation program will proceed in 2020 as follows:

- February 2020: 1st Quarter water quality event
- May 2020: 2nd Quarter water quality event
- June 2020: Nitrate solution infiltration #3
- July 2020: 3rd Quarter water quality event
- October 2020: 4th Quarter water quality event.
- November 2020: Nitrate solution infiltration #4.

The schedule summarized above was developed to provide two quarterly performance sampling events between nitrate solution treatments for 2020. The actual schedule may require adjustment based on review of quarterly groundwater performance and/or surface water data, which may indicate the need to postpone or advance treatment events. Any schedule modifications will be coordinated between the Port and Ecology.

Monitoring results indicate that the IHS concentrations are decreasing significantly. However, because only 1 year of injections and performance sampling has been completed, there is not yet enough data to reliably predict the restoration timeframe through trend analysis. LAI anticipates continued decreases in IHS concentrations throughout 2020, and will provide an estimated restoration timeframe in the 2020 annual groundwater quality report based on trend analysis.

5.0 USE OF THIS REPORT

This report has been prepared for the exclusive use of the Port of Bellingham for specific application to the Blaine Marina, Inc. cleanup site. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of LAI. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by LAI, shall be at the user's sole risk. LAI warrants that within the limitations of scope, schedule, and budget, these services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. LAI makes no other warranty, either express or implied.

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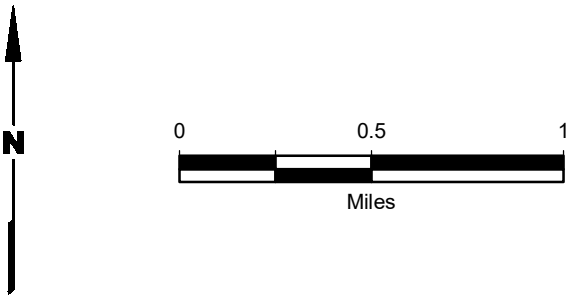

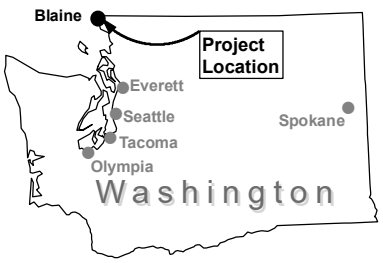

Data Source: Esri 2012

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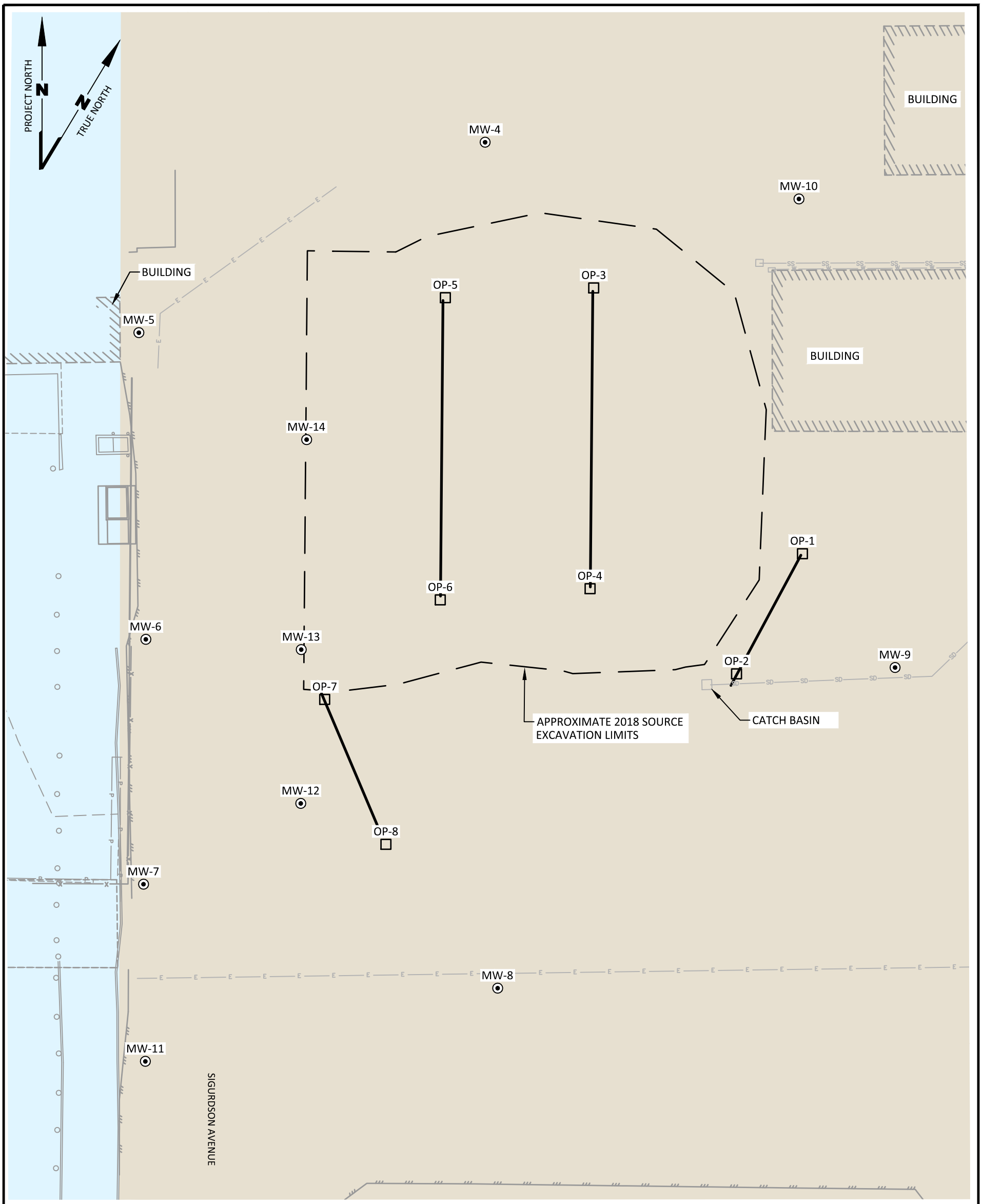
Blaine Marina, Inc. Site Blaine, Washington	**Vicinity Map**	Figure 1



Legend

- Groundwater Monitoring Well
- Observation and Bioremediation Injection Point
- Treatment Trench
- Excavation Boundary

Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Sources: Wilson Engineering topographic survey, 4/26/17; Wilson Engineering topographic survey, 11/02/11

0 20 40
Scale in Feet

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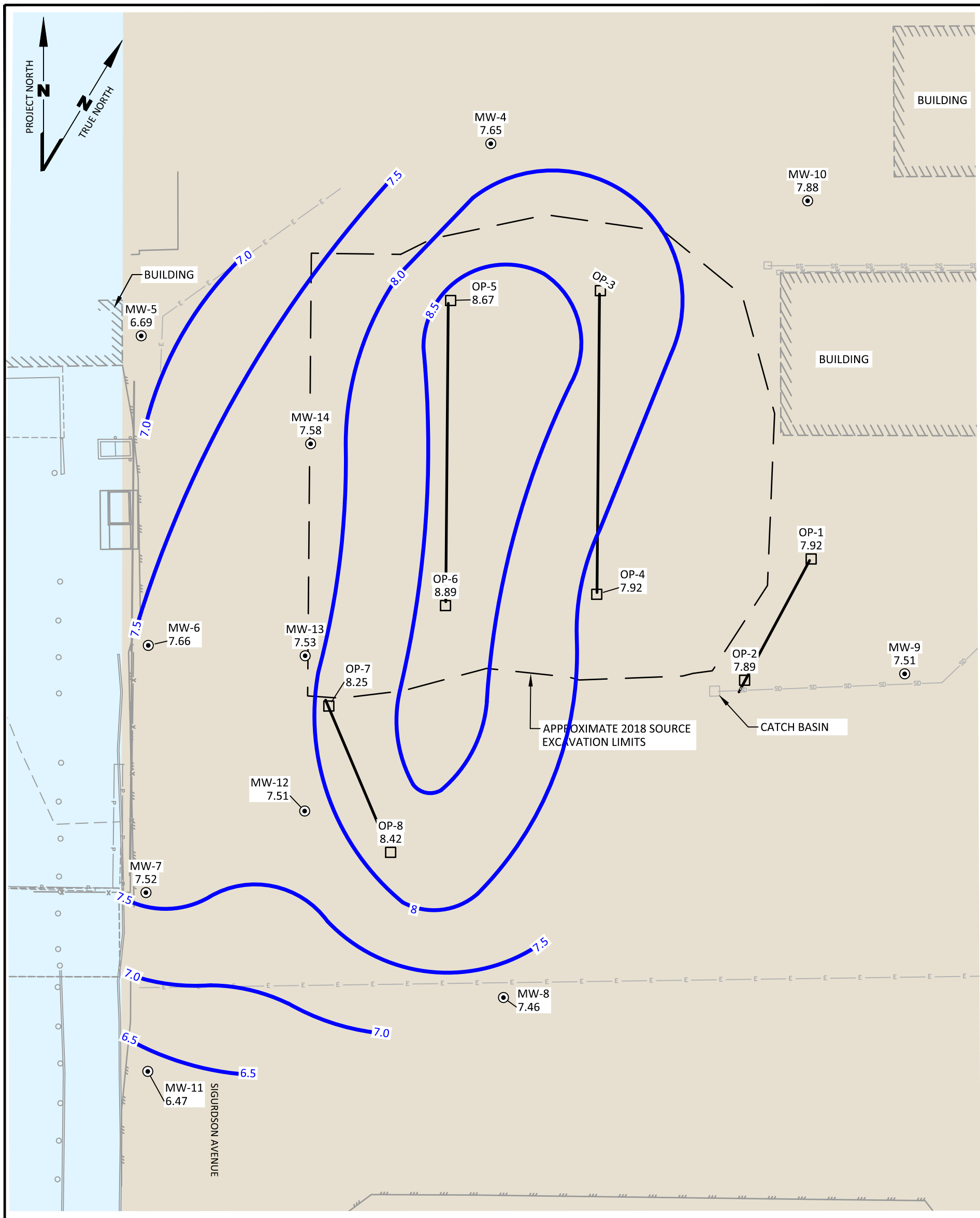
Blaine Marina, Inc. Site
Blaine, Washington

Site Plan

Figure
2



Legend

- Groundwater Monitoring Well
- Observation and Bioremediation Injection Point
- Treatment Trench
- Excavation Boundary
- 7 — Groundwater Elevation Contour

Notes

1. Groundwater elevations measured July 15, 2019.
2. Tidal elevations during measurement: falling from +3.5 to +2.0 MLLW.
3. Elevations presented in Mean Lower Low Water (MLLW).
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Sources: Wilson Engineering topographic survey, 4/26/17; Wilson Engineering topographic survey, 11/02/11

0 20 40
Scale in Feet

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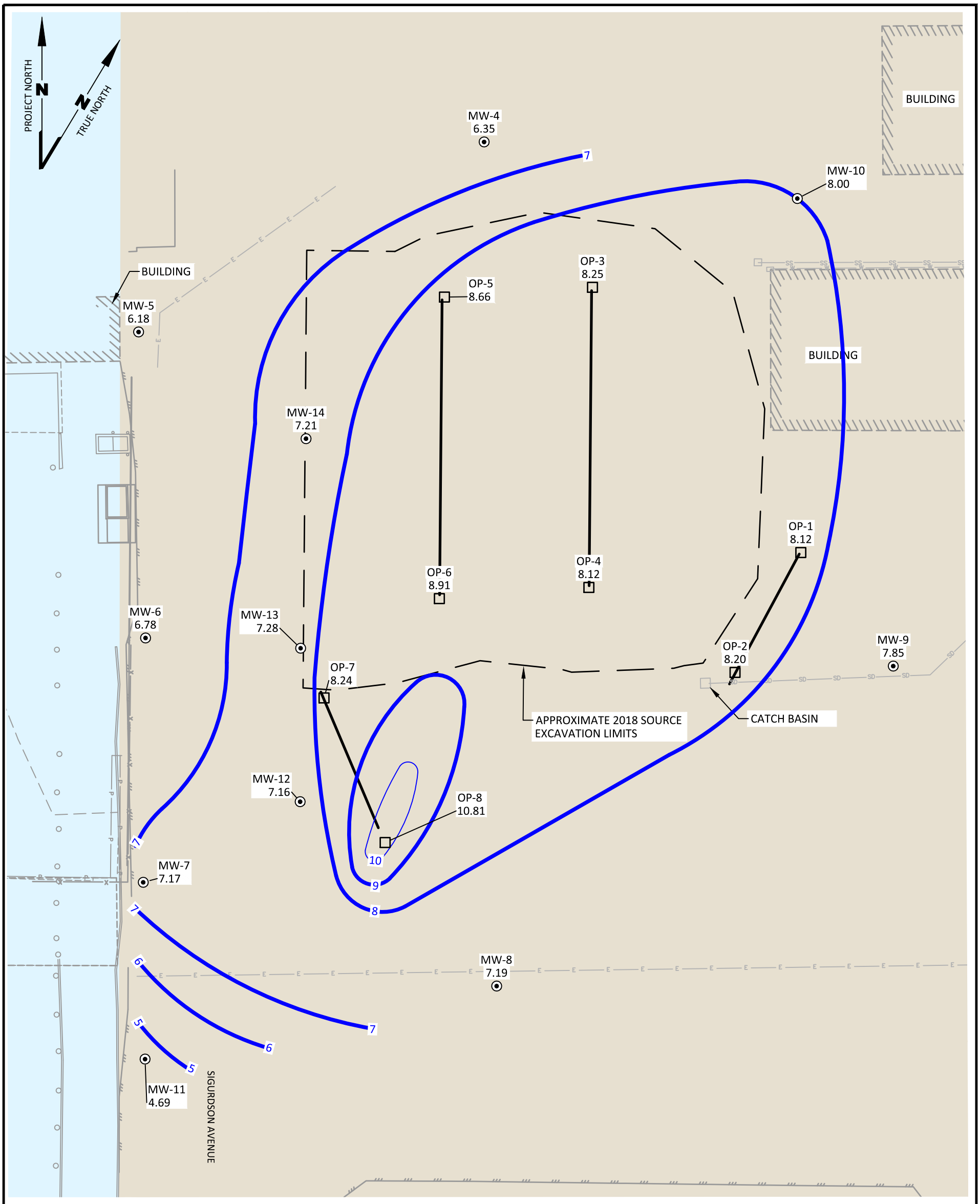
Blaine Marina, Inc. Site
Blaine, Washington

Groundwater Elevations
July 2019

Figure
3



Legend

- Groundwater Monitoring Well
- Observation and Bioremediation Injection Point
- Treatment Trench
- Excavation Boundary
- 7 — Groundwater Elevation Contour

Notes

1. Groundwater elevations measured October 7, 2019.
2. Tidal elevations during measurement: rising from +1 to +1.5 MLLW.
3. Elevations presented in Mean Lower Low Water (MLLW).
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Sources: Wilson Engineering topographic survey, 4/26/17; Wilson Engineering topographic survey, 11/02/11

0 20 40
Scale in Feet

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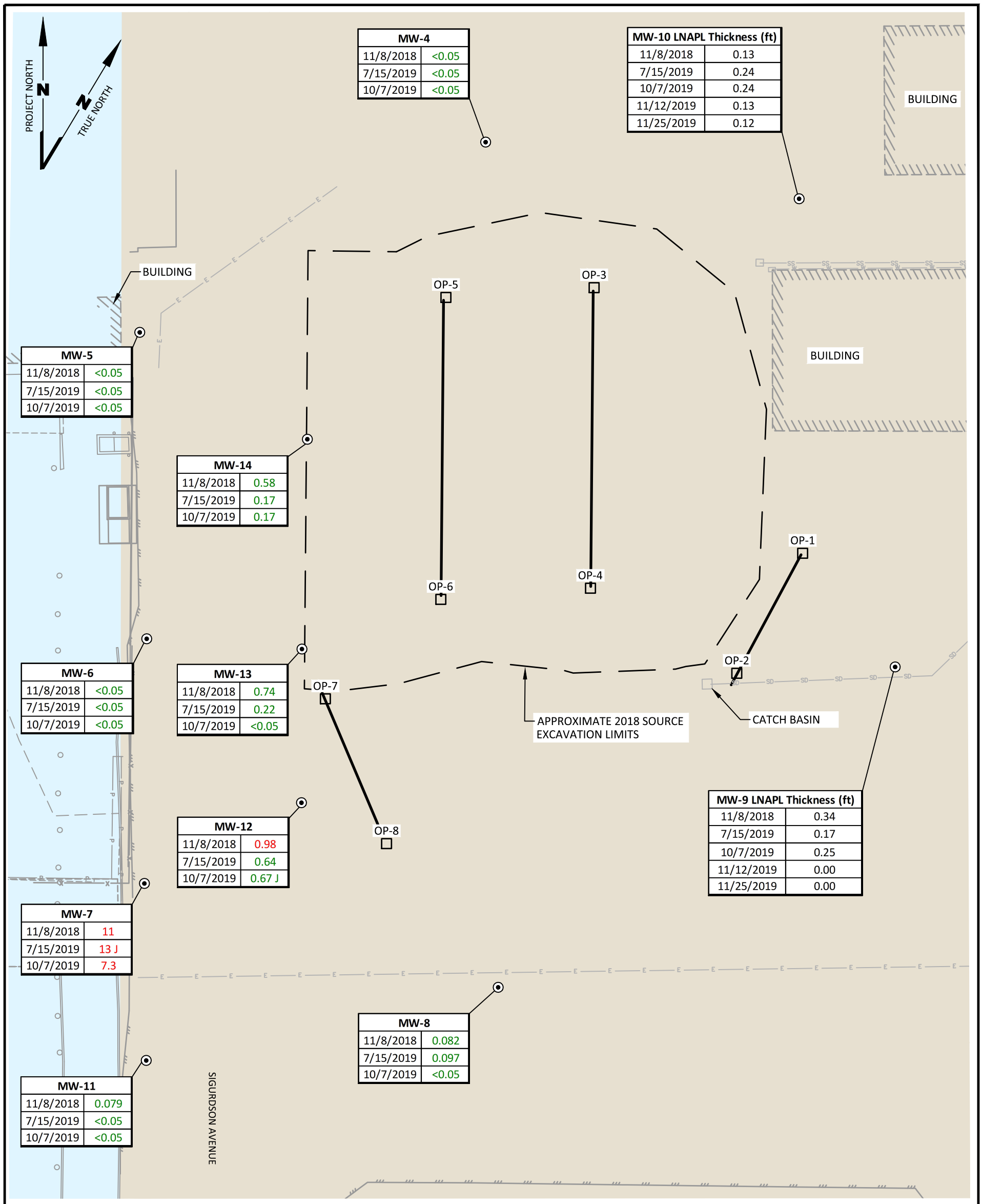
Blaine Marina, Inc. Site
Blaine, Washington

Groundwater Elevations October 2019

Figure 4



Legend

- Groundwater Monitoring Well
  - IHS Concentration(s) Exceed Cleanup Levels
  - IHS Concentration(s) are Less Than Cleanup Levels
- Observation and Bioremediation Injection Points
- Treatment Trench
- Excavation Boundary

Notes

1. All results are reported in milligrams per liter (mg/L).
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

IHS = Indicator Hazardous Substances
J = Result is an estimated quantity. Associated numerical value is the approximate concentration of the analyte in the sample.
LNAPL = Light Non-Aqueous Phase Liquid
TPH-G = gasoline-range total petroleum hydrocarbons

Cleanup level for TPH-G = 0.8 mg/L

Sampling Location	
Date	Result

Sources: Wilson Engineering topographic survey, 4/26/17; Wilson Engineering topographic survey, 11/02/11

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0 20 40
Scale in Feet

Blaine Marina, Inc. Site
Blaine, Washington

TPH-G Concentrations in Groundwater

Figure 5

PROJECT NORTH

TRUE NORTH

MW-4	
11/8/2018	<0.13
7/15/2019	<0.13
10/7/2019	0.16

MW-10 LNAPL Thickness (ft)	
11/8/2018	0.13
7/15/2019	0.24
10/7/2019	0.24
11/12/2019	0.13
11/25/2019	0.12

BUILDING

BUILDING

BUILDING

MW-5	
11/8/2018	0.35
7/15/2019	0.22
10/7/2019	0.15

MW-14	
11/8/2018	2.2
7/15/2019	0.57
10/7/2019	2

OP-5

OP-3

OP-1

OP-6

OP-4

OP-2

MW-6	
11/8/2018	<0.13
7/15/2019	<0.13
10/7/2019	<0.13

MW-13	
11/8/2018	3.2
7/15/2019	0.51
10/7/2019	0.99

OP-7

APPROXIMATE 2018 SOURCE EXCAVATION LIMITS

CATCH BASIN

MW-9 LNAPL Thickness (ft)	
11/8/2018	0.34
7/15/2019	0.17
10/7/2019	0.25
11/12/2019	0.00
11/25/2019	0.00

MW-12	
11/8/2018	0.18
7/15/2019	0.4
10/7/2019	0.61

OP-8

MW-7	
11/8/2018	3.3 J
7/15/2019	2.2 J
10/7/2019	2.4 J

MW-8	
11/8/2018	0.62
7/15/2019	0.39
10/7/2019	0.99

MW-11	
11/8/2018	<0.13
7/15/2019	<0.13
10/7/2019	<0.13

SIGURDSON AVENUE

Legend

- Groundwater Monitoring Well
  - IHS Concentration(s) Exceed Cleanup Levels
  - IHS Concentration(s) are Less Than Cleanup Levels
- Observation and Bioremediation Injection Points
- Treatment Trench
- Excavation Boundary

Notes

1. All results are reported in milligrams per liter (mg/L).
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

IHS = Indicator Hazardous Substances
J = Result is an estimated quantity. Associated numerical value is the approximate concentration of the analyte in the sample.
LNAPL = Light Non-Aqueous Phase Liquid
TPH-D = diesel-range total petroleum hydrocarbons

Cleanup level for TPH-D = 0.5 mg/L

Sampling Location	
Date	Result

Sources: Wilson Engineering topographic survey, 4/26/17; Wilson Engineering topographic survey, 11/02/11

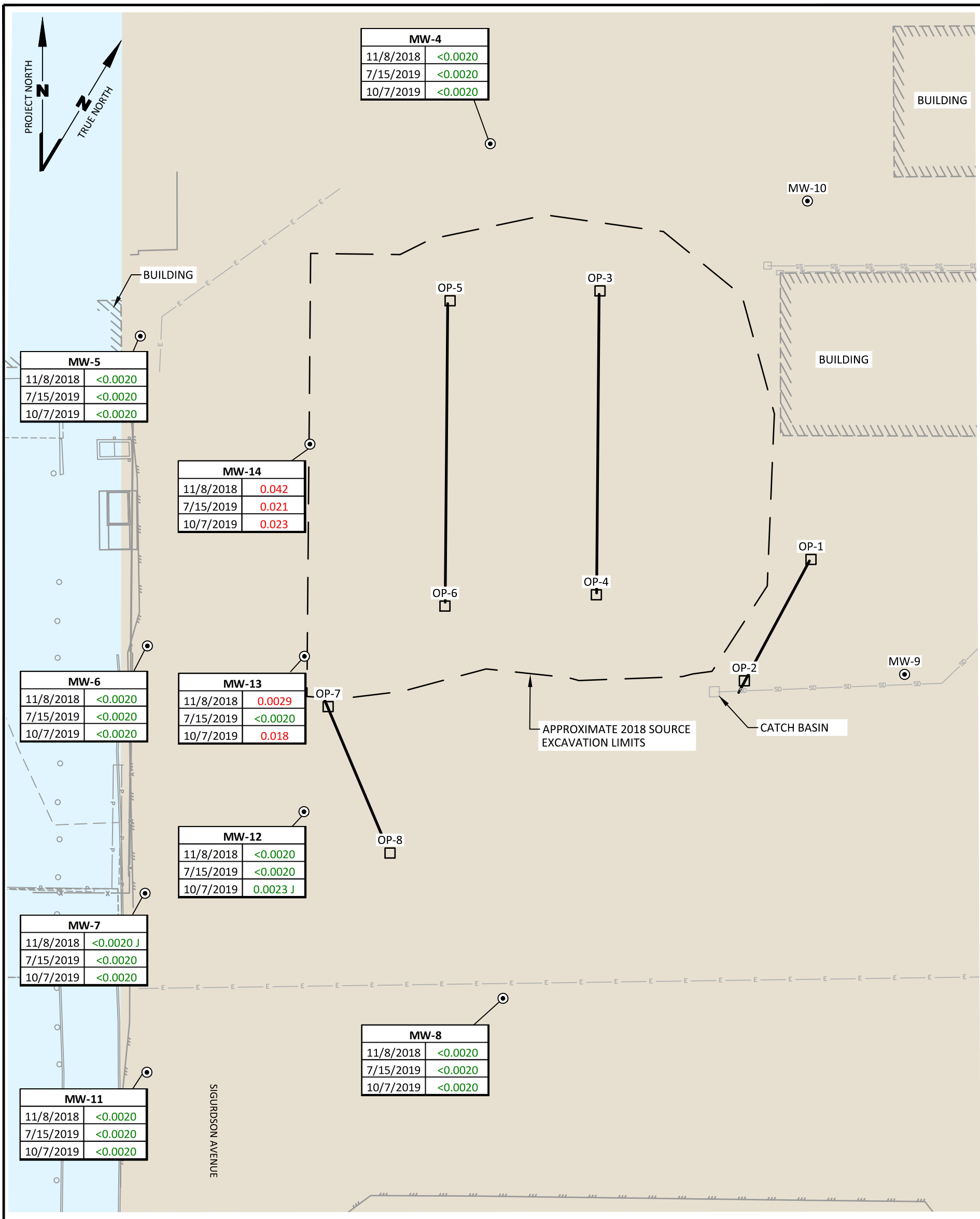
LANDAU ASSOCIATES

0 20 40
Scale in Feet

Blaine Marina, Inc. Site
Blaine, Washington

TPH-D Concentrations in Groundwater

Figure 6



Legend

- Groundwater Monitoring Well
  - IHS Concentration(s) Exceed Cleanup Levels
  - IHS Concentration(s) are Less Than Cleanup Levels
- Observation and Bioremediation Injection Points
- Treatment Trench
- Excavation Boundary

Notes

1. All results are reported in milligrams per liter (mg/L).
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

IHS = Indicator Hazardous Substances
J = Result is an estimated quantity. Associated numerical value is the approximate concentration of the analyte in the sample.

Cleanup level for Benzene = 0.0024 mg/L

Sampling Location	
Date	Result

Sources: Wilson Engineering topographic survey, 4/26/17; Wilson Engineering topographic survey, 11/02/11

LANDAU ASSOCIATES

0 20 40
Scale in Feet

Blaine Marina, Inc. Site
Blaine, Washington

Benzene Concentrations in Groundwater

Figure 7

PROJECT NORTH

TRUE NORTH

MW-4	
11/8/2018	<0.0020
7/15/2019	<0.0020
10/7/2019	<0.0020

BUILDING

MW-10

BUILDING

BUILDING

MW-5	
11/8/2018	<0.0020
7/15/2019	<0.0020
10/7/2019	<0.0020

OP-5

OP-3

MW-14	
11/8/2018	0.0069
7/15/2019	0.0025
10/7/2019	0.0032

OP-1

OP-6

OP-4

MW-6	
11/8/2018	<0.0020
7/15/2019	<0.0020
10/7/2019	<0.0020

MW-13	
11/8/2018	0.0048
7/15/2019	0.0024
10/7/2019	<0.0020

OP-7

OP-2

MW-9

APPROXIMATE 2018 SOURCE EXCAVATION LIMITS

CATCH BASIN

MW-12	
11/8/2018	<0.0020
7/15/2019	<0.0020
10/7/2019	0.0023 J

OP-8

MW-7	
11/8/2018	0.047
7/15/2019	0.03
10/7/2019	0.038 J

MW-8	
11/8/2018	<0.0020
7/15/2019	<0.0020
10/7/2019	<0.0020

MW-11	
11/8/2018	<0.0020
7/15/2019	<0.0020
10/7/2019	<0.0020

SIGURDSON AVENUE

Legend

- Groundwater Monitoring Well
  - IHS Concentration(s) Exceed Cleanup Levels
  - IHS Concentration(s) are Less Than Cleanup Levels
- Observation and Bioremediation Injection Points
- Treatment Trench
- Excavation Boundary

Notes

1. All results are reported in milligrams per liter (mg/L).
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

IHS = Indicator Hazardous Substances
J = Result is an estimated quantity. Associated numerical value is the approximate concentration of the analyte in the sample.

Cleanup level for Napthalenes = 0.083 mg/L

Sampling Location	
Date	Result

Sources: Wilson Engineering topographic survey, 4/26/17; Wilson Engineering topographic survey, 11/02/11

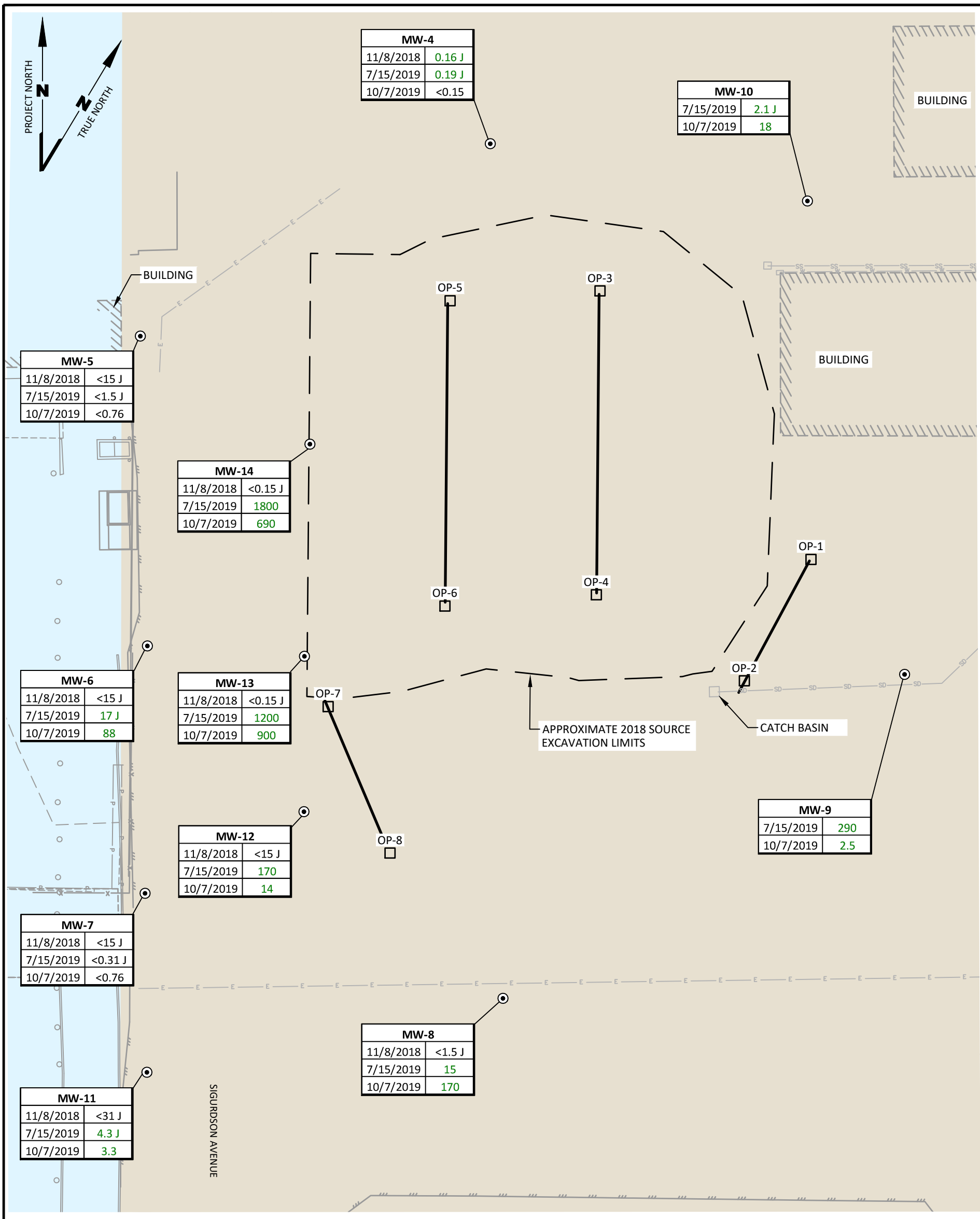
LANDAU ASSOCIATES

0 20 40
Scale in Feet

Blaine Marina, Inc. Site
Blaine, Washington

Naphthalene Concentrations in Groundwater

Figure 8



Legend

- Groundwater Monitoring Well
  - Green Text Indicates Nitrate was Detected Above the Laboratory Reporting Limit
- Observation and Bioremediation Injection Points
- Treatment Trench
- Excavation Boundary

Notes

1. All results are reported in milligrams per liter (mg/L).
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

J = Result is an estimated quantity. Associated numerical value is the approximate concentration of the analyte in the sample.

Sampling Location	
Date	Result

Sources: Wilson Engineering topographic survey, 4/26/17; Wilson Engineering topographic survey, 11/02/11

LANDAU ASSOCIATES

0 20 40
Scale in Feet

Blaine Marina, Inc. Site
Blaine, Washington

Nitrate Distribution

Figure 9

Table 1
Bioremediation Infiltration Summary
Blaine Marina, Inc.
Blaine, Washington

Injection Well Pair	First Injection - June 2019						Second Injection - November 2019					
	Nitrate Dose	Nitrate Concentration		Injection Solution			Nitrate Dose	Nitrate Concentration		Injection Solution		
		mg NO_3/L	mg NO_3-N/L	Target Volume (gal)	AN Solution (gal)	Yeast Extract (lbs)		mg NO_3/L	mg NO_3-N/L	Target Volume (gal)	AN Solution (gal)	Yeast Extract (lbs)
OP-1/2	5x	5,000	1,129	2,000	38	2	8x	8,000	1,806	2,000	62.5	2
OP-3/4	5x	5,000	1,129	18,000	338	18	5x	5,000	1,129	18,000	350	18
OP-5/6	5x	5,000	1,129	18,000	338	18	5x	5,000	1,129	18,000	350	18
OP-7/8	5x	5,000	1,129	2,000	38	2	8x	8,000	1,806	2,000	62.5	2
Totals:				**40,000**	**752**	**40**				**40,000**	**825**	**40**

Abbreviations and Acronyms:

AN = ammonium nitrate
gal = gallons
lbs = pounds
mg NO_3/L = milligrams of nitrate per liter
mg NO_3-N/L = milligrams nitrate as nitrogen per liter

Table 2
Groundwater Elevations
Blaine Marina, Inc.
Blaine, Washington

Monitoring Well	Sampling Date	TOC Elevation (ft)	Depth to LNAPL (ft from TOC)	LNAPL Thickness (ft)	Depth to Groundwater (ft from TOC)	Groundwater Elevation (ft)
MW-4	11/8/2018	16.67	--	0.00	8.33	8.34
	7/15/2019	16.67	--	0.00	9.02	7.65
	10/7/2019	16.67	--	0.00	10.32	6.35
MW-5	11/8/2018	15.61	--	0.00	7.24	8.37
	7/15/2019	15.61	--	0.00	8.92	6.69
	10/7/2019	15.61	--	0.00	9.43	6.18
MW-6	11/8/2018	15.63	--	0.00	7.12	8.51
	7/15/2019	15.63	--	0.00	7.97	7.66
	10/7/2019	15.63	--	0.00	8.85	6.78
MW-7	11/8/2018	15.77	--	0.00	7.41	8.36
	7/15/2019	15.77	--	0.00	8.25	7.52
	10/7/2019	15.77	--	0.00	8.60	7.17
MW-8	11/8/2018	15.98	--	0.00	8.08	7.9
	7/15/2019	15.98	--	0.00	8.52	7.46
	10/7/2019	15.98	--	0.00	8.79	7.19
MW-9	11/8/2018	15.61	7.29	0.34	7.63	8.252
	7/15/2019	15.61	8.07	0.17	8.24	7.506
	10/7/2019	15.61	7.71	0.25	7.96	7.85
	11/12/2019	15.61	7.35	0.00	7.35	8.26
	11/25/2019	15.61	7.77	0.00	7.77	7.84
MW-10	11/8/2018	16.12	7.67	0.13	7.8	8.424
	7/15/2019	16.12	8.19	0.24	8.43	7.882
	10/7/2019	16.12	8.07	0.24	8.31	8.002
	11/12/2019	16.12	8.22	0.13	8.35	7.874
	11/25/2019	16.12	7.8	0.12	7.92	8.296
MW-11	11/8/2018	15.62	--	0.00	7.38	8.24
	7/15/2019	15.62	--	0.00	9.15	6.47
	10/7/2019	15.62	--	0.00	10.93	4.69
MW-12	11/8/2018	16.06	--	0.00	7.71	8.35
	7/15/2019	16.06	--	0.00	8.55	7.51
	10/7/2019	16.06	--	0.00	8.90	7.16
MW-13	11/8/2018	16.13	--	0.00	7.71	8.42
	7/15/2019	16.13	--	0.00	8.60	7.53
	10/7/2019	16.13	--	0.00	8.85	7.28
MW-14	11/8/2018	16.36	--	0.00	8.01	8.35
	7/15/2019	16.36	--	0.00	8.78	7.58
	10/7/2019	16.36	--	0.00	9.15	7.21

Table 2
Groundwater Elevations
Blaine Marina, Inc.
Blaine, Washington

Monitoring Well	Sampling Date	TOC Elevation (ft)	Depth to LNAPL (ft from TOC)	LNAPL Thickness (ft)	Depth to Groundwater (ft from TOC)	Groundwater Elevation (ft)
OP-1	11/8/2018	15.41	--	0.00	6.84	8.57
	7/15/2019	15.41	--	0.00	7.49	7.92
	10/7/2019	15.41	--	0.00	7.29	8.12
OP-2	11/8/2018	14.52	5.93	0.23	6.16	8.544
	7/15/2019	14.52	6.61	0.12	6.73	7.886
	10/7/2019	14.52	6.32	0.01	6.33	8.198
	11/12/2019	14.52	7.51	-0.91	6.6	7.6
OP-3	11/8/2018	15.63	--	0.00	6.96	8.67
	7/15/2019	15.63	--	0.00	--	dry
	10/7/2019	15.63	--	0.00	7.38	8.25
OP-4	11/8/2018	15.05	--	0.00	6.44	8.61
	7/15/2019	15.05	--	0.00	7.13	7.92
	10/7/2019	15.05	--	0.00	6.93	8.12
OP-5	11/8/2018	15.93	7.20	0.01	7.21	8.728
	7/15/2019	15.93	--	0.00	7.26	8.67
	10/7/2019	15.93	--	0.00	7.27	8.66
OP-6	11/8/2018	15.42	--	0.00	6.52	8.9
	7/15/2019	15.42	--	0.00	6.53	8.89
	10/7/2019	15.42	--	0.00	6.51	8.91
OP-7	11/8/2018	15.31	--	0.00	7.18	8.13
	7/15/2019	15.31	--	0.00	7.06	8.25
	10/7/2019	15.31	--	0.00	7.07	8.24
OP-8	11/8/2018	15.72	--	0.00	7.36	8.36
	7/15/2019	15.72	--	0.00	7.30	8.42
	10/7/2019	15.72	--	0.00	4.91	10.81

Abbreviations/Acronyms:

ft = feet

LNAPL = light non-aqueous phase liquid

TOC = top of casing

Table 3
Bioremediation Performance Parameters
Blaine Marina, Inc.
Blaine, Washington

Field Parameters	Data Collection Method	Units	Information Provided
DO	Field Meter[a]	mg/L	Aquifer is considered anaerobic at DO concentrations less than 1.0 mg/L
ORP	Field Meter[a]	mV	Negative values indicate reducing conditions.
pH	Field Meter[a]	SU	Optimal for biodegradation in the 6-8 range
Ferrous Iron	Hach® Kit	mg/L	Detections indicate iron-reducing conditions

Laboratory Analyses	Analytical Method	Bottles	Allowable Holding Time	Information Provided
TPH-G and Benzene	NWTPH-Gx/ EPA Method 8260C	3x 40-mL glass, HCL	14 days	Changes in contaminant concentrations are indicative of treatment progress.
TPH-D/O	NWTPH-Dx	1x 2-Liter amber glass	7 days to extract; 40 days to analysis	Changes in contaminant concentrations are indicative of treatment progress.
Naphthalene	EPA Method 8260C	3x 40 mL glass	14 days	Changes in contaminant concentrations are indicative of treatment progress.
Nitrate/ Sulfate	EPA Method 300.0	2x 40-mL VOA unpreserved	Nitrate: 48 hours Sulfate: 28 days	Nitrate concentrations below background indicate nitrate-reducing conditions. Sulfate concentrations below background indicate sulfate-reducing conditions.

Abbreviations and Acronyms:

DO = dissolved oxygen
EPA = US Environmental Protection Agency
HCl = hydrochloric acid
mg/L = milligrams per liter
mL = milliliter
mV = millivolts
ORP = oxidation reduction potential
SU = standard unit
TPH-D = diesel-range total petroleum hydrocarbons
TPH-G = gasoline-range total petroleum hydrocarbons
TPH-O = oil-range total petroleum hydrocarbons

Notes:

[a] Measured using a flow-through cell.

Table 4
Groundwater Analytical Results
Blaine Marina, Inc.
Blaine, Washington

Analyte	Cleanup Level[a]	Sampling Location, Laboratory Sample ID, Sampling Date, Sample Type								
		MW-4 EV18110065-07 11/8/2018 N	MW-4 EV19070106-03 7/15/2019 N	MW-4 EV19100043-02 10/7/2019 N	MW-5 EV18110065-02 11/8/2018 N	MW-5 EV19070106-06 7/15/2019 N	MW-5 EV19100043-04 10/7/2019 N	MW-6 EV18110065-03 11/8/2018 N	MW-6 EV19070106-02 7/15/2019 N	MW-6 EV19100043-06 10/7/2019 N
Total Petroleum Hydrocarbons (mg/L; NWTPH-Gx/Dx)										
Gasoline Range C5-C12	0.8	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Diesel Range C12-C24	0.5	0.13 U	0.13 U	**0.16**	**0.35**	**0.22**	**0.15**	0.13 U	0.13 U	0.13 U
Motor Oil Range C24-C40	0.5	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Combined TPH[b]	0.5	0.25 U	0.25 U	**0.16**	**0.35**	**0.22**	**0.15**	0.25 U	0.25 U	0.25 U
Volatiles (mg/L; SW-846 8260C)										
Benzene	0.0024	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U
Naphthalene	0.083[c]	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U
General Chemistry (mg/L; EPA 300.0/SM 5310C)										
Nitrate (mg/L)	N/A	**0.16 J**	**0.19 J**	0.15 U	15 UJ	1.5 UJ	0.76 U	15 UJ	**17 J**	**88**
Sulfate	N/A	**130**	**110**	**120**	**2,300**	**2,000**	**1,900**	**1,700**	**1,300**	**530**
Total Organic Carbon	N/A	**1.8**	--	--	1.0 U	--	--	1.0 U	--	--

Table 4
Groundwater Analytical Results
Blaine Marina, Inc.
Blaine, Washington

Analyte	Cleanup Level[a]	Sampling Location, Laboratory Sample ID, Sampling Date, Sample Type								
		MW-7 EV18110065-08 11/8/2018 N	MW-7 EV18110065-01 11/8/2018 FD	MW-7 EV19070106-07 7/15/2019 N	MW-7 EV19070106-01 7/15/2019 FD	MW-7 EV19100043-03 10/7/2019 N	MW-7 EV19100043-01 10/7/2019 FD	MW-8 EV18110065-10 11/8/2018 N	MW-8 EV19070106-10 7/15/2019 N	MW-8 EV19100043-08 10/7/2019 N
Total Petroleum Hydrocarbons (mg/L; NWTPH-Gx/Dx)										
Gasoline Range C5-C12	0.8	**11**	**10**	**13 J**	**10 J**	**7.3**	**7.2**	**0.082**	**0.097**	0.05 U
Diesel Range C12-C24	0.5	**3.3 J**	**3.7 J**	**2.2 J**	**1.7 J**	**2.4 J**	**2.2 J**	**0.62**	**0.39**	**0.99**
Motor Oil Range C24-C40	0.5	**0.4**	**0.45**	**0.3**	**0.3**	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Combined TPH[b]	0.5	**3.7 J**	**4.15 J**	**2.5 J**	**2.0 J**	**2.4 J**	**2.2 J**	**0.62**	**0.39**	**0.99**
Volatiles (mg/L; SW-846 8260C)										
Benzene	0.0024	0.0020 UJ	0.0020 UJ	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U
Naphthalene	0.083[c]	**0.047**	**0.043**	**0.03**	**0.032**	**0.038 J**	**0.027 J**	0.0020 U	0.0020 U	0.0020 U
General Chemistry (mg/L; EPA 300.0/SM 5310C)										
Nitrate (mg/L)	N/A	15 UJ	1.5 U	0.31 UJ	1.5 UJ	0.76 U	0.76 U	1.5 UJ	**15**	**170**
Sulfate	N/A	**1,500**	**1,500**	**960**	**980**	**740**	**700**	**190**	**25**	**170**
Total Organic Carbon	N/A	**3.0**	**3.7**	--	--	--	--	**2.5**	--	--

Table 4
Groundwater Analytical Results
Blaine Marina, Inc.
Blaine, Washington

Analyte	Cleanup Level[a]	Sampling Location, Laboratory Sample ID, Sampling Date, Sample Type								
		MW-9 EV19070106-05 7/15/2019 N	MW-9 EV19100043-11 10/7/2019 N	MW-10 EV19070106-04 7/15/2019 N	MW-10 EV19100043-12 10/7/2019 N	MW-11 EV18110065-09 11/8/2018 N	MW-11 EV19070106-09 7/15/2019 N	MW-11 EV19100043-05 10/7/2019 N	MW-12 EV18110065-06 11/8/2018 N	MW-12 EV19070106-12 7/15/2019 N
Total Petroleum Hydrocarbons (mg/L; NWTPH-Gx/Dx)										
Gasoline Range C5-C12	0.8	--	--	--	--	**0.079**	0.05 U	0.05 U	**0.98**	**0.64**
Diesel Range C12-C24	0.5	--	--	--	--	0.13 U	0.13 U	0.13 U	**0.18**	**0.4**
Motor Oil Range C24-C40	0.5	--	--	--	--	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Combined TPH[b]	0.5	--	--	--	--	0.25 U	0.25 U	0.25 U	**0.18**	**0.4**
Volatiles (mg/L; SW-846 8260C)										
Benzene	0.0024	--	--	--	--	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U
Naphthalene	0.083[c]	--	--	--	--	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U
General Chemistry (mg/L; EPA 300.0/SM 5310C)										
Nitrate (mg/L)	N/A	**290**	**2.5**	**2.1 J**	**18**	31 UJ	**4.3 J**	**3.3**	15 UJ	**170**
Sulfate	N/A	**84**	**76**	**32**	**90**	**2,400**	**2,000**	**1,800**	**1,700**	**620**
Total Organic Carbon	N/A	--	--	--	--	1.0 U	--	--	1.0 U	--

Table 4
Groundwater Analytical Results
Blaine Marina, Inc.
Blaine, Washington

Analyte	Cleanup Level[a]	Sampling Location, Laboratory Sample ID, Sampling Date, Sample Type						
		MW-12 EV19100043-10 10/7/2019 N	MW-13 EV18110065-05 11/8/2018 N	MW-13 EV19070106-11 7/15/2019 N	MW-13 EV19100043-09 10/7/2019 N	MW-14 EV18110065-04 11/8/2018 N	MW-14 EV19070106-08 7/15/2019 N	MW-14 EV19100043-07 10/7/2019 N
Total Petroleum Hydrocarbons (mg/L; NWTPH-Gx/Dx)								
Gasoline Range C5-C12	0.8	**0.67 J**	**0.74**	**0.22**	0.05 U	**0.58**	**0.17**	**0.17**
Diesel Range C12-C24	0.5	**0.61**	**3.2**	**0.51**	**0.99**	**2.2**	**0.57**	**2**
Motor Oil Range C24-C40	0.5	0.25 U	**0.41 J**	0.25 U	0.25 U	**0.37 J**	0.25 U	0.25 U
Combined TPH[b]	0.5	**0.61**	**3.61 J**	**0.51**	**0.99**	**2.57 J**	**0.57**	**2**
Volatiles (mg/L; SW-846 8260C)								
Benzene	0.0024	**0.0023 J**	**0.0029**	0.0020 U	**0.018**	**0.042**	**0.021**	**0.023**
Naphthalene	0.083[c]	0.0020 UJ	**0.0048**	**0.0024**	0.0020 U	**0.0069**	**0.0025**	**0.0032**
General Chemistry (mg/L; EPA 300.0/SM 5310C)								
Nitrate (mg/L)	N/A	**14**	0.15 UJ	**1,200**	**900**	0.15 UJ	**1,800**	**690**
Sulfate	N/A	**360**	**98**	**69**	**330**	**55**	**35**	**46**
Total Organic Carbon	N/A	--	**8.8**	--	--	**15**	--	--

Notes:

All reported results are from post-source removal, which occurred in summer 2018.

MW-9 and MW-10 were not included in the baseline sampling event due to the presence NAPL.

U = The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.

J = The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.

UJ = The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.

Bold = detected compound -- = not analyzed

Green Box = detected concentration is greater than the associated screening level.

[a] Cleanup level based on lowest Water Quality Standard or Practical Quantitation Limit (PQL).

[b] Combined TPH represents the sum of detected diesel- and motor oil-range constituents. If both diesel- and motor oil-range constituents were not detected at a concentration greater than the laboratory reporting limit, the greater of the two reporting limits is presented as the Combined TPH result.

[c] Cleanup level based on total naphthalenes.

Abbreviations/Acronyms:

EPA = US Environmental Protection Agency
FD = field duplicate
ID = identification
mg/L = milligrams per liter
N = primary sample
N/A = not applicable
NAPL = non-aqueous phase liquid
NWTPH = Northwest Total Petroleum Hydrocarbon
PQL = practical quantitation limit
SM = Standard Methods
TPH = total petroleum hydrocarbons

Table 5
Cumulative Bioremediation Program Results Summary
Blaine Marina, Inc.
Blaine, Washington

Well Location	Sampling Date	Elapsed Time from Injection (Days)	Petroleum Hydrocarbons			Volatiles		Redox Conditions						Aquifer Parameters					Comments
			GRO mg/L	DRO mg/L	ORO mg/L	Benzene mg/L	Naphthalene mg/L	DO mg/L	ORP mV	Nitrate mg/L	Nitrate mg-N/L (calc.)	Iron II mg/L	Sulfate mg/L	Cond. (µS/cm)	Temp. (°C)	Turbidity (NTU)	TOC mg/L	pH (SU)	
Groundwater Cleanup Level[a]:			0.8	0.5	0.5	0.0024	0.083[b]	--	--	--	--	--	--	--	--	--	--	--	
MW-4	11/8/2018	Baseline	0.05 U	0.13 U	0.25 U	0.0020 U	0.0020 U	0.39	-87.6	0.16 J	0.036 J	1.0	130	2,612	15.9	4.72	1.8	6.73	
	7/15/2019	33	0.05 U	0.13 U	0.25 U	0.0020 U	0.0020 U	0.63	-62.4	0.19 J	0.043 J	4.0	110	1,755	16.5	23.10	--	6.93	
	10/7/2019	117	0.05 U	0.16	0.25 U	0.0020 U	0.0020 U	1.77	-3.9	0.15 U	0.034 U	1.0	120	1,688	15.9	37.82	--	6.87	
MW-5	11/8/2018	Baseline	0.05 U	0.35	0.25 U	0.0020 U	0.0020 U	1.62	149.0	15 UJ	3.4 UJ	0.0	2,300	34,024	12.6	2.2	1.0 U	7.11	
	7/15/2019	33	0.05 U	0.22	0.25 U	0.0020 U	0.0020 U	0.47	-225.6	1.5 UJ	0.34 UJ	1.0	2,000	36,516	18.3	9.8	--	7.42	
	10/7/2019	117	0.05 U	0.15	0.25 U	0.0020 U	0.0020 U	0.61	-6.0	0.76 U	0.17 U	0.5	1,900	25,170	16.1	25.2	--	7.34	
MW-6	11/8/2018	Baseline	0.05 U	0.13 U	0.25 U	0.0020 U	0.0020 U	0.72	195.0	15 UJ	3.4 UJ	0.0	1,700	25,802	13.4	19.57	1.0 U	6.79	
	7/15/2019	33	0.05 U	0.13 U	0.25 U	0.0020 U	0.0020 U	4.34	6.1	17 J	3.8 J	0.0	1,300	25,900	20.0	27.84	--	7.03	
	10/7/2019	117	0.05 U	0.13 U	0.25 U	0.0020 U	0.0020 U	3.94	65.9	88	20	0.0	530	7,637	15.2	16.90	--	7.18	
MW-7	11/8/2018	Baseline	**11**	**3.3 J**	0.4	0.0020 UJ	0.047	0.56	-369.7	15 UJ	3.4 UJ	0.4	1,500	33,063	14.0	9.0	3.0	6.94	
	7/15/2019	33	**13 J**	**2.2 J**	0.3	0.0020 U	0.03	--	-389.5	0.31 UJ	0.070 UJ	0.4	960	27,198	17.7	0.98	--	7.04	Equipment malfunction prevented DO measurement
	10/7/2019	117	**7.3**	**2.4 J**	0.25 U	0.0020 U	0.038 J	1.70	-279.3	0.76 U	0.17 U	0.0	740	15,810	15.3	3.62	--	7.05	
MW-8	11/8/2018	Baseline	0.082	**0.62**	0.25 U	0.0020 U	0.0020 U	0.43	-221.9	1.5 UJ	0.34 UJ	0.6	190	5,522	14.3	0.73	2.5	7.15	
	7/15/2019	33	0.097	0.39	0.25 U	0.0020 U	0.0020 U	0.46	-114.1	15	3.4	0.8	25	1,520	19.2	8.64	--	7.55	
	10/7/2019	117	0.05 U	**0.99**	0.25 U	0.0020 U	0.0020 U	0.42	107.8	170	38	0.0	170	1,590	18.0	0.72	--	7.46	
MW-9	11/8/2018	Baseline	--	**--**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Not sampled due to NAPL
	7/15/2019	33	--	--	--	--	--	0.62	-13.5	290	66	0.0	84	3,216	19.2	4.66	--	7.42	
	10/7/2019	117	--	--	--	--	--	5.65	96.4	2.5	0.57	1.6	76	1,545	16.9	--	--	7.03	
MW-10	11/8/2018	Baseline	--	**--**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Not sampled due to NAPL
	7/15/2019	33	--	--	--	--	--	0.74	-34.7	2.1 J	0.47 J	0.0	32	883	16.8	11.75	--	7.52	
	10/7/2019	117	--	--	--	--	--	2.96	160.4	18	4.1	0.0	90	825	14.6	--	--	7.38	
MW-11	11/8/2018	Baseline	0.079	0.13 U	0.25 U	0.0020 U	0.0020 U	1.70	-102.9	31 UJ	7.0 UJ	0.8	2,400	36,231	14.7	0.11	1.0 U	7.13	
	7/15/2019	33	0.05 U	0.13 U	0.25 U	0.0020 U	0.0020 U	2.92	-41.6	4.3 J	0.97 J	1.2	2,000	31,825	17.5	8.93	--	7.26	
	10/7/2019	117	0.05 U	0.13 U	0.25 U	0.0020 U	0.0020 U	2.86	138.2	3.3	0.75	0.0	1,800	26,293	15.4	0.16	--	7.29	
MW-12	11/8/2018	Baseline	**0.98**	0.18	0.25 U	0.0020 U	0.0020 U	0.10	-291.9	15 UJ	3.4 UJ	0.0	1,700	33,594	15.0	0.88	1.0 U	7.34	
	7/15/2019	33	0.64	0.4	0.25 U	0.0020 U	0.0020 U	0.21	-122.9	170	38	0.0	620	12,938	18.4	3.72	--	8.17	
	10/7/2019	117	0.67 J	**0.61**	0.25 U	0.0023 J	0.0020 UJ	0.14	-115.8	14	3.2	0.2	360	12,568	18.0	9.76	--	8.09	
MW-13	11/8/2018	Baseline	0.74	**3.2**	0.41 J	**0.0029**	0.0048	0.13	25.4	0.15 UJ	0.034 UJ	0.0	98	4,085	15.1	18.74	8.8	7.03	
	7/15/2019	33	0.22	**0.51**	0.25 U	0.0020 U	0.0024	0.36	129.4	1,200	271	0.0	69	3,412	18.9	3.83	--	7.53	
	10/7/2019	117	0.05 U	**0.99**	0.25 U	**0.018**	0.0020 U	0.20	22.0	900	203	0.0	330	2,533	16.5	62.02	--	7.78	
MW-14	11/8/2018	Baseline	0.58	**2.2**	0.37 J	**0.042**	0.0069	0.97	150.1	0.15 UJ	0.034 UJ	0.0	55	1,160	14.5	0.71	15	7.02	
	7/15/2019	33	0.17	**0.57**	0.25 U	**0.021**	0.0025	0.30	85.6	1,800	407	0.0	35	3,832	21.1	1.37	--	6.70	
	10/7/2019	117	0.17	**2**	0.25 U	**0.023**	0.0032	0.23	70.1	690	156	0.0	46	1,733	18.9	1.04	--	6.88	

Table 5
Cumulative Bioremediation Program Results Summary
Blaine Marina, Inc.
Blaine, Washington

Notes:

All reported results are from post-source removal, which occurred in summer 2018.

[a] Cleanup level based on lowest Water Quality Standard or Practical Quantitation Limit.

[b] Cleanup level based on total naphthalenes.

U = The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.

J = The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.

UJ = The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.

Bold = detected concentration is greater than the associated screening level.

Abbreviations and Acronyms:

µg/L = micrograms per liter
µS/cm = microSiemens per centimeter
°C = degrees Celsius
calc. = calculated
DO = dissolved oxygen
DRO = diesel-range organics
GRO = gasoline-range organics
mg/L = milligrams per liter
mg-N/L = milligrams nitrogen per liter
NAPL = non-aqueous phase liquid
NTU = nephelometric turbidity units
ORO = oil-range organics
ORP = oxidation reduction potential
SU = standard unit
TOC = total organic carbon

Table 6
Surface Water Analytical Results
Blaine Marina, Inc.
Blaine, Washington

Sampling Location	Laboratory Sample ID	Sampling Date	Analytical Method, Analyte, Unit of Measurement, Screening Level					
			EPA 300.0 Nitrate mg/L	Calc. Nitrate mg-N/L	EPA 300.0 Nitrite mg/L	Calc. Nitrite mg-N/L	Calc. Nitrate+Nitrite mg-N/L	EPA 350.1 Ammonia mg/L
			N/A	N/A	N/A	N/A	20	N/A
SW-1	EV18100074-01	10/9/2018	1.5 U	0.34 U	1.4 U	0.043 U	0.34 U	0.060
SW-1	EV19070105-01	7/15/2019	1.8	0.41	14 U	0.43 U	0.41	--
SW-1	EV19100044-01	10/7/2019	1.5 U	0.34 U	71 U	2.2 U	2.2 U	--
SW-2	EV18100074-02	10/9/2018	1.5 U	0.34 U	1.4 U	0.043 U	0.34 U	0.051
SW-2	EV19070105-02	7/15/2019	1.5 U	0.34 U	14 U	0.43 U	0.43 U	--
SW-2	EV19100044-02	10/7/2019	1.5 U	0.34 U	71 U	2.2 U	2.2 U	--

Note:

U = The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.

Abbreviations and Acronyms:

-- = not analyzed
calc. = calculated
EPA = US Environmental Protection Agency
ID = identification
mg/L = milligrams per liter
mg-N/L = milligrams nitrogen per liter
N/A = not applicable