APPENDIX E

HYDRODYNAMIC MODELING EVALUATION

APPENDIX E.1

FINAL TIDAL MARSH HYDRODYNAMICS REPORT
WILLOW CREEK DAYLIGHT EARLY
FEASIBILITY STUDY

FINAL TIDAL MARSH HYDRODYNAMICS REPORT
WILLOW CREEK DAYLIGHT EARLY FEASIBILITY STUDY

Prepared for

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LIST OF ACRONYMS AND ABBREVIATIONS

City	City of Edmonds
Confluence	Confluence Environmental
ft/s	feet per second
HEC-RAS	Hydrologic Engineering Center River Analysis System
LiDAR	Light Detection and Ranging
Marsh	Edmonds Marsh
MLLW	mean lower low water
NAVD 88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
psu	practical salinity unit
S&W	Shannon and Wilson, Inc.
SR	State Route
WSDOT	Washington State Department of Transportation

1 INTRODUCTION

Anchor QEA, LLC, was retained by Shannon and Wilson, Inc. (S&W) to complete a preliminary evaluation of existing tidal hydrodynamics within Edmonds Marsh (Marsh), as well as predicted future tidal hydrodynamics in the Marsh based on a proposed new entrance channel to the project site (preferred alternative). This work was completed to support the Willow Creek Daylight Early Feasibility Study being conducted by S&W, Confluence Environmental (Confluence), and Anchor QEA for the City of Edmonds (City) (S&W 2012).

2 PURPOSE OF HYDRODYNAMIC EVALUATION

The purpose of the early feasibility hydrodynamic evaluation was to evaluate, assess, and compare tidal hydrodynamics in the Marsh for existing and proposed conditions (preferred alternative for new entrance channel) for typical spring fish migration flow and approximate 100-year flow conditions in the basin. The results of this study were used to assess the potential to maintain a permanent connection between the Marsh and Puget Sound, inform an evaluation of potential fish passage and use of the restored Marsh and evaluate potential for upland flood impacts due to construction of the new entrance channel.

3 SITE DESCRIPTION

Edmonds Marsh is an approximate 27-acre estuarine marsh located within the City of Edmonds (Figure 1). It is bordered by State Route 104 to the east; Harbor Square to the north; the BNSF Railroad tracks to the west; and the Unocal property (and 216th Street SW) to the south. The Marsh is tidally influenced by Puget Sound; the current connection between the Sound and the Marsh is a complex system of pipes, culverts, gates, and storage ponds (SAIC 2012; S&W 2012). The Marsh also receives freshwater runoff from approximately 900 acres, including two creeks and run-off from surrounding properties (Sea-Run Consulting 2007). Elevations within the Marsh (based on the digital elevation model developed by S&W; see Table 2) range from approximately 4 feet North American Vertical Datum of 1988 (NAVD 88) (6.2 feet mean lower low water [MLLW]) to 13 feet NAVD 88 (15.2 feet MLLW). Detailed information regarding existing and historical site conditions of the Marsh can be found in the *Alignment Alternatives Screening Analysis Report* (S&W 2012).

4 EVALUATION OF TIDAL HYDRODYNAMICS

Existing and future tidal hydrodynamics (post-restoration) within the Marsh were evaluated using a combination of site specific data collection and numerical modeling. Data collection included targeted site survey (conducted by Perteet in June 2012) and water level loggers installed in the Marsh and in Puget Sound within the Port of Edmonds Marina (by Shannon and Wilson from September 2012 to present). These data were used to evaluate tidal attenuation through the current connection of the marsh with Puget Sound (tide gage system) and the corresponding tidal inundation of the Marsh.

Modeling efforts included development of a one–dimensional hydraulic model for both existing and proposed conditions (preferred new channel alternative). The models were used to evaluate tidal inundation, water depths, and in-channel velocities in the Marsh for both existing and future proposed conditions based on typical low flow and approximate 100-year flood flow conditions. The model used for the evaluation was HEC-RAS, a one-dimensional hydraulic model developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS).

4.1 Tidal Information and Water Level Data

Tidal elevations for the project site were taken from the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service (NOS) tidal benchmark in Elliott Bay, Seattle, Washington (gage #9447130). Tidal heights at Elliott Bay were compared to water level data measured in Port of Edmonds Marina (see Appendix A) for the same time period, and the data were found to be in phase and have the same magnitude (within a few tenths of a foot). Therefore, tidal data at Elliott Bay was determined to be representative of tidal heights in the Sound at the project location. Conversion between MLLW and NAVD 88 was taken from NOAA's VDATUM software. This information is provided in Table 1.

Table 1
Tidal Elevations at the Project Site (based on NOAA Gage #9447130)

Tidal Elevation (feet)	Based on MLLW Datum (feet)	Based on NAVD 88 Datum (feet)
Mean higher high water	11.2	9.3
Mean high water	10.3	8.4
Mean tide level	6.5	4.4
Mean low water	2.7	0.6
NAVD 88 (feet)	2.1	0.0
Mean lower low water	0.0	-2.1

Notes:
NAVD 88 = North American Vertical Datum of 1988
MLLW = mean lower low water

Extreme high tide at the project site is approximately 12 feet NAVD 88 (14 feet MLLW), but occurs only a few times per year based on hourly water level data at Elliott Bay (Appendix A).

Water level data was collected synoptically in the Marsh, above SR 104 in Shellabarger Creek and in Puget Sound (Port of Edmonds Marina) from September 2012 through the present. The loggers measured water level, salinity, and temperature over the deployment time period.

A map showing the locations of the data loggers and water level, salinity, and temperature data from September 1 to September 14, 2012, is provided in Appendix A.

- Water surface elevations in the Marsh (Location LTC-2) oscillate between 6 feet NAVD 88 (8.2 feet MLLW) and approximately 7.5 feet NAVD 88 (9.7 feet MLLW).
- The highest water level in the Marsh (over the tidal cycle) lags behind the high tide elevation in Puget Sound (Location LTC-1). Also, water surface elevations in the Marsh drop more slowly than those in Puget Sound. This is typical of systems where the tidal incursion is limited by control structures (i.e., culverts, tide gates, weirs, etc.).
- Water levels in Shellabarger Creek remain relatively constant over the tidal cycle (at just higher than 10 feet NAVD 88 [12.2 feet MLLW]).

- Salinity in Shellabarger Creek is quite low (less than 1 practical salinity unit [psu]) and remains relatively constant over the tidal cycle.
- Salinity in the marsh tends to oscillate between 30 psu (the salinity measured in Puget Sound) and approximately 15 psu (see Appendix A, Figure 3). However, there are times when the salinity drops significantly to below 5 psu due to freshwater inflows from Shellabarger or Willow creeks or other upland stormwater flows that drain into the Marsh. Salinities in the creek are also reduced when the tide gate is closed, which limits salt water intrusion into the creek.
- Temperature in the Marsh (over the period of record shown in Appendix A) appears to be relatively constant in Puget Sound and in Shellabarger Creek, but oscillates between 12 degrees Celsius and 18 degrees Celsius.
    - The increase with temperature on incoming tide (above the water temperature in Puget Sound) is not unusual. However, it may be due to water that was previously held downstream within stormwater pipes and storage ponds now being transported upstream into the Marsh during incoming tide. The water temperatures in the Marsh decrease after September 9 or 10, which may be a result of a higher flow event in Shellabarger Creek during that time.

4.2 Existing Conditions HEC-RAS Model

An existing conditions HEC-RAS model of the project area was developed using topography, water level, and flow data from several sources, as listed in Table 2.

Table 2
Data Sources Utilized in Existing Conditions HEC-RAS Model

Date Type	Source	Spatial Extent	Temporal Extent
Topography/Stream Geometry	Shannon & Wilson; Digital Terrain Model	Project Area	N/A
Culvert Geometry	Shannon & Wilson; Survey Data	Project Area	N/A
Spring Tidal Data	NOAA	Lower Willow Creek	May 1-15, 2008
High Flow Tidal Data	NOAA	Lower Willow Creek	Dec 17-31, 2007

Date Type	Source	Spatial Extent	Temporal Extent
Spring Flow Conditions	Provided by Shannon & Wilson; taken from SR-104 HSPF Model (SAIC 2012)	Shellabarger Creek & Upper Willow Creek	May 1-15, 2008
High Flow Conditions	Provided by Shannon & Wilson; taken from SR-104 HSPF Model (SAIC 2012)	Shellabarger Creek & Willow Creek	Dec 1-14, 2007
Predicted Water Surface Elevation Data in the Marsh (High Flows)	Provided by Shannon & Wilson; taken from SR-104 HSPF Model (SAIC, 2012)	Willow Creek (at Section 1285 as shown in Figure 2)	Dec 1-14, 2007

Note:
NOAA = National Oceanic and Atmospheric Administration

Surface data from S&W were processed using HEC-GeoRAS, a tool developed for ArcGIS to process geospatial data for use in the HEC-RAS model. HEC-RAS geometry data were developed from HEC-GeoRAS at cross-sections within the project area. The cross-sections and existing surface data are shown in Figure 2.

Cross-sections were adjusted and culverts were added as necessary using survey data provided by S&W. Manning's roughness coefficients were estimated using professional judgment and available literature.

The HEC-RAS model was run as an unsteady flow model to simulate tidal cycles during a typical spring period (see Figure 4) and a typical low-flow and high-flow event. Low flows were provided by SAIC and represent average flows during May in Shellabarger and Upper Willow creeks (0.5 cfs and 0.3 cfs, respectively). The high-flow event was provided by flood modeling work completed by SAIC and represents a flow event in December 2007 (see Figure 5). To improve the stability of the model, the model was split into three reaches (Upper Willow Creek, Shellabarger Creek, and Lower Willow Creek). To further improve stability, the downstream boundary location was set at the storm vault entrance upstream of the tide gate. Downstream boundary conditions for Lower Willow Creek were set to the higher of the bottom of the storm vault entrance or NOAA tidal data (spring)/SAIC water surface elevations (high flow). Downstream boundary conditions for Upper Willow Creek and Shellabarger Creek were set to the water surface elevation at the uppermost cross-section of Lower Willow Creek. Flow conditions were assumed to be concurrent such that the Lower Willow Creek flow was equal to the sum of the Upper Willow Creek and Shellabarger Creek flows. Simulation time periods were set for 2 weeks.

4.3 Proposed Conditions Model

The proposed conditions model was developed based on the existing conditions model and geometry for the preferred alternative for the proposed new channel developed by S&W (S&W 2012). Data sources used to develop the proposed conditions model are the same as those provided in Table 2. However, a new digital terrain model was provided by S&W that included the preferred alternative design for the new entrance channel in the topography. The thalweg of the new entrance channel just above the railroad bride is similar in elevation to the existing downstream thalweg in Willow Creek —approximately 4 feet NAVD 88 (6.2 feet MLLW).

Cross-section locations were kept the same as the existing model, where possible. In new channel areas, cross-sections were moved to capture likely flow paths. Figure 3 shows the proposed model cross-section locations and proposed surface. The downstream boundary location for Lower Willow Creek in the proposed conditions is at the channel outlet to Puget Sound. All other conditions remained the same as those described in the existing conditions model.

4.4 Model Results

Four model simulations were completed: one low-flow and one high-flow simulation for both existing and proposed conditions. Each simulation was run for a 2-week timeframe with a tidal downstream boundary condition (see Figure 4). Results for the low- and high-flow simulations are described in detail below.

4.4.1 Low-flow Model Runs

The purpose of the low-flow model runs was to evaluate tidal inundation based on existing and proposed conditions and to provide predictions of in-channel flow velocities in the Marsh to assess fish access.

Figures 6, 7, and 8 show predicted inundation areas for existing and proposed condition, and a comparison of these inundation areas, based on results of the low-flow HEC-RAS model runs. Figures 10 to 17 provide average in-channel velocities for existing and proposed conditions at various locations (see Figure 9) within the project area as predicted by the HEC-RAS model. Following is a summary of model results for the low-flow HEC-RAS simulations:

- Predicted Inundation at low flows is not *significantly* different between existing and proposed conditions (16.8 acres compared to 19.2 acres, respectively). However, the proposed conditions do show a slightly larger inundation area (based on available topography and hydrodynamic conditions modeled).
- Predicted Maximum velocities in Willow Creek in the salt marsh area would increase because of proposed conditions from 0.2 feet per second (ft/s) to 0.6 ft/s, because of an increase in the tidal prism once the new channel is constructed (Figure 13).
- Predicted Maximum velocities in Willow Creek in the channelized section parallel to the railroad would increase because of proposed conditions from 1 ft/s to 3 ft/s (Figure 14).
- Predicted Maximum velocities in the proposed new outlet channel would be 1.8 ft/s upstream of the railroad bridge and could get as high as 5 ft/s in the channel outlet on the beach (at low tide) (Figures 15, 16, and 17).
- Predicted velocities in Shellabarger Creek and Upper Willow Creek are higher for existing conditions than for proposed conditions (Figures 10 and 11). This is due to an increase in channel cross-section in this area due to excavation proposed as part of the preferred alternative.

4.4.2 High-flow Model Runs

Figures 18 and 19 provide flow and velocity information, respectively, predicted by the HEC-RAS model for existing and proposed conditions in the Marsh. A summary of model results for the high flow HEC-RAS simulations is provided below:

- Low tide water surface elevations just upstream of the railroad bridge (in the proposed new channel) are increased during the flood event, but high tide water surface elevations are not noticeably higher than normal high tide conditions during the flood event.

- Water surface elevations just downstream of the confluence of Shellabarger and Willow creeks increase to just below 13 feet NAVD 88 (15.2 feet MLLW) for existing conditions. This elevation compares well with the reported 100-year flood elevation for the Marsh provided in SAIC 2012.
- Water surface elevations just downstream of the confluence of Shellabarger and Willow creeks for proposed conditions do not get above 11 feet NAVD 88 (13.2 feet MLLW) during the flood event.

5 PRELIMINARY CONCLUSIONS AND NEXT STEPS

Based on the review of site-specific data (Section 4.1) and results of the modeling effort (Section 4.2), several preliminary conclusions can be made regarding the performance of the preferred alternative (new channel) compared to existing conditions in the Marsh:

- The increase in conveyance in the channel due to proposed conditions does not appear to significantly increase water surface elevations in the Marsh during the approximate 100-year flood event (compared to published flood elevations in the marsh for existing conditions). It may decrease water surface elevations in Willow Creek and the Marsh (when tide gate is open) due to increased conveyance in the system post-project.
- The thalweg of the proposed new entrance channel (approximately 4 feet NAVD 88, 6.2 feet MLLW) will control the low tide elevation of water in the Marsh at low tide; it will equal the thalweg elevation. It will also control the frequency of tidal inundation into the Marsh, and the grade and velocity of flow in the beach channel during lower tides for proposed conditions. Based on tidal elevations in Puget Sound at Elliot Bay (Appendix A), tides are higher than 6.2 feet MLLW approximately 60% of the time on an annual basis.
- Water surface elevations in the Marsh are currently controlled by the existing tide gate system and are lower than high tide elevations in Puget Sound during the portions of the year that the existing tide gate is closed (October through March). If the gate is removed (and not replaced), the Marsh site and adjacent streams will see water surface elevations up to mean high tide elevations (9.3 feet NAVD 88) on an almost daily basis. The area could also see water surface elevations up to highest high tide elevations (astronomical), approximately 12 feet NAVD 88) a few times throughout the year. At the low flows modeled as part of this study, these increased tidal elevations in the Marsh area will likely not impact water surface elevations in the upstream culvert at SR-104 (13.4 feet NAVD88).
- Salinity intrusion in the Marsh system based on proposed conditions was not modeled explicitly. However, some general thoughts on salinity post-project in the Marsh area have been developed based on evaluation of salinity data collected as part of this work by S&W (see Appendix A, Figure 3).

  - Maximum salinity in the Marsh area at low flows (when the tide gate is open) at higher tides is currently at Puget Sound levels. Therefore, increased conveyance should not increase the maximum salinity in the Marsh, but may decrease the salinity range (by increasing salinity at lower tides).
  - Elevations within the Marsh area at the upper end of the tidal range (9 to 12 feet NAVD 88) may see some increase in average and maximum salinities at low flows due to increased conveyance of the proposed new channel outlet.
  - During high-flow events, portions of Willow Creek and the Marsh area upstream of the new opening may experience lower salinities (compared to existing conditions) due to increased conveyance of the proposed new channel outlet.

- A tide gate could be installed on the outflow channel to the Marsh (at the bridge) to limit water surface elevations in the Marsh, as is done currently. However, this will also limit conveyance through the bridge opening and the amount of time that fish will be able to enter or exit the marsh. Since fish access to the marsh is a primary goal of the project, a separate alternatives analysis of with and without tide gate is recommended for the feasibility phase of study.
- There needs to be additional hydraulic study to quantify other stormwater flows into the Marsh that are not captured in the current run-off model. These sources include the Washington State Department of Transportation (WSDOT) Edmonds Way manhole overflow, Edmonds Point stormwater system, and any additional back flooding from the Dayton stormwater system.
- There needs to be additional survey in the Marsh to increase data coverage (in areas where Light Detection and Ranging (LiDAR) could be impacted by vegetation) and decrease uncertainty in the inundation maps developed as part of this phase of work.
- There needs to be additional alternatives analysis and subsequent design refinement to the outflow channel on the beach to account for impacts of wind-waves, littoral drift (in-filling), and planned park and public uses.

6 UNCERTAINTY DISCUSSION

The results of the preliminary tidal hydrodynamic evaluation for this project were based on the best available data at the time and targeted to meet the specific needs of the early feasibility evaluation. Uncertainties in the model are due to limitations of the input data to the model (i.e., topography, flows, and water levels) and assumptions made by the model itself. Specific potential sources of uncertainty with this study include:

- Multiple sources of topography information, with different spatial resolutions, coverage areas, and collection times, were used to create the digital elevation models used to develop both existing and proposed conditions hydrodynamic (HEC-RAS) models.
- Flow data was provided by a run-off model completed by SAIC (SAIC, 2012); there are no stream gage data available for project area.
- The existing conditions model was not calibrated based on concurrent measured flow and water level data in the Marsh, due to lack of data.
- Some stormwater inflows to the marsh are not currently quantified.

7 REFERENCES

SAIC, 2012. *Dayton Street and SR 104 Storm Drainage Alternatives Study (DRAFT).* Prepared for the City of Edmonds. November 2012.

Sea-Run Consulting, TetraTech, Inc., Reid Middleton, Inc., and Pentec, 2007. *City of Edmonds; Shoreline Master Program Update; Shoreline Inventory & Characterization*. SMA Grant Agreement No. 60600108. Prepared for City of Edmonds. November 2007.

Shannon and Wilson, Inc., 2012. *Alignment Alternatives Screening Analysis; Willow Creek Daylight Early Feasibility Study*. Prepared for People for Puget Sound. September 2012.

FIGURES

NOTES:
Base Map: ESRI Data and Maps [DVD]. (2009). Redlands, CA: Environmental Systems Research Institute
Aerial: Bing Maps

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Feet
0 300 600

Figure 1
Site Location Map
Tidal Marsh Hydrodynamics Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

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NOTES:
Existing surface source: Shannon & Wilson
Aerial source: Bing

Feet
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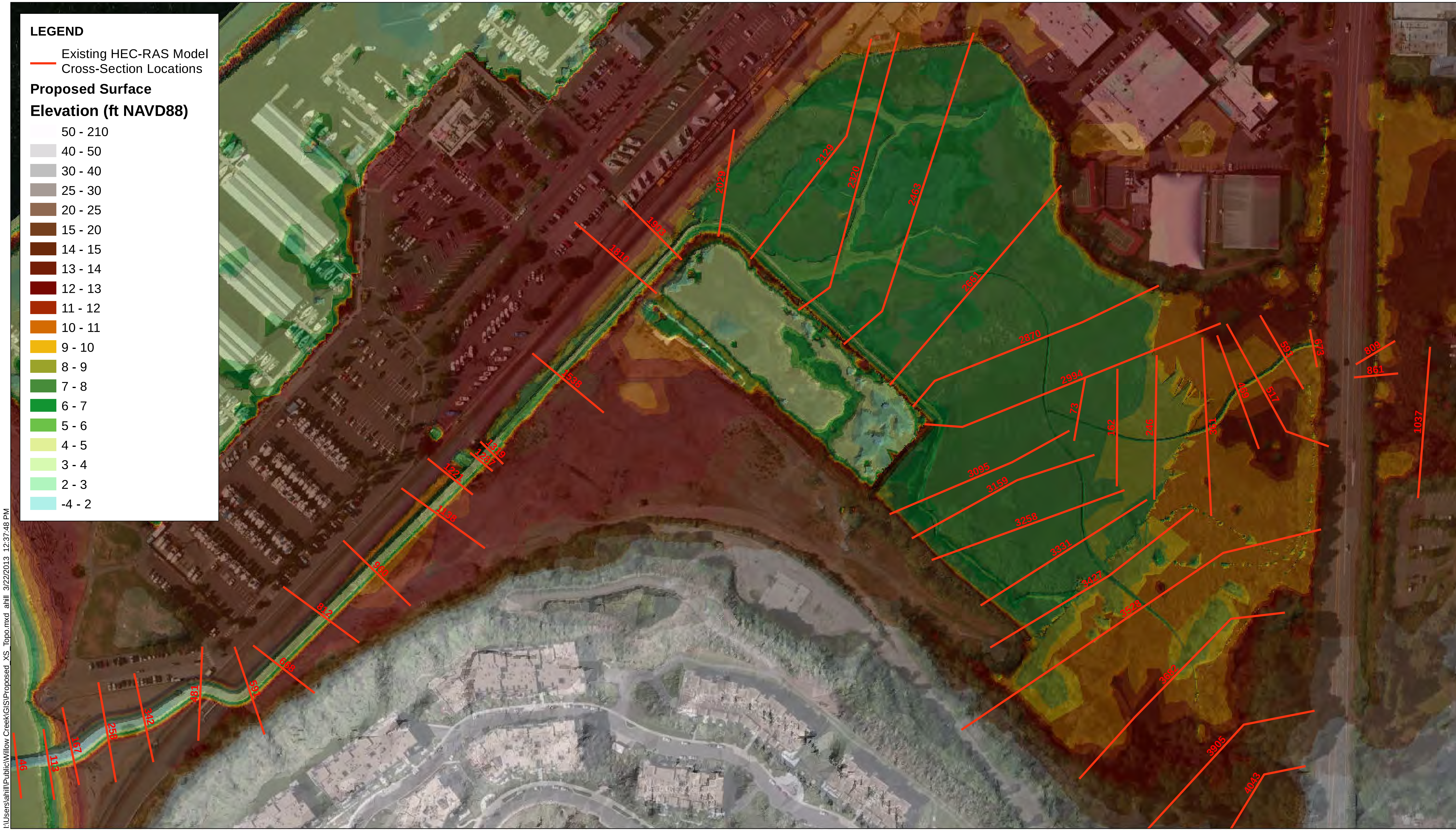
Figure 2
Existing Marsh Topography and HEC-RAS Model Cross-Section Locations
Tidal Marsh Hydrodynamics Report (DRAFT)
Willow Creek Daylight Early Feasibility Study



NOTES:
Proposed surface source: Shannon & Wilson
Aerial source: Bing

Feet
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Figure 3
Proposed Marsh Topography and HEC-RAS Model Cross-Section Locations
Tidal Marsh Hydrodynamics Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

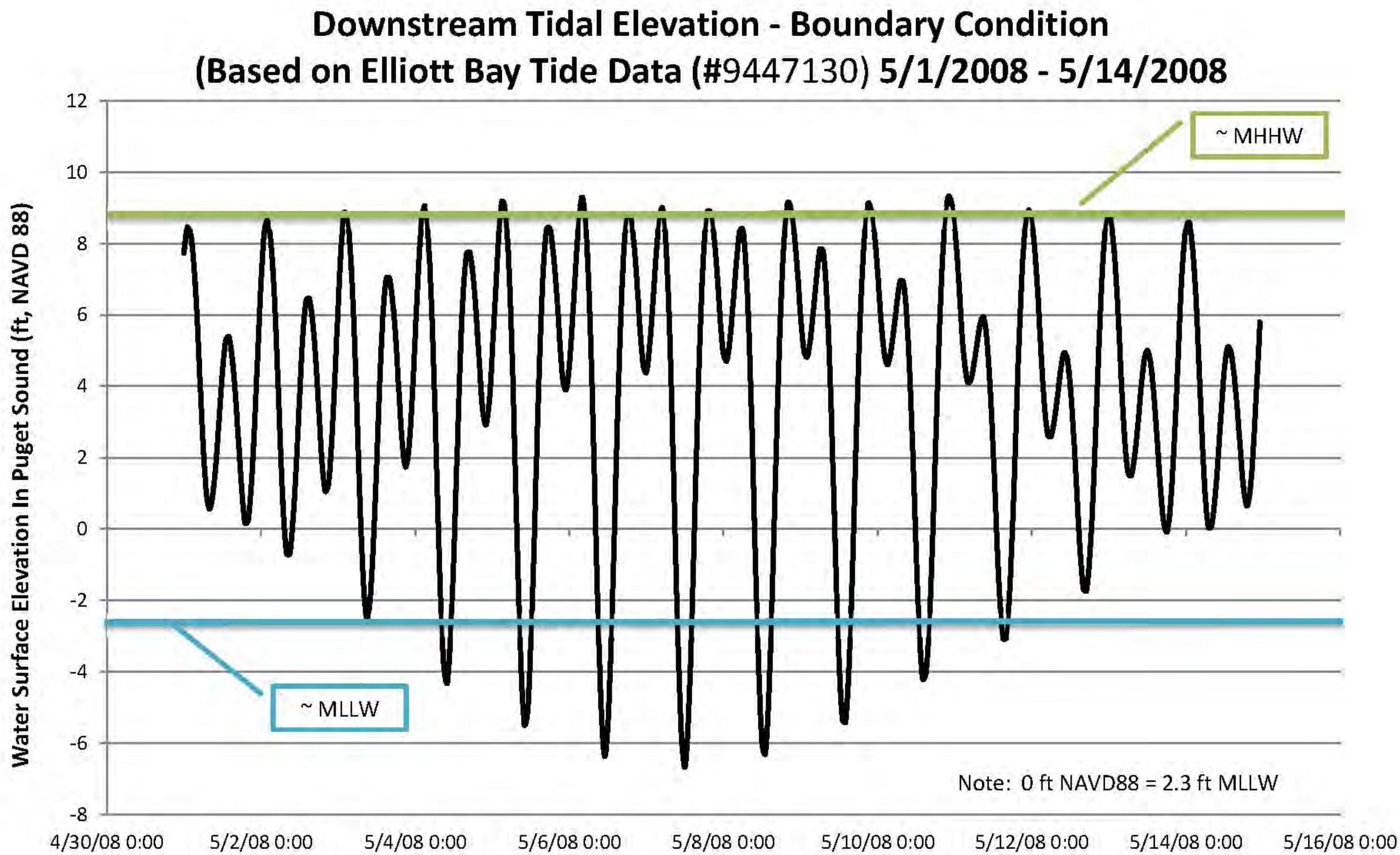

Figure 4
Tidal Boundary Conditions
Tidal Marsh Hydrodynamic Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

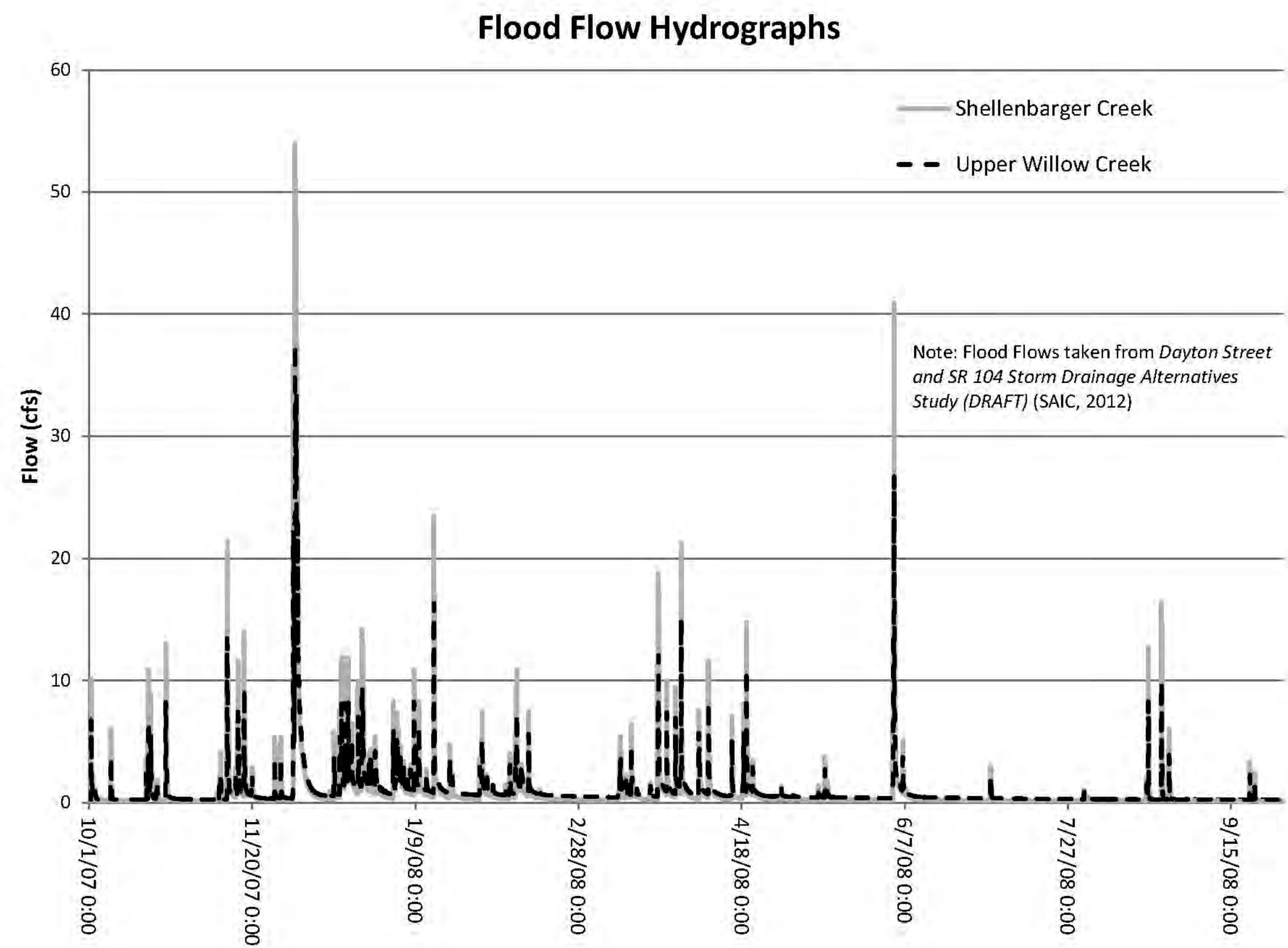

Figure 5
Flood Flow Hydrographs
Tidal Marsh Hydrodynamic Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

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NOTES:
Inundation areas based on HEC-RAS maximum water surface model outputs.
Existing surface source: Shannon & Wilson
Aerial source: Bing

Feet
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Figure 6
Estimated Inundation Areas - Existing Spring Conditions
Tidal Marsh Hydrodynamics Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

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NOTES:
Inundation areas based on HEC-RAS maximum water surface model outputs.
Proposed surface source: Shannon & Wilson
Aerial source: Bing

Figure 7
Estimated Inundation Areas - Proposed Spring Conditions
Tidal Marsh Hydrodynamics Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

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NOTES:
Inundation areas based on HEC-RAS maximum water surface model outputs.
Aerial source: Bing

Feet
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Figure 8
Comparison of Estimated Inundation Areas - Spring Conditions
Tidal Marsh Hydrodynamics Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

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NOTES:
Aerial source: Bing

Feet
0 100 200 300 400

Figure 9
Approximate Locations of Plotted Velocities
Tidal Marsh Hydrodynamics Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

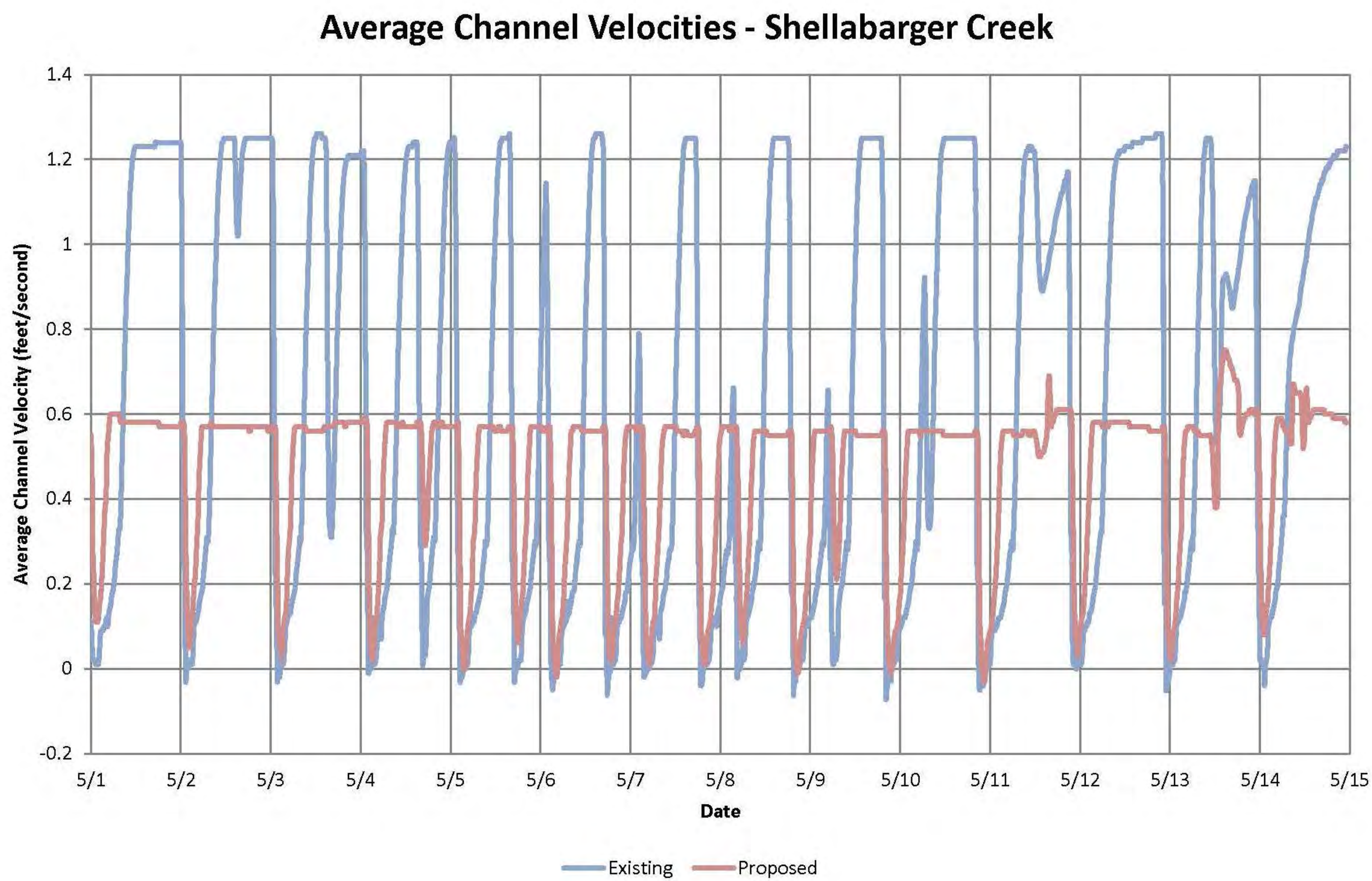

Figure 10
Comparison of Average Channel Velocities: Existing and Proposed Conditions—Shellabarger Creek
Tidal Marsh Hydrodynamic Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

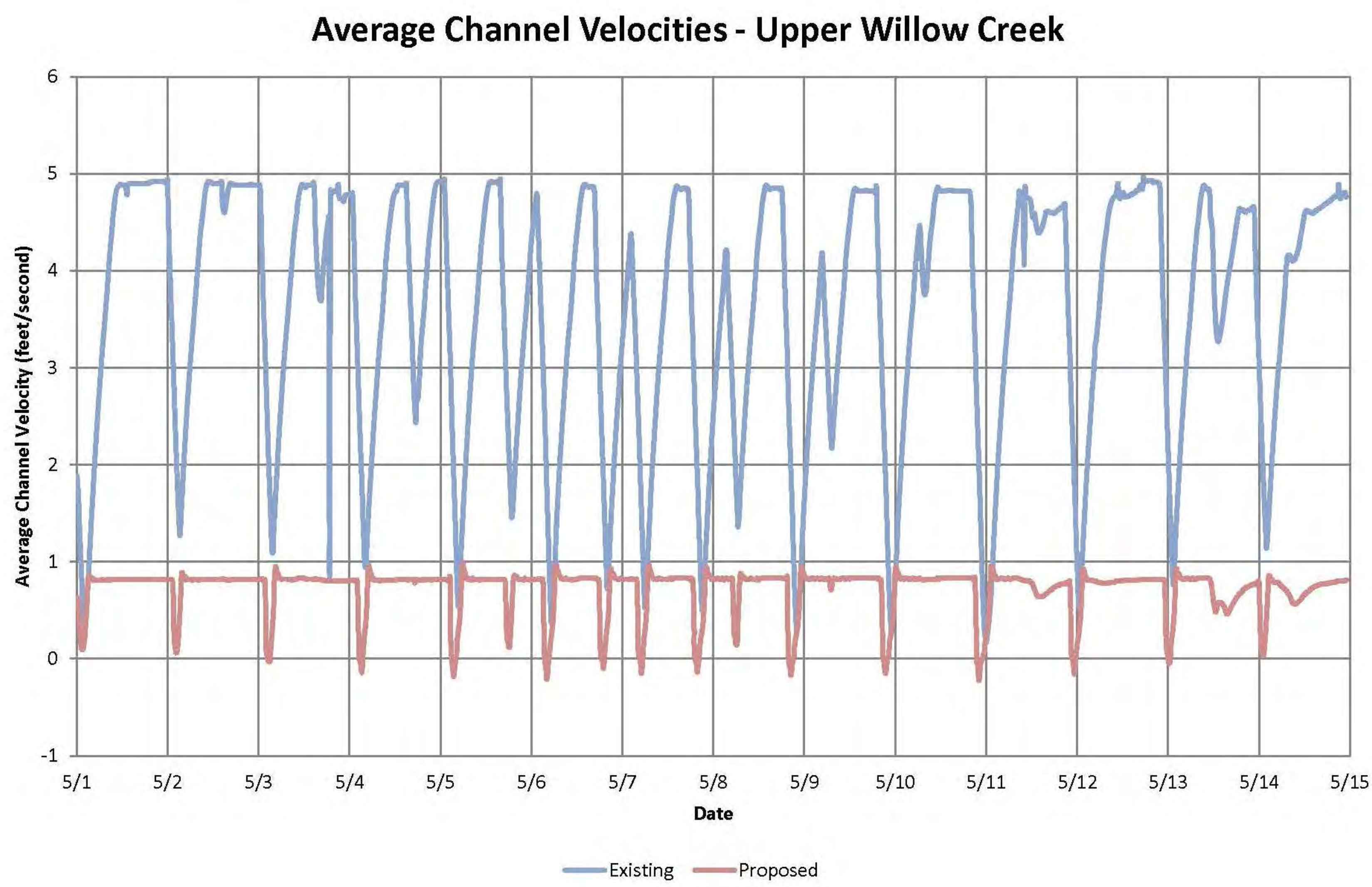

Figure 11
Comparison of Average Channel Velocities: Existing and Proposed Conditions—Upper Willow Creek
Tidal Marsh Hydrodynamic Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

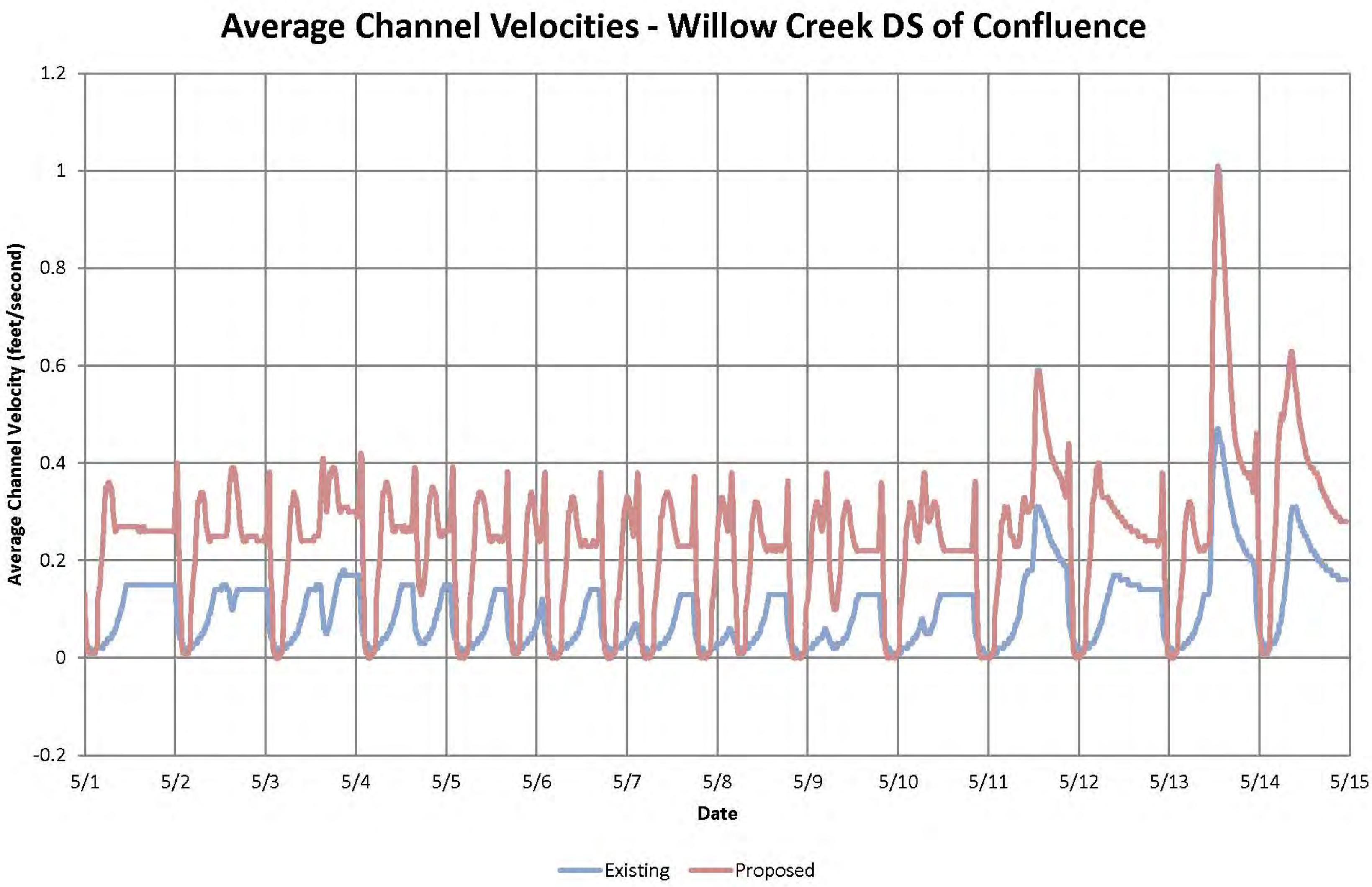

Figure 12
Comparison of Average Channel Velocities: Existing and Proposed Conditions—Willow Creek DS of Confluence
Tidal Marsh Hydrodynamic Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

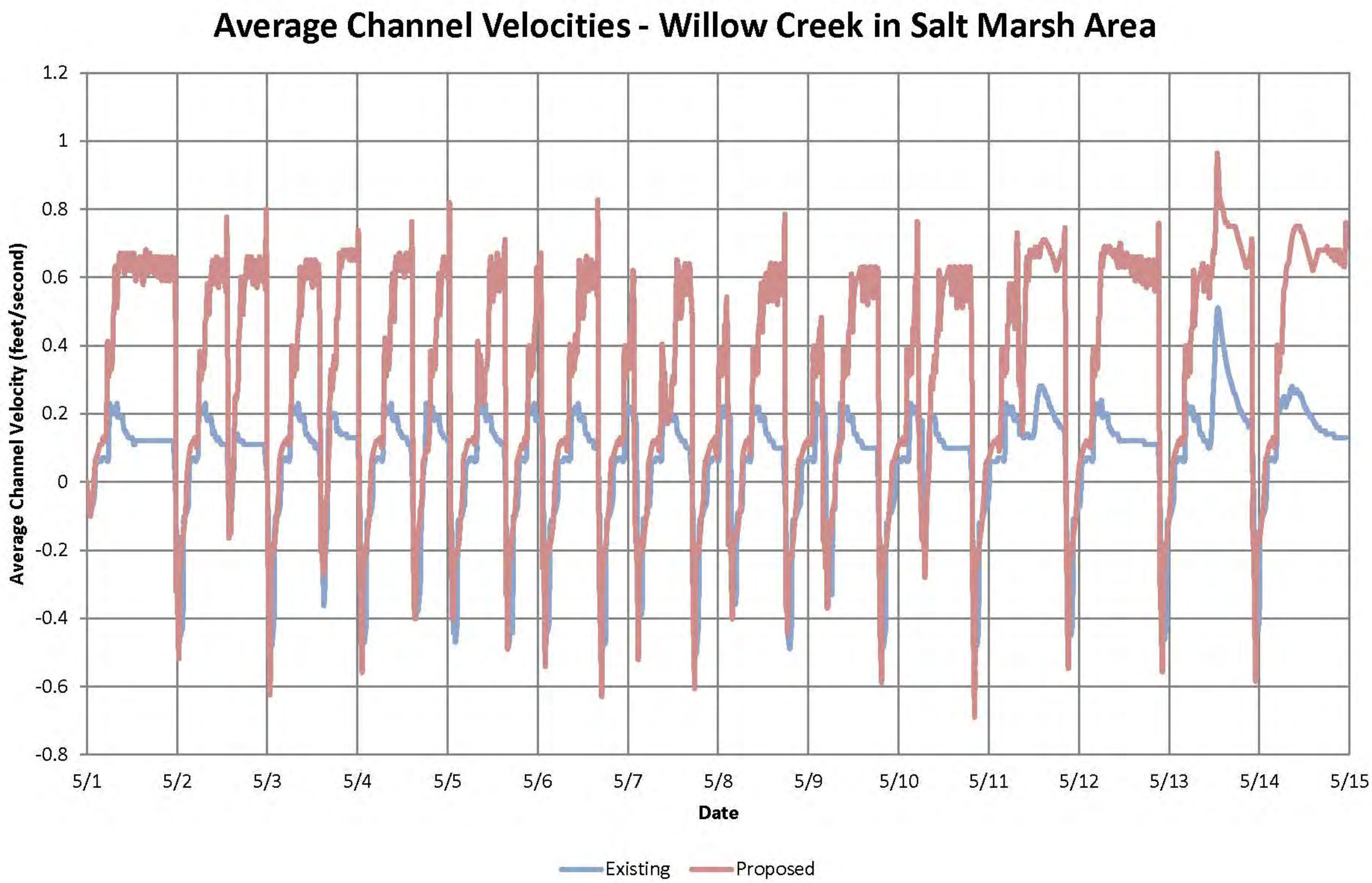

Figure 13
Comparison of Average Channel Velocities: Existing and Proposed Conditions—Willow Creek in Salt Marsh Area
Tidal Marsh Hydrodynamic Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

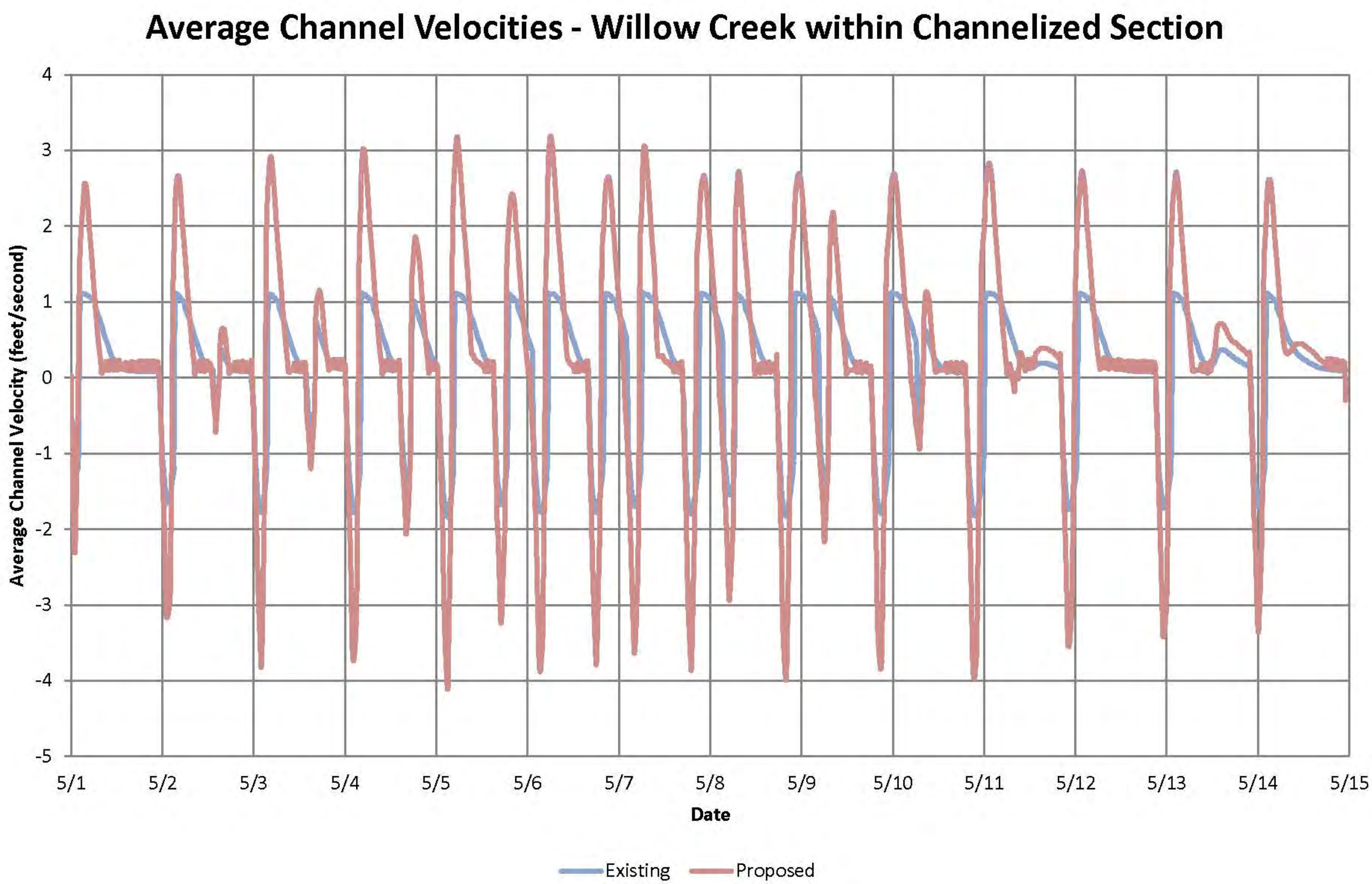

Figure 14

Comparison of Average Channel Velocities: Existing and Proposed Conditions—Willow Creek within Channelized Section

Tidal Marsh Hydrodynamic Report (DRAFT)

Willow Creek Daylight Early Feasibility Study

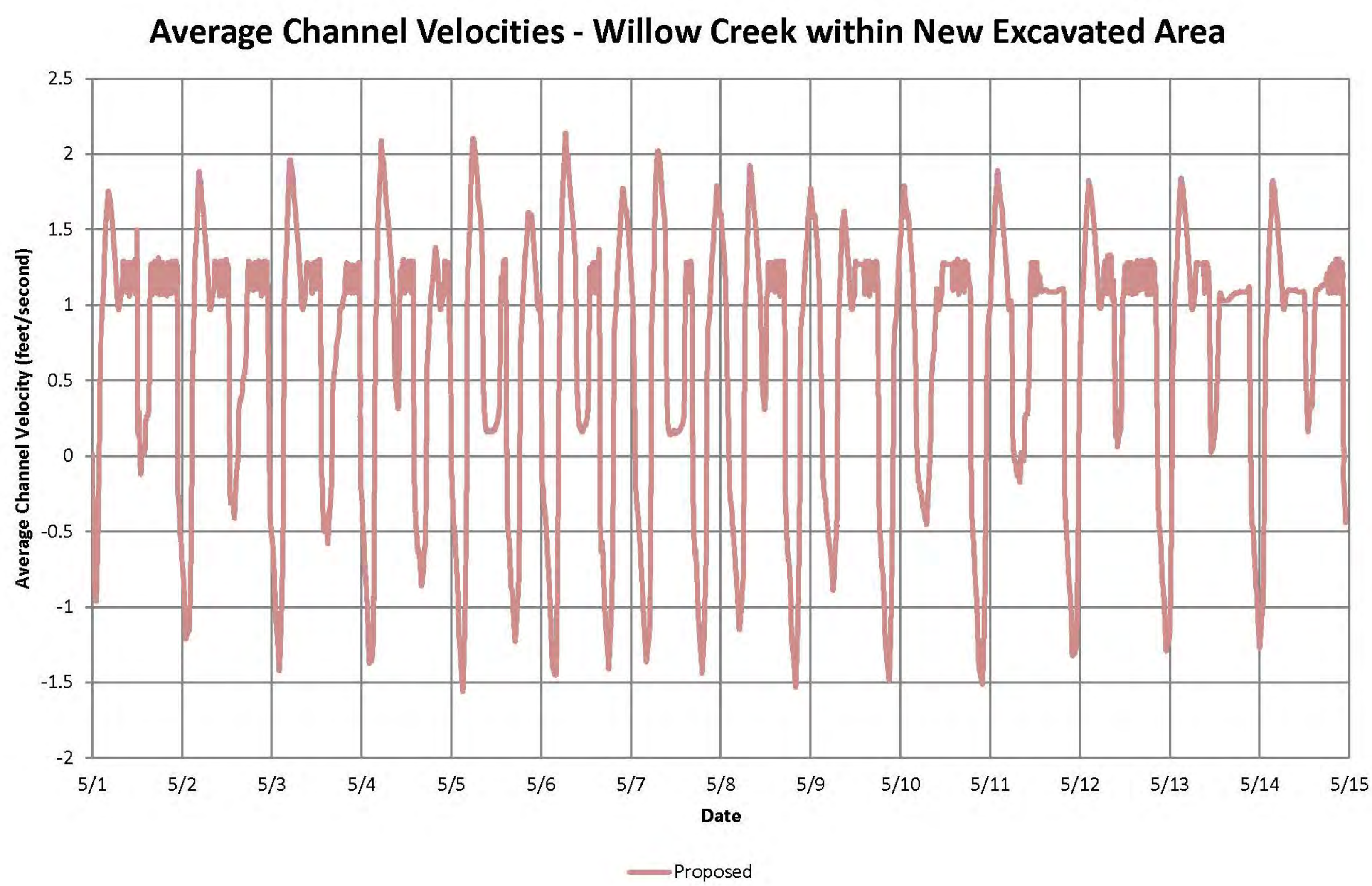

Figure 15

Comparison of Average Channel Velocities: Existing and Proposed Conditions—Willow Creek within New Excavated Area

Tidal Marsh Hydrodynamic Report (DRAFT)

Willow Creek Daylight Early Feasibility Study

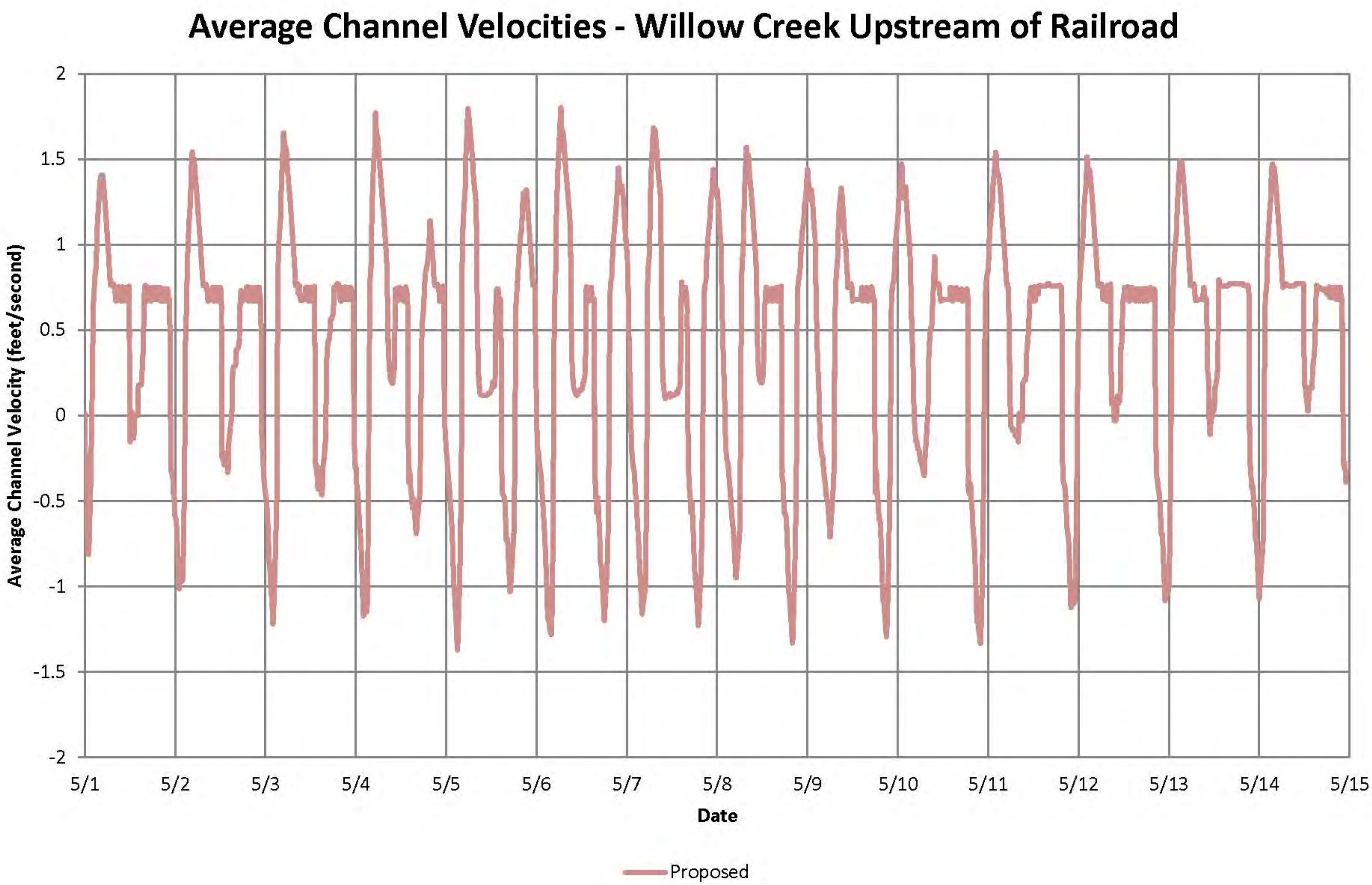

Figure 16
Comparison of Average Channel Velocities: Existing and Proposed Conditions—Willow Creek Upstream of Railroad
Tidal Marsh Hydrodynamic Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

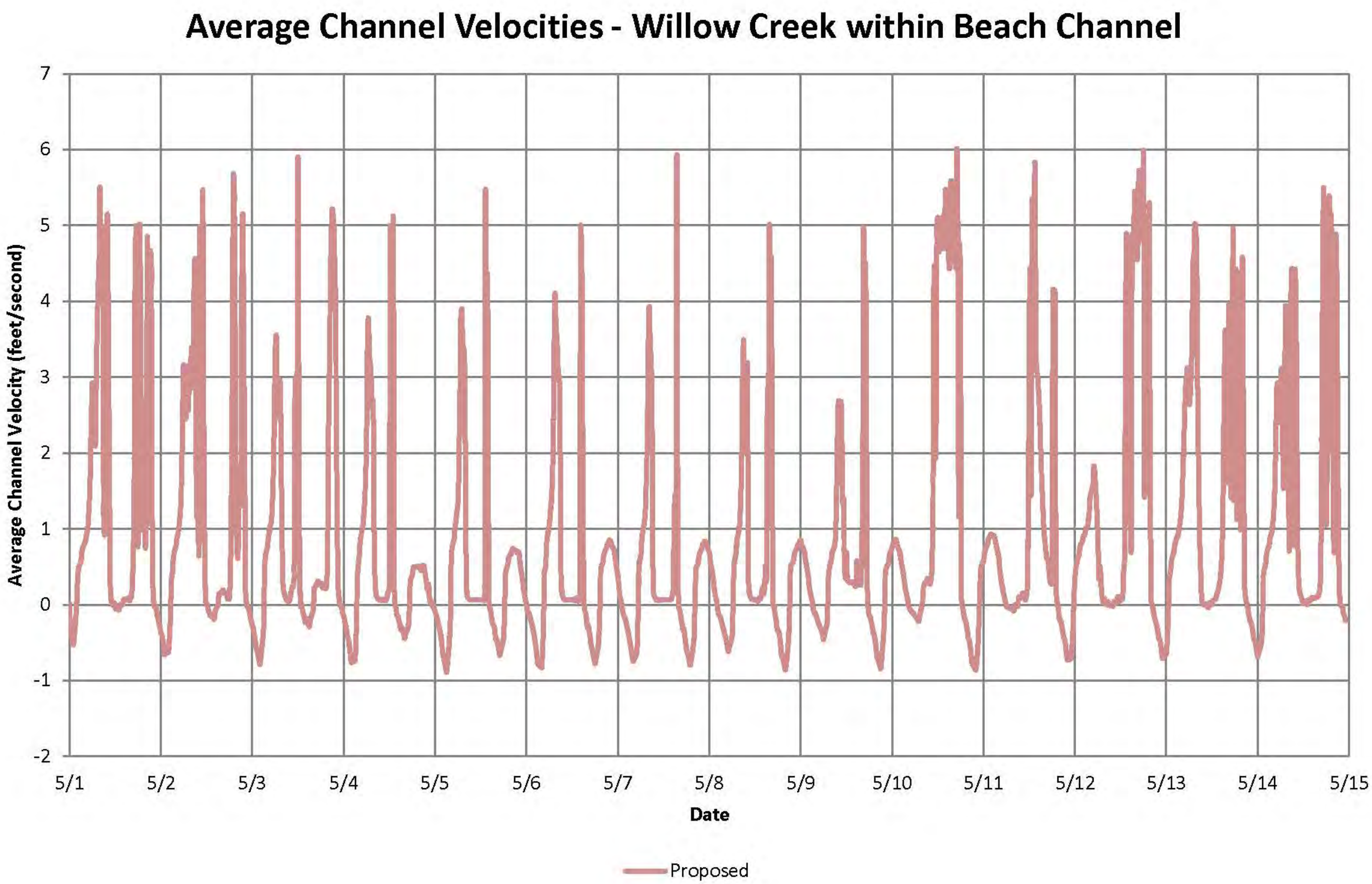

Figure 17
Comparison of Average Channel Velocities: Existing and Proposed Conditions—Willow Creek within Beach Channel
Tidal Marsh Hydrodynamic Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

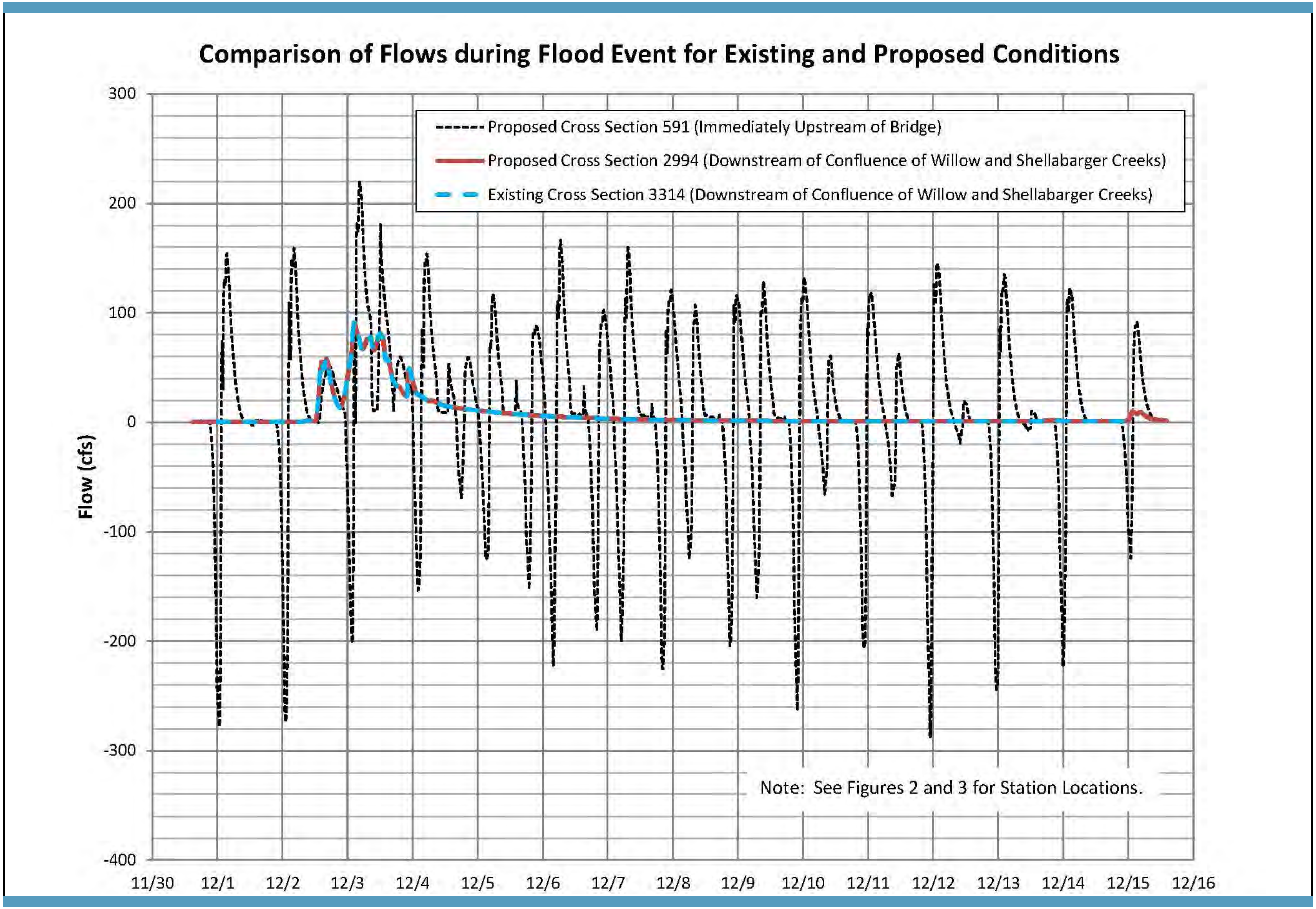

Figure 18
Comparison of Flows during Flood Event for Existing and Proposed Conditions
Tidal Marsh Hydrodynamic Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

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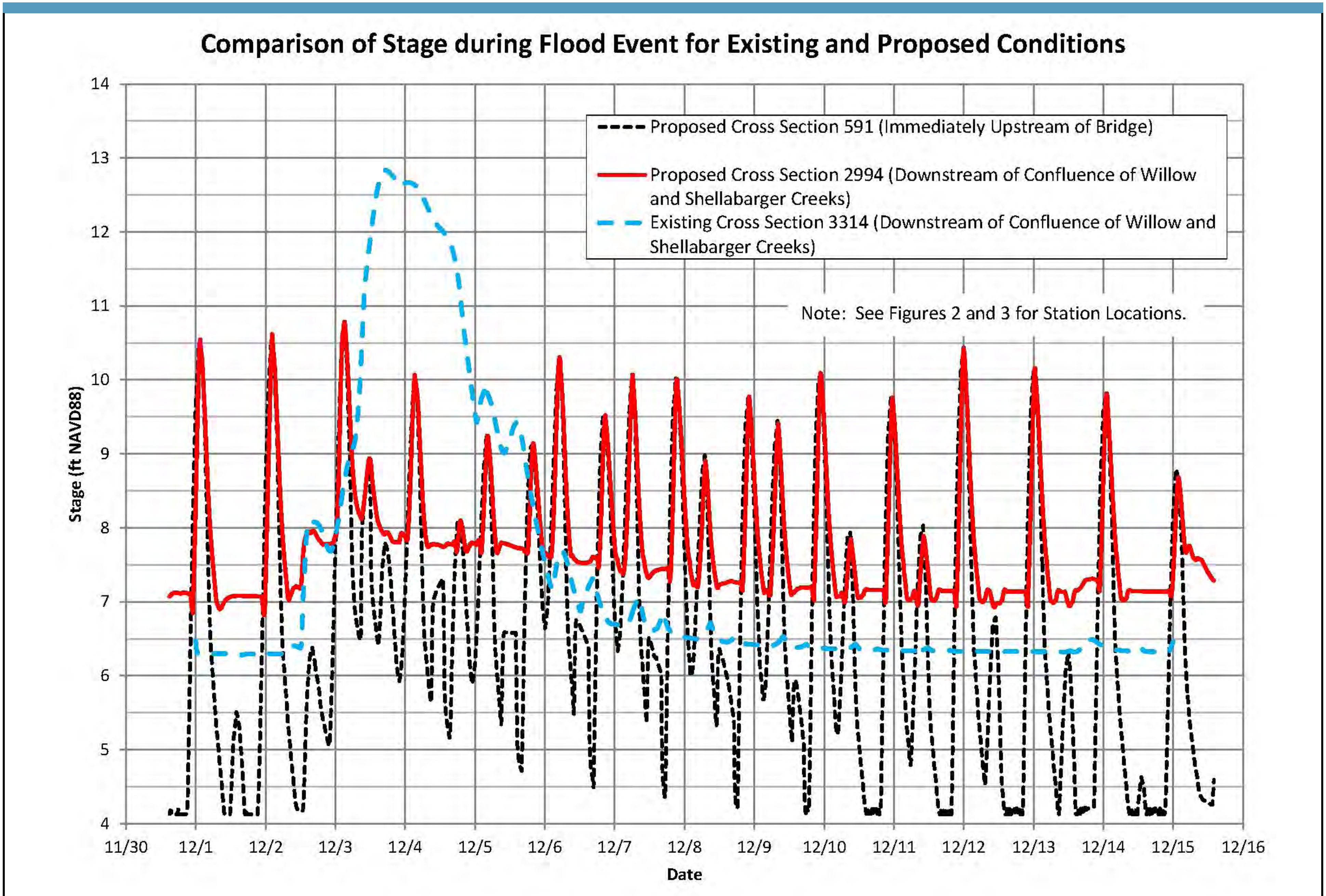

Figure 19
Comparison of Flows during Flood Event for Existing and Proposed Conditions
Tidal Marsh Hydrodynamic Report (DRAFT)
Willow Creek Daylight Early Feasibility Study

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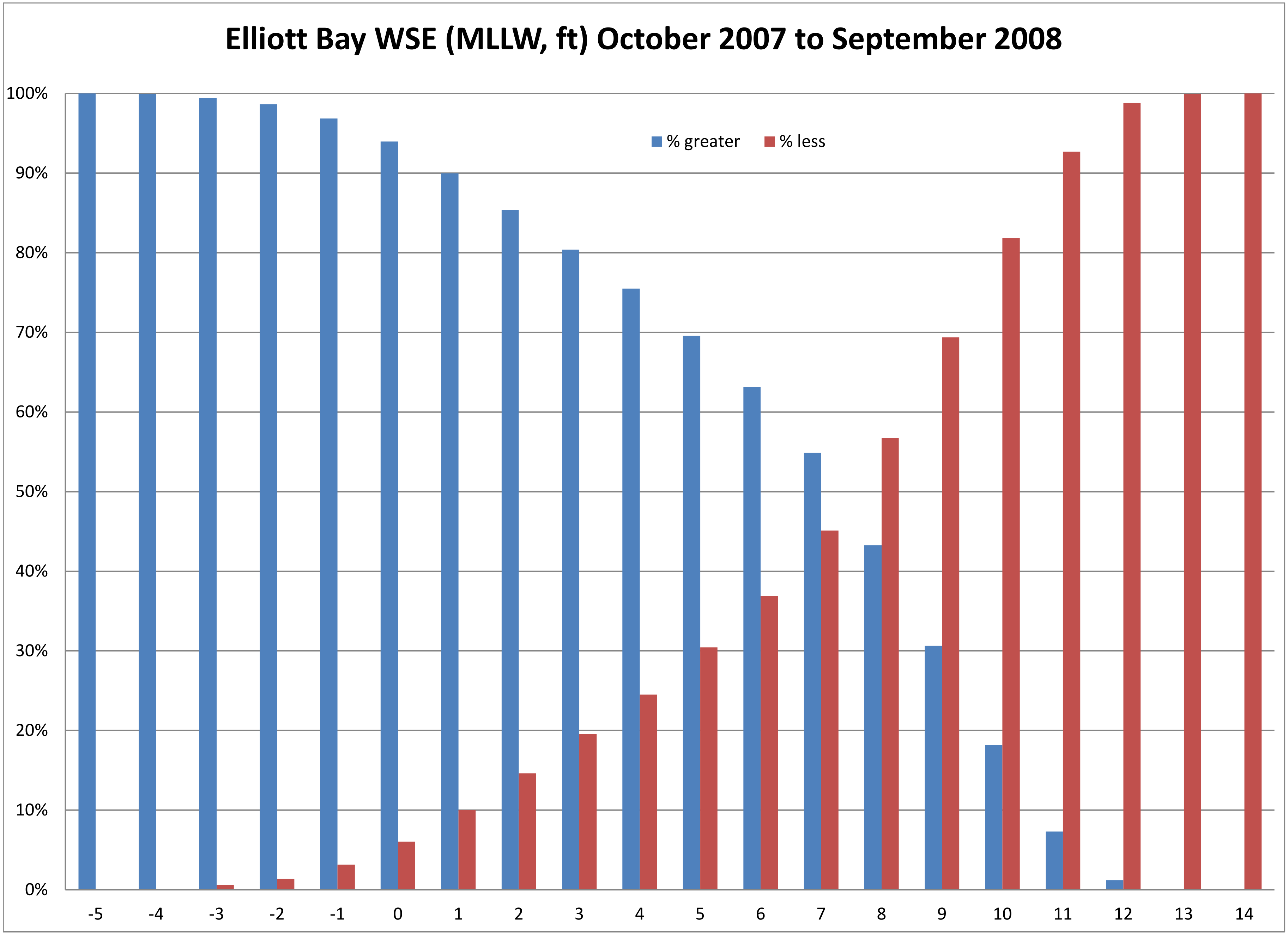
APPENDIX A
WATER LEVEL, SALINITY AND TEMPERATURE DATA PLOTS


Elliott Bay WSE (MLLW, ft) October 2007 to September 2008
% greater
% less
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
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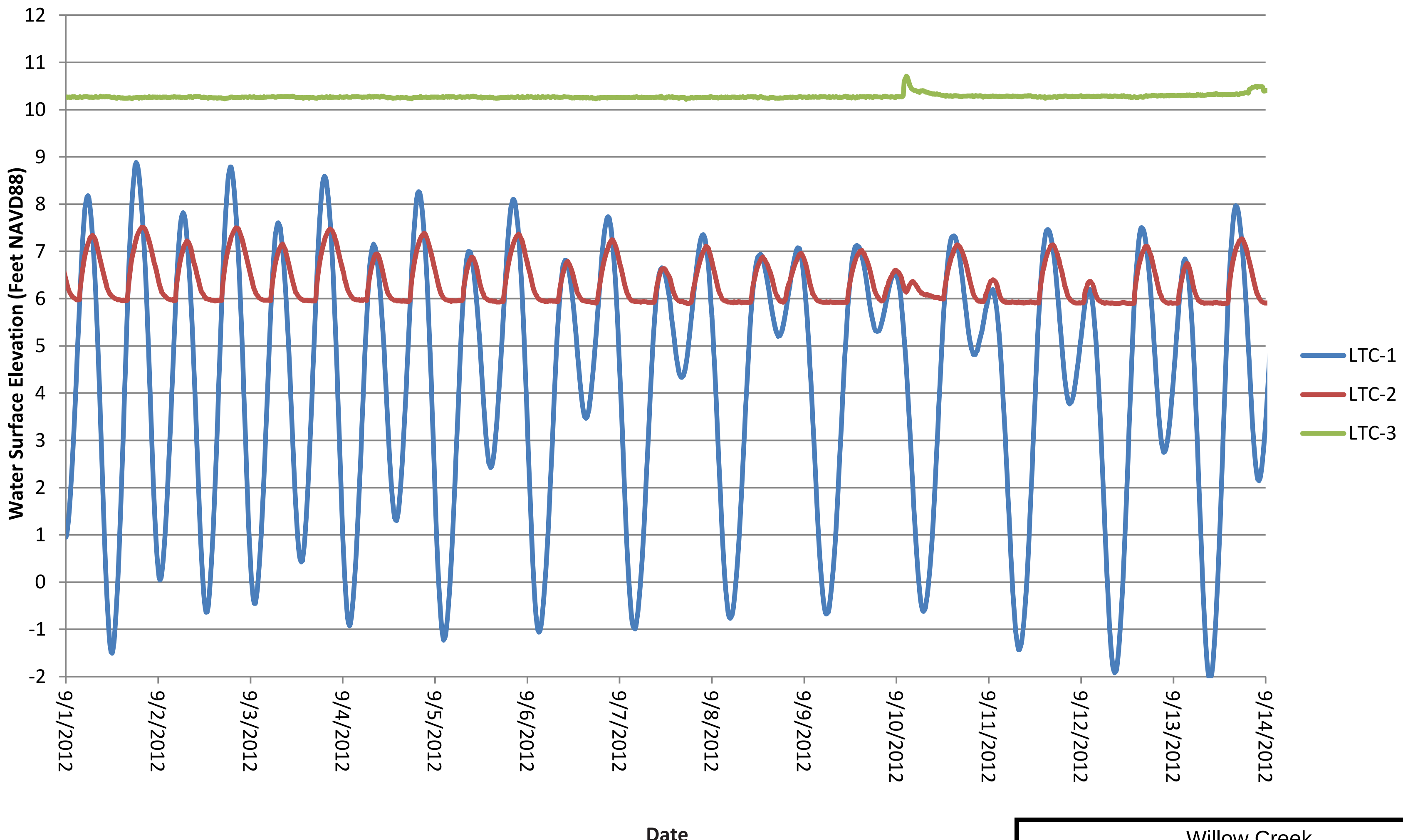

Willow Creek

Edmonds, WA

WATER LEVELS
SEPTEMBER 2012

September 2012 21-1-12393-102

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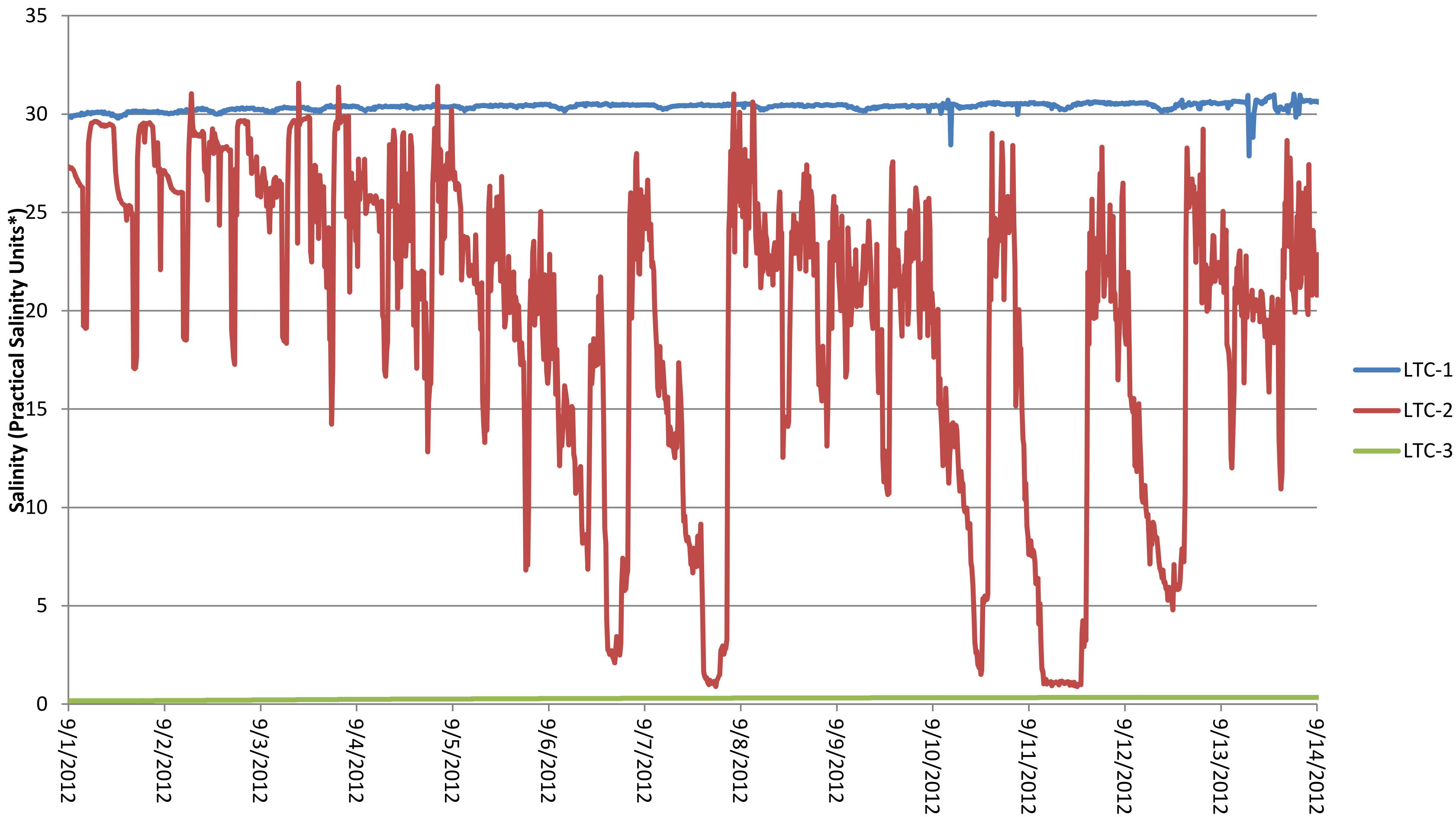
FIG. 2

FIG. 2

I:\Users\ahill\Public\Willow Creek\WILLOW_CRK_MASTER_20120904 <Chart-WSE>



*Practical Salinity Units (PSU) are approximately equivalent to Parts Per Thousand (ppt)

Willow Creek

Edmonds, WA

SALINITY
SEPTEMBER 2012

September 2012 21-1-12393-102

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FIG. 3

FIG. 3

I:\Users\ahill\Public\Willow Creek\WILLOW_CRK_MASTER_20120904 <Chart-Salinity>

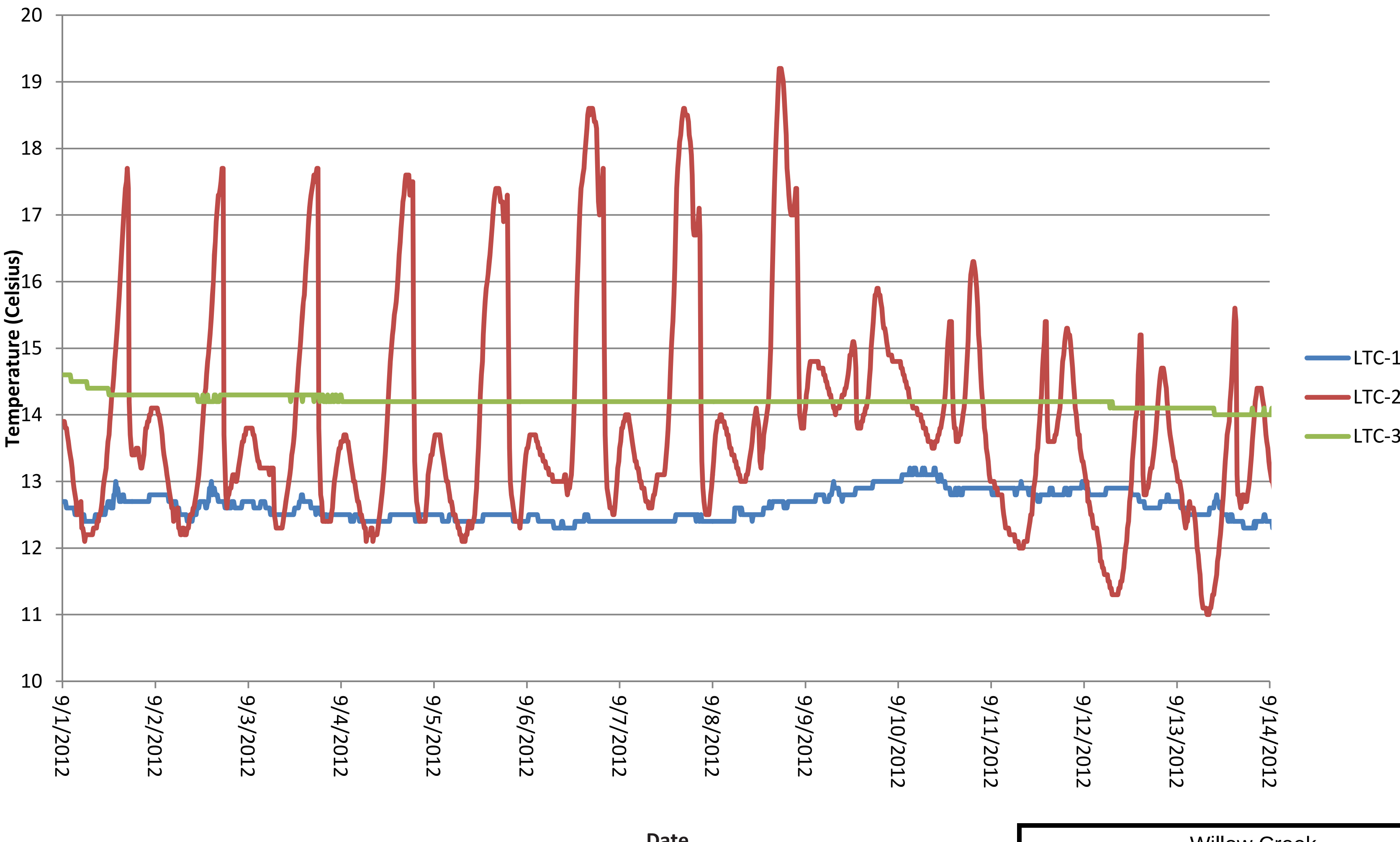

FIG. 4

Willow Creek

Edmonds, WA

TEMPERATURE
SEPTEMBER 2012

September 2012 21-1-12393-102

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FIG. 4

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APPENDIX E.2

BEACH OUTLET AND HYDRODYNAMIC EVALUATION REPORT WILLOW CREEK DAYLIGHT FINAL FEASIBILITY STUDY

BEACH OUTLET AND HYDRODYNAMIC EVALUATION REPORT
WILLOW CREEK DAYLIGHT FINAL FEASIBILITY STUDY

Prepared for
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January 2015

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LIST OF ACRONYMS AND ABBREVIATIONS

1-D	one-dimensional
ACES	Automated Coastal Engineering System
City	City of Edmonds
Confluence	Confluence Environmental
ft/s	foot per second
HEC-RAS	Hydrologic Engineering Center River Analysis System
LiDAR	Light Detection and Ranging
Marsh	Edmonds Marsh
MLLW	mean lower low water
NAVD 88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
S&W	Shannon and Wilson, Inc.
SR	State Route
USACE	U.S. Army Corps of Engineers

1 INTRODUCTION

Anchor QEA, LLC, was retained by Shannon and Wilson, Inc. (S&W) to complete an evaluation of coastal processes and tidal hydrodynamics to inform the final feasibility evaluation and conceptual design of proposed daylight channel alignments for Willow Creek/Edmonds Marsh. The primary objective for the Daylight project is to provide (and maximize) juvenile salmon passage into Willow Creek over a range of tidal conditions that occur during the spring and summer rearing period.

This evaluation builds on previous modeling work conducted by Anchor QEA (Anchor QEA 2013) as part of the *Willow Creek Daylight Early Feasibility Study* (S&W 2013). The earlier study characterized existing tidal hydraulics in Willow Creek/Edmonds Marsh and included preliminary modeling of a daylight channel to identify potential for increased fish passage and upstream flooding impacts. The current work, summarized in this report, includes additional one-dimensional (1-D) hydrodynamic modeling of two proposed daylight channel alignments to evaluate potential for fish passage and upstream flooding impacts and a coastal engineering/geomorphic evaluation of Marina Beach Park (and vicinity) as needed to inform selection of the preferred channel alignment and evaluate the long-term sustainability of the design. This current work was completed to support the Willow Creek Daylight Final Feasibility Study being conducted by S&W, Confluence Environmental (Confluence), and Anchor QEA for the City of Edmonds (City).

2 SITE DESCRIPTION

Edmonds Marsh (the Marsh) is an approximately 27-acre estuarine marsh located within the City of Edmonds (Figure 1). It is bordered by State Route 104 to the east, Harbor Square to the north, the BNSF Railroad tracks to the west, and the Chevron/Unocal property (and 216th Street SW) to the south. The Marsh is tidally influenced by Puget Sound; the current connection between the Sound and the Marsh is a complex system of culverts, gates, and storage ponds (SAIC 2013; S&W 2012). The Marsh also receives freshwater runoff from approximately 900 acres, including two creeks and run-off from surrounding properties (Sea-Run Consulting et al. 2007). Elevations within the Marsh range from approximately 4 feet North American Vertical Datum of 1988 (NAVD 88) (6.2 feet mean lower low water [MLLW]) to 13 feet NAVD 88 (15.2 feet MLLW). Detailed information regarding existing and historical site conditions of the Marsh can be found in the *Alignment Alternatives Screening Analysis* (S&W 2012).

3 BEACH OUTLET CHANNEL EVALUATION

The proposed location for the daylight channel for Willow Creek/Edmonds Marsh is through an existing railroad bridge (constructed as part of a previous mitigation effort) and through the City of Edmonds Marina Beach Park, which is a Puget Sound shoreline park to the southwest of the Marsh (see Figure 1). In order to develop a viable design for the daylight channel outlet through Marina Beach Park, an existing coastal processes evaluation was conducted to provide historical context for the project site (Marina Beach Park), evaluate tides and wave climate for the area, and inform design of the beach outlet channel.

3.1 Historical Marsh Outlet Channel

Historical topographic surveys and historical aerial photos are available for the project site and were reviewed to establish the unaltered (pre-development) conditions for the area. Figure 2 shows a historical topographic survey (T-sheet) from 1872 that illustrates the Marsh's original configuration and connection to Puget Sound. The historical mouth of the creek was oriented to the north and was separated from the Sound by a large spit. This suggests that the net littoral drift along the shoreline at the project location is from the south to the north. This is in agreement with the Washington State Department of Ecology's current designation for net littoral drift at Marina Beach Park, which is also south to north (Washington Department of Ecology, 2002).

From the 1890s until 1951, the Edmonds waterfront was characterized by industrial uses, included sawmills and shingle mills; the last of which was closed in 1951. A Unocal bulk fuel terminal began construction on the site in 1923 and the marsh was used for cattle pasture in the 1940s. In the early 1960's, marsh filling was begun and completion of Edmonds Marina (1962) included rerouting of the Willow Creek Drainage south (to its current condition) (Shannon and Wilson, 2013). The creek currently flows to the Sound through a series of outfall pipes (S&W 2012) located along a shore-perpendicular alignment south of Edmonds Marina within the Marina Beach Park. The new daylight channel for the creek will be routed parallel to the BNSF railroad, then through the existing BNSF bridge, south of the Marina across the Marina Beach Park to the daylight point at the Puget Sound. This places the new mouth of the creek south of the location of its historical outlet.

3.2 Tidal and Flood Elevation Information

3.2.1 Tidal Elevations

Tidal elevations for the project site were taken from the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service (NOS) tidal benchmark in Elliott Bay, Seattle, Washington (gage No. 9447130; NOAA, 2003). Conversion between MLLW and NAVD 88 was taken from NOAA's VDATUM software (http://vdatum.noaa.gov/welcome.html). This information is provided in Table 1.

Table 1

Tidal Elevations at the Project Site (based on NOAA Gage No. 9447130)

Tidal Elevation (feet)	Based on MLLW Datum (feet)	Based on NAVD 88 Datum (feet)
Mean higher high water	11.3	9.1
Mean high water	10.4	8.2
Mean tide level	6.6	4.4
Mean low water	2.8	0.6
NAVD 88 (feet)	2.2	0.0
Mean lower low water	0.0	-2.2

Notes:
MLLW = mean lower low water
NAVD 88 = North American Vertical Datum of 1988

Estimates of extreme coastal water levels (in Puget Sound) at the project site were taken from NOAA estimates for NOAA gage No. 9447130. The annual maximum tide (king tide) elevation, represented by the 99% annual exceedance water level, is 12.9 feet MLLW (10.7 feet NAVD88). The 1% exceedance water level (approximate 100-year return period water level) is 14.7 feet MLLW (12.5 feet NAVD88).

3.2.2 Published Flood Elevations

The FEMA flood insurance map for the project area (Map Number 53061C1292E) has an effective date of November 8, 1999 and lists the 100-year floodplain elevation for the coastal areas of the project site as approximately 13.6 feet NAVD88 (15.8 feet MLLW). FEMA flood insurance maps for coastal areas of Snohomish County are in the process of being updated. Preliminary maps of 100-yr flood elevations along the coastal areas of the project site range from

13 to 16 feet NAVD88, with lower elevations predicted for areas north of the project site. Final maps are due for publication in 2015.

The 100-year floodplain elevation in Edmonds Marsh is not provided in the current FEMA floodplain map (Dated November 1999). Therefore, the 100-year floodplain elevation in the marsh is taken from the Dayton Street and SR-104 Storm Drain Alternatives Study completed by SAIC for the City of Edmonds (SAIC, 2013). This study also provided estimates of the 2-year, 10-year, and 25-year return period water surface elevations in the Marsh, as summarized below (see Table 1-3, Node 51 in SAIC, 2013):

- 2-year – 9.1 feet NAVD88 (11.3 feet MLLW)
- 10-year – 10.8 feet NAVD88 (13.0 feet MLLW)
- 25-year – 11.7 feet NAVD88 (13.9 feet MLLW)
- 100-year – 13.1 feet NAVD88 (15.3 feet MLLW)

The preliminary maps of the 100-year flood elevations referenced above provide a 100-year floodplain elevation in the marsh (from coastal processes only) of 12 feet NAVD88 (14.2 feet NAVD88).

For the purposes of comparing proposed conditions to existing conditions in this evaluation, the existing conditions 100-year flood elevation are taken to be 13.6 feet NAVD88 for the beach areas of the site (from November 1998 FEMA flood insurance map) and 13.1 feet NAVD88 for Edmonds Marsh west of SR-104 (SAIC, 2013).

3.3 Wave Climate

Wave data in Puget Sound near the project site are not available. Therefore, the wave conditions at Marina Beach Park were estimated through a wind-wave hindcast using standard methodology outlined in the U.S. Army Corps of Engineers (USACE) Coastal Engineering Manual (USACE 2002). This methodology uses long-term wind data and wind-wave growth formulas to estimate wave parameters from wind information.

For the project site, wind data from the Point No Point Lighthouse Coast Guard weather station (NOAA No. 742065) in Hansville, Washington, were used. The wind data encompassed wind speeds collected every 3 hours (2-minute averages) from the years 1975 to 1990. Figure 3 is a wind rose (frequency of occurrence based on wind speed and wind direction) for the wind data over the period of record. Winds are predominantly from the northwest, south-southwest, and southeast, with large wind speeds recorded for all three of these directions. Based on the wind data, waves will also approach Marina Beach Park predominantly from the northwest, southwest, and southeast. However, Marina Beach Park is somewhat sheltered from direct wave impact from the northwest by the Port of Edmonds breakwater located to the north of the park and from the south-east due to the orientation of the shoreline to the south (Point Edmund). However, waves from the north-west and south-east could have a small impact due to wave refraction (change in wave direction due to influence of bathymetry) that can change the direction of wave approach as it nears the shoreline. But, waves from the south-west to west are anticipated to dominate wave-related coastal processes at Marina Beach Park. This is in agreement with documented net littoral drift rates (from south to north) by the Washington State Department of Ecology (2002).

The wind data were used to predict wind and wave conditions associated with the 2-, 10-, 20-, 50-, and 100-year return period storm events. The extreme wind speeds and wave parameters were evaluated for each 45-degree wind direction bin from true north (e.g., 0 to 45 degrees, 45 to 90 degrees, etc.).

Predicted values of extreme wind speeds were used as input into the Automated Coastal Engineering System (ACES) using the Windspeed Adjustment and Wave Growth module (fetch limited) to predict significant wave heights and peak wave periods generated by the extreme winds (USACE 1992). Results of the wave growth analysis for all directional bins of interest and return periods are provided in Appendix A. The highest predicted waves are from the northwest and west southwest (as shown in both Figure 3 and Table 2) and range from approximately 3 feet for a 2-year wind event to almost 6 feet for a 100-year wind event.

Storm waves are therefore large enough to impact the beach channel alignment that is located within the surf zone during the event. The portion of the channel alignment located in the surf zone during the storm event will depend on the tide at the time of the storm; and the area of impact will include all elevations within the tidal range. Beach areas adjacent to the beach channel alignment lie between -2.2 feet NAVD88 (0 feet MLLW) and 9.1 feet

NAVD88 (11.3 feet MLLW) could be impacted during larger storms (due to waves). Impacts from storm waves on the beach outlet channel include sediment accumulation in the channel, migration of the channel alignment at lower elevations on the beach, and erosion of the channel banks.

3.4 Beach Substrate

A sediment exploration was conducted of the two proposed channel locations and included two borings and five test pits at various locations in Marina Beach Park (S&W 2015). The surface sediments are primarily silty sand with some gravel. The deeper borings revealed more gravel at depths over 40 feet. The surface sediments are expected to be erodible under predicted creek flows and from wind wave conditions (See Section 5). The constructed beach outlet channel will likely develop a somewhat deeper low-flow channel post-construction due to erosion of the surface sediments under creek flows. This is typical of tidal creeks in Puget Sound (see Section 3.5).

3.5 Tidal Outlet Reference Site Information

Reference sites throughout Puget Sound similar to Edmonds Marsh were reviewed to determine the size of the Marsh system and associated outlet channel width and thalweg elevation. This information was used to inform design of the bed elevation (initial) of the Marina Beach Park outlet channel through the existing bridge and out onto the beach.

Seven reference sites within the Puget Sound were analyzed to establish similar conditions for the creek. The seven sites are as follows:

1. Meadowdale Beach County Park (Lunds Gulch Creek) in Edmonds, Washington
2. Race Lagoon in Coupeville, Washington
3. Foulweather Bluff in Hanville, Washington
4. Camp Indianola in Indianola, Washington
5. Point Heyer in Point Heyer, Washington
6. Unnamed west creek on Squaxin Island, Washington
7. Unnamed east creek on Squaxin Island, Washington

The reference sites were chosen to represent similar creeks to the unmodified Willow Creek. Each creek's marsh area, channel width, depth, and outlet elevations were compared using georeferenced aerial photographs and LiDAR elevations. Summary information for the reference sites and proposed geometry for Willow Creek based on review of these sites are provided in Table 2.

Table 2
Reference Site Summary Information

Site Location	Estimated Size of Marsh **(hectares)**	Estimated Elevation of Channel Thelweg at Outlet[1]		**Estimated Wetted Top-Width of Channel[2]**		**Estimated Depth of Channel[3]**	
		(feet, MLLW)	(feet, NAVD88)	**(meters)**	**(feet)**	**(meters)**	**(feet)**
Meadowdale	160.0	9.8	7.6	1.5	5.0	0.6	2.0
Race Lagoon	10.4	6.4	4.2	15.0	49.0	0.6	2.0
Foulweather Bluff	9.6	9.5	7.3	4.5	15.0	0.6	2.0
Indianola, WA	30.8	10.5	8.3	7.6	25.0	0.6	2.0
Point Heyer, WA	2.0	10.5	8.3	3.6	12.0	0.3	1.0
Squaxin Island-west	7.0	6.2	4.0	3.6	12.0	0.3	1.0
Squaxin Island-east	2.3	8.0	5.8	12.1	40.0	1.0	3.3
Willow Creek (Proposed)	8.0	6.0[4]	3.8	4 to 12[5]	13 to 40[5]	n/a	n/a

Notes:
MLLW = mean lower low water datum
NAVD 88 = North American Vertical Datum of 1988
1 = Estimated channel elevation found using 2005 Puget Sound lowlands Light Detection and Ranging (LiDAR). May not represent the actual thelweg elevation.
2 = Estimated channel width found using Google Earth
3 = Estimated channel depth found using Google Earth and various reports on the sites
4 = Willow Creek channel outlet elevation is +6 feet MLLW (+4 ft NAVD88) based on the railway underpass elevation.
5 = Estimated channel width for Willow Creek estimated using reference site comparisons

The estimated size of the marsh at Willow Creek (8 hectares) is closest in size to three reference sites: Race Lagoon, Foulweather Bluff, and Squaxin-Island west. The estimated wetted width of channel at Willow Creek is more in-line with two of those sites; Foulweather Bluff and Squaxin-Island West. For these two reference sites, the estimated elevation of the thelweg at the outlet is approximately 4 feet NAVD88 (6 feet MLLW). Therefore, based on review of these reference sites, the thalweg elevation of the beach outlet at Willow Creek is proposed as 4.0 feet NAVD 88 (approximately 6.0 feet MLLW) at the culvert location and beach outlet, daylighting at that same elevation on the beach, which is roughly the mean tide elevation. This is consistent with the modeled geometry in the initial phase of work conducted for this project (Anchor QEA 2013) and is similar to thalweg elevations of the existing Willow Creek Daylight channel upstream from Marina Beach Park and the BNSF bridge.

3.6 Proposed Beach Outlet Channel Options

S&W, with input from Anchor QEA as documented in this report, developed two options for the beach outlet channel (S&W 2014). Figures developed by S&W for the beach outlet channel options are provided in Appendix B. Option A and Option B channels differ downstream of the bridge, however the channel alignments and geometry upstream of the bridge are identical, and were developed by S&W.

Option A is similar to the original alignment developed as part of the Willow Creek Early Feasibility Study (S&W 2013) and is aligned through the approximate center of the dog off-leash area at Marina Beach Park. This alignment requires the channel to make a 90-degree turn directly downstream of the bridge. The channel is approximately 450 feet long from the bridge to the point where it outlets at +4 feet NAVD88.

Option B is oriented north of Option A and allows for a straighter channel alignment directly downstream of the bridge. The northerly alignment is more similar to the historical channel alignment prior to development in the project area. The channel is approximately 600 feet long from the bridge to the point where it outlets at +4 feet MLLW.

3.7 Channel Migration Considerations

Option A minimizes required excavation to construct the channel by minimizing the channel length between the bridge and the +4 ft NAVD88 contour (see Appendix B). However, the 90-degree bend in the channel downstream of the bridge may need to be armored due to high velocities in the bend during high flow events. In addition, the outlet will be oriented to the south-west and will likely trend towards the north-west in the long-term due to the south to north net littoral drift direction at the project site. This could impact the armored point to the north of the proposed outlet.

Option B requires more excavation downstream of the bridge to construct the channel than Option A, and also bisects the existing parking lot and lawn area. However, the channel has a more natural, straighter alignment downstream of the bridge which should reduce the need for bank armoring downstream of the bridge likely required for Option A. The outlet for Option B is initially oriented to the north-west, which more closely matches the orientation of the historical inlet and the equilibrium location of the inlet channel given net littoral drift is from south to north. Therefore, the channel alignment for Option B may be more stable than Option A in the long-term.

In addition to the longer-term process of littoral drift, large storm waves could cause erosion and sedimentation in and around the portion of the outlet channel subjected to direct wave breaking. Storm waves can mobilize sediment along the beach which could accumulate in the channel mouths reducing conveyance in the channel at lower flows. A large flow event from the creek could mobilize the accumulated sediment and move it out of the channel. However, there will likely be a period of time between a sedimentation causing wave event and channel opening flow event that could result in a constricted flow condition. This is a natural process for tidal creek outlets subject to waves, and is therefore in line with process based restoration efforts. Both Option A and Option B will be impacted by this process; as storm waves can approach either channel obliquely (storm waves can approach the site from the south-west clockwise to the north-west). However, the outlet for Option B is somewhat sheltered from storm waves form the north-west due to the Port of Edmonds breakwater located to the north of the park. The south-west direction is predicted to produce the largest storm waves. The outlet for Option A is oriented with the south-west direction, and may exhibit less sedimentation during storm events from the south-west than Option B, which is aligned almost parallel with that storm wave direction.

4 HYDRODYNAMIC EVALUATION OF PROPOSED CHANNEL ALIGNMENTS

Hydrodynamic modeling (1-D, Hydrologic Engineering Center River Analysis System [HEC-RAS]) was conducted to evaluate low- and high-flow tidal hydrodynamics for the two proposed beach outlet options (A and B). This modeling built upon modeling work conducted by Anchor QEA as part of the early feasibility study, and information regarding development and calibration of the model can be found in the *Final Tidal Marsh Hydraulics Report* (Anchor QEA 2013).

Low-flow model runs for each option were developed to evaluate potential fish passage into the Marsh based on typical spring and summer rearing periods. High-flow model runs for each option were developed to evaluate potential for flooding in the Marsh and upstream in Shellabarger Creek.

4.1 Model Development

The proposed conditions models for Options A and B were developed based on the existing topography and proposed channel geometry developed by S&W (S&W 2014). Data sources used to develop the proposed conditions models are listed in Table 3. Digital terrain models of both options were provided to Anchor QEA by S&W for use in the modeling effort. The thalweg of the beach outlet channel is approximately 4 feet NAVD 88 (6.0 feet MLLW), as discussed in Section 3.6.

Table 3
Data Sources Utilized in HEC-RAS Model

Date Type	Source	Spatial Extent	Temporal Extent
Topography/Stream Geometry	S&W; Digital Terrain Model	Project Area	N/A
Spring Tidal Data	NOAA	Lower Willow Creek	May 1–15, 2008
High-flow Tidal Data	NOAA	Lower Willow Creek	December 17–31, 2007
Spring Flow Conditions	Provided by S&W; taken from SR-104 HSPF Model (SAIC 2013)	Shellabarger Creek and Upper Willow Creek	May 1–15, 2008
High-flow Conditions	Provided by S&W; taken from SR-104 HSPF Model (SAIC 2013)	Shellabarger Creek and Willow Creek	December 1–14, 2007

Note:
HEC-RAS = Hydrologic Engineering Center River Analysis System
NOAA = National Oceanic and Atmospheric Administration
SR = State Route

Surface data from S&W were processed using HEC-GeoRAS, a tool developed for ArcGIS to process geospatial data for use in the HEC-RAS model. HEC-RAS geometry data were developed from HEC-GeoRAS at cross-sections within the project area. The cross-sections and existing surface data are shown in Appendix B for Options A and B, respectively.

Cross-sections were adjusted and the railroad bridge was added using survey data provided by S&W. Manning's roughness values were taken from the original model (Anchor QEA 2013).

4.2 Model Boundary Conditions

The low- and high-flow HEC-RAS models were run as unsteady flow models to simulate tidal cycles during a typical spring period for a typical spring/summer low-flow and predicted 100-year flow. Low flows were provided by the City of Edmonds, Dayton Street flood study model (SAIC, 2013) and represent average flows during May in Shellabarger and Upper Willow creeks (0.5 and 0.3 cubic foot per second, respectively). The high-flow event was provided the City of Edmonds, Dayton Street flood study model, taken from flood modeling work completed by SAIC (SAIC 2013) and represents a flow event in December

2007. To improve the stability of the model, the model was split into three reaches (Upper Willow Creek, Shellabarger Creek, and Lower Willow Creek). Figures 4 and 5 show the Lower Willow Creek model reach. Flow conditions were assumed to be concurrent such that the Lower Willow Creek flow was equal to the sum of the Upper Willow Creek and Shellabarger Creek flows. Simulation time periods were set for 2 weeks. Time-series plots for tidal elevations and 100-year high flow are provided in Appendix C.

4.3 Model Results

Four model simulations were completed: one low-flow and one high-flow simulation for each channel alignment alternative (Option A and Option B). Each simulation was run for a 2-week timeframe with a tidal downstream boundary condition. Results for the low- and high-flow simulations are described in detail below.

4.3.1 Low-flow Model Runs

The purpose of the low-flow model runs was to evaluate in-channel flow velocities in the daylight channel and Marsh to assess potential for fish access. Anchor QEA provided predicted depth and cross-sectional averaged velocities, water surface elevations, and water depths at each model cross-section/station (see Figures 4 and 5) to Confluence Environmental Company (Confluence). Confluence conducted an evaluation that compared the low flow model results with metrics desirable for fish passage. This evaluation is documented in a technical memorandum developed by Confluence for S&W entitled *Analysis of Proposed Fish Habitat with Willow Creek Daylighting and Restoration* (Confluence, 2015). Time series plots of velocity and elevation at various model cross-sections are provided in Appendix C.

A summary of predicted velocities in the daylight channel upstream of the railroad bridge is provided in Table 4 as a percent occurrence of in-channel current speeds greater than or equal to 1 ft/s or 2 ft/s. Cross-section/station numbers reference Option B numbering (Figure 5). Predicted model velocities for portions of the daylight channel upstream of the bridge are identical for both Option A and Option B.

Table 4
Low-flow Model Results Summary; Upstream of the Railroad Bridge

(Options A and B)

Cross-section/Station (Based on Option B)	Percent of Time Velocities ≤ 1 ft/s	Percent of Time Velocities ≤ 2 ft/s
3158.385	97%	98%
3034.243	99%	99%
2824.682	74%	97%
2626.523	71%	86%
2483.468	75%	76%
2292.697	96%	99%
2193.34	83%	98%
2066.47	66%	92%
1973.912	66%	88%
1702.128	65%	87%
1568.822	36%	58%
1382.35	58%	99%
1302.334	62%	99%
1123.483	68%	99%
976.2018	74%	99%
833.6823	80%	100%
737.4906	84%	100%
668.7243	83%	100%
617.8932	81%	100%

Note:
ft/s = foot per second

Plots of predicted in-channel velocities and water depths for select model sections are provided in Appendix C.

A majority of cross-section/station locations have velocities that are less than or equal to 1 ft/s over 60% of the simulation time period. Station locations in the Marsh and at the bridge location meet the 1 ft/s criterion over 70% of the time, with many cross-sections in the 80% and 90% ranges. The highest velocities occur in the straight portion of the channel (Sections 2066 through 1123), and one Station at 1568 meets the 1 ft/s criterion just under 40% of the time. The 2 ft/s criterion is met over 75% of the time for all Stations, with the majority being above 90%, except for Station 1568, which is around 60% of the time. The 0.5 foot depth criterion is met for all stations over 70% of the time, with the majority of locations at over 90%.

The results for sections downstream of the bridge for Options A and B are shown in Table 5. Similar to stations upstream of the railroad bridge, stations downstream of the bridge meet the 1 ft/s criterion over 60% of the time, with many stations over 70% of the time. The 2 ft/s criterion is met over 80% of the time for all stations, with the majority being above 90%.

Table 5
Low-flow Model Results Summary; Downstream of the Railroad Bridge
(Options A and B)

Option A			Option B		
Cross-section/Station	Percent of Time Velocities ≤ 1 ft/s	Percent of Time Velocities ≤ 2 ft/s	Cross-section/Station	Percent of Time Velocities ≤ 1 ft/s	Percent of Time Velocities ≤ 2 ft/s
388	73%	81%	451	66%	98%
233	82%	88%	374	65%	97%
162	89%	93%	285	64%	95%
66	85%	92%	165	61%	91%
			97	60%	89%

Note:
ft/s = foot per second

The higher velocities in the straight portion of the channel are not unexpected, because the channel has a straight alignment for approximately 1,300 feet due to site constraints that limit where the channel can be located. However, during design, rough channel elements (such as large woody debris) can be added to the straight portion of the channel to provide to provide variable velocities, which in turn can help improve fish passage by lowering velocities below those predicted in this model.

4.3.1.1 Low-flow Model Sensitivity Analyses

Two model sensitivity analyses were conducted to evaluate the sensitivity of the low-flow model results (velocity and water depth) to incremental changes in upstream in flow volume and changes to mean seal level (sea level rise). The purpose of the sensitivity analysis is to identify potential uncertainty in the low-flow model results based on variability of chosen input boundary conditions.

The low-flow model upstream flow rate was 0.8 cubic feet per second for all runs. For the sensitivity analysis, the in-flow rate was varied by plus or minus 20% (0.64 and 0.96 cubic feet per second). Appendix D provides a comparison of velocities below 2 feet per second and water depths greater than 0.8 feet for all three in-flow rates as predicted by the model. The results of the model varied by less than 2% for based on velocity threshold and less than 3% based on water depth threshold between the three simulations.

Appendix D also provides a similar comparison for low flow model results that used the same in-flow rate (0.8 cubic feet per second) but varied mean sea level. Median predicted increases in sea-level for Seattle (NRC, 2012) for the years 2030 (7 centimeters) and 2050 (17 centimeters) were added to the tidal elevation time series used as the downstream boundary condition for the model. Appendix D provides a comparison of velocities below 2 feet per second and water depths greater than 0.8 feet for the three different mean sea level elevations as predicted by the model. The results of the model varied by less than 2% based on velocity threshold and 3% based on water depth threshold between the three simulations.

4.3.2 High-flow Model Runs

The high-flow model developed as part of the early feasibility study (Anchor QEA 2013) was modified to represent the proposed channel alignments, Options A and B (see Appendix B). Boundary conditions and other model parameters remain unchanged from the previous high flow modeling work (Anchor QEA, 2013), and represent an approximate 100-year hydrograph taken from a storm event in December 2007 (SAIC, 2013). Predicted velocities and water surface elevations from the updated high-flow model are the same upstream of the bridge as the initial high-flow modeling work (for both Options A and B) conducted by Anchor QEA in 2013 as part of the Early Feasibility Study (Anchor QEA, 2013). Figure 6 shows a comparison of water surface elevations in the marsh for existing and proposed (Options A or B) conditions, as well as water surface elevation just upstream of the bridge for proposed conditions (Options A or B). These results are summarized below:

- Water surface elevations in the marsh for exiting conditions reach a maximum of almost 13 feet NAVD88. This elevation compares well with the reported 100-year flood elevation for the Marsh provided in SAIC 2013 (13.2 feet NAVD 88)(see Section 3.2.2).
- Water surface elevations in the marsh for proposed conditions (Options A and B) are lower than existing conditions, reaching maximum elevations of approximately 11 feet NAVD88. This is less than the existing documented and predicted 100-year flood elevation in the marsh by approximately 2 feet.
- Other than at the peak of the flood event (12/4), water surface elevations in the marsh are lower for existing conditions (which include the current outfall system for Willow Creek)) than for proposed conditions (when the channel is daylighted and hasno hydraulic controls).

4.4 Flooding Considerations

The Daylight project high-flow (100-year) model simulation predicts that water surface elevations in the Marsh are not significantly higher than the predicted existing condition 100-year flood elevation in the Marsh provided by SAIC 2013 (13.2 feet NAVD88). However, water surface elevations in the Marsh can reach approximate high tide elevations on a regular basis once the daylight channel is constructed. The mean higher high tide level of 9.1 feet NAVD88 is close to the 2-year flood elevation in the marsh and the king tide elevation of 10.7 feet NAVD88 is close to the 25-year flood elevation in the marsh (SAIC, 2013)(see Section 3.2.2). This will increase the frequency of occurrence of high water in the Marsh and Shellabarger Creek compared to existing conditions, where there are currently hydraulic controls on the creek outlet to attenuate the high tide elevation in the marsh. At present, the City of Edmonds has an existing tide gate, located at the end of the Port of Edmonds pipe in a vault in Marina Beach Park, that is closed manually from October through March each year. For reference, low spots on SR-104 are at elevation 12.0 feet NAVD88 near Harbor Square and as low as 10.6 feet NAVD88 at the SR-104 and Dayton Street intersection.

In order to reduce the risk of flooding at low spots adjacent to the marsh, such as the SR-104 and Dayton Street intersections, due to tidal inundation during large storm events, a self-regulating tide gate could be constructed in Willow Creek. The tide gate could be constructed near the location of the existing Willow Creek channel overflow into the Port of Edmonds storm drain pipes to reduce the propagation of higher tides into the marsh. The tide gate would need to be designed to limit tidal flooding potential to roadways and upland areas within defined operational criteria.

In order to evaluate the potential benefit to flood reduction and impact to fish passage of a tide gate constructed in the channel at the existing overflow (about Model Station 1450 in Figure 5), additional HEC-RAS model runs were conducted with the proposed gate inserted into the model. In addition to modeling, a GIS evaluation was conducted to look at potential storage at different water surface elevations in the marsh above 8.0 feet NAVD88. The tide gate utilized in the model consisted of three 4 foot diameter culverts with invert elevations of 5.5 feet NAVD 88.

A low flow model run was conducted with the tide gate in place to evaluate velocities in the tide gate culvert pipes (with the gate open) over the range of tidal elevations when the gate would remain open. The water surface elevation when the gate would shut was assumed to be 9.5 feet NAVD88 for the low flow run. Water depths and velocities at select stations in the model, including the upstream and downstream end of the culvert were provided to Confluence for inclusion in their fish passage evaluation (Confluence, 2015). Based on preliminary results of the fish passage evaluation, an additional low-flow tide gate simulation was conducted with the middle culvert barrel invert lowered to 4.0 feet NAVD 88. The results of this model run were also provided to Confluence for inclusion in their fish passage evaluation (Confluence, 2015). Plots of water depth and velocity for select sections for the tide gate simulations are provided in Appendix C.

High flow events were simulated in the HEC-RAS model using a series of closure water surface elevations for the self-regulating tide gate and associated time periods when the tide would stay above the closure water surface elevation as the storm duration. The storm inflow was taken to be the approximate average of the 100-year flow hydrograph used in previous modeling work (early December 2007); approximately 72 cubic feet per second. The peak flow during that event was approximately 91 cubic feet per second.

To ground truth and augment model results, a GIS stage-storage evaluate was conducted for the marsh for water surface elevations above 8.0 feet NAVD88. At this elevation, the marsh is basically a bath tub model and the relationship between water surface elevation and storage volume is approximately linear. Appendix E summarizes the augmented results of the HEC-RAS modeling and GIS evaluation, and provides estimates of the storage volume in the marsh above 8.0 feet NAVD88 and predicted water surface elevations for various flow rates and gate closure heights. Figure 7 provides a graphical representation of the summary table in Appendix E.

Figure 7 shows predicted water surface elevations in the marsh based on tide closure elevations of 8.0 feet to 9.5 feet NAVD88. Each closure elevation has an associated time of closure which is equal to the approximate length of time the tide remains higher than the closure elevation over a typical tidal cycle. As the closure depth for the gate is decreased, the time the gate will remain closed increases. While the initial water surface elevation and water volume in the marsh is less when the gate shuts, the marsh must endure a longer period of inflow before the gate can open again and drain the marsh. Therefore, there is a relatively complicated relationship between closure height for the gate and predicted water surface elevation in the marsh.

Water surface elevations remain at least 2 feet below the existing 100-year elevation in the marsh over the range of inflow condition (up to 140 cfs) and storm durations evaluated (up to 5 hours). Closing the gate at 8.0 feet NAVD88, even with the 5 hour closure duration, provides the best performance in terms of flood reduction in the marsh at high flows due to large volume of storage in the marsh above 8.0 feet. Closure heights of 8.5, 9.0 and 9.5 feet NAVD88 all perform about the same due to variable closure durations and all would be viable options for flood control in the marsh. For instance, the predicted water surface elevation in the marsh for the average 100-year inflow (~ 72 cfs) would be 10.15, 10.25, and 10.3 feet, respectively. Each of these predicted water surface elevations is below 10.6 feet NAVD88, which is the elevation of the SR-104 and Dayton Road intersection.

5 UNCERTAINTY DISCUSSION

The results of the tidal hydrodynamic evaluation for this project were based on the best available data at the time and targeted to meet the specific needs of the final feasibility evaluation. Uncertainties in the model are due to limitations of the input data to the model (i.e., topography, flows, and water levels) and assumptions made by the model itself. Specific potential sources of uncertainty with this study include the following:

- Multiple sources of topography information, with different spatial resolutions, coverage areas, and collection times, were used to create the digital elevation models used to develop both the existing and proposed conditions hydrodynamic (HEC-RAS) models.
- Flow data were provided by a run-off model completed by SAIC (SAIC 2013); there are no stream gage data available for the project area.
- The existing conditions model was not calibrated based on synoptic measured flow and water level data in the Marsh due to lack of data.

6 RECOMMENDATIONS

6.1 Beach Outlet Options

Option A and B for the beach alignment have the same hydraulic conditions upstream of the bridge, and very similar hydraulic conditions downstream of the bridge (creek flow velocity and water depth) out onto the beach. Option A is routed through the existing off-lease dog park, whereas Option B is bisecting the existing parking lot and lawn area, which would need to be relocated and/or redesigned.

Option B is aligned in the direction of the historical inlet (to the north-west) and is more aligned with the net littoral drift direction (south to north), which will tend to push the inlet to the north-west. Option A is aligned to the south-west, and would therefore be at higher risk of channel migration as the outlet tries to align itself with the net littoral drift direction. Option B has a straight alignment downstream of the bridge, whereas Option A has a sharp 90 degree turn downstream of the bridge that would likely require bank armoring to remain stable during high creek flows.

References

Therefore, based on hydraulic and coastal processes considerations, Option B is the preferred option for the beach outlet channel. However, as the alignment for Option B greatly impacts the existing Marina Park infrastructure, public usage and park design will need to be taken into consideration when choosing a final preferred alignment.

6.2 Tide Gate Considerations

A self-regulating tide gate set to close at 9.5 feet NAVD88 (11.7 feet MLLW) could be a viable solution to flooding concerns in the marsh, even for low lying areas such as the SR-104 and Dayton road intersection. The proposed elevation for gate closure (9.5 feet NAVD88) is 0.4 feet above mean higher high water at the site. It is expected that once closed, tides can remain higher than 9.5 feet NAVD88 for up to three hours. The gate will provide a fish barrier when tidal elevations are above 9.5 feet NAVD88 and the gate is closed, but this is expected to occur only a few hours at a time on certain days of the month. Elevations in the culvert do not appear to be significantly higher than in the straight channel without the tide gate.

However, the self-regulating tide gate will need to be consistently maintained to ensure that it continues to function as designed. Situations where the gate is stuck open or closed could result in undesirable flooding of lower-lying roadways and upland areas surrounding the marsh.

In addition, water surface elevations in the marsh predicted by the HEC-RAS modeling based on proposed restoration actions at the project site should be used to update the downstream boundary conditions in the flood routing model developed for SR-104 by the City of Edmonds (SAIC, 2013). The flood routing model should be re-run with these updated boundary conditions to verify there are no flooding risks due to proposed hydraulic changes in the marsh upstream of the extent of the HEC-RAS model.

References

7 REFERENCES

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FIGURES

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NOTE: Aerial photo and background data provided by ESRI.

Figure 1
Site Location Map
Tidal Marsh Hydrodynamics Report
Willow Creek Daylight Early Feasibility Study

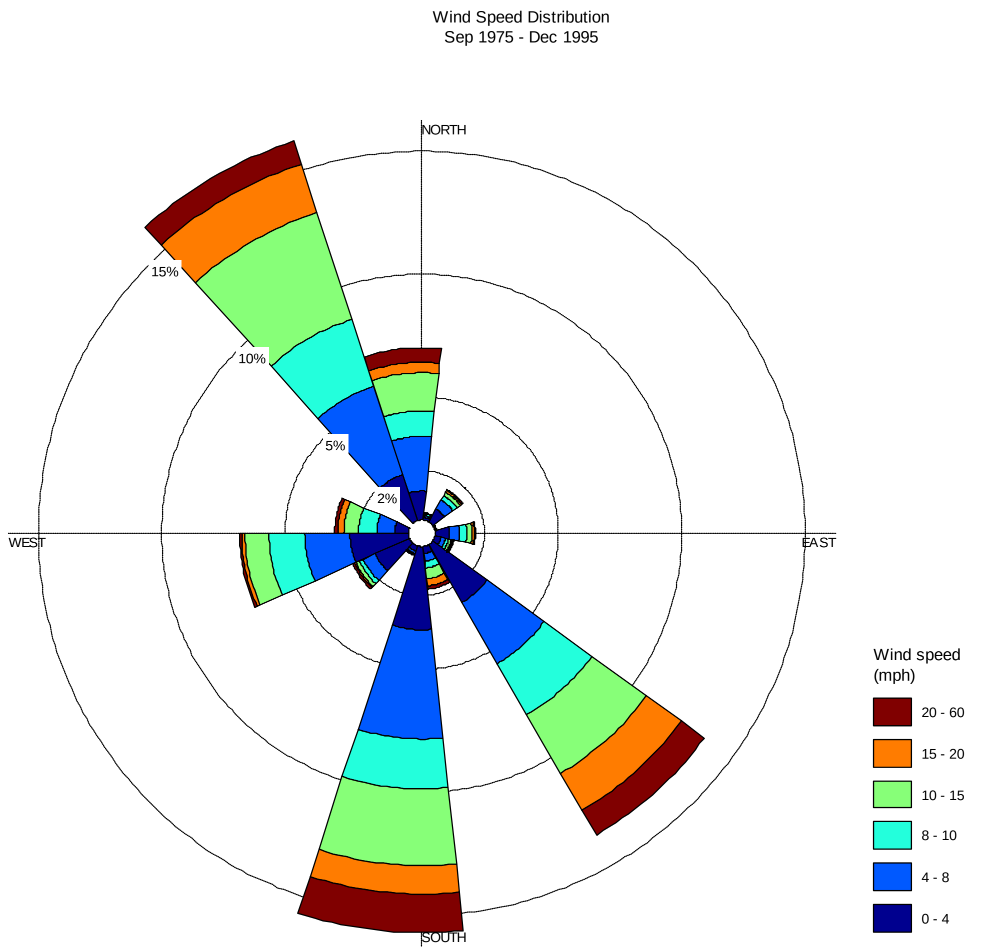
ANCHOR QEA

NOTE: Aerial photo provided by ESRI.

ANCHOR QEA

0 300 600
Feet

Figure 2
T-Sheet for Admiralty Inlet
Tidal Marsh Hydrodynamics Report
Willow Creek Daylight Early Feasibility Study



B:\Projects\City of Edmonds\Willow Creek (140017-01)\Report\Figures\Figure 3.docx

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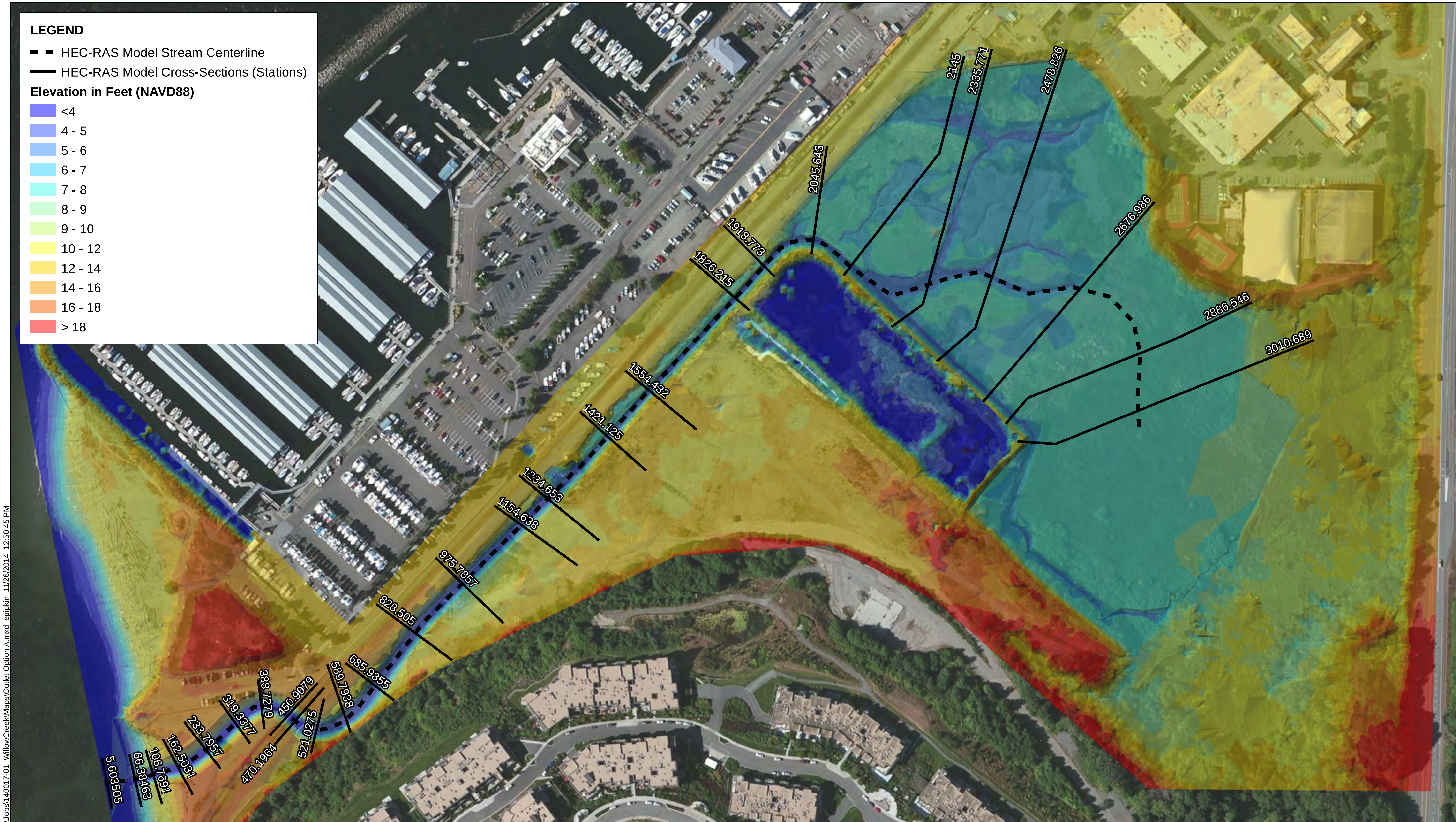
Figure 3

Wind Speed Distribution for Point No Point Lighthouse Wind Speed Distribution (1975-1995)

Hydrodynamic Evaluation Report

Willow Creek Final Feasibility Study



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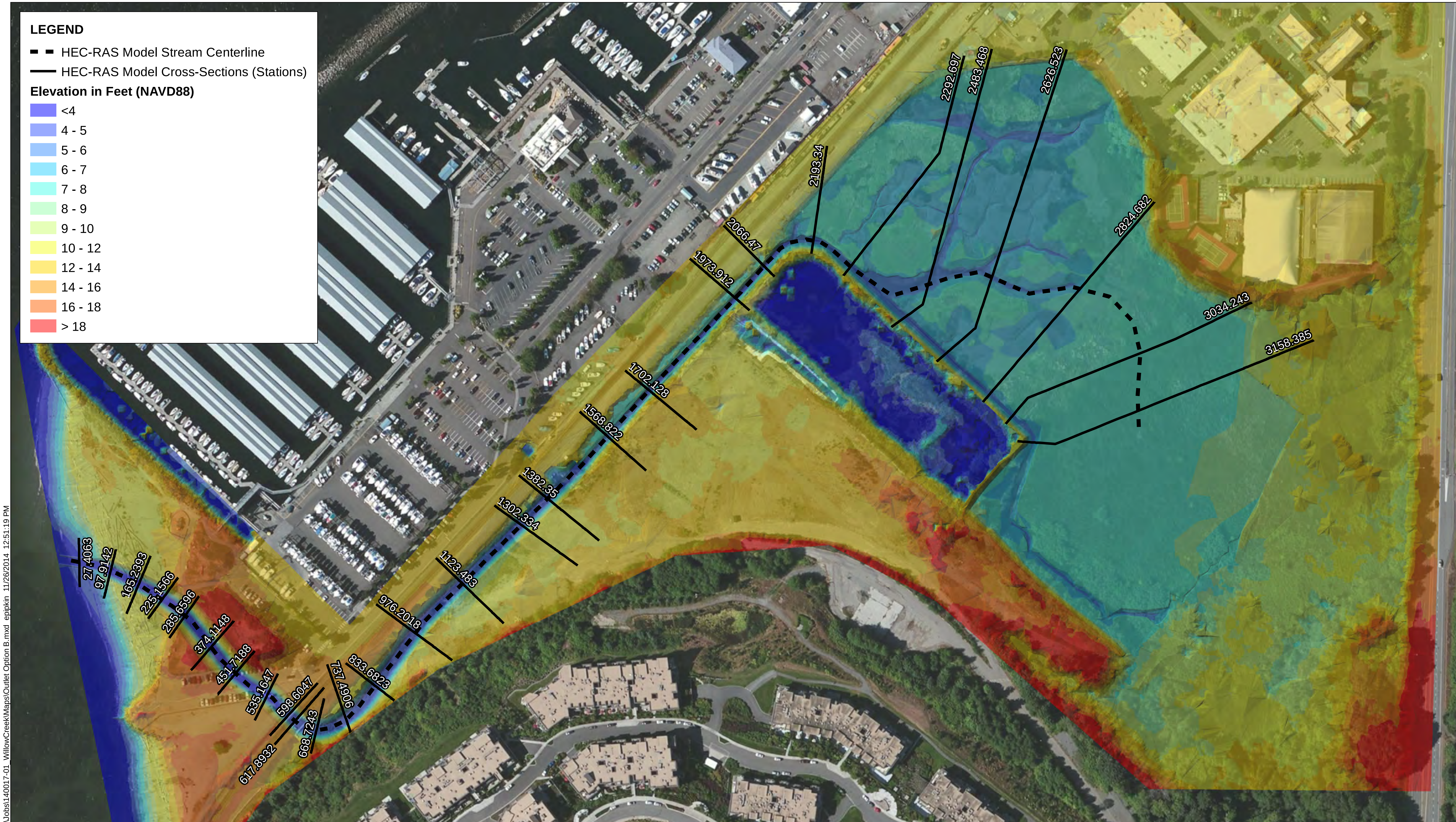
NOTES:
1. Horizontal datum is WA State Plane North Zone, NAD83, feet.
2. Vertical datum is NAVD88, feet.
3. Aerial photo provided by ESRI.

0 100 200
Feet

Figure 4
Proposed Conditions (Outlet Option A)
Topography and HEC-RAS Model Cross-Section Locations
Tidal Marsh Hydrodynamics Report
Willow Creek Daylight Early Feasibility Study



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NOTES:
1. Horizontal datum is WA State Plane North Zone, NAD83, feet.
2. Vertical datum is NAVD88, feet.
3. Aerial photo provided by ESRI.

Figure 5
Proposed Conditions (Outlet Option B)
Topography and HEC-RAS Model Cross-Section Locations
Tidal Marsh Hydrodynamics Report
Willow Creek Daylight Early Feasibility Study

APPENDIX A
EXTREME WIND AND WAVE SUMMARY

Appendix A: Wind-Wave Hindcast Data and Results Summary Table (See Section 3.3)

(Wind Data Source: Point No Point Lighthouse, NOAA #742065, 1975-1995)

				2-year			**10-year**			**20-year**		
Start Degrees	**End Degrees**	**Fetch (mi)**	**Depth (ft)**	**Windspeed (mph)**	**Wave Height (ft)**	**Wave Period (s)**	**Windspeed (mph)**	**Wave Height (ft)**	**Wave Period (s)**	**Windspeed (mph)**	**Wave Height (ft)**	**Wave Period (s)**
0	45	n/a	n/a	7	n/a	n/a	12	n/a	n/a	12	n/a	n/a
46	90	n/a	n/a	14	n/a	n/a	24	n/a	n/a	28	n/a	n/a
91	135	n/a	n/a	13	n/a	n/a	25	n/a	n/a	28	n/a	n/a
136	180	n/a	n/a	30	n/a	n/a	37	n/a	n/a	38	n/a	n/a
181	225	12	100	7	0.5	1.5	12	1.1	2.1	14	1.4	2.4
226 [a]	270 [a]	4.3	90	19 [a]	1.1 [a]	2.0 [a]	39 [a]	2.7 [a]	3.1 [a]	49 [a]	3.6 [a]	3.5 [a]
271	315	5.8	90	11	0.6	1.5	29	2.0	2.7	37	2.7	3.1
316	360	12	80	29	3.4	3.6	37	4.7	4.1	39	5.0	4.3
				50-year			**100-year**			**Maximum Observed**		
Start Degrees	**End Degrees**	**Fetch (mi)**	**Depth (ft)**	**Windspeed (mph)**	**Wave Height (ft)**	**Wave Period (s)**	**Windspeed (mph)**	**Wave Height (ft)**	**Wave Period (s)**	**Windspeed (mph)**	**Wave Height (ft)**	**Wave Period (s)**
0	45	n/a	n/a	13	n/a	n/a	13	n/a	n/a	13	n/a	n/a
46	90	n/a	n/a	33	n/a	n/a	36	n/a	n/a	28	n/a	n/a
91	135	n/a	n/a	31	n/a	n/a	32	n/a	n/a	30	n/a	n/a
136	180	n/a	n/a	41	n/a	n/a	42	n/a	n/a	39	n/a	n/a
181	225	12	100	15	1.5	2.5	16	1.6	2.5	15	1.5	2.5
226 [a]	270 [a]	4.3	90	64 [a]	5.1 [a]	4.1 [a]	77 [a]	6.6 [a]	4.6 [a]	60 [a]	4.8 [a]	4.0 [a]
271	315	5.8	90	46	3.6	3.5	53	4.3	3.9	37	2.7	3.2
316	360	12	80	42	5.5	4.4	44	5.8	4.6	40	5.3	4.4

Notes:

n/a Wind direction not applicable for wave generation at the project site

a. Highest observed wind speed of 60 mph may be an outlier. Wave parameters estimated from winds in this directional bin may be over predictions.

APPENDIX B
PROPOSED CHANNEL ALIGNMENTS PROVIDED BY SHANNON AND WILSON

Willow Creek Daylighting
Edmonds Marsh
Edmonds, Washington

FIELD EXPLORATION AND PROPOSED CHANNEL OPTION A

March 2015 21-1-12393-404

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A

Filename: T:\Project\21-1\12393_Edmonds_Marsh\AV_mxd\ExplorAndProposedChannelSurfaces.mxd Date: 3/6/2015 brl

Willow Creek Daylighting
Edmonds Marsh
Edmonds, Washington

FIELD EXPLORATION AND PROPOSED CHANNEL OPTION B

March 2015 21-1-12393-404

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. B

Filename: T:\Project\21-1\12393_Edmonds_Marsh\AV_mxd\ExplorAndProposedChannelSurfaces.mxd Date: 3/6/2015 brl

APPENDIX C
TIME SERIES PLOTS OF PREDICTED VELOCITY AND WATER DEPTHS AT SELECT MODEL CROSS-SECTIONS

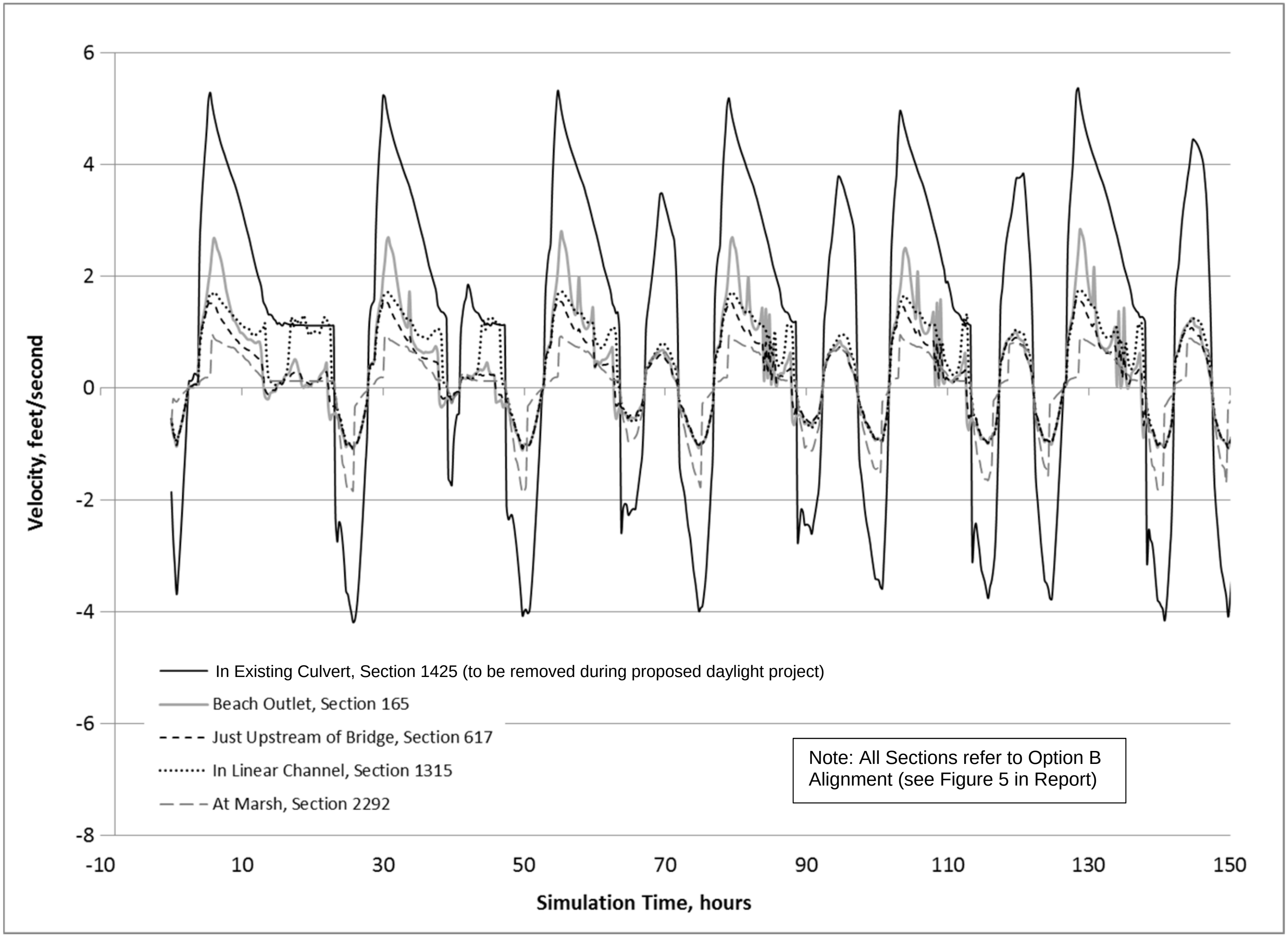

Figure C1
Low-Flow Simulation, Velocities at Select Model Sections
Beach Outlet and Hydrodynamic Evaluation Report
Willow Creek Daylight Final Feasibility Study

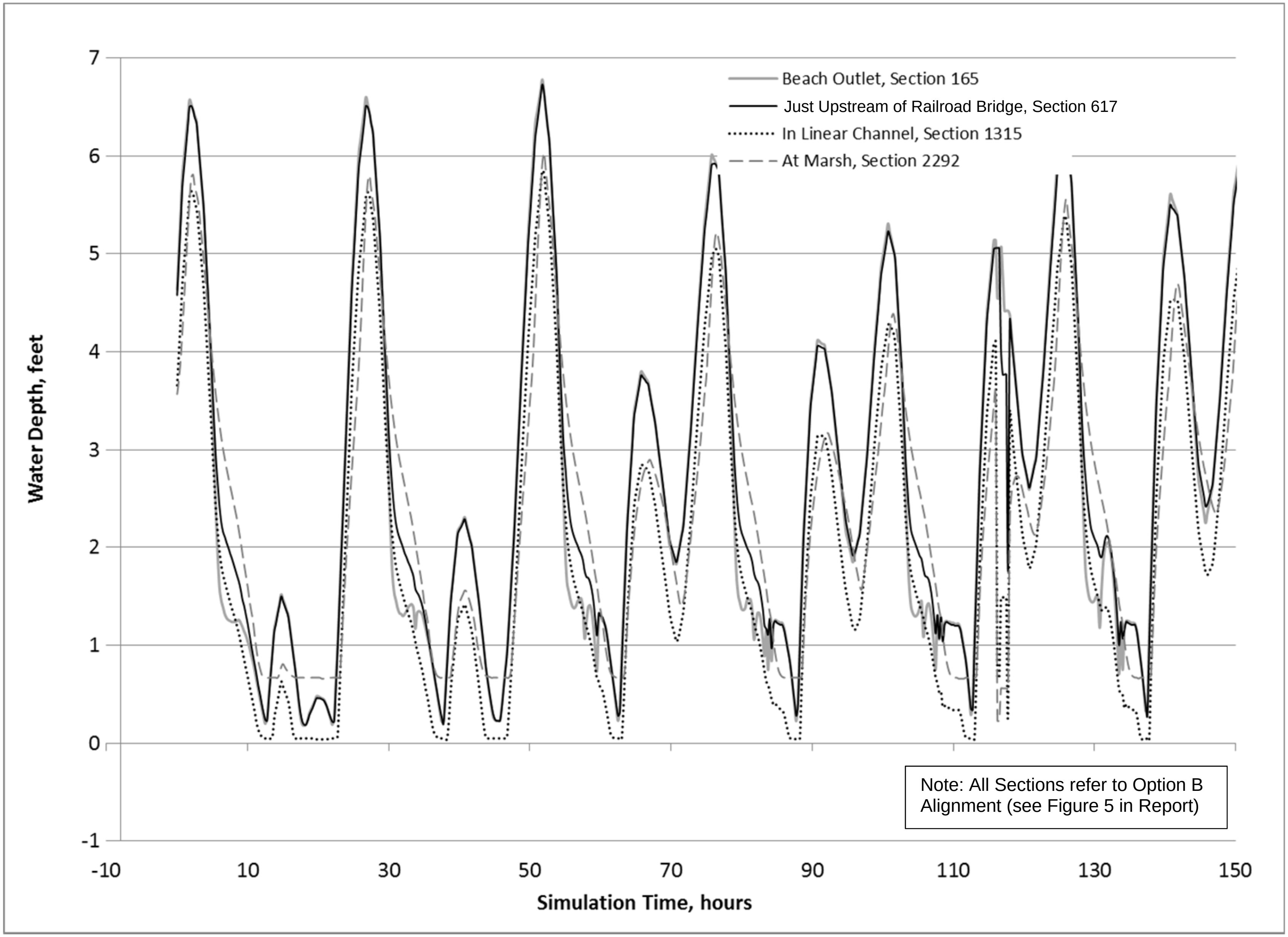

Figure C2
Low-Flow Simulation, Water Depths at Select Model Sections
Beach Outlet and Hydrodynamic Evaluation Report
Willow Creek Daylight Final Feasibility Study

ANCHOR QEA

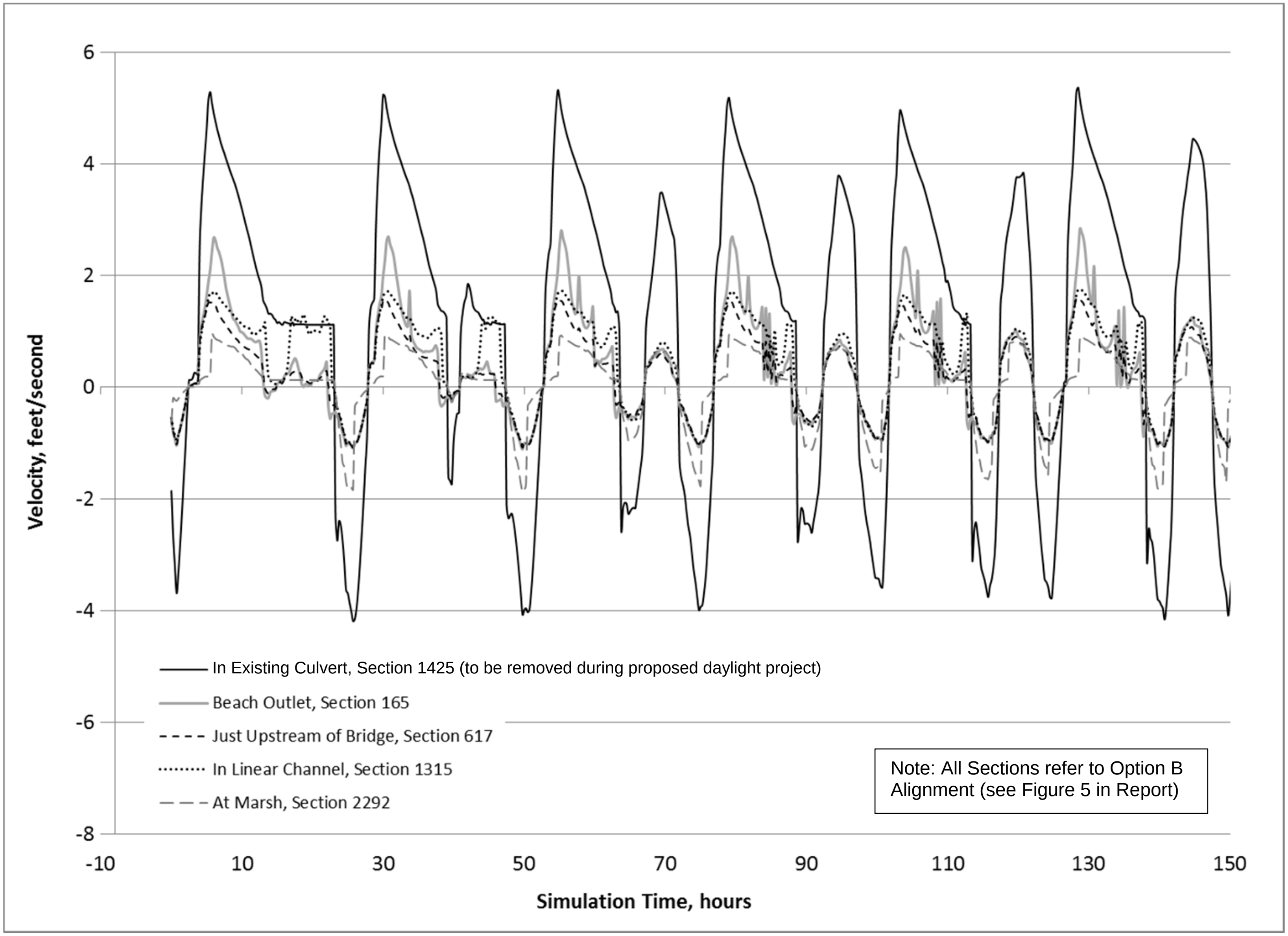

Figure C3
Low-Flow Tide Gate (Invert +5.5 feet NAVD88) Simulation, Velocities at Select Model Sections
Beach Outlet and Hydrodynamic Evaluation Report
Willow Creek Daylight Final Feasibility Study

ANCHOR QEA

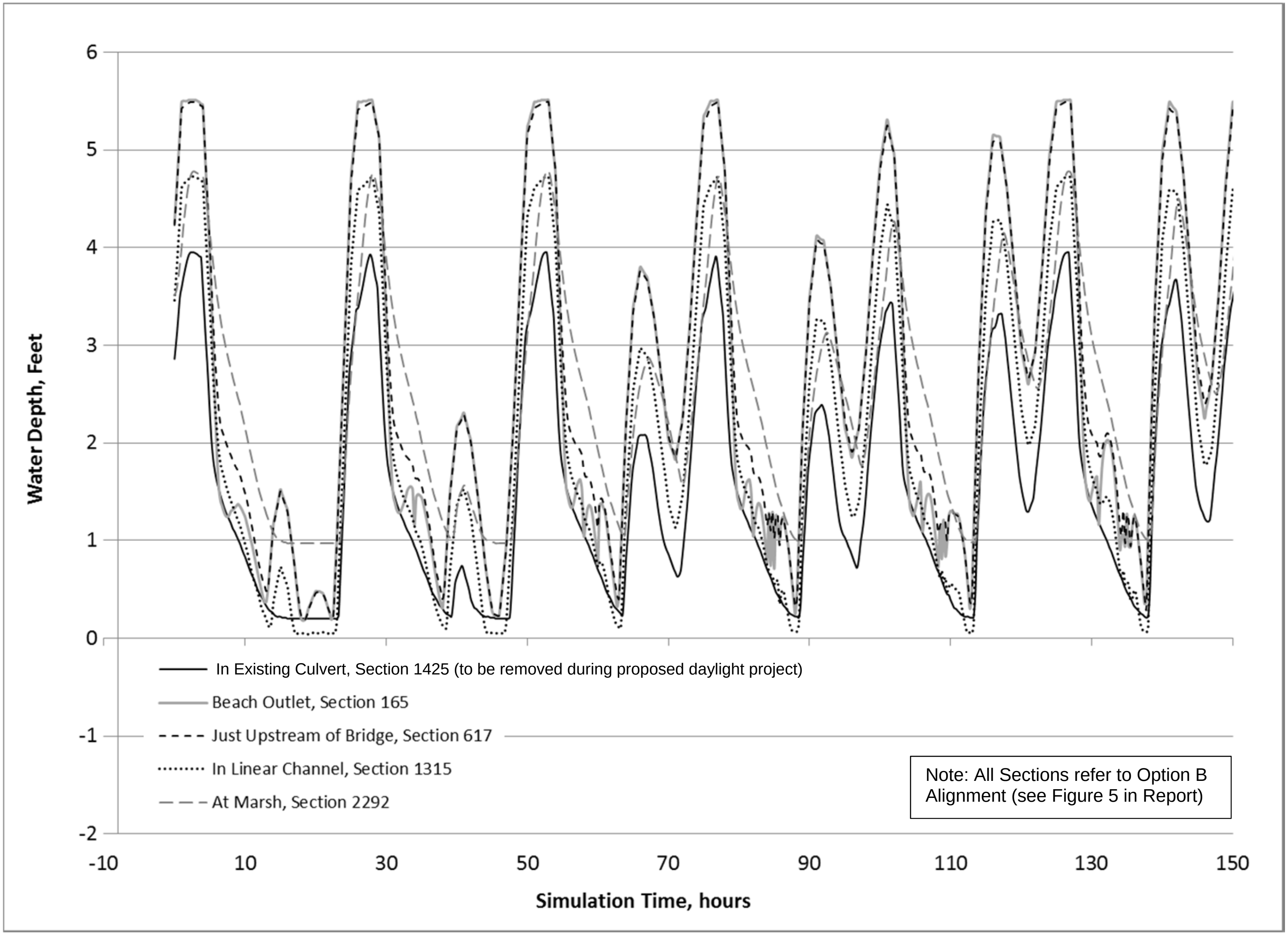

Figure C4
Low-Flow Tide Gate (Invert +5.5 feet NAVD88) Simulation, Water Depths at Select Model Sections
Beach Outlet and Hydrodynamic Evaluation Report
Willow Creek Daylight Final Feasibility Study

ANCHOR QEA

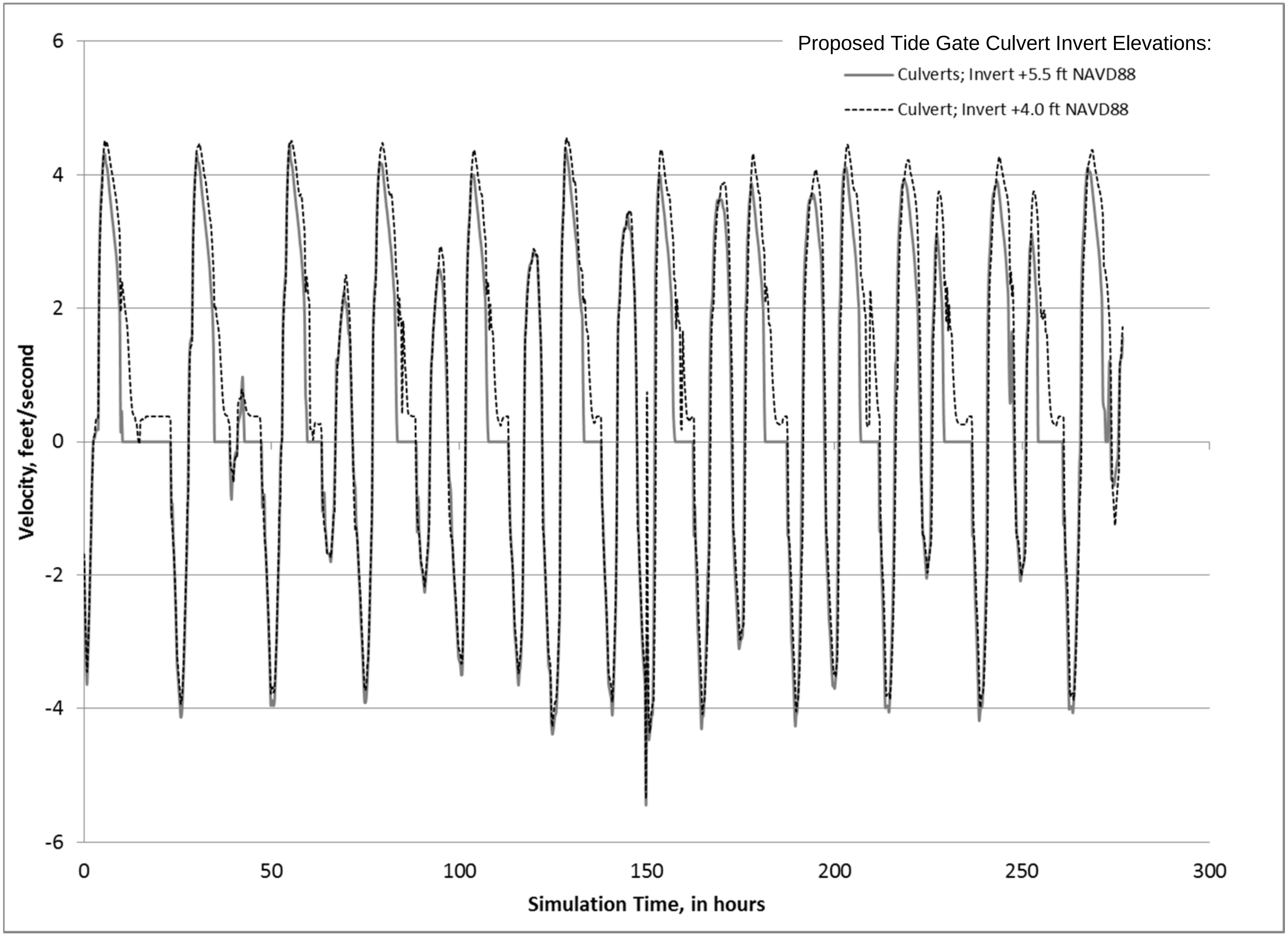

Figure C5
Low-Flow Tide Gate (Variable Inverts +5.5 and 4.0 feet NAVD88) Simulation, Velocities
Beach Outlet and Hydrodynamic Evaluation Report
Willow Creek Daylight Final Feasibility Study

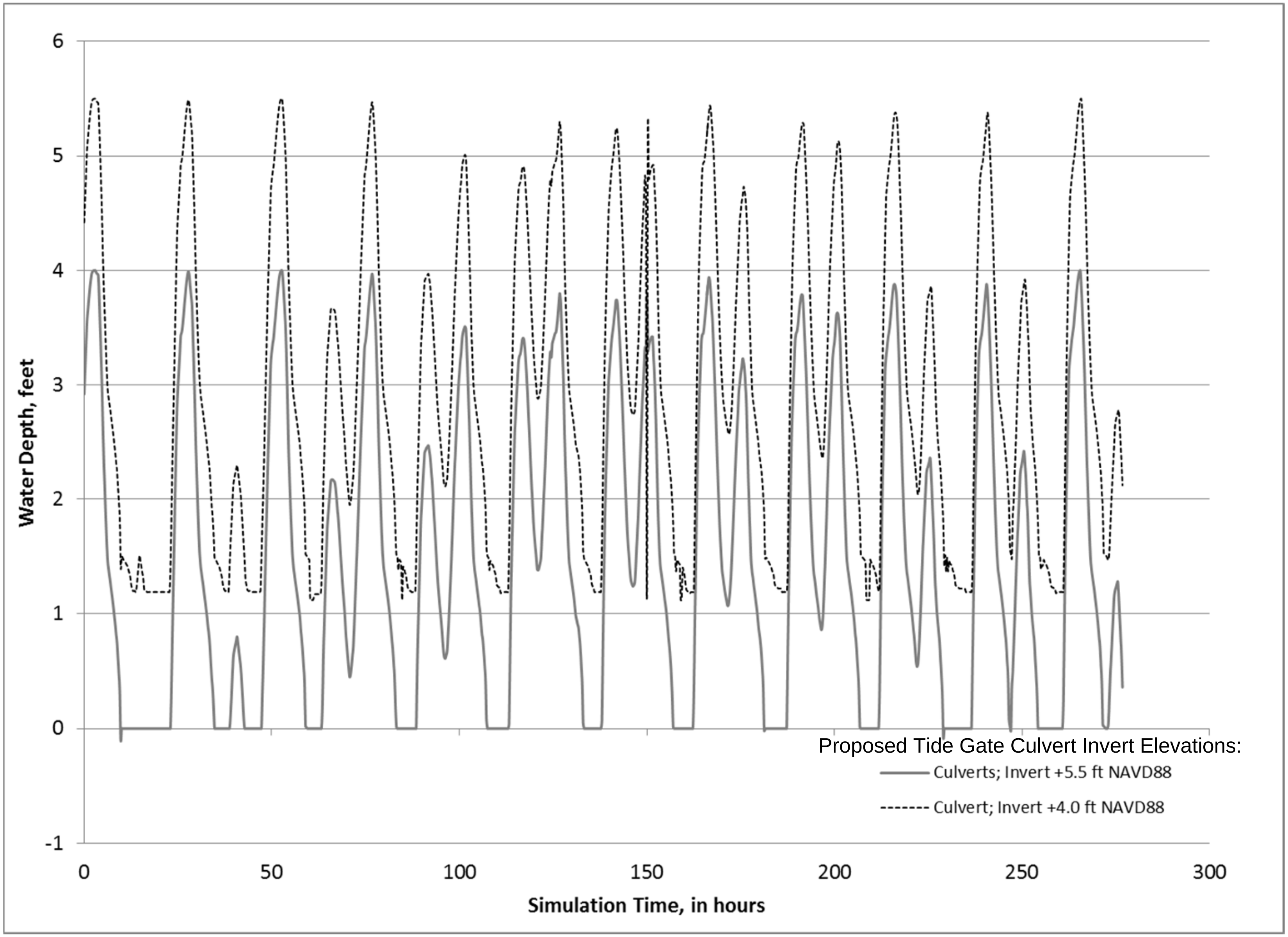

Figure C6

Low-Flow Tide Gate (Variable Inverts +5.5 and 4.0 feet NAVD88) Simulation, Water Depths

Beach Outlet and Hydrodynamic Evaluation Report

Willow Creek Daylight Final Feasibility Study

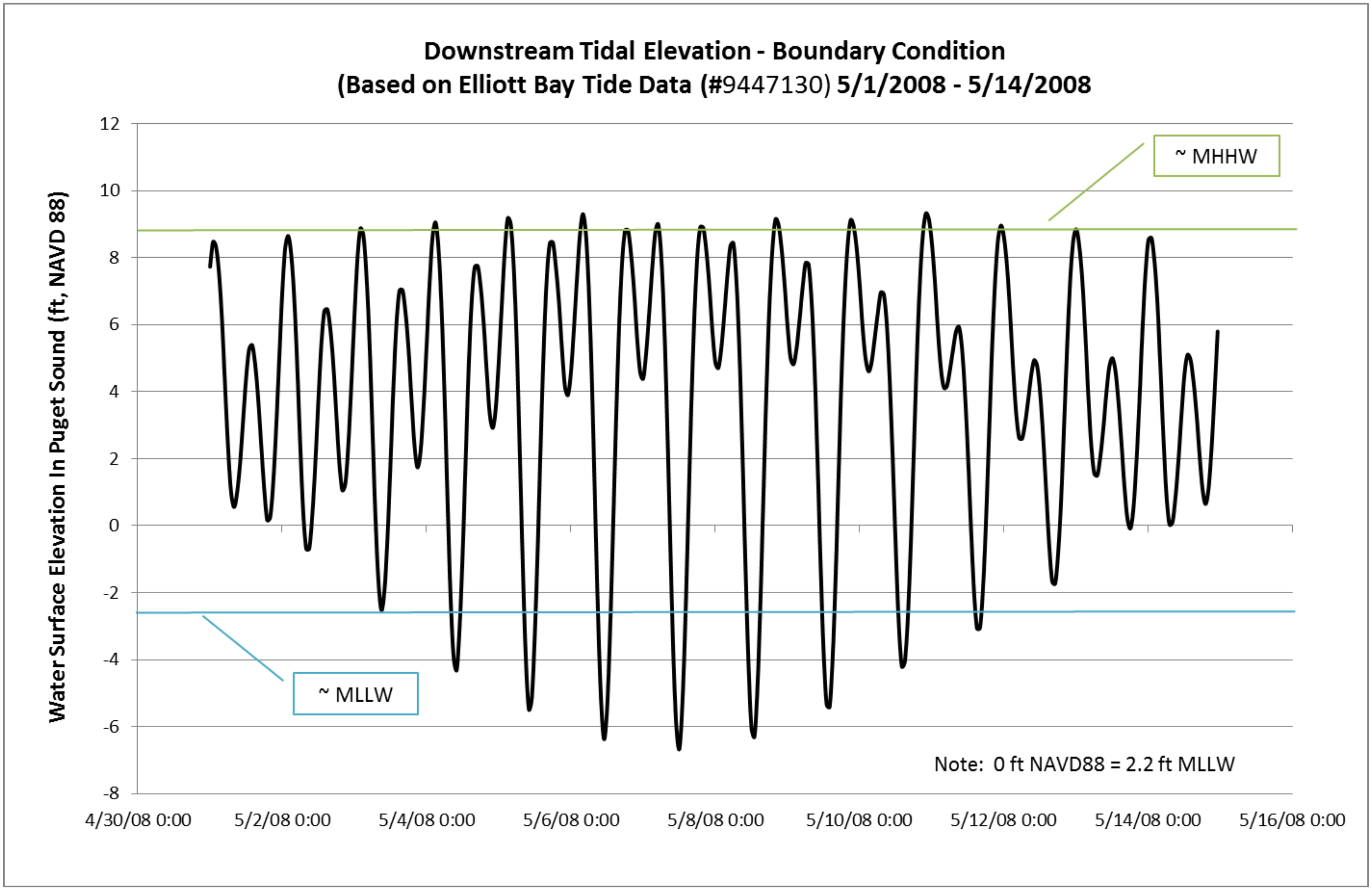

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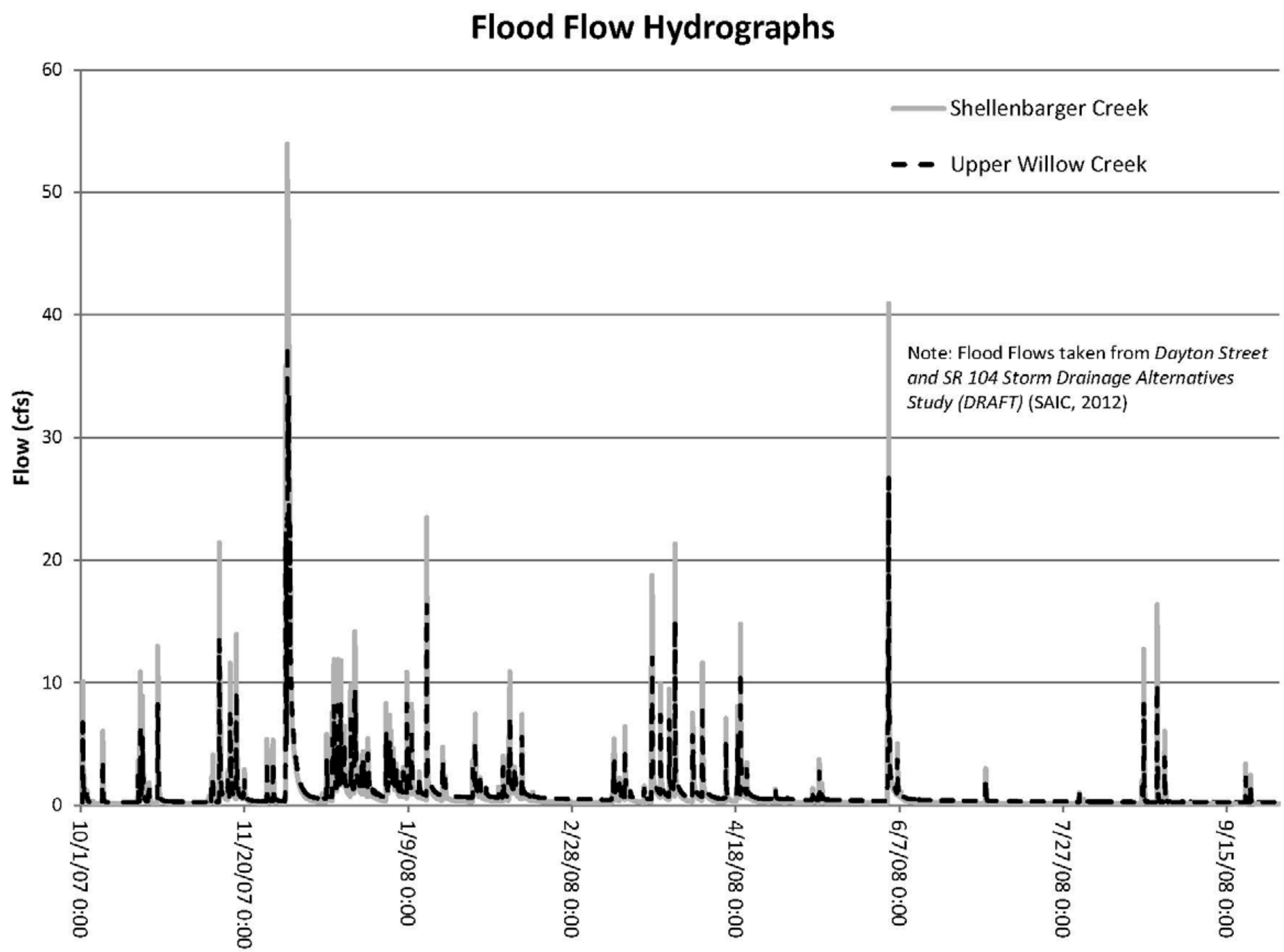
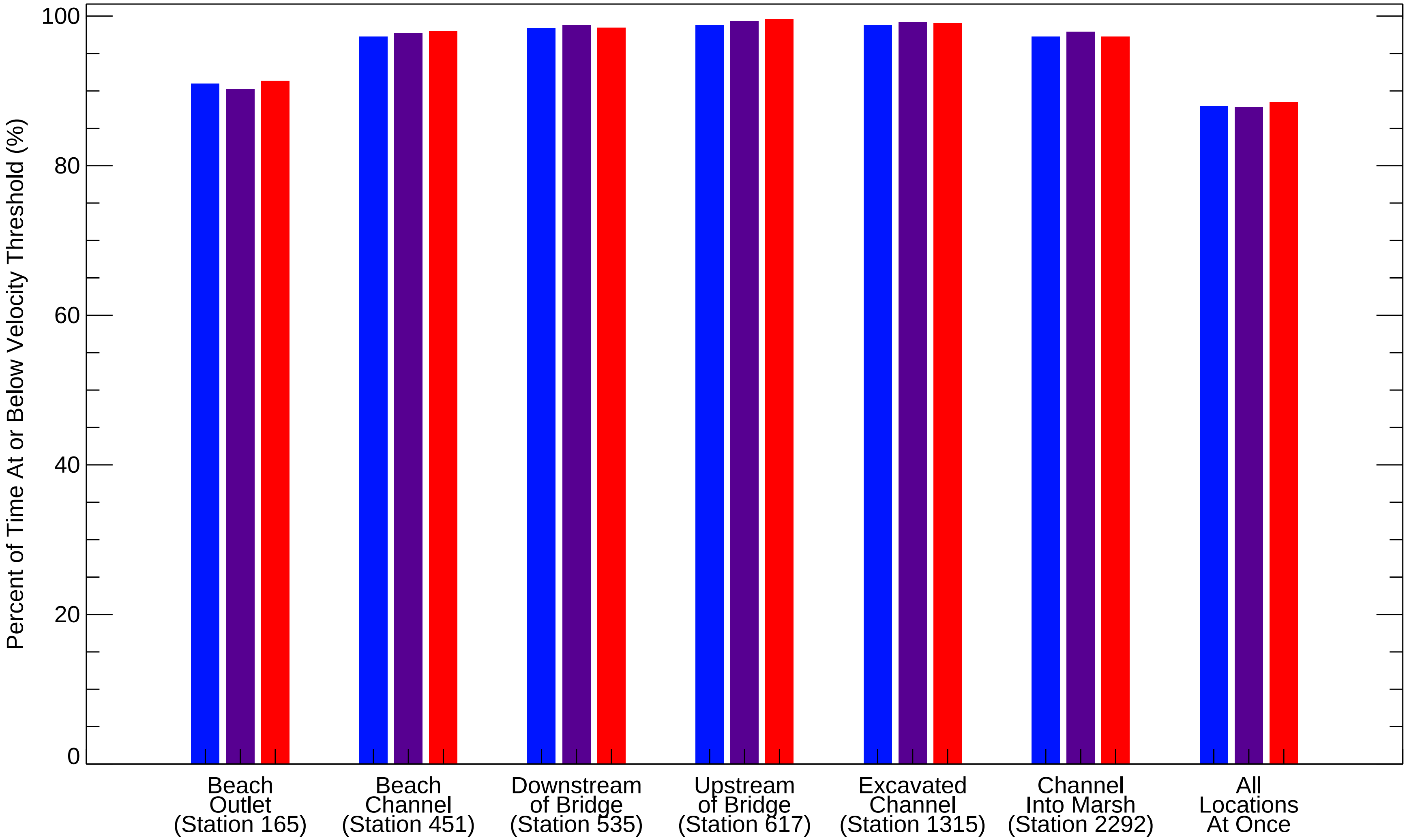
Figure C7
Downstream Tidal Boundary Condition for all Model Simulations
Beach Outlet and Hydrodynamic Evaluation Report
Willow Creek Daylight Final Feasibility Study



ANCHOR QEA

Figure C8
100-Year Flow Hydrographs, Upstream Boundary Condition
Beach Outlet and Hydrodynamic Evaluation Report
Willow Creek Daylight Final Feasibility Study

APPENDIX D
LOW FLOW MODEL SENSITIVITY ANALYSES: IN-FLOW RATE AND MEAN SEA LEVEL



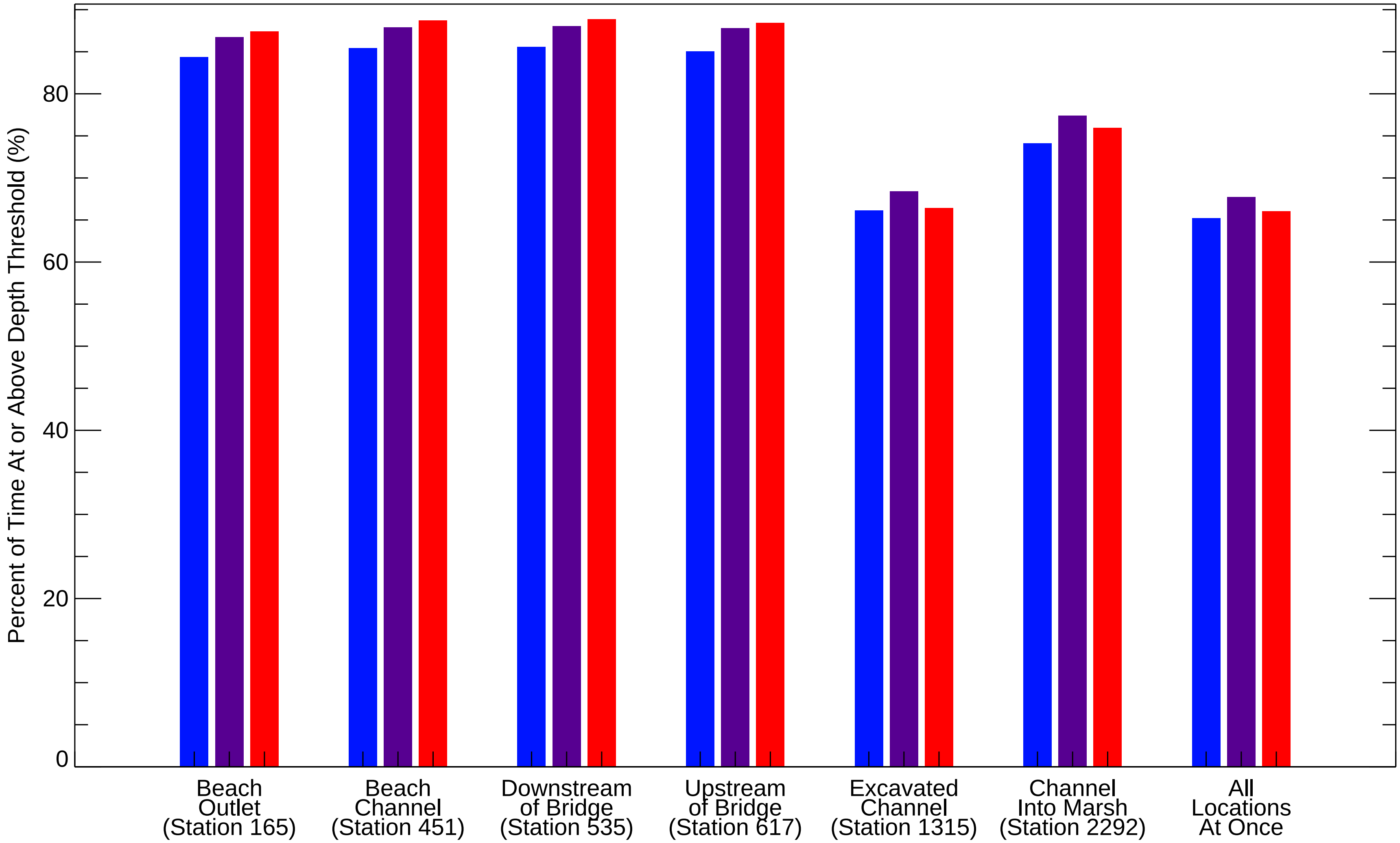
Willow Creek - Beach Outlet Option B

Percent of Time At or Below Velocity Threshold

Velocity threshold: 2 ft/s.

ANCHOR QEA

- 0.64 cfs Inflow Rate
- 0.80 cfs Inflow Rate
- 0.96 cfs Inflow Rate



Willow Creek - Beach Outlet Option B

Percent of Time At or Above Depth Threshold

Depth threshold: 0.8 ft.

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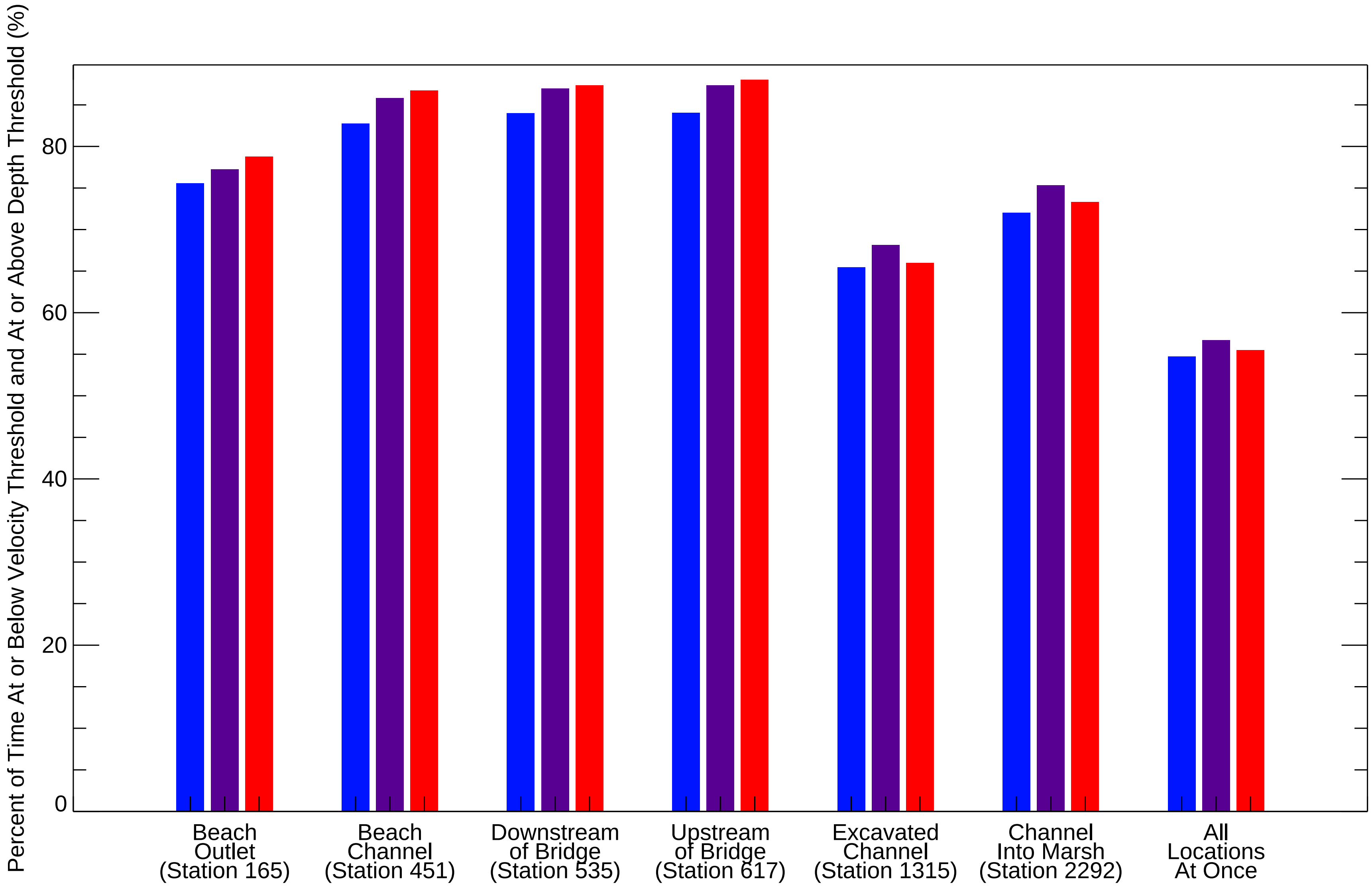


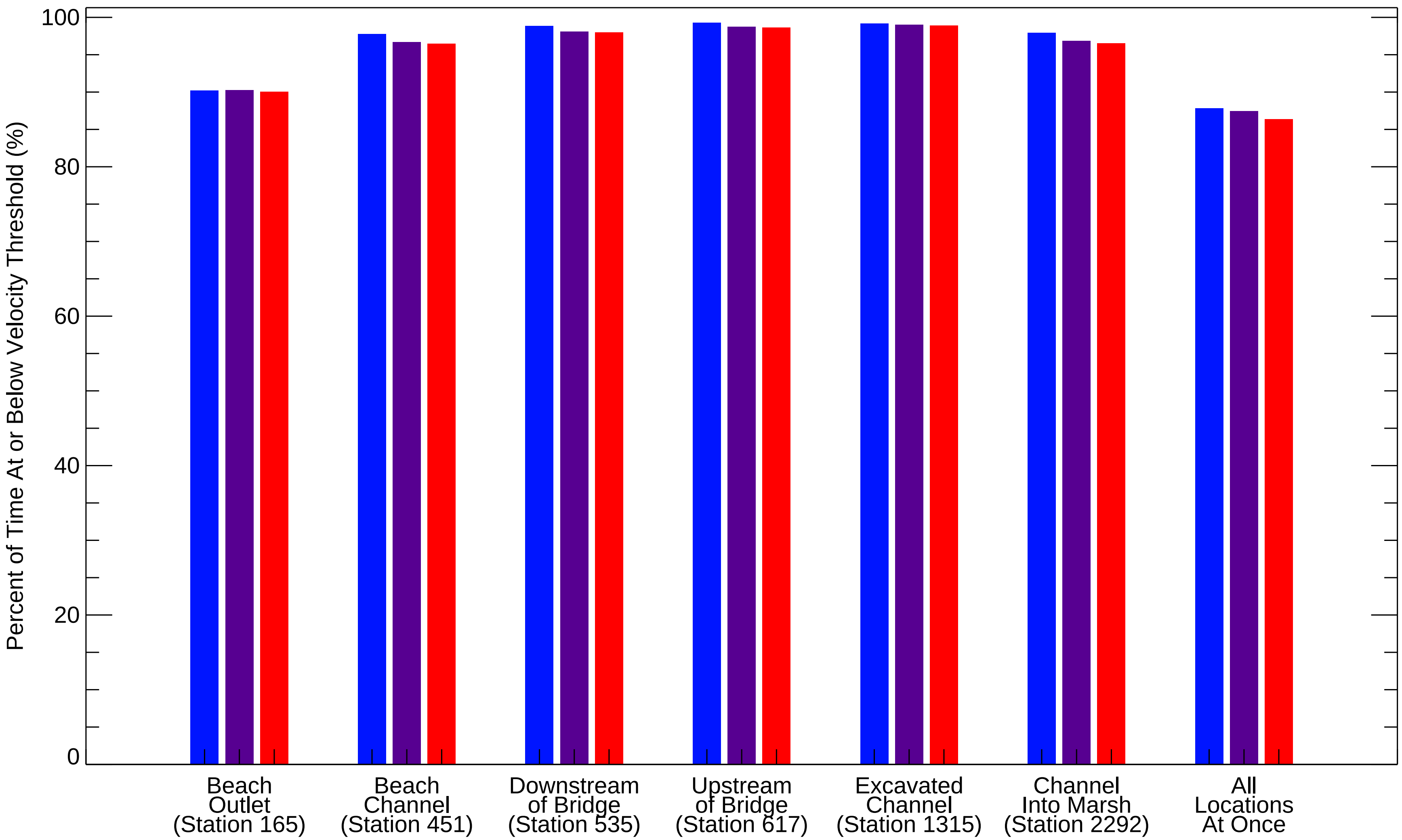
Willow Creek - Beach Outlet Option B

Percent of Time At or Below Velocity Threshold and At or Above Depth Threshold At Same Time

Depth threshold: 0.8 ft. Velocity threshold: 2 ft/s.

ANCHOR QEA

- 0.64 cfs Inflow Rate
- 0.80 cfs Inflow Rate
- 0.96 cfs Inflow Rate



Willow Creek - Beach Outlet Option B

Percent of Time At or Below Velocity Threshold

Velocity threshold: 2 ft/s.

ANCHOR QEA

- Current Sea Level
- 2030 Sea Level
- 2050 Sea Level

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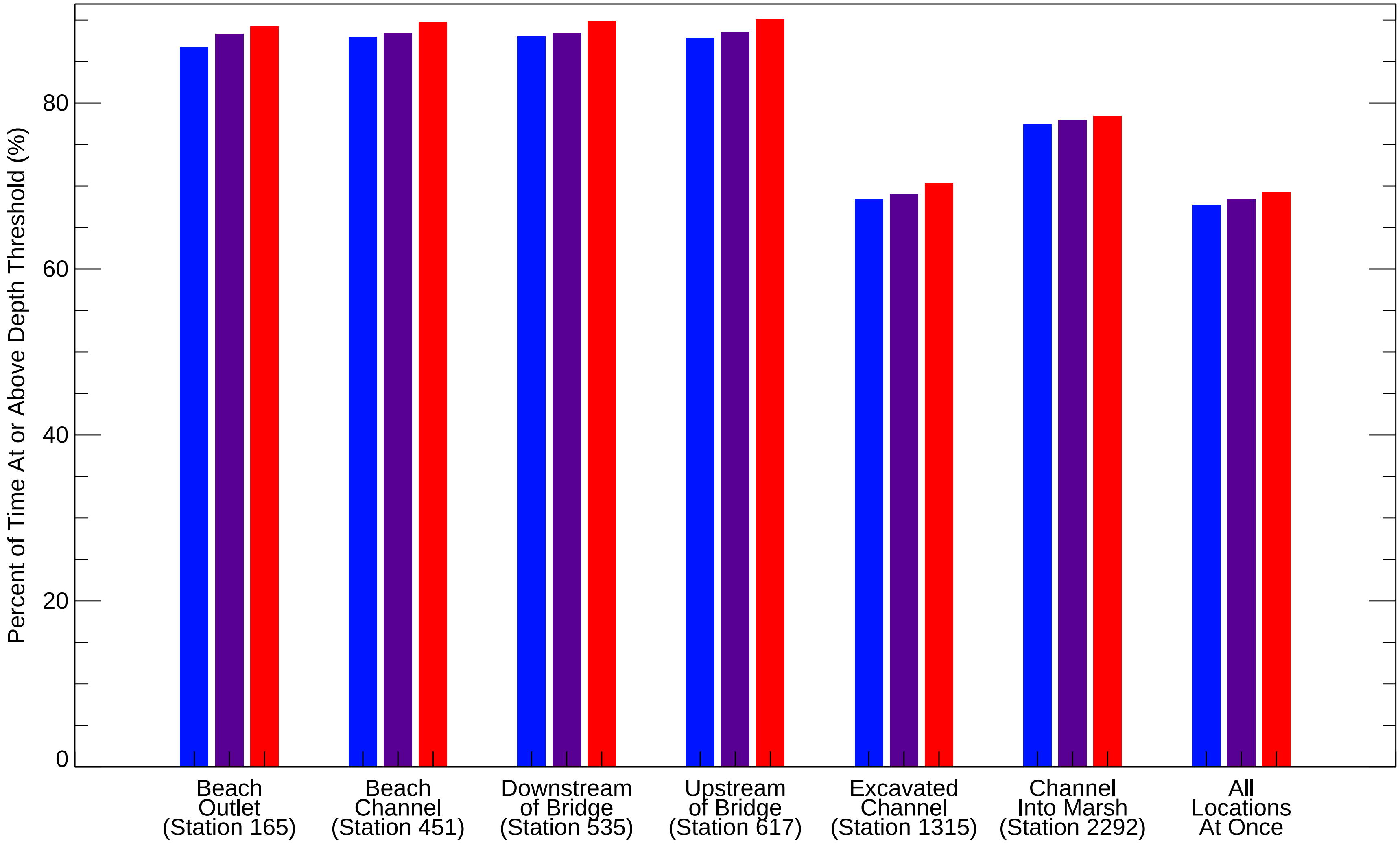


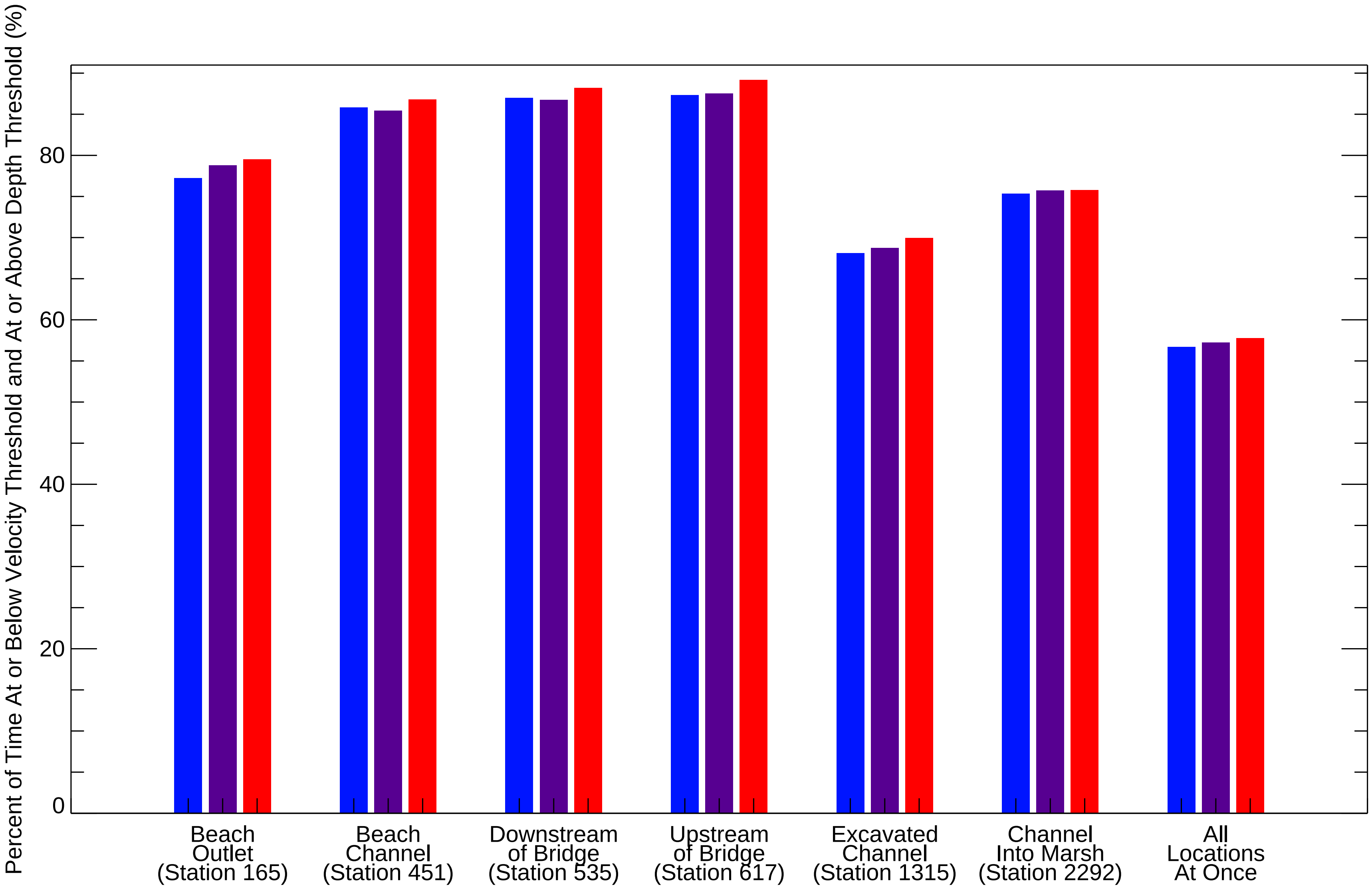
Willow Creek - Beach Outlet Option B

Percent of Time At or Above Depth Threshold

Depth threshold: 0.8 ft.

ANCHOR QEA

- Current Sea Level
- 2030 Sea Level
- 2050 Sea Level



Willow Creek - Beach Outlet Option B

Percent of Time At or Below Velocity Threshold and At or Above Depth Threshold At Same Time

Depth threshold: 0.8 ft. Velocity threshold: 2 ft/s.

ANCHOR QEA

- Current Sea Level
- 2030 Sea Level
- 2050 Sea Level

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APPENDIX E
SUMMARY OF TIDE GATE EVALUATION RESULTS

APPENDIX E: SUMMARY OF TIDE GATE EVALUATION RESULTS

Water Surface Elevation (ft NAVD88)	Storage Volume in Marsh (cf)	Storage Volume Between WSE Intervals (cf)	Volume (cf) Above Gate Closure Elev. to Fill Marsh to Elev. Intervals				Inflow rate (cfs) to Fill Marsh Above Gate Closure Elev. to Elev. Intervals, Based on Duration of Tidal Level Above Gate Closure Elev.			
			Close at 8.0'	Close at 8.5'	Close at 9.0'	Close at 9.5'	Close at 8.0'	Close at 8.5'	Close at 9.0'	Close at 9.5'
8.00	543,136									
8.25	713,909	170,773	170,773				9			
8.50	892,143	178,234	349,007				19			
8.75	1,075,016	182,873	531,880	182,873			30	10		
9.00	1,261,684	186,668	718,548	369,541			40	21		
9.25	1,451,999	190,315	908,863	559,856	190,315		50	31	13	
9.50	1,646,022	194,023	1,102,886	753,879	384,338		61	42	27	
9.75	1,844,047	198,025	1,300,911	951,904	582,363	198,025	72	53	40	18
10.00	2,046,461	202,414	1,503,326	1,154,319	784,778	400,440	84	64	54	37
10.25	2,284,160	237,699	1,741,024	1,392,017	1,022,476	638,138	97	77	71	59
10.50	2,528,392	244,232	1,985,256	1,636,249	1,266,708	882,370	110	91	88	82
10.75	2,779,180	250,789	2,236,045	1,887,038	1,517,497	1,133,159	124	105	105	105
11.00	3,036,425	257,244	2,493,289	2,144,282	1,774,741	1,390,403	139	119	123	129

Duration (hrs): tidal level above gate closure elev.	5	5	4	3	5	5	4	3
Duration (sec): tidal level above gate closure elev.	18,000	18,000	14,400	10,800	18,000	18,000	14,400	10,800

Estimated 100-year Storm Flows	
Peak Flow, cfs	Average Flow, cfs
91	72

APPENDIX F

FISH HABITAT EVALUATION

APPENDIX F.1

ANALYSIS OF PROPOSED FISH HABITAT WITH WILLOW CREEK DAYLIGHTING AND RESTORATION APRIL 2013

CONFLUENCE
ENVIRONMENTAL COMPANY

To: Dave Cline, PE (Shannon & Wilson, Inc.)

From: Paul Schlenger

Date: April 3, 2013

Re: Analysis of Proposed Fish Habitat with Willow Creek Daylighting and Restoration

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The following information is the analysis of fish habitat conditions that would be provided through the proposed restoration options in the City of Edmond's Willow Creek Daylighting project. This proposed fish habitat analysis complements the earlier analysis on existing fish habitat conditions that was included in the alternatives analysis. It is expected that this proposed fish habitat analysis will be used as a section of the project team's preliminary feasibility report.

PROPOSED CONDITIONS

Access to the Marsh

The proposed daylighting of Willow Creek will achieve its primary objective of restoring the connection between Puget Sound and Edmonds Marsh. A surface water connection routed through the City's Marine Park and under the BNSF railroad tracks via a recently constructed bridge will provide water depth and velocity conditions that will enable juvenile salmon, other fish, and other nearshore fauna to enter the marsh system during portions of the tidal cycle. As described below in more detail, the accessibility of fish to the marsh will vary throughout tidal cycles such that there will be times when tidal water will be moving into the marsh which provides the easiest access and times when access would require fish to swim upstream as the marsh system drains. Overall, access to the marsh will be provided during almost every high tide period with some additional access during periods of falling tides.

The restoration design used in the hydrodynamic modeling assumes the thalweg of the proposed entrance channel is +4.0 feet NAVD88 (+6.2 feet MLLW). With this proposed design elevation, it is estimated that water levels in Puget Sound (on an annual basis) will be high enough to inundate at least the lower part of the marsh entrance channel up to 60% of the time if no tide gate is used. If a tide gate is included in the design, the time percentages drop to between 30 to 42% depending on whether the tide gate blocks tidal water at +9 feet MLLW or +10 feet MLLW, respectively. For large portions of these time periods, the tidal inundation will extend up the entire 1,600 foot long entrance channel, thus enabling fish to enter the main salt marsh area while the net direction of water flow is upstream into the marsh.

When the tide is at high slack or a falling tide, the net direction of flow in the entrance channel will be outward to Puget Sound and the accessibility of the marsh to juvenile salmon will be limited to those times when suitable depths and velocities are available in the entrance channel. The National Marine Fisheries Service (NMFS 2011) design criteria for juvenile salmonid upstream passage is a maximum average velocity of 1 foot per second (fps)[1] and minimum water depth of 0.5 feet. To inform the estimated depth and velocity conditions provided by the design, hydrodynamic modeling was conducted for three locations along the entrance channel to the marsh and one in the beach area downstream of the BNSF bridge. The modeling was based on spring tidal data collected by NOAA in lower Willow Creek from May 1 to May 15, 2008 and observed Puget Sound water levels. The analysis indicates that juvenile salmon access to enter the marsh system will be very limited during times when the Puget Sound water levels are not inundating the entrance. Estimated water depths and/or velocities will not meet NMFS design criteria except for an approximately 1 to 2 hour period after slack high tide. Depending on the location within the entrance channel, maximum water velocities out of the marsh are predicted to be between 2 and 3 fps. Water velocities in the restored channel across the beach are estimated to range even higher.

Depending on the restoration design in the beach area, storms may deposit large quantities of sediment and large wood that impacts fish access to the marsh until marsh outflows are sufficient to transport the material away. Such limitations to fish access may be very short-term or more prolonged depending on the design; however, a design that promotes more of the natural processes of sediment movement and large wood accumulation would be more desirable than a more engineered design to minimize any interruptions to access.

Puget Sound Shoreline Function

The proposed daylighting of Willow Creek is expected to improve the rearing conditions along the Puget Sound shoreline for juvenile salmon. By restoring a surface water connection to the marsh, the brackish marsh water and all the prey items and detritus (decaying plant and animal material) will enter the marine nearshore. Currently, all of these inputs enter Puget Sound via a subtidal pipe and may therefore be largely undetected or unavailable to the surface-oriented juvenile salmon rearing and migrating along the shoreline. Regardless of whether the fish enter the marsh system, these inputs can be expected to improve the habitat conditions for juvenile salmon. More prey items will be available in the upper portion of the water column. These prey items will include numerous insects that offer particularly high caloric content and foster rapid fish growth. The brackish water will also provide fish access to lower salinity water to provide a physiological refuge while the juvenile fish continue their acclimation to the marine environment.

Habitat Structure in the Marsh

Habitat conditions for juvenile salmon in the marsh will be improved by the daylighting of the creek and the proposed channel excavation between the creeks and the greater marsh area. The combination of

[1] Calculated based on the 50% exceedance flow.

these actions is expected to expand the portion of the marsh that will support salt tolerant vegetation and improve the connectivity to the Willow and Shellabarger Creek watersheds.

As described in the existing conditions section of this report, the western third of Edmonds Marsh currently supports salt tolerant vegetation and there is an abrupt transition to a dense thicket of cattails with no discernible surface channel to the creeks. The conceptual restoration design is expected to expand the extent of salt marsh vegetation and accessible habitat for fish, including the creek systems draining into the marsh. The daylighting of the creek to Puget Sound will increase tidal exchange within the marsh to more natural levels especially if no tide gate is included in the design. In this way, if a tide gate is not included in the restoration design, then the daylighted creek would be expected to allow high tide inundation elevations to match the water surface elevations along the Puget Sound shoreline, thus alleviating the tidal muting issue noted in existing conditions. This increased tidal exchange and restored channel connections in the marsh will promote the expansion of the area of salt tolerant vegetation species in the marsh.

Salt marshes typically support a wide range of vegetation species with transitions in vegetation community occurring depending on salinity, inundation patterns, and elevation conditions, as well as other environmental parameters. To generally characterize the changes in the vegetation community that can be expected through restoration, anticipated elevations in the marsh were used to estimate the vegetation community that can be supported in different areas in the marsh. General salt marsh vegetation zones based on elevation were applied using vegetation observations in the Snohomish River system (Rice et al. 2012) and other Puget Sound locations[2]. Areas with elevations between the mean tide level and mean high water (MHW) are likely to support low marsh vegetation species, such as Lyngby's sedge (*Carex lyngbyei*), three-square bulrush (*Scirpus americanus*), pickleweed (*Salicornia virginica*), and seashore saltgrass (*Distichlis spicata*). High marsh vegetation will be supported in elevations from MHW to above mean higher high water (MHHW). Common high marsh vegetation species include tufted hairgrass (*Deschampsia* caespitosa), Puget Sound gumweed (*Grindelia integrifolia*), Pacific silverweed (*Potentilla anserina*), American beachgrass (*Elymus mollis*), and common cattail (*Typha latifolia*).

Based on the NOAA tidal data for Edmonds (gage #9447427), the project site's approximate range for low marsh vegetation is between 4.2 and 7.9 feet NAVD88 (6.4 and 10.1 feet MLLW). By this approach, the high marsh range is between 7.9 and 9.7 feet NAVD88[3] (10.1 and 11.9 feet MLLW). Available elevation data in the marsh indicate that much of the western two-thirds of the marsh area provide elevations suitable to support low marsh vegetation species. Compared to existing conditions this is a substantial expansion in area. As a result of this anticipated expansion in the low marsh, there is an equivalent contraction of the high marsh that can be anticipated. It can also be expected that some of

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[2] Additional salt marsh vegetation observations were used from the Skagit River estuary (Hood 2009; Cline unpubl.), Duwamish (Hummel pers. comm.), Nisqually (Belleveau 2012), and Commencement Bay (Thom et al. 2000).
[3] Upper end of range approximated as one foot above MHHW.

the currently vegetated low marsh areas transition to unvegetated tide flats. Overall, the marsh can be expected to shift from a cattail dominated system to a more diverse vegetation assemblage.

With these anticipated changes in the vegetation structure in the salt marsh, a shift in prey production can be expected as different insects and invertebrates are associated with different vegetation types and elevations. The availability of these prey types will be substantially increased through both the fish access to the marsh and the outflow of the marsh into the Puget Sound shoreline. However, the amount of prey production would be expected to be similar between existing and proposed conditions (Cordell pers. comm.).

The restoration design could include the removal of cattails in the central portion of the marsh where the vegetation community is expected to transition from the dense growth of cattails (high marsh) to more of a low marsh plant assemblage. While this could potentially accelerate the natural transition process that is expected, there is some uncertainty to estimating to extent and caution is advised. It is recommended that cattail removal is either: 1) not included in the initial construction, but instead considered as an adaptive management measure to be implemented if the salt marsh does not develop as expected or 2) conducted only in a very limited area along the western extent of the cattail area currently.

Access to Willow and Shellabarger Creeks

The conceptual restoration design includes the excavation of channels to provide clear connections between the creeks and the salt marsh. Since there are no channels currently, this is expected to improve fish access to the creeks. Due to the increase in tidal exchange and flushing of the marsh, there is expected to be sufficient energy for the channels to be sustainable over time.

Contaminant Impacts to Habitat

As described in the existing conditions section, sediment and water quality may be contaminated through stormwater and previous industrial operations. The quality of fish habitat within the marsh should continue to be considered impaired to some degree by chemical contaminants, unless it is demonstrated otherwise that the cleanup remediation actions are comprehensive and complete. Stormwater can also be assumed to continue to introduce contaminants to the marsh system. Since the contaminants levels in the marsh and in the stormwater are not known at this time, the potential effects of contaminants on fish in the marsh are unknown. This potential impact to habitat quality was not considered in this current early feasibility study.

Preliminary Findings and Recommended Next Steps

This preliminary analysis of benefits to fish identified the following findings regarding the proposed restoration project:

- The proposed daylighting of Willow Creek will restore the connection between Puget Sound and Edmonds Marsh and provide conditions that will enable juvenile salmon, other fish, and other nearshore fauna to enter the marsh system during portions of the tidal cycle. Generally, access to the marsh will be provided during almost every high tide period with some additional access for fish during periods of falling tides.
- The distribution of salt tolerant vegetation in the marsh will adjust to the restored tidal exchange. It is expected that there will be a larger areas of both unvegetated mud flat and vegetated low marsh, while the vegetated high marsh area will diminish in size. As a result, there will be a smaller area of cattails (high marsh plant) and more of a variety of low marsh vegetation species.
- Access to the salt marsh will provide juvenile salmon to a productive estuarine prey base. The production of insects and other invertebrates can be expected to shift with the changes in vegetation and tidal inundation, but the amount of prey produced may or may not increase with the restoration.
- Fish access to Willow and Shellabarger creeks will be restored.

It is recommended that subsequent restoration feasibility and design work provide information in the following areas to more comprehensively assess the restoration potential of the site for juvenile salmon:

- Collect more comprehensive and accurate vegetation and elevation data in the marsh to support more detailed understanding of existing conditions and the potential changes through restoration design.
- Conduct hydrodynamic modeling of multiple scenarios in entrance channel upstream and downstream from BNSF railroad bridge to assess potential to reduce water velocities and increase the amount of time the marsh would be accessible to juvenile salmon.
- Determine the extent of contamination in surface and subsurface sediments that are or may become bioavailable through the restoration. Assess the impacts and toxicity to the food web that such contaminants and concentrations may cause.
- Determine the contaminant loading to the marsh through stormwater transport. Assess the impacts and toxicity to the food web that such contaminants and concentrations may cause.

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APPENDIX F.2

ANALYSIS OF PROPOSED FISH HABITAT WITH WILLOW CREEK DAYLIGHTING AND RESTORATION FEBRUARY 2015

To: Dave Cline, PE (Shannon & Wilson, Inc.)

From: Paul Schlenger (Confluence Environmental Company)

Date: February 23, 2015

Re: Analysis of Proposed Fish Habitat with Willow Creek Daylighting and Restoration

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The City of Edmonds hired a consultant team led by Shannon & Wilson to complete a final feasibility evaluation of the proposed restoration of a tidal connection between Edmonds Marsh and Puget Sound. The proposed restoration entails daylighting the lowermost reach of Willow Creek to create a new outlet channel from the marsh, including a section of the channel which would pass through the Marina Beach Park to connect to the marine shoreline. The daylighted portion of Willow Creek is entirely within the intertidal zone. As part of the consultant team, Confluence Environmental Company (Confluence) was tasked with evaluating juvenile salmon habitat and access to the salt marsh. This memorandum describes the findings of the evaluation and includes recommended considerations for the restoration design. This evaluation builds upon previous analysis conducted by Confluence as part of the Willow Creek Daylight Early Feasibility Study (Shannon & Wilson 2013). The Early Feasibility Study includes more introductory information, including: Puget Sound shoreline function, habitat structure in the marsh, and potential contaminant impacts to habitat. This memorandum is intended to provide text that will be incorporated into the final feasibility study report.

BEACH OUTLET CHANNEL EVALUATION

During the early feasibility study (Shannon & Wilson 2013), a range of potential alignments to daylight Willow Creek were evaluated and a preferred alternative was selected. The selected alternative entails constructing a daylighted channel for Willow Creek that will run south adjacent to the BNSF railroad tracks before flowing through an existing railroad bridge and flowing out through the City's Marina Beach Park.

In this final feasibility study, two potential beach outlet channel alignments through the park are being evaluated (see Anchor QEA [2015] for figures showing the alignments). In this evaluation, the term beach channel outlet refers to the portion of the daylighted creek that is downstream of the railroad bridge. Both options are identical upstream of the railroad bridge and have the proposed channel bottom elevation under the railroad bridge at +4 feet NAVD88 (+6.2 feet mean lower low water [MLLW]). Option A would turn the beach outlet channel sharply to the south after flowing under the railroad bridge. This option would flow through the existing dog off-leash area of the park and its length downstream of the railroad bridge would be approximately 450 feet. Option B would be oriented north of Option A and avoid any sharp turns downstream from the railroad bridge. In this option, the channel alignment extends through the existing parking lot and lawn area. The channel downstream of the railroad bridge in Option B is approximately 600 feet long.

The beach outlet channel will provide habitat for juvenile salmon originating from within the Willow Creek and Shellabarger Creek systems, as well as those fish originating from other river and creek systems. Recent research has documented the presence of juvenile salmon using the lower creek and estuaries of creek systems other than the one the fish originated in. Beamer et al. (2004) documented the preferential use of non-natal pocket estuaries by juvenile salmon compared to other marine nearshore habitats. More recently, Beamer et al. (2013) studied juvenile salmon distributions in the lower creek habitats of smaller tributaries and regularly found juvenile salmon in the lower reaches (i.e., lower 600 ft) of non-natal creeks. As a result of this increasing understanding of juvenile salmon utilization of pocket estuaries and lower creek habitats, restoration of these habitats has been a focus of nearshore restoration efforts throughout Puget Sound.

The beach outlet channel will provide two main functions for juvenile salmon: 1) entrance corridor to the entire marsh system, and 2) habitat for species using this portion of the project. A comparison of how the two beach outlet channel options provide these functions is described below.

In considering juvenile salmon utilization of the overall restoration project, the beach outlet channel is particularly important because it forms the entrance point for juvenile salmon access into the channel and marsh system. Fish access from Puget Sound into the restored habitats will be dependent upon the extent to which the restored outlet channel stays open. Given the adjacent infrastructure constraints as well as onsite constraints associated with providing areas for recreational and habitat purposes, either beach outlet channel option will present design challenges for maintaining juvenile salmon access while also avoiding or minimizing the use of rock. Shoreline sediment transport and log accumulation are natural processes along the marine nearshore, but both can affect the accessibility of the restored habitats. Net shore-drift of sediment along this stretch of the Puget Sound shoreline is from south to north. This sediment transport process would naturally tend to push a creek channel to the north. From this perspective, the more northerly outlet alignment provided by Option B is more appropriate given the natural processes acting on the site and is more likely to be sustainable while avoiding or minimizing the use of rock.

For a number of reasons, beach channel outlet Option B would be expected to provide better juvenile salmon habitat downstream of the railroad bridge. First, the outlet location of Option B would be in a more natural channel alignment and would provide a better opportunity to design it to work with natural processes while using less rock than the Option A channel. The sharp turn that Option A would take just downstream of the bridge is one specific area already identified as likely to require rock armoring to keep in place. Second, Option B would be longer and provide more estuarine habitat for juvenile salmon to utilize. For juvenile salmon migrating along the shoreline, the beach outlet channel habitats would be the first part of the Willow Creek/Edmonds Marsh system they encounter. While a subset of the juvenile salmon will move further into the creek and marsh system, there will be other juvenile salmon that only utilize the beach outlet channel portion of the site. The additional habitat will provide more estuarine habitat for the fish to use. Third and finally, the Option B alignment would be expected to provide fewer disturbances to fish than the Option A alignment. The rationale for this is that Option A would flow through the existing off-leash dog area. Dogs would be more likely to enter the creek throughout the spring and early summer period of the year when most juvenile fish may be present. Dogs would also be more likely to damage riparian vegetation which would otherwise form a visual barrier between the creek and adjacent park areas. Option B would run through the existing park area and could result in people entering the creek; however, that is less likely to happen except during the summer when fewer juvenile salmon would be expected to be present. The potential disturbance associated with the options may change in the future based on the outcome of the park master planning work that is underway.

Based on the considerations described above, beach outlet channel alignment Option B provides better habitat and access for juvenile salmon. The design will need to focus on the alignment, channel geometry, and materials that are conducive to providing regular access to the channel and marsh system, while also providing productive rearing habitat and minimizing or avoiding the use of large rock. To the extent possible given the park needs, the beach outlet channel could be designed to provide better habitat if there is space available for channel movement over time and side slopes that are not steep.

JUVENILE SALMON ACCESS TO EDMONDS MARSH

The primary ecological objective of the proposed daylighting of Willow Creek is to restore the connectivity between Edmonds Marsh and Puget Sound for water, fish, invertebrates, and organic matter contributing to the marine food web. This will be achieved by daylighting the lowermost portion of Willow Creek to provide a surface water connection between the marsh and the marine nearshore. An important aspect of the connectivity is providing flow conditions that support juvenile salmon passage into the daylighted channel and marsh habitats

Semi-diurnal tidal cycles provide continuous changes in water surface elevations in the nearshore areas with two daily high tides and two low tides. These changes in water surface elevations throughout the tidal cycle result in corresponding changes in flow velocities and channel depths as water inundates and drains marsh systems. In barrier estuaries with substantial freshwater sources, such as Edmonds Marsh, there is additional depth and flow variability resulting from runoff from upland areas. Variations in the inundation of the outlet channel and the associated flow velocities result in naturally intermittent access to barrier estuary habitats for juvenile salmon migrating along marine shorelines.

When the tide is rising, the direction of water flow is into these barrier estuary systems. Thus, during rising tides, fish can actively migrate into the areas or passively move with the water as it enters the habitats. In contrast, when the tide is falling, the direction of flow is out of the barrier estuary system and requires fish to swim upstream to access the marsh habitats. As a result, juvenile salmon movement into marshes occurs more often during the rising tide as fish move with the water. Research by Hering et al. (2010) documented that approximately 80% of juvenile salmon movements in a tidal channel were in the direction of tidal currents.

Fish passage requirements are less clear in tidal areas compared to freshwater streams (WDFW Water Crossing Design Guidelines by Barnard et al. 2013). The law requires that fish passage is provided at manmade barriers, such as water crossings (RCW 77.57.030), but it is not clear how efficiently or continuous over time that passage needs to be provided (Barnard et al. 2013). The complication of fish passage in tidal environments is that access to or through intertidal habitats is naturally intermittent because of tidal processes.

Allowable depth and velocity criteria for juvenile salmon in tidal systems have not been explicitly developed by WDFW, instead criteria for adult trout (>6 inches long) established in WAC 220-110-070 are the most applicable. The fish passage maximum velocity criteria are presented in Table 1. The minimum depth criterion is 0.8 ft.

Table 1. Most Applicable Fish Passage Velocity Criteria

Culvert Length	Maximum Velocity
10 – 100 ft	4 ft/s
100 – 200 ft	3 ft/s
>200 ft	2 ft/s

Maximum allowable velocities for fish passage range between 2 and 4 ft/s depending on the length of the water crossing (i.e., bridge or culvert). Other research reported in Barnard et al. (2013) indicates that maximum velocities as low as 1 ft/s may be more appropriate for small fish such as juvenile salmon. Barnard et al. (2013) report the following:

> "Based on an evaluation of juvenile passage through culverts conducted by P. D. Powers (Powers and Bates 1997), the recommended design velocities for fry and fingerlings are 1.1 and 1.3 fps respectively. Fry are spring-migrating juveniles generally less than 60 mm in fork length. Fingerlings are fall-migrating fish, generally greater than 60 mm in fork length."

Barnard et al. (2013) also notes that the Muckleshoot Indian Tribe reports that the maximum velocity for fish passage through culverts was found to be 1 ft/s.

In the Willow Creek daylighting project, there will be one or two water crossings. One is the railroad bridge separating the lower creek from the beach. The other is a possible floodgate[1] that may be included in the design to avoid flooding. The floodgate would be approximately 800 feet upstream from the railroad bridge. Both possible water crossings would be much shorter than 100 feet long; therefor,

[1] The term floodgate is used instead of tidegate because if it were included in the design, the floodgate would only close at elevations above mean higher high water (MHHW). These closures would only be for flood control purposes. MHHW at the site is +9.1 ft NAVD 88 (+11.3 ft MLLW) (Anchor QEA 2015).

the maximum velocity criterion is 4 feet per second (ft/s). However, as noted above there are other observations suggesting velocities as low as 1 ft/s would be more typically utilized.

Although fish passage is naturally intermittent in barrier estuary systems such as Edmonds Marsh, it is necessary – and the primary ecological objective – to provide adequate fish passage past the railroad bridge (a water crossing) and past a one is included in the design, as well as the entire daylighted channel alignment.

The suitability of passage conditions for juvenile salmon moving from Puget Sound into Edmonds Marsh was evaluated using depth and velocity predictions from a one-dimensional (1-D) hydrodynamic model prepared for the project (Anchor QEA 2015). The hydrodynamic model was prepared for a two-week spring period (May 1-14, 2008) which is considered representative of conditions during the spring rearing period. The two week timeframe allowed the analysis to encompass one spring and neap tide cycle. The model was run assuming flows from Willow and Shellabarger creeks were 0.8 cfs combined. Throughout the analysis period, depths and velocities were estimated in 15 minute intervals.

The analysis was conducted for two scenarios: with and without a floodgate in the Willow Creek channel. The floodgate scenario is described fully in Anchor QEA (2015). The floodgate would occur approximately 800 feet upstream of the railroad crossing (station 1402). The floodgate would consist of three culverts, one of which is lower than the other two (one at +4.0 ft NAVD 88 and two at +5.5 ft NAVD 88) in order to allow more fish passage during low flow conditions. The floodgate would be open when water levels are below +9.5 ft NAVD 88 (+11.7 ft mean lower low water [MLLW]). The floodgate closure at those water levels is intended to protect SR-104 and Dayton Street areas from tidal flooding during extreme tide and storm surge conditions.

The analysis indicated that during 26% of the time, water will be flowing into the marsh with the rising tide and minimum depths of 0.8 ft will be provided throughout the entire route to the marsh (Table 2). That translates to approximately 3 hours per tidal cycle, flows throughout the daylighted channel will allow for fish to migrate into the marsh without having to swim upstream. In presenting the results of the overall evaluation of fish passage, the percentages are described based on the model results compared to the maximum velocity criteria indicated. Minimum depths of >0.8 ft were available during all times that were considered fish passable. In the no floodgate scenario, maximum velocities of <4 ft/s will be provided during 65% of the time. Fish will be able to access the marsh and encounter no velocities higher than 2 ft/s during 57% of the time. The percentage of time drops to 38% when considering maximum velocities of 1 ft/s.

Suitable conditions for fish passage can also be provided with a floodgate, although the percentage of time is reduced compared to the no floodgate scenario. Due to the constricted release of water through the floodgates, some increases in water velocities is expected to allow the marsh to drain. Considering a maximum velocity of <4 ft/s, a floodgate would have minimal effect on fish passage as the criteria would be achieved 63% of the time (compared to 65% with no floodgate). However, more substantial reductions in the suitability of conditions are expected to occur when evaluating maximum velocities of

3 ft/s and 2 ft/s (47% and 36% of time, respectively). The percentage of time in which maximum velocities are <1 ft/s is 30% in the floodgate scenario.

Table 2. Percentage of Time Providing Fish Passage

Criteria	No Floodgate	With Floodgate
Incoming tide and minimum depth >0.8 ft	26%	26%
Maximum velocity <4 ft/s and minimum depth >0.8 ft[a]	65%	63%
Maximum velocity <3 ft/s and minimum depth >0.8 ft	65%	47%
Maximum velocity <2 ft/s and minimum depth >0.8 ft	57%	36%
Maximum velocity <1 ft/s and minimum depth >0.8 ft	38%	30%

Note: Most applicable criteria per WAC 220-110-070

This analysis shows that depth and velocity conditions allowing juvenile salmon to move into the daylighted creek and marsh will be regularly provided. Based on this analysis, it is reasonable to expect that some juvenile salmon migrating along the Puget Sound shoreline will enter the daylighted creek and marsh system. Given the length of the daylighted channel, not all fish entering the daylighted creek would be expected to move all the way up to the marsh. However, juvenile salmon would be expected to use the pocket estuary and lower portion of the creek. These fish would benefit from the additional rearing habitat and productive prey resources entering these areas from the marsh. In addition, the plant material entering Puget Sound from the marsh would contribute to the food web and increase nearshore productivity near the creek mouth.

SUMMARY OF FINDINGS AND RECOMMENDED DESIGN CONSIDERATIONS

This analysis of the beach outlet channel and fish passage conditions into Edmonds Marsh made the following findings regarding the proposed restoration project:

- The beach outlet channel between the main portion of the marsh and the beach provides important rearing habitat for juvenile salmon while also functioning as a migratory corridor for the fish. The outlet channel can provide highly functional habitat for rearing fish and is an important component of the overall benefits to juvenile salmon.
- Beach outlet channel Option B which would run toward the northern part of the City's existing Marina Park is the better beach outlet channel alignment for juvenile salmon because it would provide more habitat for fish and is in a more sustainable and natural location than an outlet to the south.

- The proposed daylighting of Willow Creek will restore the connection between Puget Sound and Edmonds Marsh and provide conditions that will enable juvenile salmon, other fish, and other nearshore fauna to enter the marsh system during portions of the tidal cycle.
- In the scenario with no floodgate, suitable conditions for juvenile salmon passage will be provided throughout the entire channel length to the marsh from 38% to 65% of the time depending on maximum velocities evaluated.
- Juvenile salmon will be able to move with the water flowing into the marsh and have suitable water depths during approximately 26% of the time. This equates to approximately 3 hours in each tidal cycle.
- More fish access to the marsh is provided in a scenario without a floodgate. Based on the floodgate configuration evaluated, having a floodgate in the channel will increase velocities and there will be more time in which velocities are between 2 and 4 ft/s.

The following considerations are highlighted for incorporation into future design work at the site:

- The beach outlet channel design will need to focus on alignment, channel geometry, and materials that are conducive to providing regular access to the daylighted channel and marsh system, while also providing productive juvenile salmon rearing habitat and minimizing the use of large rock.
- To the extent possible given the park needs, the beach outlet channel could be designed to would provide better habitat if there is space available for channel movement over time and side slopes that are not steep.
- Regardless of the beach outlet channel alignment, dogs should not be allowed to enter the channel. If the channel goes through a dog off-lease area, it is recommended that fencing or other materials are used to prevent dogs from accessing the creek. Restricting people from entering the creek would also benefit fish and the ecological conditions in the creek.
- A vegetated buffer along the outlet channel is important as it will provide multiple functions. A vegetated buffer would reduce behavioral disturbance to fish and other animals in the stream from the activities of park visitors. Riparian vegetation in upland areas along the beach outlet channel would also be beneficial for providing prey inputs, shade, and separation from park visitors.
- Refinement of the channel cross-section geometry to provide a low flow channel can create more suitable fish habitat during the fall tide and low flows. Such refinement should consider the resulting effects on depth and velocity to work toward a design that maximizes fish passage and fish habitat within the channel over a range of flow conditions.
- Instream wood should be included in the outlet channel design to provide habitat structure and lower velocity areas for juvenile salmon. These elements will improve the fish passage conditions for the fish, as well as improve the rearing habitat quality in the channel.
- To the extent possible along the entire alignment, riparian vegetation should be included in the design with a focus on providing shade to the channel. Riparian vegetation overhanging the channel will provide cover for fish from birds and separate the channel from activities on adjacent properties.

- If space allows given other constraints, habitat in the outlet channel would be improved if some sinuosity could be incorporated so the channel is not a prolonged straight channel. If the channel is shifted to the east, there could be more room to provide a vegetated riparian buffer.
- Sediment loads into the daylighted channel should be considered in the channel design. Design techniques should be incorporated to transport sediment through the system in order to reduce the potential for excessive sedimentation in the channel, including the beach outlet portion of the channel.
- In Edmonds Marsh, some removal of cattails and other dominant freshwater vegetation should be considered to facilitate the transition of the marsh to more of a salt marsh. Freshwater vegetation currently encroaches on areas in the marsh where more salt water is expected by daylighting Willow Creek.

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APPENDIX G

TOPOGRAPHIC SURVEY

Willow Creek Daylight Project
Edmonds, Washington

WILLOW CREEK DAYLIGHT
TOPOGRAPHIC SURVEY

December 2015   21-1-12393-409

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIGURE G1

Filename: I:\WIP\21-1\12393 Willow Creek Daylight\CAD\03. BASE_DWG\Grading Base.dwg   Date: 12-18-2015   Login: cmh

APPENDIX H

CULTURAL RESOURCES ASSESSMENT

Cultural Resource Consultants, Inc.

TECHNICAL MEMO 1405F-2

DATE: September 19, 2014

TO: David Cline
Shannon & Wilson, Inc.

FROM: Margaret Berger, Project Archaeologist
Glenn Hartmann, Principal Investigator

RE: Cultural Resources Assessment, Willow Creek Daylighting Project, Edmonds, Snohomish County, WA

The attached short report form constitutes our interim report for the above referenced project. No previously recorded cultural resources are in the project location, and the majority of the project is considered to have a low probability to impact archaeological sites. Additional subsurface investigations are recommended in the eastern part of the Park Survey area, historically the base of a sand spit. Please contact me should you have any questions about our findings and/or recommendations.

435 Ericksen Avenue NE, Suite 103
PO Box 10668, Bainbridge Island, WA 98110
Phone 206 855-9020 - info@crcwa.com

CULTURAL RESOURCES REPORT COVER SHEET

Author: Margaret Berger

Title of Report: Cultural Resources Asessment, Willow Creek Daylighting Project, Edmonds, Snohomish County, WA

Date of Report: September 19, 2014

County(ies): Snohomish   Section: 23 & 26   Township: 27 N Range: 3 E

Quad: Edmonds West, WA   Acres: ca. 15

PDF of report submitted (REQUIRED) ☒ Yes

Historic Property Inventory Forms to be Approved Online? ☐ Yes ☒ No

Archaeological Site(s)/Isolate(s) Found or Amended? ☐ Yes ☒ No

TCP(s) found? ☐ Yes ☒ No

Replace a draft? ☐ Yes ☒ No

Satisfy a DAHP Archaeological Excavation Permit requirement? ☐ Yes # ______ ☒ No

Were Human Remains Found? ☐ Yes DAHP Case # ______ ☒ No

DAHP Archaeological Site #:

____
____
____
____
____
____
____
____
____

- Submission of PDFs is required.
- Please be sure that any PDF submitted to DAHP has its cover sheet, figures, graphics, appendices, attachments, correspondence, etc., compiled into one single PDF file.
- Please check that the PDF displays correctly when opened.

Management Summary

On behalf of the City of Edmonds, Shannon & Wilson, Inc. requested that Cultural Resources Consultants, Inc. (CRC) prepare a cultural resources assessment for the Willow Creek Daylighting Project in Edmonds, Snohomish County, Washington. This report addresses potential impacts to cultural resources in the project location and presents the results of archaeological survey including monitoring of geotechnical testing in the Park Survey area of the project. This assessment was developed to identify any previously recorded archaeological or historic sites and evaluate the potential for the proposed work to affect cultural resources. All previously recorded archaeological and historic sites are located outside the proposed work area, and no further work is recommended in the Stormwater Outfalls and Berm Survey, Marsh Channel Survey, or Daylight Channel Survey areas. Archaeological monitoring of ground-disturbing work that may intersect native sediments is recommended in the portion of the Park Survey area situated on a former spit (see Attachment B).

1. Administrative Data

Report Title: Cultural Resources Assessment, Willow Creek Daylighting Project, Edmonds, Snohomish County, WA

Author (s): Margaret Berger

Report Date: September 19, 2014

Location: The project is located on an assemblage of parcels near Point Edwards in Edmonds, Washington, including Port of Edmonds property (parcel 27032300411300), Unocal property (parcel 2703260010240), and City of Edmonds property (parcels 27032300409400 and 27032600200300 and adjacent beach) (Snohomish County Assessor's Office 2014). The project is located is in the NW¼ of the NE¼ and NE¼ of the NW¼ of Section 26, and the SW¼ of the SE¼ of Section 23, Township 27 North, Range 3 East, Willamette Meridian (Figure 1).

USGS 7.5' Topographic Map (s): Edmonds West, WA (1981)

Total Area Involved: ca. 15 acres

Objective (Research Design): CRC developed this assessment as a component of preconstruction environmental review with the goal of ensuring that no cultural resources are disturbed during construction of the proposed project by determining the potential for any as yet unrecorded cultural resources within the project area. CRC's work was intended, in part, to assist in addressing state regulations pertaining to the identification and protection of cultural resources (e.g., RCW 27.44, RCW 27.53) and compliance with the National Environmental Policy Act (NEPA); the State Environmental Policy Act (SEPA); and Section 106 of the National Historic Preservation Act (NHPA), as amended, and implementing regulations (36 CFR 800). The Archaeological Sites and Resources Act (RCW 27.53) prohibits knowingly disturbing archaeological sites without a permit from the Washington State Department of Archaeology and Historic Preservation (DAHP), and the Indian Graves and Records Act (RCW 27.44) prohibits knowingly disturbing Native American or historic graves. Under Section 106, agencies involved in a federal undertaking must take into account the undertaking's potential effects to historic properties (36 CFR 800.16(l)(1)). Under SEPA and NEPA, agencies must consider the environmental consequences of a proposal, including impacts to cultural resources, before taking action.

Assessment methods consisted of review of available project plans and related information provided by Shannon & Wilson, Inc., local environmental and cultural information, and historical maps. CRC also contacted cultural resources staff at Muckleshoot Indian Tribe, Snohomish Tribe, Snoqualmie Nation, Stillaguamish Tribe, Swinomish Tribe, Suquamish Tribe, and Tulalip Tribes to inquire about project-related cultural information or concerns (Attachment A). This assessment utilized a research design that considered previous studies, the magnitude and nature of the undertaking, the nature and extent of potential effects on historic properties, and the likely nature and location of historic properties within the area of potential effect (APE), as well as other applicable laws, standards, and guidelines (per 36CFR800.4 (b)(1)).

<u>Recorded Cultural Resources Present:</u> Yes [ ] No [x]
No archaeological or historic sites have been previously recorded within the project.

<u>Project Background:</u> On behalf of the City of Edmonds, Shannon & Wilson requested a cultural resources assessment of the Willow Creek Daylighting Project in Edmonds, Snohomish County, Washington. The project is in the Final Feasibility Study phase. The goal of the overall project is to restore tidal inflow and to improve fish passage conditions into Edmonds Marsh, by daylighting Willow Creek. This is expected to entail dredging tidal channels in Edmonds Marsh, replacing outfall culverts on the north side of the marsh, excavating a daylight channel and removing an existing outfall inlet on Unocal property, and excavating a beach channel and abandoning the existing Willow Creek outfall at Marina Beach Park.

The Early Feasibility Study prepared for the project identified the Edmonds Marina Beach Park alignment (Alignment Alternative 1) as the preferred alternative. A described in that report, this alternative includes

> constructing a new channel across the beach park area from the BNSF railway. Depending on the alignment, the length of the park beach channel would vary from 350 feet if located in the dog park area to the south, or up to 700 feet if located north through the existing parking lot and grassy areas of the park. Appropriate habitat features would be included to make the channel both biologically functional and aesthetically pleasing to park users. For example, instream wood, step pools, and riparian vegetation would improve flow complexity and cover conditions in the channel…
>
> At the BNSF railway, the daylighted creek would cross under the railroad embankment through a pair of two bridges. These bridges were installed as an agreement between BNSF and Sound Transit, and federal and local resource agencies for Sound Transit's plans for a third rail improvements between Seattle and Everett… Additional research and coordination with BNSF, Sound Transit,

and WSDOT would be required to determine the structural and hydraulic sufficiency of the existing structure. If not adequately designed, retrofit and modification may be necessary.

Upstream from the BNSF bridges, Willow Creek would be daylighted. The exact configuration of the daylight channel is unknown. In its simplest form, the channel would be 700 feet long flowing straight next to the BNSF railway and on the Unocal property… For the purposes of this study, we evaluated a straight channel daylighting on the beach, passing underneath the railroad, and then following a relatively straight alignment to the existing confined channel. The plan form configuration of the channel may be revised in later phases of feasibility and design work, depending upon the availability of the Unocal property for realignment. [Shannon & Wilson 2013:21–22]

For purposes of this assessment, the area of potential effects (APE) to cultural resources is understood to be the locations of the proposed actions as described above and depicted in Figures 1 and 2.

2. Background Research

Background research was conducted in June and September 2014.

Archival Sources Checked:

DAHP WISAARD	Recorded sites are not located in or adjacent to the project location.
Web Soil Survey	Soil units mapped within the project are Mukilteo muck and Urban Land (USDA NRCS 2014).
Library	Various historical, archaeological, and ethnographic references at the Seattle Public Library and in CRC's library.

Environmental and cultural context information for this project is derived from relevant published reports, articles, and books (e.g., Cameron 2005; Nelson 1990; Suttles and Lane 1990); historical maps and documents (e.g., USCS 1872; USSG 1860); geological and soils surveys (e.g., USDA NRCS 2014; WA DNR 2014); ethnographic accounts (e.g., Snyder 1968; Waterman ca. 1920, 2001); and archaeological reports (e.g., Bard and McClintock 1996; Shantry et al. 2011) in the local area. The following discussion of project area geology, archaeology, history, and ethnography incorporates context information from CRC's prior work in the Edmonds area by reference (e.g., Kelly 2012).

Environmental Context: The project area is geographically situated within the Willamette-Puget Lowland physiographic province, a province that is characterized by the wide "trough" between the Coast and Cascade Ranges (McKee 1972:290). The project is within the *Tsuga heterophylla* (Western Hemlock) vegetation zone typical of much of lowland western Washington (Franklin and Dyrness 1973). Native plants in this zone include dense forests of western hemlock, western red cedar, and Douglas fir with dense understory of Oregon grape, salal, snowberry, and sword fern. Vegetation on the upland part of the project consists of lawn grass and other plantings; the beach is sandy to cobbly and vegetation includes eelgrass and algae. The project is on the eastern shoreline of Admiralty Inlet. Willow Creek flows through Edmonds Marsh and across the project area through a culvert into Admiralty Inlet.

The geomorphology of the project area was shaped in part by glacial events that took place during the Late Pleistocene following the advance of several glaciations that originated in Canada and extended between the Cascade and Olympic mountain ranges into the Puget Lowland (Downing 1983; Kruckeberg 1991). At the end of the Fraser Glaciation, glacial advance and retreat scoured and compacted underlying geology while meltwaters carved drainage channels and deposited till and outwash over the Puget Lowland (Booth et al. 2003; Thorson 1981). The interplay of Holocene climate change, sea level change, and seismic activity, along with related geomorphic processes such as stream incision, bluff erosion, and alluvial deposition, further shaped the project area landscape. Sea levels began to rise rapidly after 8000 BP and then rates of increase slowed in the late Holocene. Sea level was within several meters of modern sea level by about 5000 BP and within one meter by about 1000 BP (Eronen et al. 1987). The project is in the Southern Whidbey Island Fault Zone. Stratigraphic markers of subduction-thrust earthquakes and the uplift, subsidence, and deformation that accompany them have been observed at multiple locations on Puget Sound (Troost and Stein 1995). Evidence of seismic deformation nearest to the project comes from sediment cores collected from two marshes on southern Whidbey Island, which show uplift north of a fault strand and subsidence south of it between 2,900 and 3,400 years ago (Johnson et al. 2004).

Nineteenth and twentieth century developments have altered the landscape of the project. Historically, Edmonds Marsh was a barrier or pocket estuary marsh with a sand spit (USCS 1872; USGS 1895; USSG 1860). The sand spit had formed due to longshore transport of sediments eroded from bluffs to the south (Downing 1983). Pocket estuaries are partially enclosed bodies of marine water connected at least part time to a larger estuary, and diluted by freshwater (Pritchard 1967, in Shipman 2008:20). Barrier estuaries typically are formed as shoreline features such as embayments, lagoons and ponds that develop behind coastal geologic and depositional features and include sand spits, barrier embayments and coastal inlets (Collins and Sheikh 2005; Shipman 2008).

Edmonds Marsh has been estimated to have been more than 100 acres in size historically (Gersib 2008, in Shannon & Wilson 2013), extending from Point Edmonds north to Brackett's Landing, where the intersection of Main Street and SR 104 is now. The present-day marsh area west of SR 104 is approximately 27 acres (Shannon & Wilson 2013:3). Prior to placement of fill to support industrial and commercial development on the Edmonds waterfront, features of the marsh included the sand spit near what is now the central part of the Port of Edmonds Marina, as well as tidal channels, streams, a lagoon, and a wetland. Willow Creek historically meandered through the marsh, and was relocated to its current channel in the 1950s (CH2M HILL 2004:3.41).

The surface geologic units mapped for the project location are Qf (artificial fill, including modified land) and Qa (Quaternary alluvium) (WA DNR 2014). Minard (1983) maps the Park Survey and Daylight Channel Survey areas as modified land, which occurs on the shoreline where land has been modified by cutting, filling, and riprapping, particularly in association with the railroad bed. In the Park Survey area, Minard (1983) notes that "the dock area at, and north of, Edwards point has been dredged and filled." The Marsh Channel Survey and Stormwater

Outfalls and Berm Survey areas contain Holocene marsh, which is described as "mostly fine-grained, organic-rich alluvium, probably overlying tidal-flat deposits" (Minard 1983).

The soil units mapped in the project location are Mukilteo muck and Urban Land (USDA NRCS 2014). The Urban Land roughly corresponds to the area mapped as fill/modified land and the Mukilteo muck corresponds to the areas mapped as alluvium/marsh. Urban Land consists of nearly level to gently sloping areas covered by streets, buildings, parking lots, and other structures that obscure or alter native soils (Debose and Klungland 1983). Mukilteo muck is a very poorly drained soil that ponds frequently and formed in depressions from organic parent material derived mostly from sedges (Debose and Klungland 1983). The typical profile includes of muck, mucky peat, and fine sandy loam, and the water table is typically at the ground surface (USDA NRCS 2014).

Archaeological Context: Regional and local studies have provided an archaeological and historical synthesis of approximately the last 10,000 years of human occupation in western Washington (e.g. Larson and Lewarch 1995; Morgan 1999; Nelson 1990). Similar to other areas throughout the state, chronological land use sequences have been constructed for the northern Puget Sound (see Blukis Onat 1987).

Archaeological evidence suggests human occupation in the Puget Sound occurred following the last glacial retreat at the end of the Pleistocene, approximately 14,000 - 10,000 years ago. Changes to the landscape following deglaciation significantly influenced the spatial distribution of human activities, based on the availability of resources and the suitability of certain landforms for occupation. The earliest evidence of a human presence in the region, consisting primarily of a few chronologically diagnostic stone tools and flakes, indicates that humans colonized the Puget Sound shortly after the retreat of ice from the last glaciation at the end of the Pleistocene (Carlson 1990). Recently, a Paleoindian component was identified in stratified sediments at a site in Redmond on Bear Creek, a tributary of the Sammamish River (Kopperl et al. 2010), approximately 16 miles southeast of the project.

Archaeologists have identified an early period of occupation dated to between 9000 – 5000 BP (before present) based on broad similarities in lithic assemblages. Many of the early sites are associated with the Olcott Complex in Western Washington, which are contemporaneous with similar Cascade Phase sites identified east of the Cascade Mountains. Olcott sites have been defined partly by the shared distribution of laurel-leaf-shaped bifaces and upland or upper river terrace site locations (Miss and Campbell 1991; Morgan and Hartmann 1999; Nelson 1990). These sites are found on or near the ground surface of glacial landforms. The Olcott complex is believed to be representative of highly mobile hunter-gatherers who typically did not utilize marine resources (Carlson 1990), and several Olcott sites have been documented and studied throughout Western Washington and the Olympic Peninsula. Many Olcott sites have been identified in Snohomish County (see Miss and Campbell 1991), including the Olcott type-site (Kidd 1964).

After 5000 BP, archaeological evidence suggests a change in settlement patterns and subsistence economy in the region. From 5000 to 3000 BP an increasing number of tools were manufactured by grinding stone, and more antler and bone material was used for tool production. Living floors with evidence of hearths and structural supports suggesting more long-term site occupation are more common during this period in contrast to the Olcott Complex. On Puget Sound, evidence of task-specific, year-round, broad-based activities, including salmon and clam processing, woodworking, and basket and tool manufacture, date from approximately 4200 BP (Larson and Lewarch 1995).

Characteristic of the ethnographic pattern in Puget Sound, seasonal residence and logistical mobility, occurred from about 3000 BP. Organic materials, including basketry, wood and food stuffs, are more likely to be preserved in sites of this late pre-contact period, both in submerged, anaerobic sites and in sealed storage pits. Sites dating from this period represent specialized seasonal spring and summer fishing and root-gathering campsites and winter village locations. Sites of this type have been identified in the Puget Sound lowlands, typically located adjacent to, or near, rivers or marine transportation routes. Fish weirs and other permanent constructions are often associated with large occupation sites. Common artifact assemblages consist of a range of hunting, fishing and food processing tools, bone and shell implements and midden deposits. Similar economic and occupational trends persisted throughout the Puget Sound region until the arrival of European explorers. Beginning approximately two hundred years ago, relatively rapid social changes occurred under the pressures of acculturation. Contact between peoples of the Puget Sound region and those of Europe and the United States stimulated the local introduction and adoption of new technologies and political organization (Marino 1990; Suttles and Lane 1990).

Ethnographic Context: As previously discussed by Kelly (2012:4), the project is located within lands traditionally used by the Suquamish tribe, a Southern Lushootseed-speaking southern Coast Salish group whose territory centered on Kitsap Peninsula, Bainbridge Island, and Whidbey Island, with fishing, gathering, and other traditional use areas also including marine waters and coastal areas of Puget Sound (Lane 1975a, 1975b; Ruby and Brown 1992:226; Smith 1940; Spier 1936:34; Suttles and Lane 1990:Figure 1). Precontact settlements were often located on major waterways, heads of bays, or inlets, and people practiced a seasonal subsistence economy that included hunting, fishing, and plant food horticulture. In the winter, people lived at large permanent village settlements and they spent the summer hunting, fishing, and gathering at specialized, temporary camps located near food resources. There was an abundance of plant and animal resources available in estuarine and marine environments in the region. A combination of fish, shellfish, marine mammals, waterfowl, game, roots, and berries served as a rich, diverse, and relatively reliable resource base (Suttles and Lane 1990:489).

Ethnographers (Smith 1940, 1941; Snyder 1968; Spier 1936; Waterman ca. 1920, 2001) gathered locations of Suquamish villages and names for resource areas, water bodies, and other landscape features from informants. One ethnographically recorded place name is associated with Point Edwards, *Stu*^{u}*bus*, translated as “like a man; face of a man” (Waterman 2001:55). A small creek just north of Edmonds was called *S*^{3}*baL*, “a person undergoing the ministrations of a shaman; a patient” (Waterman 2001:55). Toponyms were also recorded for landforms on the shoreline north and south of Edmonds (Waterman 2001:Map 5.1).

Historic Context: Early Euro-American settlement of Snohomish County began on the heels of the Donation Land Claim Act of 1850. In 1853, the United States organized Washington

Territory and appointed Isaac I. Stevens as its governor. Following several years of conflict, the Point Elliot Treaty was signed at Mukilteo on January 22, 1855. The treaty called for cession of lands to the United States and the maintenance of fishing rights and annuities, as well as the concentration of Indian people living in western Washington upon reservation lands (Marino 1990). The Suquamish, the Tulalip, and many other neighboring tribes were forced to abandon most of their Northern Puget Sound villages and relocate to reservations. The treaty dissolved Indian title to their traditional and accustomed lands and by 1855-1856 the federal government used military force to contain Indian people dissatisfied with the poor quality of reservation lands.

The logging industry was attracted to the project area by the great timber potential offered by coastal forests of cedar (Whitfield 1926). Euro-American settlement in the Edmonds area began in the 1860s but remained sparse until the 1880s. The town of Edmonds was platted in 1884 by George Brackett, who was in the logging business and had purchased land there in 1876 (LeWarne 2008). Early commercial and industrial developments were located on the waterfront north of the current project, and included a store, a mill, and a wharf (LeWarne 2008). The railroad corridor that passes east of the project has been in use since the late nineteenth century, with the Great Northern Railroad reaching Edmonds in 1891 (Cameron 2005:106-108; O'Donnell 1993).

By the early twentieth century, three mills were in operation on the Edmonds waterfront north of the project, near the ferry terminal and the north side of the Marina (Sanborn Map Company 1909). The Washington Steel & Bolt Co. and Edmonds Elec. Light & Power Co. were the structures nearest to the project at the time, situated in what is now the marina west of the end of Walnut Street between a saltwater pond and rail spur to the east and the shoreline to the west. By 1926, the saltwater pond had been filled and the former Washington Steel & Bolt and Edmonds Elec. Light & Power buildings were vacant (Sanborn Map Company 1926, 1932). The cedar shingle mills yielded to the Union Oil Company of California's fuel terminal as the dominant industrial activity in the area in the middle twentieth century. This period also saw increased commercial development and construction of the Port of Edmonds' Marina north of the project.

<u>Land Use History:</u> Nineteenth century maps reviewed in this assessment did not reveal the locations of any buildings, trails, villages, or other cultural features within or adjacent to the project (USCS 1872; USGS 1895, 1897; USSG 1860). The General Land Office (GLO) conducted its cadastral survey of the area in the late 1850s (United States Surveyor General [USSG] 1860). This early map of the project area shows a stream flowing west through Edmonds Marsh and curving to the north-northeast before draining into Admiralty Inlet north of the project (USSG 1860) (Figure 3). The Coast Survey chart from the early 1870s shows the Park Survey area as including tideflats and the base of the sand spit, and saltwater marsh in the other three areas of the project (USCS 1872) (Figure 4). According to an online search of GLO land records on file at the Bureau of Land Management, land containing portions of the project in Section 26 was deeded to James C. Purcell (Accession/Serial No. WAOAA 076459, Homestead Entry patent, 79 acres in N½ of NW¼ and NW¼ of NE¼, S. 26, T. 27 N., R. 3 E., November 20, 1880) and land containing parts of the project in Section 23 was deeded to William H. Hamlin (Accession/Serial No. WAOAA 076461, Sale-Cash Entry patent, 52.5 acres in Lot 3, S. 23, T. 27 N., R. 3 E., January 20, 1882) (BLM 2014).

Early USGS maps show the project location among “cut areas, not restocking,” indicating that it had already been logged (USGS 1897). By 1910, lands containing the project in Section 26 were owned by F. R. Atkins, with smaller tracts to the north owned by Island Lime Company, Invincible Rail Joint Co., and the Edmonds Chamber of Commerce, while land containing the portions of the project in Section 23 was owned by J. W. Lyke (Anderson Map Company 1910). Sanborn maps were reviewed but did not include coverage of the project location (Sanborn Map company 1909, 1926, 1932). By 1934, Union Oil Co. of California had acquired the portions of the project in Section 26 (Kroll Map Company 1934). A 1936 map shows the entire project area as owned by Union Oil Co. of California with the exception of one parcel owned by N. Alhadeft in the northern part of present-day Marina Beach Park (Metsker 1936). A few years later, C. J. Burton owned Alhadeft’s parcel and Union Oil owned all other portions of the project (Kroll Map Company 1943). By 1960, the Port of Edmonds had acquired land along Admiral Way, including the area now occupied by Marina Beach Park (Kroll Map Company 1960).

Review of maps and other historical resources did not identify any structures or other developments in portions of the project within the present-day marsh. According to Shannon & Wilson (2013:6), the marsh area was farmed and used for cattle pasture in the 1940s. Filling of the marsh in what is now Harbor Square commercial development along the northern edge of the Stormwater Outfalls and Berm Survey area began in 1963 (Shannon & Wilson 2013:6).

Review of twentieth century topographic maps (USGS 1944, 1955, 1958, 1969, 1976) shows that the configurations of the shoreline and Willow Creek were altered significantly in the twentieth century, primarily through development of the Port of Edmonds Marina north of the project and the Unocal fuel station, formerly within the project location. In 1962, the Port of Edmonds completed construction of the Edmonds Marina, which included rerouting the Willow Creek drainage to the south into its current alignment through a series of concrete pipes under the BNSF railway and Admiral Way, into a 48-inch corrugated metal pipe that flows south to Edmonds Marina Beach Park, from which point the creek flows into a storm vault with a top-hinge steel tidegate (Shannon & Wilson 2013:7).

Historical aerial imagery shows that sediments accumulated on the nearshore in the Park Survey area between the former Unocal Pier and the Marina after the latter was constructed; prior to 1967, only a few shoals or sand bars appear to be present (Washington State Department of Ecology 2012). Aerial imagery from 1990 shows the pier extending west-southwest from the end of the parking lot in the Park Survey area, as well as structures and facilities associated with the fuel station in the Daylight Channel Survey area (USGS 1990).

The Park Survey and Daylight Channel Survey areas formerly contained fuel station facilities including a pier, railroad spur, railcar loading/unloading racks, slop tanks, and truck loading racks (Arcadis 2013:Figure 3; Emcon 1994:Figures 3-1 and 3-2). Unocal operated its Edmonds fuel station from 1923 to 1991, with fuel arriving via a “fuel dock that was located underneath the south parking lot at today’s Edmonds Marina Beach Park” (Shannon & Wilson 2013:7). Development of the fuel terminal involved placing fill material up to 11 feet thick (Emcon 1994:2-13). The fuel station facilities have since been removed from the project location and the Park Survey area now contains Marina Beach Park and an off-leash dog area. The Daylight

Channel Survey area is vacant, with ground surface conditions noted as compact dirt, gravel and natural vegetative cover (Arcadis 2013:3). Soil, sediment, and groundwater remedial actions were conducted in this area in 2007 and 2008, monitoring is ongoing, and further cleanup work is being planned (Arcadis 2013; Shannon & Wilson 2013:9). Remediation included removal of 108,000 tons of petroleum impacted soil in Phase I (Arcadis 2013:5) and removal of 14,825 tons of petroleum impacted soil in Phase II (Arcadis 2013:7). Prior to this recent work, remedial investigations and actions were completed 1994–1996, in 2001, and in 2003, some of which also involved soil removal (Shannon & Wilson 2013:8)

Prior Investigations: Nine cultural resource studies within one mile from the current project are on file at DAHP (2014) (Table 1). The majority of recent investigations have been related to proposed transportation improvements including the Edmonds Crossing project (e.g., Bard and McClintock 1996; Juell 2006; Shantry et al. 2011). Assessment methods have included pedestrian surveys, documentation of historic structures, subsurface testing, and monitoring of construction excavations. None of these investigations have identified any cultural resources that would be affected by the current project.

One prior investigation included test trenches within the current project location (Bard and McClintock 1996). Trenches 12, 13, 14A, and 14B were located in the Daylight Channel Survey area. Trench 12 contained brown gravelly sand from 0 to 4 ft and gray silty sand from 4 to 6.5 ft (fill). Trench 13 contained concrete, asphalt, and crushed rock 0 to 1 ft, brown gravelly sand with “miscellaneous debris” from 1 to 2 ft, mixed sands with plant matter and woody debris (fill) from 2 to 9 ft, and unbroken shells interpreted as the original ground surface (either Whidbey Formation on glaciomarine deposits) at 9 ft below surface (Bard and McClintock 1996:18, Appendix B). Trench 14A contained compact crushed gravel 0 to 1 ft, quarry spalls, concrete debris, rebar, and woody debris in a sand matrix (fill) from 1 to 7 ft, and loose silt with wood, plant matter, and charcoal (fill) from 7 to 9 ft, with a possible original ground surface 9 ft below surface. Trench 14B was abandoned at 3 ft when pipes were encountered, but contained compact crushed gravel 0 to 1 ft and quarry spalls, concrete debris, and rebar (fill) from 1 to 3 ft (Bard and McClintock 1996:Appendix B). Test trenches 15A and 15B were located in the Park Survey area south of the former Unocal Pier (Bard and McClintock 1996:Figure 2). Trench 15A encountered a thin layer of dark sand with roots from surface vegetation, unsorted sand and gravel from 1 to 6 ft below surface, a thin layer of fine sand, and coarse sand with decomposing wood and plant debris to the bottom of the pit at 7 ft below surface. Trench 15B contained coarse brown sand and gravel from 0 to 6 ft, a layer of fine sand from 6 to 7 ft, coarse sand from 7 to 8.5 ft, and peat from 8.5 to 9 ft (Bard and McClintock 1996:Appendix B). Excavation halted in the test trenches when sidewalls collapsed or they became inundated with groundwater. In general, thick fill deposits were present. All of the test trenches were negative for archaeological material (Bard and McClintock 1996:18–19). Archaeological monitoring of construction was recommended as a precautionary measure (Bard and McClintock 1996:20).

Only two archaeological sites have been recorded within a distance of one mile from the project (Table 2). Site 45SN310, located near the Deer Creek Hatchery access road, was identified as finely crushed mussel, barnacle and cockle shell that is visible in patches at the ground surface (Bard and McClintock 1996:6). This site is on the hillside south of the Marsh Channel Survey area. Subsurface testing has not been conducted at this site and its significance has not been evaluated. Site 45SN574 was identified as a fill layer containing historic-era artifacts associated with the Great Northern Railroad's section foreman's house, water tower, and cabin. This site was discovered in test pits excavated by backhoe during an archaeological survey for proposed storm drain improvements at the Edmonds Rail Station (Shantry et al. 2011:1). Archaeological monitoring and testing were conducted to collect samples of archaeological material and document site stratigraphy. Based upon the results of these investigations, site 45SN574 was recommended eligible for the NRHP because it was considered to have the potential to provide significant information about the past, namely details about working class life on the Edmonds waterfront in the early twentieth century (Shantry et al. 2011:39).

Nine historic sites within approximately one mile from the project have been listed on the National Register of Historic Places (NRHP), Washington Heritage Register (WHR), and Edmonds Register of Historic Places (ERHP) (Table 3). The historic site nearest to the project is Brackett's Landing, located approximately .3 mile northeast of the project. None of these historic properties would be affected by the proposed project.

Archaeological Expectations:

The DAHP statewide predictive model uses environmental data about the locations of known archaeological sites to identify where previously unknown archaeological sites are more likely to be found. The model correlates locations of known archaeological to environmental data "to determine the probability that, under a particular set of environmental conditions, another location would be expected to contain an archaeological site (Kauhi and Markert 2009:2–3). Environmental data categories included in the model are elevation, slope, aspect, distance to water, geology, soils, and landforms. The model classifies the portion of the project waterward of the historical shoreline "Survey Contingent Upon Project Parameters: Low Risk," with the remainder of the project described as "Survey Highly Advised: Very High Risk" (DAHP 2014).

Local archaeological and ethnographic contexts generally support these rankings. The project area was likely used for hunting, fishing, and collection of shellfish and plant resources. Habitation sites in the region tend to be located on protected bays and on lakes and prairies from which year-round food resources and fresh water were accessible (Blukis Onat 1987). Camping or other occupation sites would be expected to occur on dry terrain elevated above the historical estuary, potentially on the base of the spit in the southeastern part of the Park Survey area. However, historical environmental conditions in the Daylight Channel Survey, Stormwater Outfalls and Berm Survey, and Marsh Survey areas suggest that these areas would not have been favorable for habitation or other activities with the potential to generate significant archaeological deposits.

Based on existing archaeological data for this area, the types of precontact archaeological materials that might be present here could potentially include lithic scatters, fire-cracked rock concentrations, shell middens, or other features, which could reflect a range of domestic, subsistence, and ceremonial activities. Historic-period archaeological sites would likely be related to logging, milling, railroad, and oil terminal operations. Geological and soils information for the project area suggest that archaeological deposits could be found below the depth of recent littoral drift deposits, fill, or other historical modifications (Minard 1983; Shannon & Wilson 2013; USDA NRCS 2014; WA DNR 2014). Dredging and filling associated with development of the Marina, railroad, and former Unocal facilities may have obscured, removed, or deeply buried archaeological sites. Based upon the results of prior subsurface testing (Bard and McClintock 1996), fill deposits in the Park Survey portion of the project are expected to be up to 6 to 7 feet thick, and fill in the Daylight Channel Survey area are expected to be up to 9 ft thick.

3. Field Investigations

The author conducted the field investigations; notes and digital photographs are on file at CRC.

Stormwater Outfalls and Berm Survey Area

Reconnaissance survey was conducted for this portion of the project on August 28 from along the southern edge of the Harbor Square commercial development (Figure 5). This area contains a boardwalk at the western end of the Edmonds Marsh Trail, paved parking areas/access roads at the southern edge of Harbor Square, and the northern edge of the marsh. The paved areas are elevated above the marsh approximately 4 feet and inspection of available soil profiles found brown gravelly loam and exposed edges of geotextile fabric as well as existing culverts (Figure 6). The marsh is densely vegetated and contains soft, mucky sediments with some ponding. For these reasons, it was determined that intensive survey would not be productive.

Marsh Channel Survey

Reconnaissance survey was conducted for this portion of the project on August 28 from along the west side of SR 104 right-of-way (Figure 7). This portion of the project is occupied entirely by the marsh. The marsh is densely vegetated and contains soft, saturated sediments with many areas of standing water (Figure 8). For these reasons, it was determined that intensive survey would not be productive.

Daylight Channel Survey Area

Right-of-entry has not been granted to conduct field investigations within this portion of the project at this time (Figure 9).

Park Survey Area

Archaeological monitoring of geotechnical borings and test pits was conducted in the Park Survey area on August 28–29 and September 5, 2014 (Figures 11 –13). Pedestrian survey was also conducted on the morning of September 5 during low tide using meandering transects. This portion of the project contains Marina Beach Park, an off-leash dog area, and associated parking lot. The shoreline at the west end of the parking lot is rip-rapped. The park and off-leash area mostly have level terrain elevated above the beach, with the exception of a knoll with trees and lawn grass in the park. The beach west of the developed park and off-leash area is gently sloped and has excellent surface visibility. Pedestrian survey did not identify any archaeological material.

Two geotechnical exploration borings were drilled to a maximum of 40 feet and five test pits were excavated to a maximum depth of 14 feet. The borings were conducted using a truck mounted drill rig using mud rotary auger techniques. The borings reached depths of 21.5 feet (B-1) and 41.5 feet (B-2). The geologist collected samples from the borings every 2.5 feet for the first 20 feet, and then every 5 feet thereafter. The author inspected the samples for archaeological materials or signs of archaeological deposits (e.g., midden matrix). No artifacts, bone fragments, midden, or other archaeological material was seen in the boring samples.

The test pits were excavated with a standard rubber-tire backhoe along proposed nearshore channel alignments and across the beach profile. The test pits were 9 to 14 feet deep and had plan dimensions of about 4 feet wide by 10 feet long. The author inspected trench walls and spoils from each test pit. The occasional piece of modern debris (e.g., metal, glass, or plastic fragments) was observed but no historic or precontact archaeological material was found, nor were any potentially archaeological strata observed in the trench walls. In general, sediments observed during geotechnical testing consisted of fill over gravelly and sandy beach deposits, with a thin, intermittent layer of fine sand with plant matter thought to represent marsh deposits about 7 ft below surface in three of the test pits (Figures 14 and 15; Table 4). Conditions were generally consistent with those observed by Bard and McClintock (1996:18-19, Figure 2) in test pits (15A and 15B) south of the former Unocal Pier.

4. Results and Recommendations

Cultural Resources Identified: None.

Project Conclusions, Findings and Recommendations: Background research and field investigations have not identified any archaeological or historic sites in the project location. Subsurface investigations consisted of archaeological monitoring of geotechnical testing in the Park Survey area, and no evidence of buried archaeological sites was observed. Based upon historical environmental conditions, historical land use, and precontact settlement patterns, the Daylight Channel Survey, Marsh Survey, and Stormwater Outfalls and Berm Survey portions of the project and the part of the Park Survey area west of the historical shoreline are considered to have a low potential to contain archaeological sites. No further cultural resource investigations are recommended in these portions of the project.

The portion of the Park Survey area that was historically at the base of the spit shown in the 1870s T-Sheet is considered to have a higher potential to contain archaeology (Figure 16). Archaeological sites, if present, would be found on or near buried native surfaces beneath fill material, approximately 7 feet below surface based upon the results of geotechnical testing for the current project and prior archaeological test pits in this area (Bard and McClintock 1996). It is archaeological monitoring be conducted during any ground-disturbing work anticipated to intersect native sediments. A proposed monitoring and inadvertent discovery protocol is attached (Attachment B), outlining monitoring procedures and steps to follow in the event that cultural resources are found.

In the event that ground disturbing or other activities do result in the inadvertent discovery of archaeological deposits, work should be halted in the immediate area and contact made with the State Department of Archaeology and Historic Preservation (DAHP) in Olympia. Work should be halted until such time as further investigation and appropriate consultation is concluded. In the unlikely event of the inadvertent discovery of human remains, work should be immediately halted in the area, the discovery covered and secured against further disturbance, and contact effected with law enforcement personnel.

Attachments:

Figures	[x]
Photographs	[x]
Other	[x] Copies of project correspondence between CRC and cultural resources staff at the Muckleshoot Indian Tribe, Snohomish Tribe, Snoqualmie Nation, Stillaguamish Tribe, Swinomish Tribe, Suquamish Tribe, and Tulalip Tribes. [x] Proposed monitoring and inadvertent discovery protocol.

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6. Limitations of this Assessment

No cultural resources study can wholly eliminate uncertainty regarding the potential for prehistoric sites, historic properties or traditional cultural properties to be associated with a project. The information presented in this report is based on professional opinions derived from our analysis and interpretation of available documents, records, literature, and information identified in this report, and on our field investigation and observations as described herein. Conclusions and recommendations presented apply to project conditions existing at the time of our study and those reasonably foreseeable. The data, conclusions, and interpretations in this report should not be construed as a warranty of subsurface conditions described in this report. They cannot necessarily apply to site changes of which CRC is not aware and has not had the opportunity to evaluate.

7. Figures and Tables

Figure 1. Project location marked on portion of Edmonds West, WA (USGS 1981) topographic quadrangle.

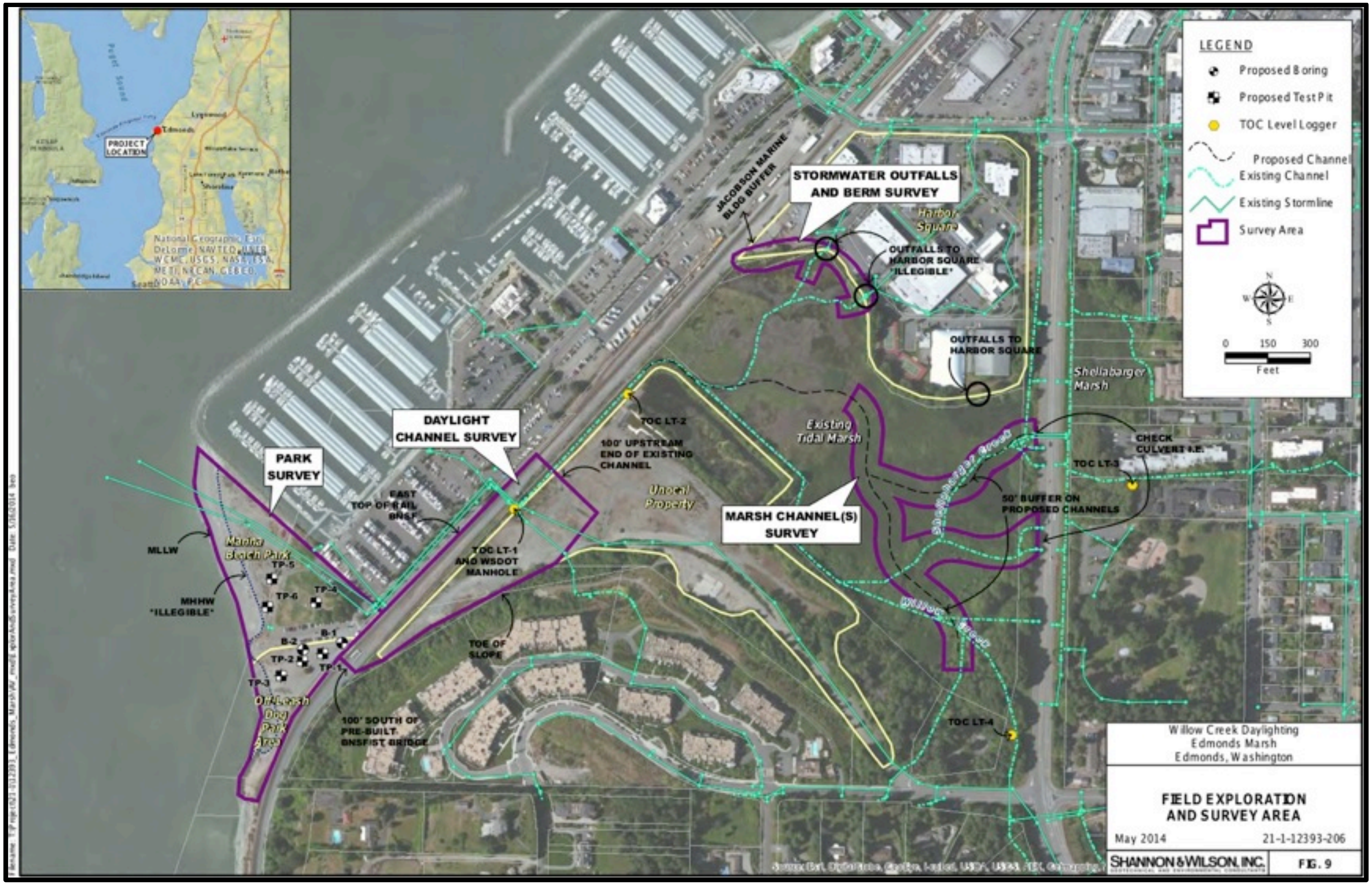

Figure 2. Project map provided by Shannon & Wilson. The four survey areas bounded in purple are addressed in this report.

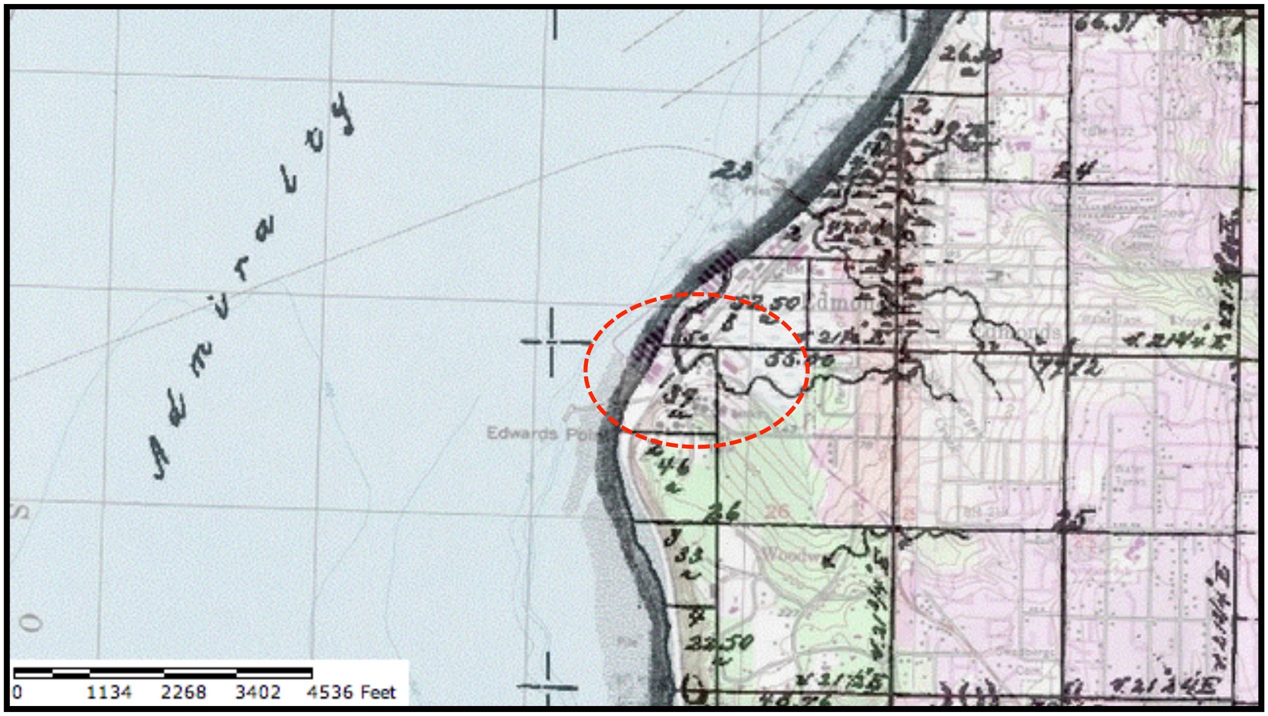

Figure 3. Project vicinity marked on georeferenced cadastral survey map (DAHP 2014; USSG 1860).

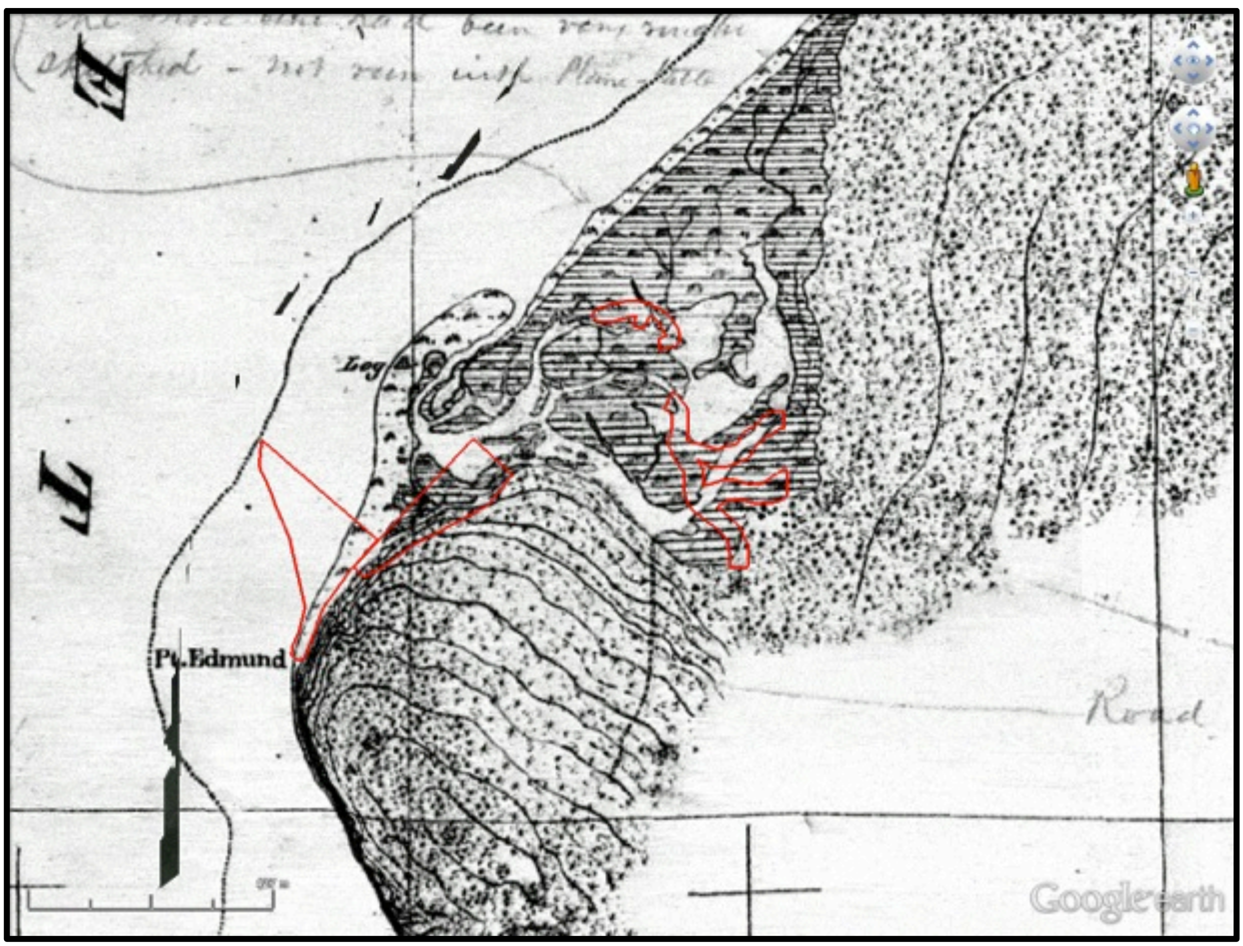

Figure 4. Project area marked on georeferenced historical topographic sheet (Fox 2009; USCS 1872).

Table 1. Prior cultural resource surveys within one mile from the Marina Beach Park testing area.

Author	Date	Title	Distance from Project	Results
Bard and McClintock	1996	Edmonds Crossing Discipline Report Supplement, Presence Absence Testing for Archaeological Resources	Overlaps eastern end of project.	Pedestrian survey identified archaeological site 45SN310 at Deer Creek Fish Hatchery, east of the project. Subsurface testing north and east of the project did not identify any archaeological material, but archaeological monitoring recommended for construction in these areas.
Cox and Bard	1996	Draft The Unocal Edmonds Bulk Fuel Terminal A Determination of National Register Eligibility	Adjacent to east.	Conducted background research and field documentation to evaluate the former fuel terminal for NRHP eligibility. The site was considered representative of historical trends but was recommended not eligible because did not play a significant role, nor did it retain integrity adequate to convey any historical significance.
Demuth	1998	Historic, Cultural, and Archaeological Resources Assessment for Everett-to-Seattle Commuter Rail Project Environmental Impact Statement	Adjacent to east.	Provided cultural resources overview of rail corridor and station locations between Everett and Seattle, and evaluated commuter rail project alternatives for potential impacts to cultural resources. No archaeological or historic sites identified in the location of the current project.
Boyle	2004	A Historic Survey of Downtown Edmonds	Encompasses project.	Presented a historical overview of the City of Edmonds. Inventoried 83 historic buildings in the City of Edmonds. No historic sites inventoried in the current project. The nearest inventoried property was the Railroad Station at 201 Railroad Avenue.
Juell	2006	Archaeological Site Assessment of Sound Transit's Sounder: Everett-to-Seattle Commuter Rail System, King and Snohomish Counties, Washington	Adjacent to east.	Survey identified many areas of thick fill deposits, ballast, and steep side slopes; no further work recommended in these areas. Subsurface testing and/or monitoring of trench excavation were recommended in select locations where construction would reach native soils.
Rinck	2010	Archaeological Investigations at the Edmonds Commuter Rail Station	.6 mile NE	Background research and subsurface testing were conducted to determine whether archaeological deposits would be affected by improvements to the rail station. Fill was present to a mean depth of 5.4 ft. Historic-era (ca. 1900-1957) archaeological material was found in a discrete layer in three test pits and later recorded as site 45SN574. Further testing was recommended to evaluate this deposit for potential NRHP eligibility.
Shong and Miss	2010	Results of Archaeological Monitoring for the Deer Creek Culvert Extension Project, Snohomish County, Washington	.5 mile S	Archaeological monitoring was conducted during construction of drainage improvements. Excavated trenches and sediments were examined but no archaeological material was found. Sediments encountered consisted of displaced glaciolacustrine material (i.e. landslide deposits) and dredge spoils. No further work recommended.

Author	Date	Title	Distance from Project	Results
Johnson	2011	City of Edmonds Historic Resources Survey – 2011		Conducted a supplemental survey of historic structures in Edmonds. Inventoried 122 properties and made recommendations for further research about 42 properties meeting local landmark criteria.
Shantry et al.	2011	Archaeological Monitoring and Testing at the Edmonds Commuter Rail Station, Snohomish County, Washington	.6 mile NE	Background research and archaeological sampling were conducted to evaluate site 45SN574 for NRHP eligibility. Sediment samples were collected from a trench excavated to accommodate new stormwater facilities. The density of artifacts in the vicinity of the foreman's house was considered to have potential for providing significant information about its occupants' work and domestic lives.

Table 2. Archaeological sites recorded within one mile from the project.

Site Number	Site Name	Site Type	Distance from Project	NRHP/WHR Status	Potential Project Effects
45SN310	Deer Creek Hatchery Shell Scatter	Precontact shell midden	250 ft S of Marsh Channel Survey	Unevaluated.	None.
45SN574	Edmonds Station	Historic debris scatter/concentration, historic structure unknown	500 ft NE of Stormwater Outfalls and Berm Survey	Recommended eligible for NRHP.	None.

Table 3. Historic properties recorded within approximately one mile from the project.

Register Name	Address	Date	Historic Register Status	Potential Project Effects
Brackett's Landing	Waterfront at foot of Main Street	1870	Listed on WHR in 1970.	None.
Edmonds Carnegie Library	118 Fifth Avenue North	1910	Listed on WHR and NRHP in 1973; listed on ERHP in 2004.	None.
Edmonds High School	410 4th Avenue North	1909-1939	Listed on WHR in1986.	None.
Ganahl-Hanley Log Cabin	120 5th Avenue North	1930	Listed on WHR in 1999; listed on ERHP in 2009.	None.
IOOF Cemetery	North of Edmonds Way & 100th Street	1894	Listed on WHR in 1972.	None.
IOOF (Oddfellows) Hall	542 Main Street	1894	Listed on WHR in 1972; listed on ERHP in 2008.	None.
Olympic View Hotel	Second Avenue & Bell Street	1894	Listed on WHR in 1972; listed on ERHP in 2009.	None.
Site of First School in District No. 15	233 Third Ave N	1884	Listed on WHR in 1972; listed on ERHP in 2008.	None.
Wells House	120 Edmonds Street	1891	Listed on WHR in 1975.	None.

Figure 5. Existing conditions in the Stormwater Outfalls and Berm Survey Area; view is to the east.

Figure 6. Typical surface conditions in the Stormwater Outfalls and Berm Survey Area; view is to the northeast.


Figure 7. Typical conditions in the eastern part of the Marsh Survey Area; view is to the west.


Figure 8. Surface conditions in the Marsh Survey Area as seen at existing culvert west of SR-104.

Figure 9. View across northwest edge of Edmonds towards Daylight Channel Survey area (access not granted); view is to the southwest.

Figure 10. Existing conditions at Marina Beach Park in the Park Survey area, as seen from near the low tide line; view is to the northeast.

Figure 11. Existing conditions in the Park Survey area on the beach south of the former pier; view is to the northeast towards TP-3.

Figure 12. Geotechnical boring in the Park Survey Area; view is to the west-southwest.

Figure 13. Locations of monitored geotechnical borings and test pits in the Park Survey area marked on satellite imagery (base map: Google Earth).

Figure 14. Sample form boring B-2, typical of sandy sediments observed in borings in the Park Survey Area.

Figure 15. Typical subsurface conditions in the Park Survey Area as seen in test pits TP-4 (left) and TP-2 (right).

Table 4. Summary of archaeological monitoring of geotechnical testing for the Willow Creek Daylighting Project.

Test #	Location (WGS84 Zone 10 UTM, +/- 5 m)	Stratigraphic Description	Archaeological Materials Found
B-1	545424E, 5294764N	0-15 ft: grayish brown coarse gravelly sand; 15-20 ft: extremely gravelly gray sand; 20-25 ft: bluish gray very gravelly medium sand; 25-30 ft: dark gray medium-coarse sand; 30-35 ft: dark gray fine sand and silt; 35-45 ft: dark gray medium-coarse gravelly sand; 45-46.5 ft: dense, dark gray gravelly coarse sand and silt.	None.
B-2	545383E, 5294756N	0-10 ft: grayish brown coarse gravelly sand, with groundwater at about 9 ft below surface; 10-12.5 ft: dark gray coarse gravelly sand; 12.5-15 ft: grayish brown coarse gravelly sand; 15-17.5 ft: extremely gravelly gray sand; 17.5-20 ft: brown very gravelly mixed sand and silt; 20-21.5 ft: grayish brown gravelly coarse sand.	None.
TP-1	545404E, 5294752N	0-7 ft: chipped gravel surface, underlain by grayish brown gravelly sand, one piece of dimensional lumber; 7-7.5 ft: iron-oxide stained and bluish gray fine sand with plant debris (wood and roots); 7.5-9 ft: grayish brown coarse sand with some gravels. Excavation halted due to caving.	None.
TP-2	545382E, 5294743N	0-7 ft: chipped gravel surface, underlain by grayish brown gravelly sand and a few pieces of metal slag; 7:ft: patches of iron-oxide stained and bluish gray fine sand about 2 in thick, with plant debris (wood and roots); 7-9 ft: gray coarse sand with some gravels. Excavation halted due to caving.	None.
TP-3	545360E, 5294727N	0-7 ft: chipped gravel surface, underlain by grayish brown gravelly sand and gravel interbeds between 3 and 5 ft below surface; 7:ft: patches of iron-oxide stained and bluish gray fine sand about 2 in thick, with plant debris (wood and roots); 7-11 ft: g gray coarse sand with some gravels, with a few pieces of metal slag and wood about 9 ft below surface. Excavation halted due to caving.	None.
TP-4	545384E, 5294795N	0-6 in: grass surface over brown loam with roots; 6 in -6.5 ft: grayish brown mixed sand, silt, and clay with one piece of plastic and dimensional lumber (fill); 6.5-14 ft: gray gravelly sand with occasional shell fragments and one brick. Excavation halted at reach of backhoe.	None.
TP-5	545348E, 5294830N	0-6 ft: gravel beach surface, underlain by loose dry gray sand with some gravels and cobbles, and occasional glass, wood, and shell fragments; 6:ft: patches of iron-oxide stained and bluish gray fine sand about 2 in thick, with plant debris (wood and roots); 6-9 ft: gray very gravelly sand with groundwater at about 8.5 ft. Excavation halted due to caving.	None.

Figure 16. Shaded area recommended for additional subsurface investigation, within former sand spit as traced from T-Sheet (Fox 2009; USCS 1872).

Attachment A: Project correspondence between CRC and cultural resources staff at Muckleshoot Indian Tribe, Snohomish Tribe, Snoqualmie Nation, Stillaguamish Tribe, Suquamish Tribe, Swinomish Tribe, and Tulalip Tribes.

Cultural Resource Consultants, Inc.

June 4, 2014

Stillaguamish Tribe
Shawn Yanity, Chair
PO Box 277
Arlington, WA 98223-0277

Re: Cultural Resources Assessment for the Willow Creek Daylight Final Feasibility Study Project, Edmonds, Snohomish County, WA

Dear Shawn:

I am writing to inform you of a cultural resources assessment for the above referenced project and to seek additional information about the project area the Tribe may have that is not readily available through other written sources. The project is located along Edmonds Way, between W Dayton Street and Pine Street/Pine Drive in Edmonds, Snohomish County, Washington. Shannon & Wilson, Inc., on behalf of the City of Edmonds, is requesting this assessment as a part of the Willow Creek Daylight Final Feasibility Study project in Edmonds, Washington.

We are in the process of reviewing available information. Background research will include a site files search at the Washington State Department of Archaeology and Historic Preservation, review of previously recorded cultural resource reports, and review of pertinent published literature and ethnographies. Results of our investigations will be presented in a technical memo.

We are aware that not all information is contained within published sources. Should the Tribe have additional information to support our assessment, we would very much like to include it in our study. Please contact me should you wish to provide any comments. I appreciate your assistance in this matter and look forward to hearing from you.

Sincerely,

Glenn D. Hartmann
President/Principal Investigator

PO BOX 10668, BAINBRIDGE ISLAND, WA 98110
PHONE 206.855.9020 - info@crcwa.com

Cultural Resource Consultants, Inc.

June 4, 2014

Swinomish Indian Tribal Community
Larry Campbell, THPO/ Cultural Resources
11430 Moorage Way
La Conner, WA 98257

Re: Cultural Resources Assessment for the Willow Creek Daylight Final Feasibility Study Project, Edmonds, Snohomish County, WA

Dear Mr. Campbell:

I am writing to inform you of a cultural resources assessment for the above referenced project and to seek additional information about the project area the Tribe may have that is not readily available through other written sources. The project is located along Edmonds Way, between W Dayton Street and Pine Street/Pine Drive in Edmonds, Snohomish County, Washington. Shannon & Wilson, Inc., on behalf of the City of Edmonds, is requesting this assessment as a part of the Willow Creek Daylight Final Feasibility Study project in Edmonds, Washington.

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We are aware that not all information is contained within published sources. Should the Tribe have additional information to support our assessment, we would very much like to include it in our study. Please contact me should you wish to provide any comments. I appreciate your assistance in this matter and look forward to hearing from you.

Sincerely,

Glenn D. Hartmann
President/Principal Investigator

Cultural Resource Consultants, Inc.

June 4, 2014

Tulalip Tribes
Richard Young, Cultural Resources
6410 23rd Ave NE
Tulalip, WA 98271

Re: Cultural Resources Assessment for the Willow Creek Daylight Final Feasibility Study Project, Edmonds, Snohomish County, WA

Dear Mr. Young:

I am writing to inform you of a cultural resources assessment for the above referenced project and to seek additional information about the project area the Tribe may have that is not readily available through other written sources. The project is located along Edmonds Way, between W Dayton Street and Pine Street/Pine Drive in Edmonds, Snohomish County, Washington. Shannon & Wilson, Inc., on behalf of the City of Edmonds, is requesting this assessment as a part of the Willow Creek Daylight Final Feasibility Study project in Edmonds, Washington.

We are in the process of reviewing available information. Background research will include a site files search at the Washington State Department of Archaeology and Historic Preservation, review of previously recorded cultural resource reports, and review of pertinent published literature and ethnographies. Results of our investigations will be presented in a technical memo.

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Sincerely,

Glenn D. Hartmann
President/Principal Investigator

PO Box 10668, Bainbridge Island, WA 98110
Phone 206.855.9020 - info@crcwa.com

Cultural Resource Consultants, Inc.

June 4, 2014

Snohomish Tribe
Michael Evans, Chair
11014 19th Ave SE Suite 8
Everett, WA 98208

Re: Cultural Resources Assessment for the Willow Creek Daylight Final Feasibility Study Project, Edmonds, Snohomish County, WA

Dear Mr. Evans

I am writing to inform you of a cultural resources assessment for the above referenced project and to seek additional information about the project area the Tribe may have that is not readily available through other written sources. The project is located along Edmonds Way, between W Dayton Street and Pine Street/Pine Drive in Edmonds, Snohomish County, Washington. Shannon & Wilson, Inc., on behalf of the City of Edmonds, is requesting this assessment as a part of the Willow Creek Daylight Final Feasibility Study project in Edmonds, Washington.

We are in the process of reviewing available information. Background research will include a site files search at the Washington State Department of Archaeology and Historic Preservation, review of previously recorded cultural resource reports, and review of pertinent published literature and ethnographies. Results of our investigations will be presented in a technical memo.

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Sincerely,

Glenn D. Hartmann
President/Principal Investigator

PO Box 10668, Bainbridge Island, WA 98110
Phone 206.855.9020 - info@crcwa.com

Cultural Resource Consultants, Inc.

June 4, 2014

Muckleshoot Indian Tribe
Laura Murphy, Archaeologist/Cultural Resources
39015 172nd Ave SE
Auburn, WA 98092

Re: Cultural Resources Assessment for the Willow Creek Daylight Final Feasibility Study Project, Edmonds, Snohomish County, WA

Dear Laura:

I am writing to inform you of a cultural resources assessment for the above referenced project and to seek additional information about the project area the Tribe may have that is not readily available through other written sources. The project is located along Edmonds Way, between W Dayton Street and Pine Street/Pine Drive in Edmonds, Snohomish County, Washington. Shannon & Wilson, Inc., on behalf of the City of Edmonds, is requesting this assessment as a part of the Willow Creek Daylight Final Feasibility Study project in Edmonds, Washington.

We are in the process of reviewing available information. Background research will include a site files search at the Washington State Department of Archaeology and Historic Preservation, review of previously recorded cultural resource reports, and review of pertinent published literature and ethnographies. Results of our investigations will be presented in a technical memo.

We are aware that not all information is contained within published sources. Should the Tribe have additional information to support our assessment, we would very much like to include it in our study. Please contact me should you wish to provide any comments. I appreciate your assistance in this matter and look forward to hearing from you.

Sincerely,

Glenn D. Hartmann
President/Principal Investigator

PO Box 10668, Bainbridge Island, WA 98110
Phone 206.855.9020 - info@crcwa.com

Cultural Resource Consultants, Inc.

June 4, 2014

Snoqualmie Nation
Steve Mullen
PO Box 969
Snoqualmie, WA

Re: Cultural Resources Assessment for the Willow Creek Daylight Final Feasibility Study Project, Edmonds, Snohomish County, WA

Dear Steve:

I am writing to inform you of a cultural resources assessment for the above referenced project and to seek additional information about the project area the Tribe may have that is not readily available through other written sources. The project is located along Edmonds Way, between W Dayton Street and Pine Street/Pine Drive in Edmonds, Snohomish County, Washington. Shannon & Wilson, Inc., on behalf of the City of Edmonds, is requesting this assessment as a part of the Willow Creek Daylight Final Feasibility Study project in Edmonds, Washington.

We are in the process of reviewing available information. Background research will include a site files search at the Washington State Department of Archaeology and Historic Preservation, review of previously recorded cultural resource reports, and review of pertinent published literature and ethnographies. Results of our investigations will be presented in a technical memo.

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Sincerely,

Glenn D. Hartmann
President/Principal Investigator

PO Box 10668, Bainbridge Island, WA 98110
Phone 206.855.9020 - info@crcwa.com

Cultural Resource Consultants, Inc.

June 4, 2014

Suquamish Tribe
Stephanie Trudel
PO Box 498
Suquamish, WA 98392-0498

Re: Cultural Resources Assessment for the Willow Creek Daylight Final Feasibility Study Project, Edmonds, Snohomish County, WA

Dear Stephanie:

I am writing to inform you of a cultural resources assessment for the above referenced project and to seek additional information about the project area the Tribe may have that is not readily available through other written sources. The project is located along Edmonds Way, between W Dayton Street and Pine Street/Pine Drive in Edmonds, Snohomish County, Washington. Shannon & Wilson, Inc., on behalf of the City of Edmonds, is requesting this assessment as a part of the Willow Creek Daylight Final Feasibility Study project in Edmonds, Washington.

We are in the process of reviewing available information. Background research will include a site files search at the Washington State Department of Archaeology and Historic Preservation, review of previously recorded cultural resource reports, and review of pertinent published literature and ethnographies. Results of our investigations will be presented in a technical memo.

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Sincerely,

Glenn D. Hartmann
President/Principal Investigator

PO Box 10668, Bainbridge Island, WA 98110
Phone 206.855.9020 - info@crcwa.com

Tribal Historic Preservation Officer
Fisheries Department
360/394-8529
Fax 360/598-4666

THE SUQUAMISH TRIBE
P.O. Box 498 Suquamish, Washington 98392

June 13, 2014

Mr. Glenn Hartmann
Cultural Resource Consultants, Inc.
PO Box 10668
Bainbridge Island, WA 98110

RE: Willow Creek Daylight Final Feasibility Study Project, Edmonds, Snohomish County, WA
Request for Traditional Cultural Property Information
Suquamish Tribe Reference: 14-06-11-01

Dear Glenn:

Thank you for consulting with the Suquamish Tribe regarding CRC's cultural resources assessment for the Willow Creek Daylight Final Feasibility Study Project in Edmonds, Washington. The project area is within the Suquamish Tribe's adjudicated Usual & Accustomed Fishing Area, and has a high probability for cultural resources. The area was once a sand spit, a high probability landform. Several ethnographic place names have been recorded in the project vicinity.

Please contact me at 360-394-8533 or via e-mail at strudel@suquamish.nsn.us as additional project information becomes available, and please send us a copy of the finalized report for our records.

Sincerely,

Stephanie E. Trudel

Stephanie E. Trudel
Archaeologist

Cc: Gretchen Kaehler, Local Government Archaeologist, Washington State Department of Archaeology and Historic Preservation

Attachment B. Archaeological Investigation Plan and Inadvertent Discovery Protocol

Introduction

On behalf of the City of Edmonds, Shannon & Wilson, Inc., retained Cultural Resource Consultants, Inc. (CRC) to prepare a cultural resources assessment of the Willow Creek Daylighting Project in Edmonds, Snohomish County, Washington. The project is in the Final Feasibility Study phase. The goal of the overall project is to restore tidal inflow and to improve fish passage conditions into Edmonds Marsh, by daylighting Willow Creek. This is expected to entail dredging tidal channels in Edmonds Marsh, replacing outfall culverts on the north side of the marsh, excavating a daylight channel and removing an existing outfall inlet on Unocal property, and excavating a beach channel and abandoning the existing Willow Creek outfall at Marina Beach Park.

CRC's cultural resources investigations for the project have included background research and field investigations to identify any recorded archaeological sites within the project location and to assess the potential for as-yet unknown archaeological resources to be present. Based upon the results of this work, the majority of the project is considered to have a low potential to impact as-yet unknown archaeological sites, but the portion of the project in the Park Survey on a former sand spit is considered to have a higher potential to contain archaeological sites. Archaeological deposits, if present, would be buried beneath the depth of fill and other prior landscape modifications. CRC has, therefore, recommended archaeological monitoring during construction or other ground-disturbing activities with the potential to intersect native sediments in this area.

Archaeological Monitoring

Archaeological monitoring would entail having an archaeologist present during ground-disturbing work with the potential to intersect native sediments in order to observe subsurface conditions and identify any buried archaeological materials that may be encountered. Monitoring will be performed either by a "professional archaeologist" (RCW 27.53.030 (8)) or under the supervision of a professional archaeologist.

The monitoring archaeologist would stand in close proximity to construction equipment in order to view subsurface deposits as they are exposed, and would be in close communication with equipment operators to ensure adequate opportunity for observation and documentation. Archaeological monitoring will seek to identify potential buried surfaces, anthropogenic sediments, and archaeological features such as shell middens, hearths, or artifact-bearing strata. The monitoring archaeologist will inspect construction excavations and spoils piles for indications of such archaeological resources.

The archaeologist will be provided the opportunity to screen excavated sediments and matrix samples when this is judged useful to the identification process. It is not expected that fill (e.g., imported culturally-sterile construction fill) or glacial sediments would be included in screening procedures. Excavated spoils may be examined in the course of monitoring. If cultural materials are observed in spoils piles, it is expected that these would be removed for examination and that the opportunity to screen spoil sediments would be available.

Archaeological monitoring of construction will proceed until it can be determined with a greater level of confidence that cultural resources will not be impacted by construction. The archaeologist will conduct monitoring until native and fill deposits can be confidently isolated and identified based on observed sedimentary exposures. Recommendations for additional monitoring (i.e. during construction) will depend on several factors, including, but not limited to, stratigraphy of deposits observed during monitoring efforts, spatial distribution of exposures across the project, and representation of the exposures in context of the project.

Upon completion of the monitoring, the archaeologist will prepare a report on the methods and results of the work, and recommendations for any necessary additional archaeological investigations, illustrated with maps, drawings, and photographs as appropriate.

The following protocols outline procedures to follow, in accordance with state and federal laws, if archaeological materials or human remains are discovered.

Protocols for Discovery of Archaeological Resources

The Archaeological Sites and Resources Act (RCW 27.53) prohibits knowingly disturbing archaeological sites without a permit from the Washington State Department of Archaeology and Historic Preservation (DAHP), and the Indian Graves and Records Act (RCW 27.44) prohibits knowingly disturbing Native American or historic graves.

In the event that archaeological resources are encountered during project implementation, the following actions will be taken:

In work areas, all ground disturbing activity at the location will stop, and the work supervisor will be notified immediately. The work site will be secured from any additional impacts and the supervisor will be informed.

The project proponent will immediately contact the agencies with jurisdiction over the lands where the discovery is located, if appropriate. The appropriate agency archaeologist or the proponent’s contracting archaeologist will determine the size of the work stoppage zone or discovery location in order to sufficiently protect the resource until further decisions can be made regarding the work site.

The project proponent will consult with DAHP regarding the evaluation of the discovery and the appropriate protection measures, if applicable. Once the consultation has been completed, and if the site is determined to be NRHP-eligible, the project proponent will request written concurrence that the agency or tribe(s) concurs that the protection and mitigation measures have been fulfilled. Upon notification of concurrence from the appropriate parties, the project proponent will proceed with the project.

Within six months after completion of the above steps, the project proponent will prepare a final written report of the discovery. The report will include a description of the contents of the discovery, a summary of consultation, and a description of the treatment or mitigation measures.

Protocols for Discovery of Human Remains

If human remains are found within the project area, the project proponent, its contractors or permit-holders, the following actions will be taken, consistent with Washington State RCWs 68.50.645, 27.44.055, and 68.60.055:

If ground-disturbing activities encounter human skeletal remains, then all activity will cease that may cause further disturbance to those remains. The area of the find will be secured and protected from further disturbance. The project proponent will prepare a plan for securing and protecting exposed human remains and retain consultants to perform these services. The finding of human skeletal remains will be reported to the county medical examiner/coroner and local law enforcement in the most expeditious manner possible. The remains will not be touched, moved, or further disturbed. The county medical examiner/coroner will assume jurisdiction over the human skeletal remains and make a determination of whether those remains are forensic or non-forensic. If the county medical examiner/coroner determines the remains are non-forensic, then they will report that finding to DAHP, which will then take jurisdiction over the remains. DAHP will notify any appropriate cemeteries and all affected tribes of the find. The State Physical Anthropologist will make a determination of whether the remains are Indian or Non-Indian and report that finding to any appropriate cemeteries and the affected tribes. DAHP will then handle all consultation with the affected parties as to the future preservation, excavation, and disposition of the remains.

Contact Information

City of Edmonds Public Works Department, Engineering Division
121 5th Ave N., Edmonds, WA 98020
Primary Contact: Jerry Shuster, Stormwater Engineering Program Manager, 425-771-0220 ext. 1323

Shannon & Wilson, Inc.
400 N 34th Street, Suite 100, Seattle, WA 98103
Primary Contact: David Cline, 206-695-6885

Edmonds Police Department
250 5th Ave N., Edmonds, WA 98020
Lead Representative: Al Compaan, Chief of Police, 425-771-0200

Snohomish County Medical Examiner's Office
9509 29th Ave. West, M/S 203, Everett, WA 98204
Lead Representative: Norman Thiersch, M.D., Chief Medical Examiner, 425-438-6200

Washington State Department of Archaeology and Historic Preservation (WA DAHP)
P.O. Box 48343, Olympia, WA 98504-8343
Lead Representative: Allyson Brooks, State Historic Preservation Officer, 360-586-3066
Primary Contact: Rob Whitlam, Ph.D., State Archaeologist, 360-586-3080
Primary Contact for Human Remains: Guy Tasa, State Physical Anthropologist, 360-586-3534

Muckleshoot Indian Tribe
39015 172nd Ave SE, Auburn, WA 98092
Lead Representative: Virginia Cross, Chair, 253-939-3311 ext 3194
Primary Contact: Laura Murphy, Cultural Resources, 253-876-3272

Snohomish Tribe
11014 19th Ave. SE, Suite #8, PMB #1, Everett, WA 98208
Lead Representative and Primary Contact: Michael didahalqid Evans, Chair, 425-744-1855

Snoqualmie Nation
8130 Railroad Ave, Suite 103; PO Box 969, Snoqualmie, WA 98065
Lead Representative: Carolyn Lubenau, Chair, 425-888-6551
Primary Contact: Steven Mullen-Moses, Cultural Resources, 425-888-6551

Stillaguamish Tribe
3310 Smokey Point Drive, PO Box 277, Arlington, WA 98223-0277
Lead Representative: Shawn Yanity, Chair, 360-652-7362
Primary Contact: John Miller, Cultural Resources, 360-652-7362

Suquamish Tribe
15838 Sandy Hook Rd; POB 498, Suquamish, WA 98392-0498
Lead Representative: Leonard Forsman, Chair, 360-394-8461
Primary Contact: Dennis Lewarch, Cultural Resources 360-394-8529

Swinomish Tribe
11404 Moorage Way, LaConner, WA 98257
Lead Representative: Brian Cladoosby, Chair, 360-466-7205
Primary Contact: Larry Campbell, Cultural Resources, 360-466-7352

Tulalip Tribes
6406 Marine Dive NW, Tulalip, WA 98271
Lead Representative: Melvin Sheldon, Jr., Chair, 360-651-4500
Primary Contact: Richard Young, Cultural Resources, 360-716-2652

APPENDIX I

GEOTECHNICAL EVALUATION

Willow Creek Daylight Project
Conceptual Level Geotechnical Assessment
Edmonds, Washington

November 24, 2014

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Excellence. Innovation. Service. Value.
Since 1954.

Submitted To:
Mr. Jerry Shuster
City of Edmonds
121 5th Avenue N
Edmonds, Washington 98020

By:
Shannon & Wilson, Inc.
400 N 34th Street, Suite 100
Seattle, Washington 98103

21-1-12393-406

November 24, 2014

Mr. Jerry Shuster
Stormwater Engineering Program Manager
City of Edmonds
121 5th Avenue N.
Edmonds, WA 98020

RE: WILLOW CREEK DAYLIGHT PROJECT, CONCEPTUAL LEVEL GEOTECHNICAL ASSESSMENT, EDMONDS, WASHINGTON

Dear Mr. Shuster:

This letter report presents a summary of our geotechnical review of proposed channel excavation activities for the Willow Creek Daylight Project in Edmonds, Washington. The location of the project site is shown on the Vicinity Map, Figure 1. The purpose of this geotechnical assessment is to evaluate the potential effects of proposed channel excavations on adjacent property and structures and to develop conceptual level design recommendations to mitigate hazards if necessary. Shannon & Wilson, Inc. reviewed existing data and performed subsurface explorations to evaluate the stability of the proposed excavations and other geotechnical considerations for conceptual design for this Final Feasibility Phase. Results are presented herein.

BACKGROUND

The project site is located at the western edge of Edmonds (Figure 1, Vicinity Map). The City of Edmonds proposes daylighting the downstream section of Willow Creek to improve fish passage to the Edmonds Marsh, as part of a larger restoration project. Willow Creek flows from uplands through Edmonds Marsh into a stormwater pipe and into Puget Sound, as shown on the Willow Creek Restoration Area drawing, Figure 2. The downstream section of Willow Creek currently flows through culverts underneath the BNSF Railway Company (BSNF) Railroad, into a stormwater pipe along Admiralty Way, and under Marina Beach Park (the Park) to an outfall in Puget Sound. The proposed daylight channel will connect to the existing channel along BNSF and Chevron/Unocal property. It will then extend underneath the existing BNSF bridge, underneath a proposed new pedestrian and maintenance vehicle bridge at the Park, and then westward into Puget Sound, as shown in the Site and Exploration Plan, Figure 3. This general alignment selected as the preferred alternative alignment during the Early Feasibility Phase of this project. The preferred alignment through Marina Beach Park is yet to be determined, but is proposed as either Option A that extends through the off-leash dog park area or Option B that extends through the north end of the Park through the lawn to the beach (Figure 3).

Conceptual designs for this alignment include making a channel excavation from the existing open channel along the BNSF Railroad for a distance of about 750 feet to the Park (Figures 2 and 3). The preliminary dimensions of the excavations are expected to be 5 to 10 feet deep with a bottom width of 14 feet and a top width of 40 to 50 feet. Side slopes along the BNSF and Unocal property are 2 Horizontal to 1 Vertical (2H:1V). Immediately upstream from the BNSF bridge the east bank side slope is shown as 2H:1V with the possibility of a soldier pile wall installed where the channel meets the toe of the steep slope or a reduction in channel width at this location. Downstream from the bridge the side slopes are 3H:1V.

Subsurface explorations were conducted along both Park channel alignment options to characterize materials and evaluate geologic conditions present at the Park. Access limitations at this time prevented exploration in the daylight channel section along the Chevron/Unocal property and BNSF Railroad and adjacent to a steep slope just east of the BNSF bridge. We reviewed available background data and subsurface information from Arcadis reports and BNSF bridge designs to evaluate conditions for these areas where we did not have access.

SUBSURFACE EXPLORATIONS

The locations of the boring and test pits completed for this project are shown in the Site and Explorations Plan, Figure 3. Descriptions of the drilling programs, test pit programs, and the boring and test pit logs are presented in Appendix A.

Shannon & Wilson, Inc. explored subsurface conditions at seven locations in the Park (Figure 3). Subsurface explorations were performed for soil characterization, geotechnical analyses, and contamination testing on August 28 and 29 and September 5, 2014. A representative from Shannon & Wilson, Inc. was present during the field exploration periods to observe the drilling and sampling operations, retrieve representative soil samples for subsequent laboratory testing, and to prepare descriptive field logs. Additionally, an archeologist was on-site during field explorations to document the presence of pre-historic and historical items (Cultural Resource Consultants, Inc. [CRC], 2014).

Borings B-1 and B-2 were drilled by Holt Services, Inc. in two locations in the off-leash dog park. These borings extended to 45 feet below ground surface (bgs) and 20 feet bgs, respectively. The borings were drilled using mud rotary drilling techniques to advance below the ground level. Standard Penetration Tests were performed at select depth intervals and samples were collected for visual classification, water content determinations, and grain size analysis.

Test pits were excavated by Clear Creek Contractors on September 5, 2014. Test pits TP-1, TP-2, and TP-3 were excavated in the off-leash dog park along the Option A alignment to depths ranging between 9.5 and 11 feet (bgs). Test pits TP-4 and TP-5 were excavated in the park along the Option B alignment to depths of 14 and 8.3 feet, respectively. Samples were collected at select depth intervals for visual classification, water content determinations, and grain size analysis.

We screened samples on site for contamination based on visual, olfactory, or other indication of contamination. We screened samples collected near the water table, where encountered, for volatile organic compounds using a photoionization detector. No indications of hydrocarbon contamination were observed in the test pit or boring samples.

LABORATORY ANALYSES

Geotechnical laboratory tests were performed on select samples retrieved from the explorations to characterize the index and engineering properties of the subsurface soils at the project site. Laboratory testing included visual soil classification, moisture content determinations, and grain size analyses. The geotechnical laboratory testing was performed in the Shannon & Wilson, Inc. laboratory in Seattle, Washington, and in general accordance with the American Society of Testing and Materials/ASTM International (ASTM) standard procedures (ASTM, 2000 – 2011). A brief description of the laboratory test procedures and the laboratory test results are presented in Appendix B.

GEOLOGIC INTERPRETATION

We interpreted the geology and subsurface conditions along the project alignment from samples collected from geotechnical borings and test pits performed from this phase of the project, from data gathered from existing projects in the vicinity, and from geologic maps of the area. The following includes a description of geologic setting, of interpreted geologic units, and the subsurface conditions encountered in the project area from our explorations and explorations by others.

Geologic Setting

Geologists generally agree that the Puget Sound area was subjected to six or more major glacial events. Each glaciation deposited new sediment and partially eroded previous sediments. During the intervening periods when glacial ice was not present, normal stream processes, wave action, weathering, and landsliding eroded and reworked some of the glacially derived sediment, further complicating the geologic setting.

During the most recent Fraser Glaciation of the Vashon Stade that covered the central Puget Lowland, approximately 18,000 to 16,000 years before present (Porter and Swanson, 1998), the glacial ice is estimated to have been about 3,000 feet thick in the project area (Thorson, 1989). The weight of the glacial ice resulted in compaction of the glacial and nonglacial soils beneath the ice. The glacial and nonglacial deposits are overlain by younger (Holocene Epoch), relatively loose and soft, post-glacial soils that include peat, beach, and fill deposits.

Existing Information

According to geologic maps (Washington State Department of Natural Resources [DNR], 2011 and Minard, 1983), the soils along the daylight channel alignment consist of fill. The adjacent steep slope to the east consists of nonglacial soils of the Whidbey Formation, which are glacially over-ridden and typically consist of locally cross-bedded sand with silt and clay layers.

Additionally, we reviewed geologic and subsurface explorations and interpretations in the following documents include:

- Final Conceptual Site Model (Arcadis, 2013),
- Final 2011 Site Investigation Completion Report (Arcadis, 2012), and
- BNSF Final Design Services (BNSF, 2010), including borings by HWA Geosciences Inc. (HWA, 2008)

Arcadis conducted remedial site investigations for the former Unocal Edmonds Bulk Fuel Terminal property on behalf of Chevron Environmental Management Company, with reports dating back to 2001. These studies have included remediation stages involving site history, subsurface exploration, groundwater monitoring, and soil and groundwater testing in the vicinity of the daylight channel alignment east of the BNSF Railroad. Arcadis (2012) identified five geologic units along the daylight channel alignment, including:

- 2008 Fill is remediation backfill materials that consist of poorly graded, coarse gravel generally 6 to 12 inches above observed groundwater, overlain by fine to medium sand, trace silt, and fine to medium gravel to the ground surface.
- 1929 Fill consists of silty sands with gravel and sandy silts with gravel from 8 to 15 feet bgs interpreted as fill material placed circa 1929 or later.
- Marsh Deposits consists of a 6- to 12-inch-thick layer of silty and sandy silt with organic matter such as peat, wood debris, and decomposing vegetation beneath the 1929 Fill. It was generally encountered from about 8 to 14 feet bgs. The unit is directly below the 1929 Fill material and interpreted to be representative of the former marsh.
- Beach Deposits consists of poorly graded, fine to medium sand with fine gravel that contains organic material such as driftwood and seashells. This layer is interpreted to represent of the former beach environment in the area prior to development.
- Whidbey Formation. This material is a poorly graded sand layer consisting of fine to medium sand with fine gravel that contains interbedded sand with silt, and interbedded silt and sandy silt ranging in thickness from 1 inch to several feet.

Figure A-9 in Appendix A shows depths of the remediation gravel backfill of the 2008 Fill (Arcadis, 2012) and monitoring well MW-149R (Figure A-10) (Arcadis, 2013) shows the stratigraphy of remediation gravel in the north end of the daylight channel alignment east of the BNSF Railroad.

Boring logs BH-1 and BH-2 from the geotechnical report that accompanied the design plans for the BNSF Railroad bridge foundations were used in subsurface interpretations and are presented in Appendix A-11 and A-12.

Geologic Units

We identified geologic units to group the complex sediment and soil types encountered in the project explorations. The geologic unit descriptions are described herein and are shown on the boring logs presented in Figures A-2 through A-12 in Appendix A and Figure 4.

The subsurface conditions we encountered in explorations in the project area generally consist of a fill (Hf) layer overlying beach deposits (Hb) locally interlayered with a 0.5- to 1-foot-thick marsh deposit (Hm). These units are further described as:

- **Fill (Hf) –** Explorations encountered 6 to 8 feet of fill soil with variable properties. Hf generally consists of silty sand with gravel and cobbles to clayey sand with gravel and cobbles to 6 feet bgs at TP-4 at Marina Beach Park lawn area. This fill may be associated with a glacial till source. Hf encountered in Marina Beach Park outside of the lawn area consists of poorly graded sand with gravel to 8 feet bgs, and may be derived from a nearby excavation in a similar beach environment. Based on the historic land uses in this area, some deposits resembling beach deposits have been interpreted as fill.
- **Beach Deposits (Hb) –** Explorations encountered more than 20 feet to 46.5 feet of Hb below the fill unit. Hb generally consists of medium dense, poorly graded sand with silt to poorly graded sand and gravel with variable amounts of silt and wood fragments. Below about 35 feet, Hb becomes dense.
- **Marsh Deposits (Hm)** – Test pit explorations locally encountered a thin ½- to 1-foot-thick layer of silty sand laminated with sandy silt and peat between 6 to 8 feet bgs. Metal debris was found on top of, and in, the marsh deposits in TP-2 and TP-3. We encountered trace iron-oxide staining was found in marsh deposits in TP-5.

Subsurface Conditions

Interpreted subsurface conditions along the daylight channel alignment based on existing information and explorations performed for this project are presented in Cross Sections A-A' through D-D' of the Typical Stream Channel Cross Section, Figure 4.

Option A of the daylight channel alignment consists of Hb with possible fill (Hf) from a beach source in the upper 6 to 8 feet bgs as presented in Cross Section A-A' (Figure 4). Option B of the daylight channel alignment consists of fill (Hf) to 6 feet bgs, possibly from a glacial till source, overlying Hb as presented in Cross Section B-B'.

Subsurface conditions at the location of the proposed pedestrian bridge are underlain by Hb and Hf deposits of a beach origin as presented in Cross Section D, Sheet 2 of Figure 4.

Subsurface conditions at the adjacent steep slope and the base of the steep slope, where the daylight channel alignment meets the toe of the slope is shown in Cross Section C-C'. Cross Section C-C' indicates Hb and Hf are present at the base of the slope and mapped Whidbey Formation underlies the slope. There is likely a layer of colluvium mantling the slope with variable thicknesses but the exact configuration of these layers is unknown at this time. Fill in the form of remediation gravels backfilled to between 4 to 6 feet bgs will likely be encountered north of Cross Section C-C'.

Groundwater was encountered at about 9.5 feet bgs (elevation 6 feet NAVD88) at B-1, B-2, and TP-1 at Cross Section A-A'. At TP-5, on the beach, groundwater was encountered at 8 feet bgs (elevation 3.5 feet NAVD88), possibly due to close proximity to tide levels.

GEOTECHNICAL CONCLUSIONS AND RECOMMENDATIONS

Daylighting of Willow Creek will require excavation of the daylight channel at the following locations:

- Along BNSF and Chevron/Unocal property near the Washington State Department of Transportation stormwater pipe and manhole,
- Underneath the existing BNSF Railroad bridge,
- Underneath a proposed new pedestrian and maintenance vehicle bridge at the Park, and
- Into the Park preferred alternative alignment of the beach outlet.

We have performed a geotechnical assessment to evaluate the potential effects on adjacent property and structures, and to develop recommendations for preliminary design of mitigation measures. We note that a site topographic survey and a geotechnical reconnaissance of the Unocal property was not performed due to access limitations. Therefore, our assessment of the surface features, exposed geology and stability of the Unocal property and the steep slope on the east boundary of the Unocal property was not performed as part of this study and remains to be performed during the design phase.

GEOLOGIC HAZARDS

Potential geologic hazards that may affect the site include slope failure of the steep slope; liquefaction and associated effects (lateral spreading, differential settlement, and reduced bearing capacity foundations); and fault rupture. Our review of these hazards is based on historical mapping and results of subsurface explorations.

Landslides are movement of a rock and/or soil mass on a slope caused by shear failure within the rock and/or soil. Based on the Washington State Coastal Atlas (Washington State Department of Ecology [Ecology], 1979), the project site is mapped as unstable due to the steep slope east of the railroad tracks. The closest mapped landslide occurred about ½-mile south of the site, along the shoreline. Landslides can occur quickly or progressively over time, and can be either deep-seated or shallow. Potential causes that can increase the risk of landsliding include: seismically induced ground movement, increasing the water and porewater pressures in the rock and/or soil, increasing the loading on or above the slope, removing material at the toe of the slope, and strain-softening of overconsolidated clay. At the project site, it is unlikely that seismic shaking would cause a deep-seated landslide because of the dense nature of the Whidbey Formation soils that underlie the slope. Surficial sloughing of loose colluvium on the surface of the slope is possible. We estimate that the potential for this type of movement is low to moderate over most of the hillside and high in some areas where local topography is steeper.

The proposed excavation of soils for channel construction at the toe of the steep slope just east of the BNSF bridge is potentially destabilizing. In our opinion, this proposed excavation over a distance of about 50 to 100 feet will likely require either construction of a retaining wall at the toe of the slope to accommodate the 2H:1V sloped bank on the east side of the creek or a reduction in channel width. If a retaining wall option is selected, it would likely consist of a soldier pile and lagging wall, as shown on Figure 4. Vertical members (soldier piles) consist of steel sections placed in predrilled holes spaced 6 to 8 feet apart and typically backfilled with lean mix concrete. Penetration depths below the final excavation level should be designed for kick-out resistance. We anticipate that the soldier pile embedment bgs may need to be up to two times the cantilevered height of the wall. We recommend that permanent lagging be installed between soldier piles. Permanent lagging may consist of precast concrete panels and should be installed as the excavation proceeds. In general, not more than 4 feet (measured vertically) of unsupported excavation should be exposed at any one time; however, that should be evaluated after the actual soil conditions at the wall location are determined by making subsurface explorations. The actual height of vertical, unsupported excavation may vary depending on the soils encountered. The final design embedment depths should be determined by the structural designer with input from the geotechnical engineer.

To protect the base of the wall from scour it may be necessary to construct a reinforced soil slope in front of the wall. Use of a geogrid-reinforced slope is one way to accomplish this. We have prepared a sketch illustrating this concept in Figure 5, Schematic Soldier Pile Wall. A vegetated surface (green screen or green wall) can be installed in this area to provide the benefits of overhanging vegetation to this section of the channel while visually hiding the constructed wall, as shown in Figure 5.

Soil liquefaction is a phenomenon in which excess pore pressure in loose, saturated, granular soils increases during ground shaking to a level near the initial effective stress, thus resulting in a reduction of shear strength of the soil (a quicksand-like condition). Because of this reduction in shear strength during liquefaction, ground settlement and lateral spreading (ground movement on very gentle slopes) may occur. Vertical and lateral foundation restraint may also be significantly reduced. In general, the soils below about 14 feet at the site are sufficiently dense to preclude liquefaction. There is a thin layer of medium dense sand between about 10 and 14 feet that could liquefy; however, in our opinion, this would result in minimal ground settlement and no lateral spreading.

The fault nearest to the project site is the South Whidbey Island Fault, which is 7.2 miles away. Based on the distance to the nearest fault and the apparent lack of recent movement on this fault, it is our opinion that the potential for fault rupture at the site is relatively low and not a design issue.

Based on the mapped information and geotechnical analyses in the vicinity, of the potential for geologic hazards at the site is considered low provided the slope instability mitigation measures discussed above are included in the design.

Channel Side Slope Stability

In general, the proposed Willow Creek channel alignment alternatives are underlain by loose to dense, granular fill materials and beach deposits that will provide relatively stable side slopes ranging from 2H:1V to 3H:1V. During our subsurface explorations, we observed groundwater at elevation 6 feet in TP-1, 3.5 feet in TP-5, 6 feet in B-1, and 7 feet in B-2. It is likely that the groundwater elevation will fluctuate with the tides and in response to rainfall. The proposed bottom of channel is elevation 4 feet. Therefore, the proposed channel excavation will extend below the groundwater level in some areas. Groundwater control and temporary dewatering will be required in order to maintain stable slopes and allow excavation to be performed under “dry” conditions.

At the proposed Marina Beach channel, shown in Figure 4, Sections A-A’ and B-B’, the soils that will form the channel side slopes consists of loose to dense sand and gravel fill over beach sands. The proposed channel cross sections indicate that the creek will consist of a 6-foot-wide low-flow channel and a 20-foot-wide bankfull channel. These soils will generally form stable 2H:1V side slopes, steeper than the proposed 3H:1V side slope. The soils encountered in boring B-2, located adjacent to the south side of the existing parking lot, consisted of medium dense sand and gravel (fill and beach deposits). In our opinion, the proposed channel excavation for channel alignment Option A, adjacent to the parking lot, will not create a slope stability issue for the parking lot.

At the proposed pedestrian bridge channel (Section D-D’), the soils that will form the channel side slopes consists of 7 feet of medium dense sand and gravel fill materials overlying medium dense beach sand and gravel. Groundwater was observed during drilling at 9.5 feet deep (elevation 6 feet). These soils will generally form stable 2H:1V side slopes. Scour protection will be required.

Based on our review of the BNSF bridge design drawings (Sheet 1 of 3, 90% Submittal by AECOM, dated December 8, 2008), the bridge was designed for a future 6-foot bottom width, with a channel invert elevation of 4.26 feet, with 1.5H:1V slopes extending down from the top of the bridge piers to the channel bottom. The geometry of the bridge (span is 37 feet long) is such that 2H:1V sloping side channels will not allow for a 6-foot-wide bottom channel. Thus, a steeper slope (1.5H:1V) will be required underneath the bridge. In our opinion, the steeper slope is acceptable; however, these slopes will need to be armored at the surface in order to limit erosion and scour which could cause undermining and sloughing of the slopes. Special precautions should be exercised during the excavation of soils from beneath the railroad bridge. We recommend that the exposed soils be systematically compacted with a backhoe-mounted hoepack as the excavation proceeds. This will densify the existing fill materials and beach deposits and reduce the potential for sloughing. We recommend armoring the side slopes with a 1-foot layer of 6- to 8-inch quarry spalls overlain by 1- to 2-foot riprap. Future excavations beneath the bridge will need to be coordinated with BNSF Railway operations and safety requirements.

Construction of the Willow Creek Channel improvements will require close coordination with BNSF. BNSF's primary concern will be the uninterrupted passage of trains, and work windows to perform construction may be as short as a couple of hours each day. It is important that this be considered in the in the design and constructability of the structure. We recommend that the design team meet with BNSF early on to discuss the project and better understand what their concerns are and how they will accommodate construction.

Geotechnical boring logs for the BNSF bridge project (borings BH-1 and BH-2 by HWA) indicated the presence of loose to medium dense sand and silt sand to 18.5 feet, followed by dense, slightly gravelly, silty sand and sand with gravel to the bottom of the boring at 41.5 feet deep. Based on our review of the soils data, it is likely, in our opinion, that the driven steel piles that support the BNSF bridge derive their bearing from soils below a depth of 18 feet. Thus, the proposed excavation that will remove soils from beneath the bridge will not have an adverse effect on foundation bearing capacity of the existing bridge.

At the proposed channel near the bluff, just east of the BNSF bridge (Section C-C'), the soils that will form the channel side slopes consists of granular fill materials to silt, sandy silt, and sands, as noted in boring logs MW-149R and BH-1, respectively. These soils will generally form stable 3H:1V side slopes; however, the current design shows a 2H:1V bank at the east side of the channel; however, the geometry of this section of creek channel will have to be modified to accommodate the property boundary and the steep slope that rises to the east. During an earlier data acquisition site visit, we noted the presence of a large old concrete structure extending along the toe of this steep slope. The structure may have been constructed to serve as a retaining wall at the toe of the slope. Given the close proximity of the proposed channel to the toe of the slope, it is possible that the proposed channel excavation could undermine the structure at the toe of the slope and thereby cause slope instability. We recommend that additional site investigations be performed to collect data on the slope, concrete structure, and condition of soils at this location. Site-specific slope stability analysis should then be performed to determine if mitigation measures are required. For feasibility level planning purposes, we recommend the preliminary design include a retaining wall structure along the toe of the steep slope (Figure 5).

Pedestrian and Maintenance Vehicle Access Bridge Design Considerations

Foundation Design

Structural design concepts for the proposed pedestrian bridge are not available at this time. However, we assume the bridge will span 30 to 35 feet over the proposed creek channel and be designed for HS-20 loading. Our analyses based on the results of boring B-1 indicate that the medium dense soils between 9 and 14 feet deep (below the groundwater level) at the proposed bridge location are susceptible to liquefaction during a design level seismic event. Thus, the upper 14 feet of soils at the proposed bridge site would be susceptible to settlements during a seismic event and shallow spread footing foundations will not be suitable. For this reason, we recommend that the proposed bridge be supported on deep foundations that derive their capacity from medium dense to dense granular soils below 14 feet. At this site, deep foundations may consist of either drilled piles, such as auger cast-in-place piles (augercast), or driven piles such as driven steel pipe. The following sections discuss design issues for each type of pile.

Pipe Pile Foundations

Piles develop resistance through friction between the side of the pile and the soil, and from end bearing at the tip of the pile. Piles are driven until a specified depth at which the amount of developed resistance is enough to withstand the proposed loading conditions. Pipe piles are typically installed by means of an impact hammer. Vibratory hammers can also be used during installation; however, vibratory hammer installation methods do not provide a means to evaluate that the pile has reached the correct driving criteria (driving resistance). Selection of the proper hammer for the driving conditions is important to the success of the installation. The hammer selection process requires an understanding of the pile diameter and required vertical compressive loads and uplift loads.

A drivability analysis should be performed in order to select the appropriate hammer. The drivability analysis should consist of dynamic load testing coupled with a Case Pile Wave Analysis Program and wave equation analysis. This will help determine the optimal driving equipment and confirm that the pile has sufficient capacity with the desired factor of safety. We recommend that a representative of the geotechnical engineer observe the installation of driven piles on a full-time basis to evaluate the adequacy of the construction procedures.

Augercast Pile Foundations

Augercast piles are installed by rotating a continuous-flight, hollow-stem auger to a predetermined depth. After the auger is rotated to the predetermined depth, a high-strength, sand-cement grout is pumped under controlled pressure through the center of the shaft as the auger is slowly withdrawn. By maintaining pressure in the grout line and extracting the auger no faster than an equivalent volume of grout is pumped, a continuous column of concrete is formed. A single reinforcing rod can be placed through the hollow stem of the auger and/or a reinforcing cage with centering guides can be placed in the column of wet grout. Where piles are expected to experience tensile/uplift forces, the central reinforcing rod should be extended for the full length of the pile.

The quality of the augercast concrete piles depends on the procedure and workmanship of the contractor who installs them. We recommend that a representative of the geotechnical engineer observe the installation of augercast piles on a full-time basis to evaluate the adequacy of the construction procedures.

Our conceptual evaluation of bridge foundations included a preliminary analysis of pile capacity. Assuming 12-inch steel pipe piles are selected, we estimate that a capacity of 50 tons can be achieved by driving the piles approximately 40 to 50 feet deep. We also considered 12-inch-diameter augercast piles. Augercast piles installed to a depth of 40 to 45 feet can develop up to 50 tons capacity. Greater capacities could be achieved by increasing the diameter of the piles or by increasing the depth of penetration.

Estimated Settlements of Pile Foundations

Based on the subsurface conditions encountered in the borings, estimated pile design loads, and installation techniques, relatively minor settlements will occur upon loading. We estimate total settlement of the piles would be on the order of ½ inch, with differential settlements of about ¼ inch. No long-term settlements are anticipated.

Lateral Resistance

Lateral loads acting on the structure may be resisted by the passive earth pressure against the pile caps and grade beams, the frictional resistance developed between the sides of the pile cap, and the lateral resistance provided by the vertical piles.

We recommend that passive earth pressure developed from compacted granular fill against the pile caps be estimated using an equivalent fluid weight of 300 pounds per cubic foot. This value applies to soils above the groundwater table and assumes that the pile caps are founded at least 2 feet below the adjacent grade. Lateral resistance analyses should be performed after the bridge pier design details are known.

LIMITATIONS

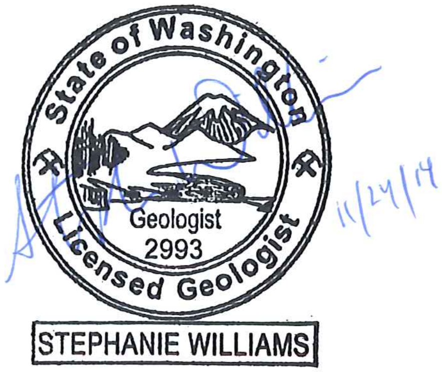
Within the limitations of scope, schedule, and budget, the conclusions and recommendations presented in this letter report were prepared in accordance with generally accepted professional geotechnical and environmental engineering principles and practices in this area at the time this letter report was prepared.

The data presented in this letter report are based on limited survey and phase of design development. It is also based on a limited number of samples. Shannon & Wilson, Inc. is not responsible for conditions or consequences arising from relevant facts that were concealed, withheld, or not fully disclosed at the time the letter report was prepared. We also note that the facts and conditions referenced in this letter report may change over time, and that the facts and conditions set forth here are applicable to the facts and conditions as described only at the time of this letter report. We believe that the conclusions stated here are factual, but no guarantee is made or implied.

This letter report was prepared for the exclusive use of City of Edmonds, and their respective representatives, and in no way guarantees that any agency or its staff will reach the same conclusions as Shannon & Wilson, Inc. This report did not include any evaluation regarding the presence or absence of wetlands or hazardous or toxic materials in the soil, surface water, groundwater, or air on or below or around the site beyond those discussed in the report. We have prepared the enclosed Appendix C, "Important Information About Your Geotechnical/ Environmental Report," to help you and others in understanding our reports.

Sincerely,

SHANNON & WILSON, INC.



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Geotechnical Engineer, LEED AP, DBIA™

Subsurface characterization and geologic interpretation was performed by Stephanie A. Williams, L.G.
Geotechnical engineering findings and recommendations were prepared by Martin W. Page, P.E., L.E.G.

SAW:DRC:MWP/mwp

Enc: References
- Figure 1 – Vicinity Map
- Figure 2 – Willow Creek Restoration Area
- Figure 3 – Site and Explorations Plan
- Figure 4 – Typical Stream Channel Cross Section, Section A-A', Section B-B', Section C-C', Section D-D' (2 sheets)
- Figure 5 – Schematic Soldier Pile Wall
- Appendix A – Subsurface Explorations
- Appendix B – Geotechnical Laboratory Test Procedures and Results
- Appendix C – Important Information About Your Geotechnical/Environmental Report

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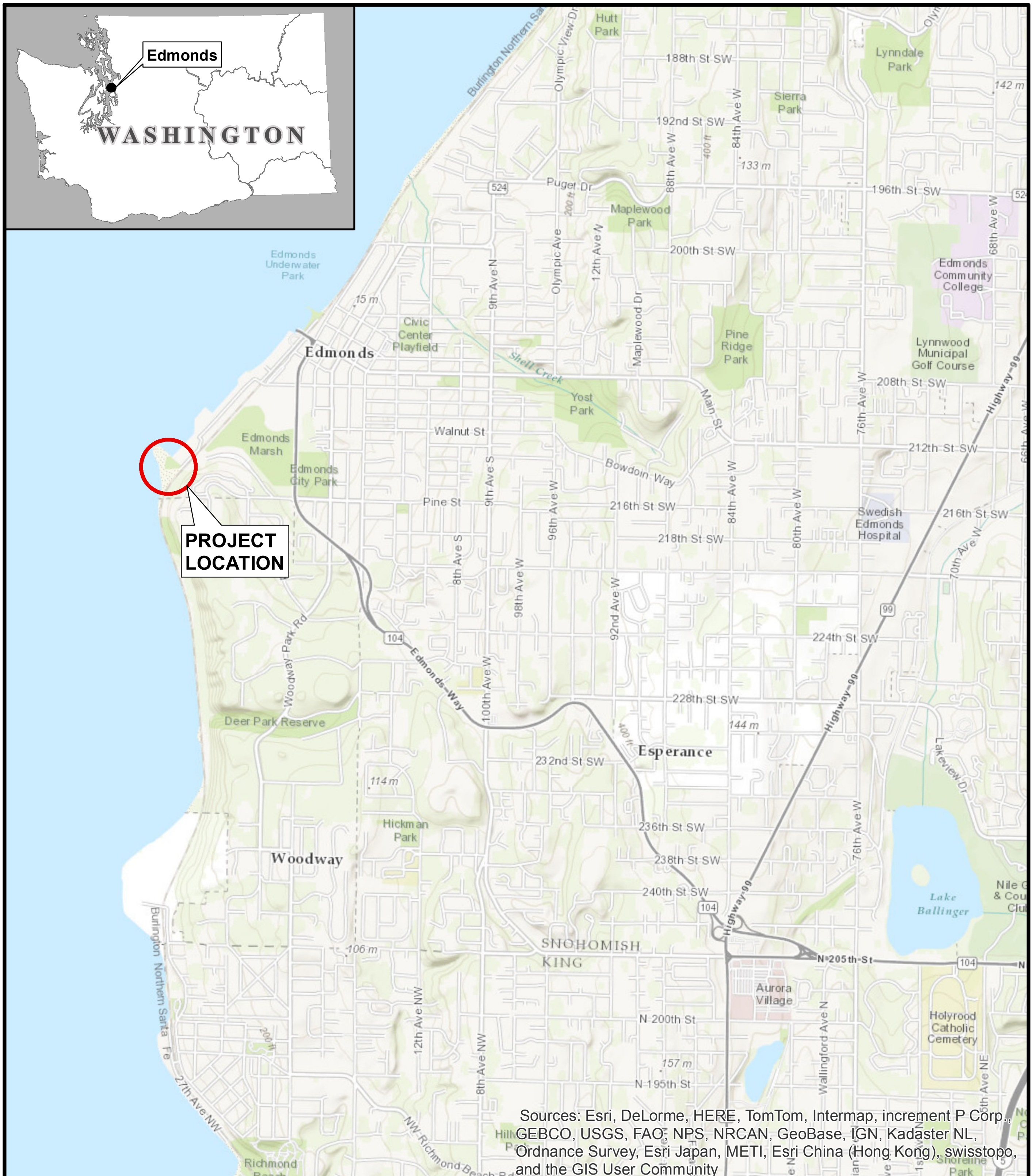

0 ½ 1

Scale in Miles

N W E S

Willow Creek Daylight Project
Geotechnical Evaluation
Edmonds, Washington

VICINITY MAP

November 2014 | 21-1-12393-406

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FIG. 1

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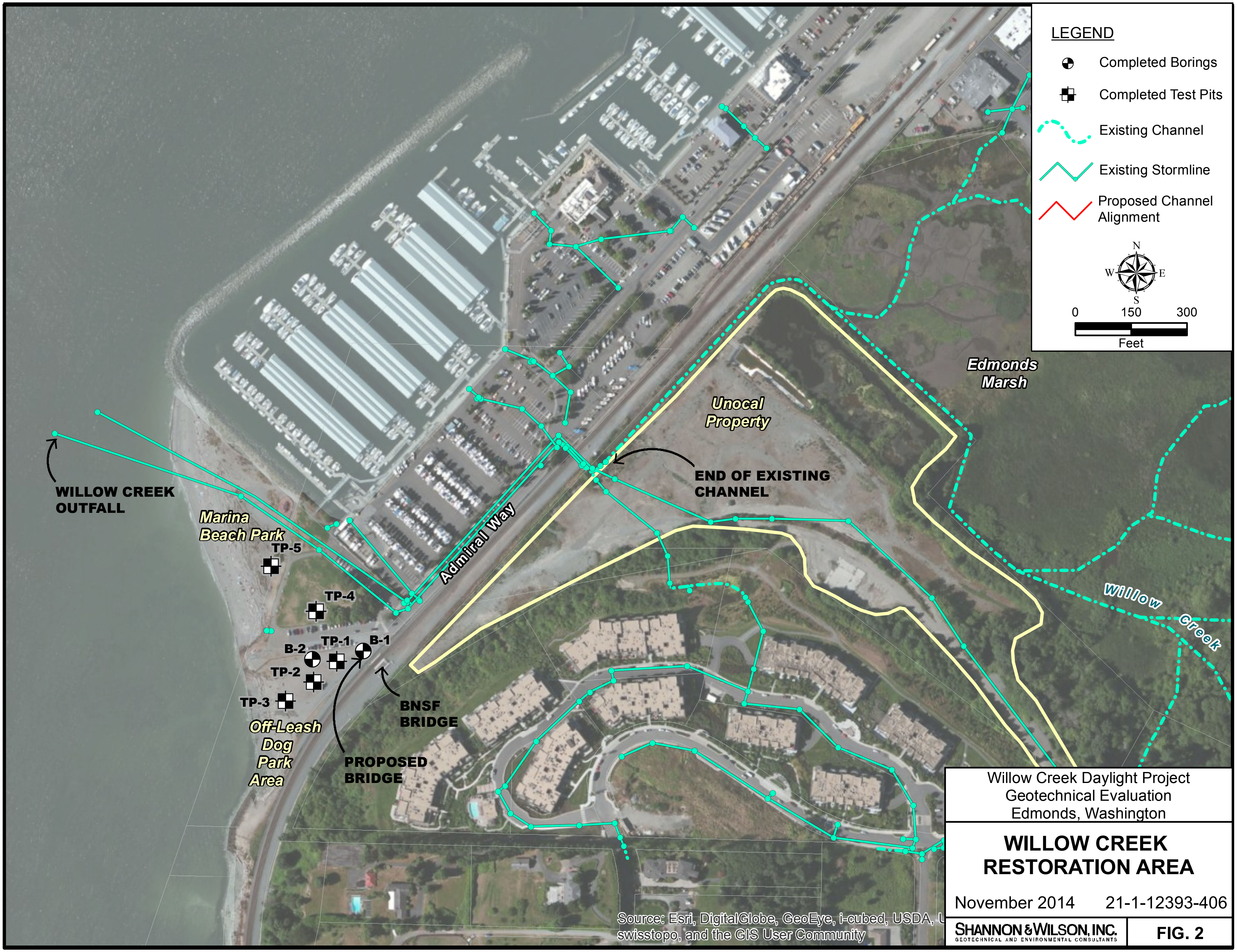

Willow Creek Daylight Project
Geotechnical Evaluation
Edmonds, Washington

WILLOW CREEK RESTORATION AREA

November 2014 21-1-12393-406

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FIG. 2

LEGEND

- Completed Boring
- Completed Test Pit
- Borings by Others
- Cross Section
- Proposed Channel Alignment

N W E S

0 100 200

Feet

Willow Creek Daylight Project
Geotechnial Evaluation
Edmonds, Washington

SITE AND EXPLORATIONS PLAN

November 2014 21-1-12393-406

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FIG. 3

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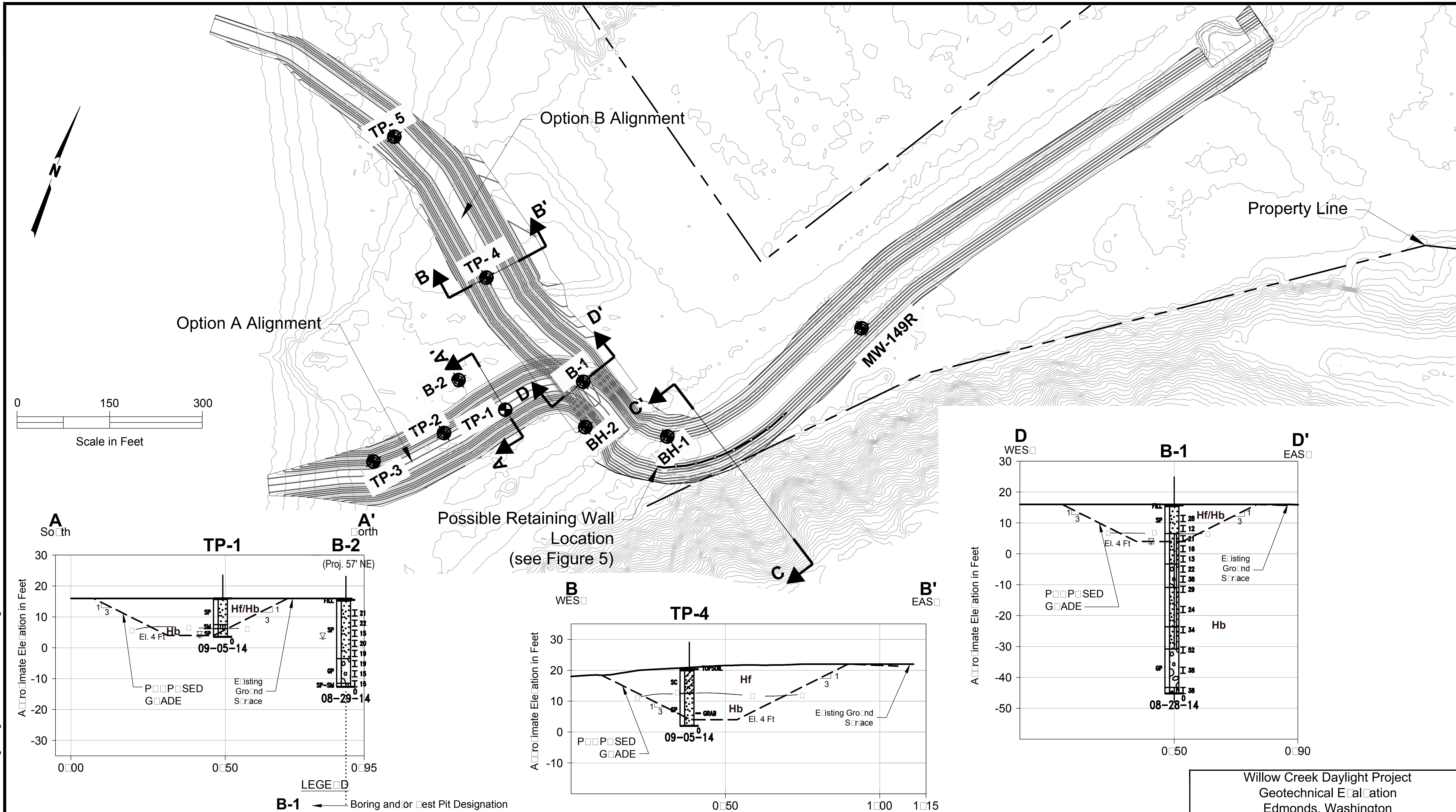

LEGEND

- B-1 — Boring and/or Test Pit Designation
- (Proj. 34' N) — Projected Distance
- 11 / 30/6" — Standard Penetration Test Blows/Foot or Blows/Inches Driven
- 15 — Modified California Sampler
- Water Level at Time of Drilling or Excavation
- USCS Symbol
- Approximate Geologic Contact
- Bottom of Boring
- 08-22-14 — Date Completed

NOTES

1. Ground surface is adapted from Site Survey and LiDAR.
2. This subsurface profile is generalized from materials observed in soil borings. Variations may exist between profile and actual conditions.
3. See Sheet 2 of Fig 4 for Section C-C'.

0 30 60
Scale in Feet
Vertical = Horizontal

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TYPICAL STREAM CHANNEL CROSS SECTION
SECTION A-A'
SECTION B-B'
SECTION D-D'

November 2014 | 21-1-12393-40

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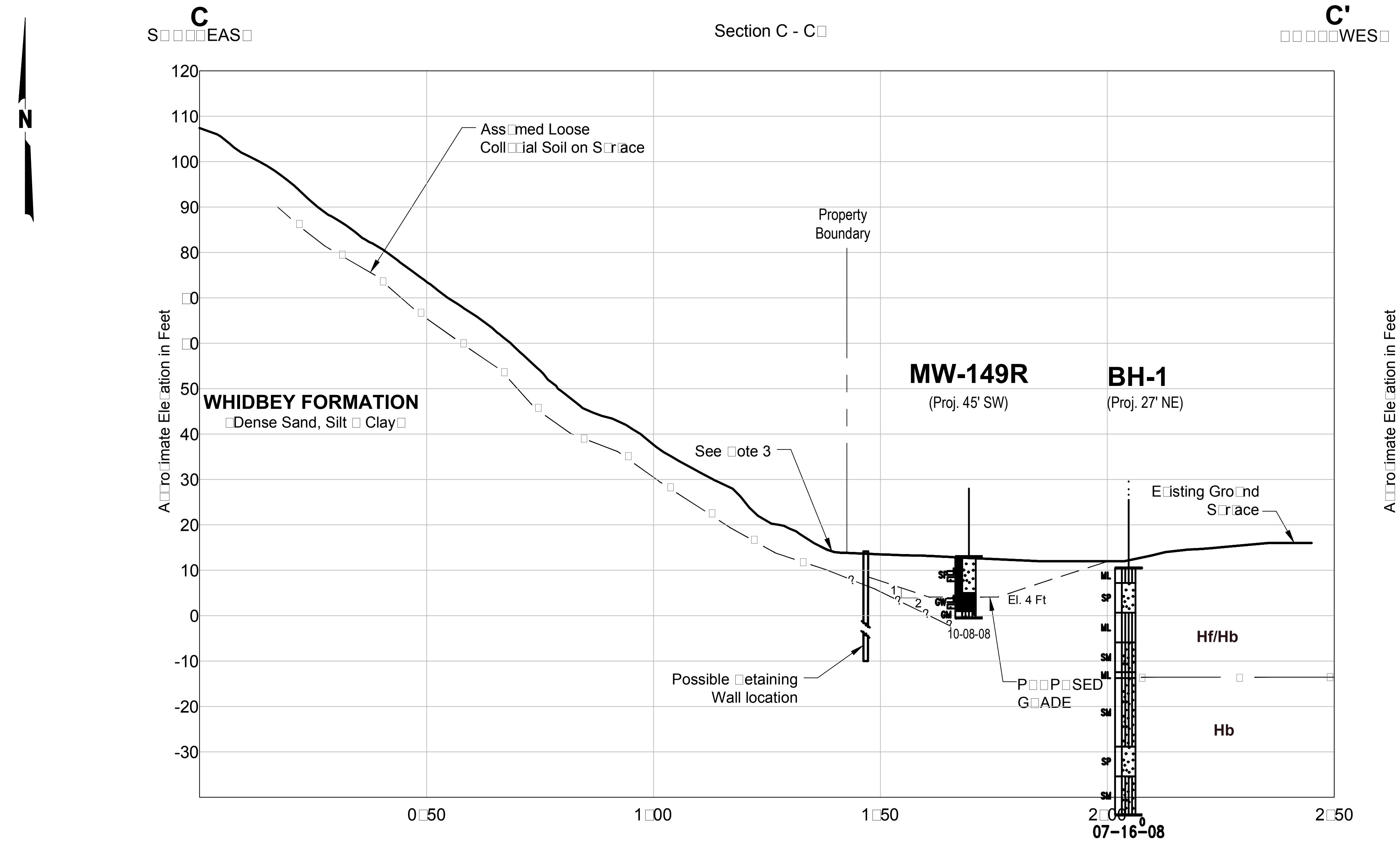
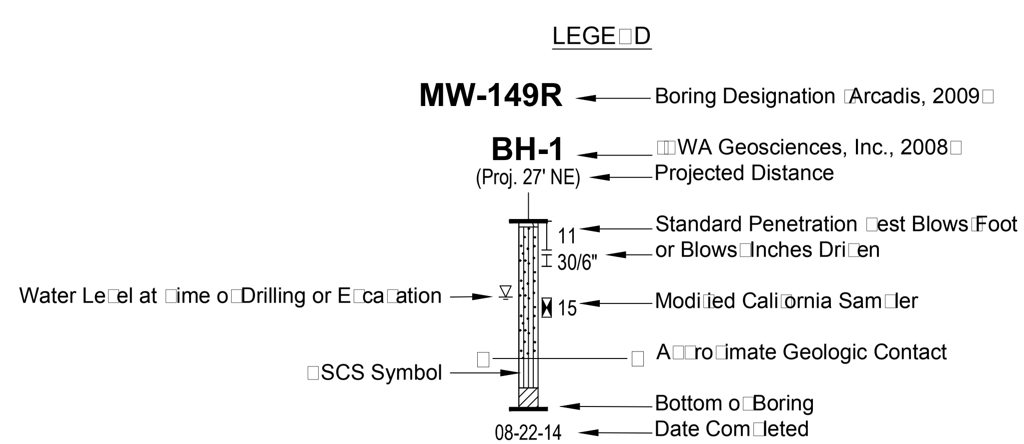
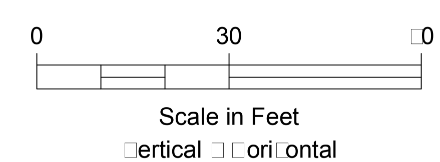
FIG. 4
Sheet 1 of 2







1. Ground surface is adapted from LiDAR.
2. This subsurface profile is generalized from materials observed in soil borings. Variations may exist between profile and actual conditions.
3. On-site topographic survey data is not available for this area. Channel location and geometry may be revised. Subsurface conditions are not known in this area.

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TYPICAL STREAM CHANNEL CROSS SECTION

SECTION C-C'

November 2014 | 21-1-12393-400

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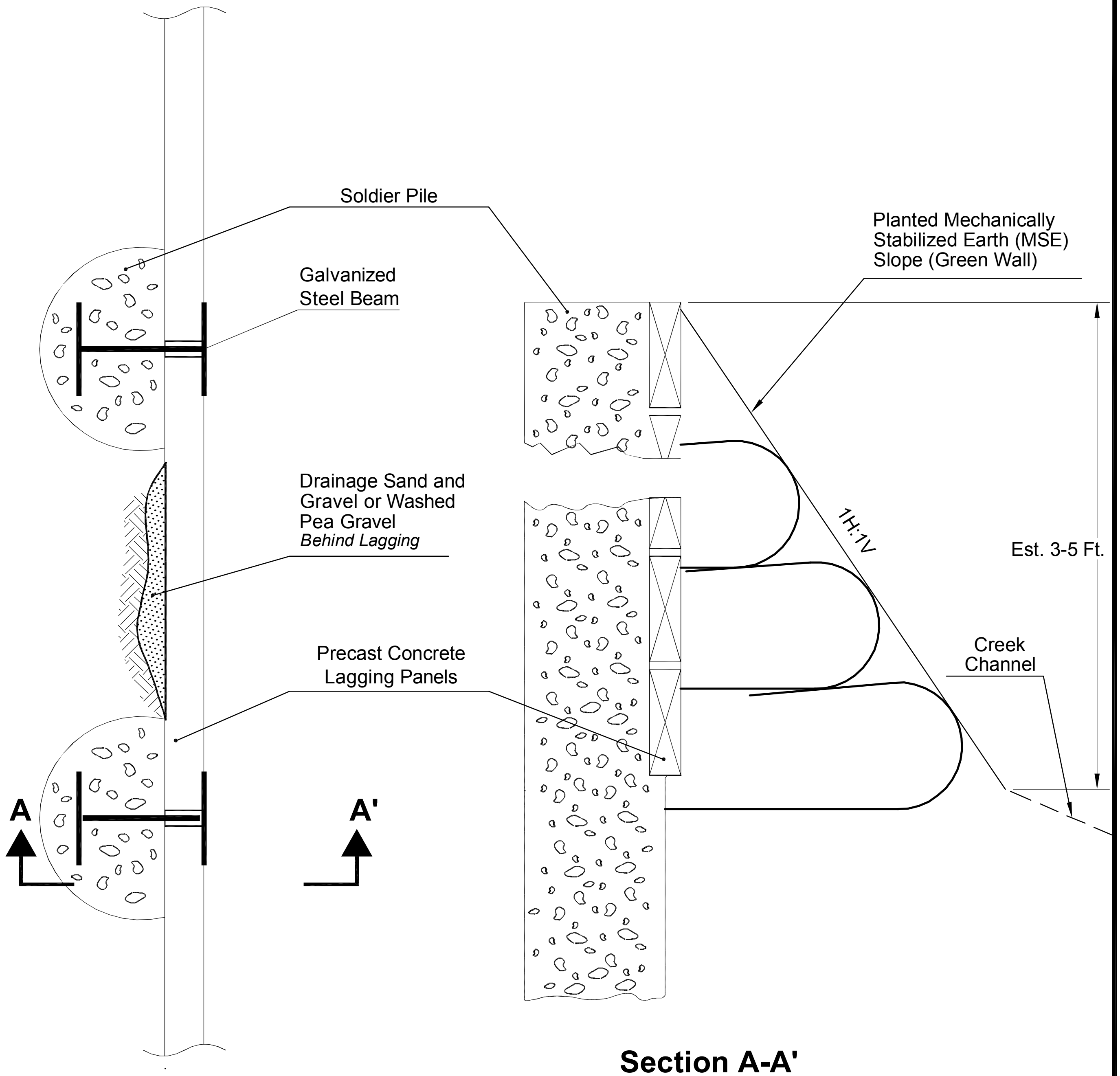
FIG. 4
Sheet 2 of 2



PLAN VIEW

Section A-A'

Not to Scale

NOTE

This drawing depicts a retaining wall concept that may be considered during design of the creek channel alignment and geometry between stations 7+00 and 8+00 to avoid excavation into the toe of the steep slope along the property boundary.

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SCHEMATIC
SOLDIER PILE WALL

November 2014 | 21-1-12393-406

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FIG. 5

File: J:\211\12393-406\21-1-12393-406 Soldier Pile Wall Schematic.dwg Date: 10-24-2014 Author: drtemp

APPENDIX A

SUBSURFACE EXPLORATIONS

APPENDIX A

SUBSURFACE EXPLORATIONS

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FIGURES

APPENDIX A

SUBSURFACE EXPLORATIONS

A.1 INTRODUCTION

To date, the field explorations performed by Shannon & Wilson, Inc. for the proposed Willow Creek Daylight Project have consisted of drilling and sampling two borings and excavating five test pits between August 28 and September 5, 2014. The borings were drilled using mud rotary drilling techniques and sampled using a 2-inch-diameter split-spoon and Standard Penetration Test (SPT). Boring B-1 was drilled to a depth of 45 feet and sampled to 46.5 feet below ground surface (bgs). Boring B-2 was drilled to a depth of 20 feet and sampled to 21.5feet. Driven soil samples were obtained generally at 2.5-foot intervals to 20 feet, then in 5-foot intervals. Five test pits were excavated to depths of between 8 and 14 feet bgs.

Approximate locations of the explorations performed at the project site are shown in Figure 2, Site and Exploration Plan. The exploration locations were recorded with a Trimble Global Positioning System device. A Soil Description and Log Key is presented in Figure A-1 as a reference for symbols and information presented on the boring logs. The logs of the explorations are presented as Figures A-2 through A-8.

A.2 EXPLORATIONS

A.2.1 Mud Rotary Drilling

Mud rotary borings are advanced by spinning a tri-cone bit attached to a string of drilling rods. Drilling mud consisting of water and bentonite or a biodegradable synthetic thickening agent is pumped out of a tank at the ground surface, down the drill rods and the tri-cone bit, up the annulus, and back into the mud tank. The circulation of drilling mud removes the cuttings generated during the drilling process from the hole and carries them to the surface, where they are screened and removed from the recirculating fluid. The drilling fluid also maintains the integrity of the borehole, thereby reducing caving or collapsing during drilling and sampling.

A.2.2 Test Pit Exavations

Test pits were excavated by Clear Creek Contractors, Inc. using a Hitachi ZAxis 75 Excavator. Contractors backfilled the test pits using the excavated material in approximately the same order it was removed from the hole.

A.3 SAMPLING

Disturbed soil samples were retrieved from the borehole and test pits locations. Disturbed soil samples from the boring were obtained by a split-spoon sampler in conjunction with an SPT and using the sonic core barrel. Grab samples were obtained from the test pits locations. The intervals where these samples were collected are shown on the boring log and test pit logs included in the Appendix A figures. Specific sampling procedures are described below.

A.3.1 Split-spoon Soil Samples

To obtain disturbed soil samples from the borings, SPTs were performed in general accordance with the ASTM International (ASTM) Designation: D1586, Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM, 2009). The SPTs were generally performed at 5-foot intervals in between sonic core runs. After performing the SPT, the sampler was brought to the ground surface and soil collected inside the barrel was examined and logged by a Shannon & Wilson, Inc. geologist. The split-spoon samples collected from the borings were placed in plastic jars with screw lids for further review and testing.

A.3.2 Grab Samples

Grab samples were collected during test pit excavation from each location. Grab samples from soil layers within the test pits were collected from the backhoe bucket or spoil pile by a Shannon & Wilson, Inc. representative. Soil samples were collected in labeled plastic jars and 5-gallon plastic bags, sealed, and transported to our laboratory for further analyses and testing. Grab samples were also collected from specific depths within the sonic core during the review process. The grab samples collected during the sonic core review process are collected in the sample manner as grab samples collected on-site.

A Shannon & Wilson, Inc. representative was present throughout the drilling and test pit procedures to collect soil samples, visually classify the samples, and to prepare an exploration log for the boring and each test pit. After classification, representative soil samples were sealed to help preserve the natural moisture content of the soil and returned to our laboratory in Seattle, Washington, for analyses.

A.4 PENETRATION TEST

To obtain disturbed soil samples, SPTs are performed in general accordance with ASTM Designation: D1586, Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM, 2009). The SPT consists of a 2-inch outside-diameter, 1.375-inch inside-diameter, split-spoon sampler driven 18 inches into the bottom of the borehole with a 140-pound hammer free falling 30 inches. The number of blows required to cause the last 12 inches of penetration is termed the Standard Penetration Resistance (N-value). Generally, when penetration resistances exceed 50 or more blows for 6 inches or less of penetration, the test is terminated, and the number of blows and corresponding penetration distance recorded. The SPT N-value is a useful parameter for estimating the relative density or consistency of the soil. This value is commonly used in engineering analyses to estimate soil strength and other characteristics.

The penetration resistances were recorded by our field representative and are plotted on the boring logs. These values are empirical parameters that provide a means of evaluating the relative density or compactness of cohesionless (granular) soils and the relative consistency (stiffness) of cohesive soils. The terminology used to describe the relative density or consistency of the soils is presented in Figure A-1.

The split-spoon sampler used during the penetration testing recovers a disturbed sample of the soil, which is useful for identification and classification purposes. The samples were classified and recorded on field logs by our geologist. The samples were sealed in jars and returned to our laboratory for testing.

A.5 EXPLORATION LOGS

Field exploration logs were prepared by our field representative for each exploration to record the encountered subsurface conditions at that time. Pertinent information, including depths, stratigraphy, engineering characteristics, and groundwater occurrence, were recorded. The summary boring logs and test pit logs presented in this report represent our interpretation of the field exploration log or test pit, and are a written record of the subsurface conditions encountered in the boring at the time of exploration, where applicable. It graphically shows the geologic units (layers) encountered in the boring and the Unified Soil Classification System symbol of each geologic layer. The stratigraphic contacts indicated on the summary logs represent the approximate boundaries between soil or rock types at those locations. The subsurface conditions were those recorded at the time of drilling, and may not necessarily represent those at other times and locations.

A.6 REFERENCE

ASTM International (ASTM), 2009, Annual book of ASTM standards, West Conshohocken, Pa.

Shannon & Wilson, Inc. (S&W), uses a soil identification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following pages. Soil descriptions are based on visual-manual procedures (ASTM D2488) and laboratory testing procedures (ASTM D2487), if performed.

S&W INORGANIC SOIL CONSTITUENT DEFINITIONS

CONSTITUENT[2]	FINE-GRAINED SOILS (50% or more fines)[1]	COARSE-GRAINED SOILS (less than 50% fines)[1]
Major	***Silt, Lean Clay, Elastic Silt,*** or ***Fat Clay***[3]	***Sand*** or ***Gravel***[4]
Modifying (Secondary) Precedes major constituent	30% or more coarse-grained: ***Sandy*** or ***Gravelly***[4]	More than 12% fine-grained: ***Silty*** or ***Clayey***[3]
Minor Follows major constituent	15% to 30% coarse-grained: ***with Sand*** or ***with Gravel***[4]	5% to 12% fine-grained: ***with Silt*** or ***with Clay***[3]
	30% or more total coarse-grained *and* lesser coarse-grained constituent is 15% or more: ***with Sand*** or ***with Gravel***[5]	15% or more of a second coarse-grained constituent: ***with Sand*** or ***with Gravel***[5]

[1]All percentages are by weight of total specimen passing a 3-inch sieve.
[2]The order of terms is: *Modifying Major with Minor*.
[3]Determined based on behavior.
[4]Determined based on which constituent comprises a larger percentage.
[5]Whichever is the lesser constituent.

MOISTURE CONTENT TERMS

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, from below water table

STANDARD PENETRATION TEST (SPT) SPECIFICATIONS

Hammer:	140 pounds with a 30-inch free fall. Rope on 6- to 10-inch-diam. cathead 2-1/4 rope turns, > 100 rpm NOTE: If automatic hammers are used, blow counts shown on boring logs should be adjusted to account for efficiency of hammer.
Sampler:	10 to 30 inches long Shoe I.D. = 1.375 inches Barrel I.D. = 1.5 inches Barrel O.D. = 2 inches
N-Value:	Sum blow counts for second and third 6-inch increments. Refusal: 50 blows for 6 inches or less; 10 blows for 0 inches.

NOTE: Penetration resistances (N-values) shown on boring logs are as recorded in the field and have not been corrected for hammer efficiency, overburden, or other factors.

PARTICLE SIZE DEFINITIONS

DESCRIPTION	SIEVE NUMBER AND/OR APPROXIMATE SIZE
FINES	< #200 (0.075 mm = 0.003 in.)
SAND	
Fine	#200 to #40 (0.075 to 0.4 mm; 0.003 to 0.02 in.)
Medium	#40 to #10 (0.4 to 2 mm; 0.02 to 0.08 in.)
Coarse	#10 to #4 (2 to 4.75 mm; 0.08 to 0.187 in.)
GRAVEL	
Fine	#4 to 3/4 in. (4.75 to 19 mm; 0.187 to 0.75 in.)
Coarse	3/4 to 3 in. (19 to 76 mm)
COBBLES	3 to 12 in. (76 to 305 mm)
BOULDERS	> 12 in. (305 mm)

RELATIVE DENSITY / CONSISTENCY

COHESIONLESS SOILS		COHESIVE SOILS	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
< 4	Very loose	< 2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
> 50	Very dense	15 - 30	Very stiff
		> 30	Hard

WELL AND BACKFILL SYMBOLS

Bentonite Cement Grout	Surface Cement Seal
Bentonite Grout	Asphalt or Cap
Bentonite Chips	Slough
Silica Sand	Inclinometer or Non-perforated Casing
Perforated or Screened Casing	Vibrating Wire Piezometer

PERCENTAGES TERMS [1, 2]

Trace	< 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

[1]Gravel, sand, and fines estimated by mass. Other constituents, such as organics, cobbles, and boulders, estimated by volume.

[2]Reprinted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

Willow Creek Daylight Project
Geotechnical Evaluation
Edmonds, Washington

SOIL DESCRIPTION AND LOG KEY

November 2014 21-1-12393-406

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 1 of 3

2013_BORING_CLASS1 21-20699.GPJ SHAN_WIL.GDT 4/22/14

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
(Modified From USACE Tech Memo 3-357, ASTM D2487, and ASTM D2488)

MAJOR DIVISIONS			GROUP/GRAPHIC SYMBOL	TYPICAL IDENTIFICATIONS
COARSE-GRAINED SOILS *(more than 50% retained on No. 200 sieve)*	Gravels *(more than 50% of coarse fraction retained on No. 4 sieve)*	Gravel *(less than 5% fines)*	GW	Well-Graded Gravel; Well-Graded Gravel with Sand
			GP	Poorly Graded Gravel; Poorly Graded Gravel with Sand
		Silty or Clayey Gravel *(more than 12% fines)*	GM	Silty Gravel; Silty Gravel with Sand
			GC	Clayey Gravel; Clayey Gravel with Sand
	Sands *(50% or more of coarse fraction passes the No. 4 sieve)*	Sand *(less than 5% fines)*	SW	Well-Graded Sand; Well-Graded Sand with Gravel
			SP	Poorly Graded Sand; Poorly Graded Sand with Gravel
		Silty or Clayey Sand *(more than 12% fines)*	SM	Silty Sand; Silty Sand with Gravel
			SC	Clayey Sand; Clayey Sand with Gravel
FINE-GRAINED SOILS *(50% or more passes the No. 200 sieve)*	Silts and Clays *(liquid limit less than 50)*	Inorganic	ML	Silt; Silt with Sand or Gravel; Sandy or Gravelly Silt
			CL	Lean Clay; Lean Clay with Sand or Gravel; Sandy or Gravelly Lean Clay
		Organic	OL	Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay
	Silts and Clays *(liquid limit 50 or more)*	Inorganic	MH	Elastic Silt; Elastic Silt with Sand or Gravel; Sandy or Gravelly Elastic Silt
			CH	Fat Clay; Fat Clay with Sand or Gravel; Sandy or Gravelly Fat Clay
		Organic	OH	Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay
HIGHLY-ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT	Peat or other highly organic soils (see ASTM D4427)

NOTE: No. 4 size = 4.75 mm = 0.187 in.; No. 200 size = 0.075 mm = 0.003 in.

NOTES

1. Dual symbols *(symbols separated by a hyphen, i.e., SP-SM, Sand with Silt)* are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart. Graphics shown on the logs for these soil types are a combination of the two graphic symbols (e.g., SP and SM).

2. Borderline symbols *(symbols separated by a slash, i.e., CL/ML, Lean Clay to Silt; SP-SM/SM, Sand with Silt to Silty Sand)* indicate that the soil properties are close to the defining boundary between two groups.

Willow Creek Daylight Project
Geotechnical Evaluation
Edmonds, Washington

SOIL DESCRIPTION AND LOG KEY

November 2014 — 21-1-12393-406

SHANNON & WILSON, INC.
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FIG. A-1
Sheet 2 of 3

GRADATION TERMS

Poorly Graded	Narrow range of grain sizes present or, within the range of grain sizes present, one or more sizes are missing (Gap Graded). Meets criteria in ASTM D2487, if tested.
Well-Graded	Full range and even distribution of grain sizes present. Meets criteria in ASTM D2487, if tested.

CEMENTATION TERMS[1]

Weak	Crumbles or breaks with handling or slight finger pressure.
Moderate	Crumbles or breaks with considerable finger pressure.
Strong	Will not crumble or break with finger pressure.

PLASTICITY[2]

DESCRIPTION	VISUAL-MANUAL CRITERIA	APPROX. PLASTICITY INDEX RANGE
Nonplastic	A 1/8-in. thread cannot be rolled at any water content.	< 4
Low	A thread can barely be rolled and a lump cannot be formed when drier than the plastic limit.	4 to 10
Medium	A thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. A lump crumbles when drier than the plastic limit.	10 to 20
High	It takes considerable time rolling and kneading to reach the plastic limit. A thread can be rerolled several times after reaching the plastic limit. A lump can be formed without crumbling when drier than the plastic limit.	> 20

ADDITIONAL TERMS

Mottled	Irregular patches of different colors.
Bioturbated	Soil disturbance or mixing by plants or animals.
Diamict	Nonsorted sediment; sand and gravel in silt and/or clay matrix.
Cuttings	Material brought to surface by drilling.
Slough	Material that caved from sides of borehole.
Sheared	Disturbed texture, mix of strengths.

PARTICLE ANGULARITY AND SHAPE TERMS[1]

Angular	Sharp edges and unpolished planar surfaces.
Subangular	Similar to angular, but with rounded edges.
Subrounded	Nearly planar sides with well-rounded edges.
Rounded	Smoothly curved sides with no edges.
Flat	Width/thickness ratio > 3.
Elongated	Length/width ratio > 3.

ACRONYMS AND ABBREVIATIONS

ATD	At Time of Drilling
Diam.	Diameter
Elev.	Elevation
ft.	Feet
FeO	Iron Oxide
gal.	Gallons
Horiz.	Horizontal
HSA	Hollow Stem Auger
I.D.	Inside Diameter
in.	Inches
lbs.	Pounds
MgO	Magnesium Oxide
mm	Millimeter
MnO	Manganese Oxide
NA	Not Applicable or Not Available
NP	Nonplastic
O.D.	Outside Diameter
OW	Observation Well
pcf	Pounds per Cubic Foot
PID	Photo-Ionization Detector
PMT	Pressuremeter Test
ppm	Parts per Million
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride
rpm	Rotations per Minute
SPT	Standard Penetration Test
USCS	Unified Soil Classification System
q_u	Unconfined Compressive Strength
VWP	Vibrating Wire Piezometer
Vert.	Vertical
WOH	Weight of Hammer
WOR	Weight of Rods
Wt.	Weight

STRUCTURE TERMS[1]

Interbedded	Alternating layers of varying material or color with layers at least 1/4-inch thick; singular: bed.
Laminated	Alternating layers of varying material or color with layers less than 1/4-inch thick; singular: lamination.
Fissured	Breaks along definite planes or fractures with little resistance.
Slickensided	Fracture planes appear polished or glossy; sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps that resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay.
Homogeneous	Same color and appearance throughout.

[1]Reprinted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

[2]Adapted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

Willow Creek Daylight Project
Geotechnical Evaluation
Everett, Washington

SOIL DESCRIPTION AND LOG KEY

November 2014 | 21-1-12393-406

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 3 of 3

Total Depth:	46.5 ft.	Northing:		Drilling Method:	Mud Rotary
Top Elevation:	~ 15.5 ft.	Easting:		Drilling Company:	Holt
Vert. Datum:		Station:		Drill Rig Equipment:	LA Rig
Horiz. Datum:		Offset:		Other Comments:	

Hole Diam.:	12 in.
Rod Diam.:	2-5/8" O.D.
Hammer Type:	Automatic

SOIL DESCRIPTION

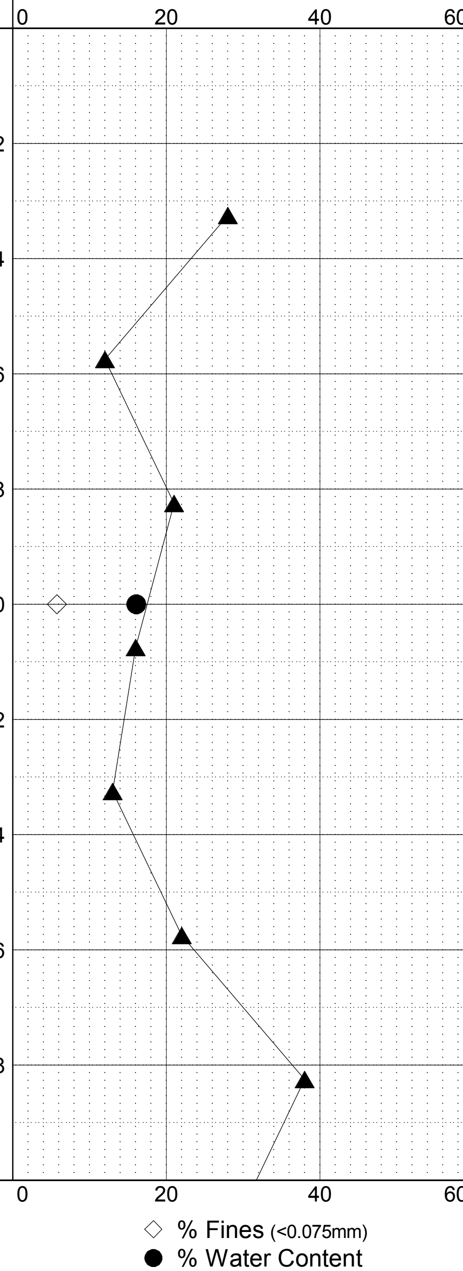
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	PID, ppm	Samples	Ground Water
Gray, chipped gravel over compacted sand and gravel.	0.3			
Medium dense, gray, *Poorly Graded Sand with Gravel (SP)*; moist; some fine to coarse, subangular to rounded gravel; fine to coarse sand; trace fines. - Sand becoming finer below 5 feet.			1 2	
Medium dense, gray to gray-brown, *Poorly Graded Sand with Silt (SP-SM)*; moist to wet, becoming wet below 9.5 feet; few fine, subrounded gravel; mostly fine to medium sand. - Groundwater assumed to be about 9.5 feet because the 10-foot sample was saturated. - Becoming more gravelly below 12.5 feet.	7.0	0 0	3 4 5	During Drilling
Medium dense to dense, gray to brown, *Poorly Graded Gravel with Silt and Sand (GP-GM)*; wet; fine to coarse, subangular to rounded gravel, mostly coarse gravel; fine to coarse sand. Fines content may be over estimated because of drilling fluid in samples S-6 and S-7. - Trace wood fragments noted by driller at 19 feet.	14.5		6 7	

CONTINUED NEXT SHEET

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



LEGEND

* Sample Not Recovered

2.0" O.D. Split Spoon Sample

Ground Water Level ATD

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.

Willow Creek Daylight Project
Geotechnical Evaluation
Edmonds, Washington

LOG OF BORING B-1

November 2014 21-1-12393-406

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2
Sheet 1 of 3

REV 3 - Approved for Submittal

Log: SAW Rev: JKP Typ: CLP

MASTER_LOG_E 21-12393.GPJ SHAN_WIL.GDT 10/20/14

Total Depth: *46.5 ft.*	Northing:	Drilling Method:	*Mud Rotary*	Hole Diam.:	*12 in.*
Top Elevation: *~ 15.5 ft.*	Easting:	Drilling Company:	*Holt*	Rod Diam.:	*2-5/8" O.D.*
Vert. Datum:	Station:	Drill Rig Equipment:	*LA Rig*	Hammer Type:	*Automatic*
Horiz. Datum:	Offset:	Other Comments:			

SOIL DESCRIPTION

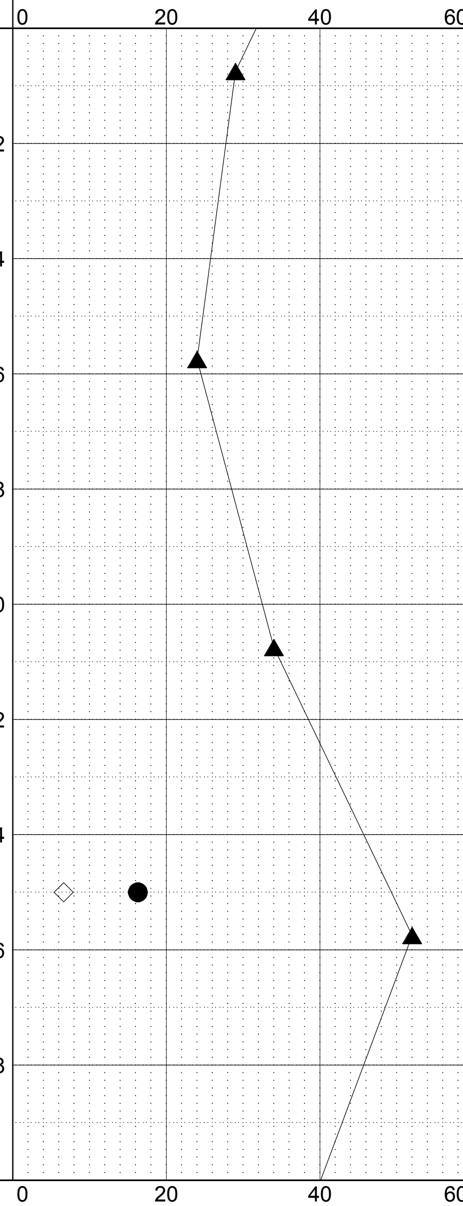
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples
Medium dense, dark gray, *Poorly Graded Sand with Silt (SP-SM)*; wet; few fine to coarse, subrounded to rounded gravel; fine to medium sand.	20.3	8, 9
Dense, dark gray, *Poorly Graded Sand with Silt (SP-SM)*, little fine, subrounded to rounded gravel; some fine to coarse sand, trace wood fragments.	30.0	10 *
Dense to very dense, dark gray, *Poorly Graded Gravel with Sand (GP)*; wet; fine to coarse, subrounded to rounded gravel; some fine to coarse sand; trace fines.	35.5	11

CONTINUED NEXT SHEET

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: *140 lbs / 30 inches*



◇ % Fines (<0.075mm)
● % Water Content

LEGEND

* Sample Not Recovered
2.0" O.D. Split Spoon Sample
Ground Water Level ATD

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.

Willow Creek Daylight Project
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LOG OF BORING B-1

November 2014 — 21-1-12393-406

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FIG. A-2
Sheet 2 of 3

Total Depth:	*46.5 ft.*	Northing:		Drilling Method:	*Mud Rotary*	Hole Diam.:	*12 in.*
Top Elevation:	*~ 15.5 ft.*	Easting:		Drilling Company:	*Holt*	Rod Diam.:	*2-5/8" O.D.*
Vert. Datum:		Station:		Drill Rig Equipment:	*LA Rig*	Hammer Type:	*Automatic*
Horiz. Datum:		Offset:		Other Comments:			

SOIL DESCRIPTION

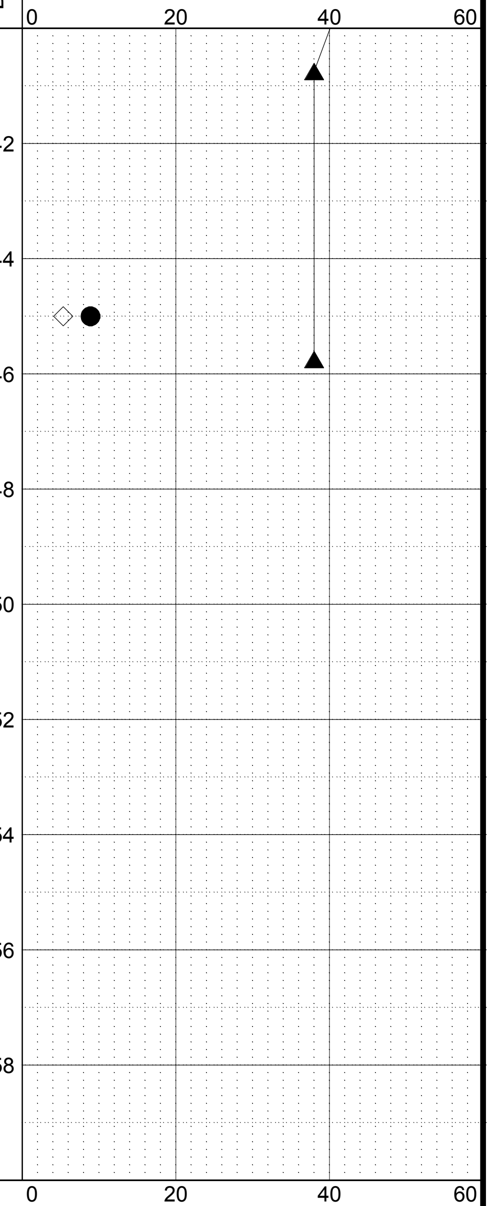
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Symbol	PID, ppm	Samples	Ground Water
- Fine to medium sand interbed with little fines from 40 to 40.8 feet. - Wood fragments around 40 feet.				12	
Dense, gray to gray-brown, *Well-Graded Gravel with Silt and Sand (GW-GM)*; wet; fine to coarse, mostly fine, subangular to subrounded gravel; some fine to coarse sand.	45.0 46.5			13	

BOTTOM OF BORING
COMPLETED 8/28/2014

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: *140 lbs / 30 inches*



◇ % Fines (<0.075mm)
● % Water Content

LEGEND

* Sample Not Recovered
2.0" O.D. Split Spoon Sample
Ground Water Level ATD

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.

Willow Creek Daylight Project
Geotechnical Evaluation
Edmonds, Washington

LOG OF BORING B-1

November 2014 21-1-12393-406

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2
Sheet 3 of 3

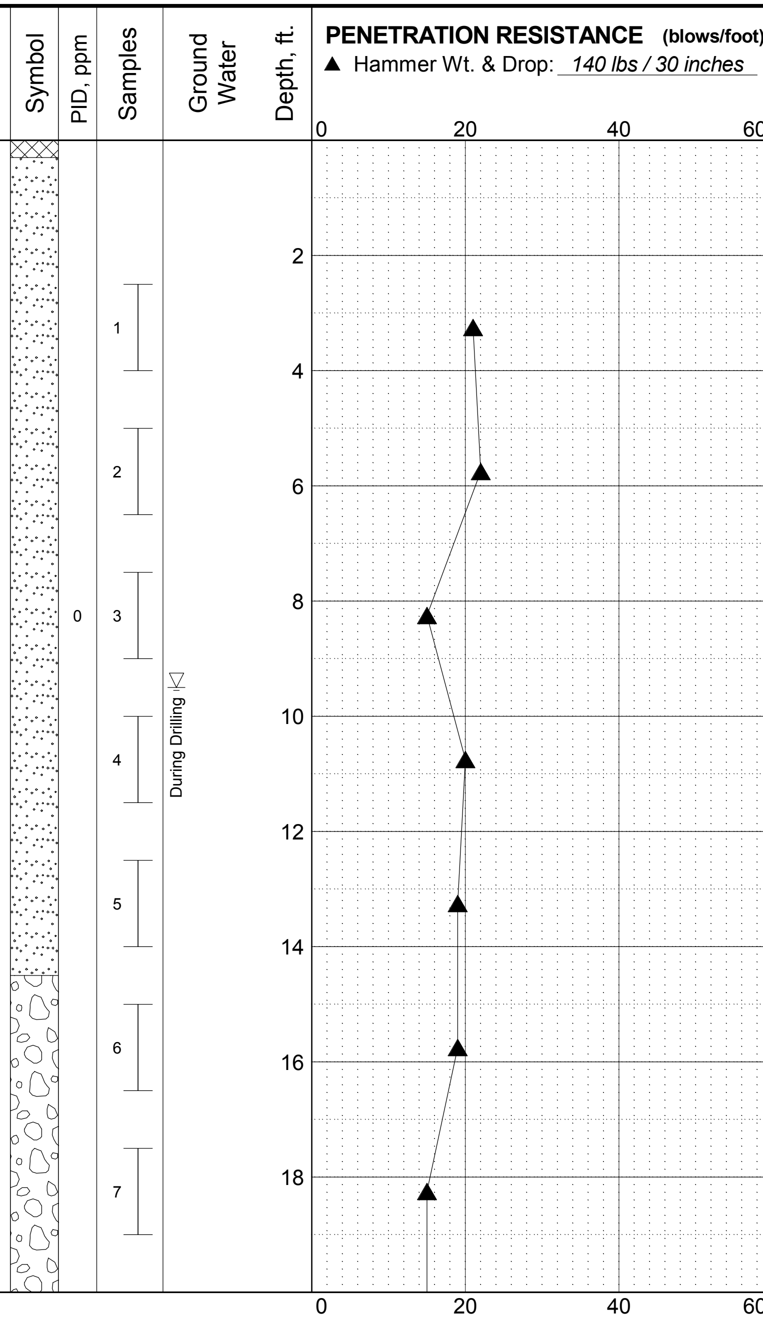
REV 3 - Approved for Submittal

Total Depth:	21.5 ft.	Northing:		Drilling Method:	Mud Rotary	Hole Diam.:	5 in.
Top Elevation:	~ 15.5 ft.	Easting:		Drilling Company:	Holt	Rod Diam.:	2-5/8" O.D.
Vert. Datum:		Station:		Drill Rig Equipment:	LA Rig	Hammer Type:	Automatic
Horiz. Datum:		Offset:		Other Comments:			

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.
Gravel chip over compacted sand and gravel.	0.3
Medium dense, gray, *Poorly Graded Sand with Gravel (SP)*; moist to wet; some fine to coarse, subrounded and broken to rounded gravel; fine to coarse sand; trace fines. Beach Sand or Fill. - More coarse gravel from 5 to 6.5 feet. - Finer gravel from 12.5 feet.	14.5
Medium dense, gray, *Poorly Graded Gravel with Sand (GP)*; wet; fine to coarse, subrounded to rounded gravel, mostly fine gravel; little fine to coarse sand; trace fines.	



CONTINUED NEXT SHEET

LEGEND

* Sample Not Recovered

2.0" O.D. Split Spoon Sample

Ground Water Level ATD

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.

Willow Creek Daylight Project
Geotechnical Evaluation
Edmonds, Washington

LOG OF BORING B-2

November 2014 21-1-12393-406

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-3
Sheet 1 of 2

REV 3 - Approved for Submittal

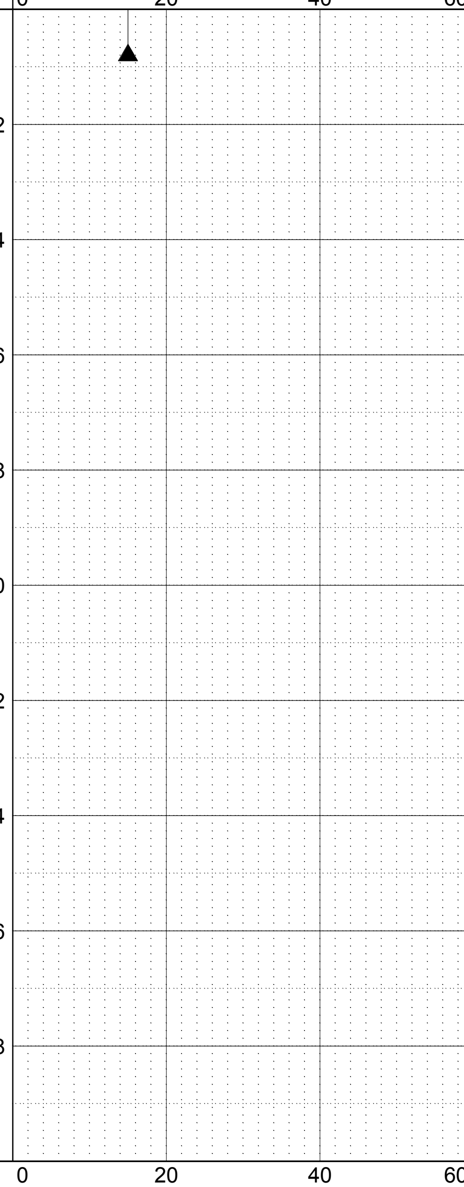
Total Depth:	21.5 ft.	Northing:		Drilling Method:	Mud Rotary
Top Elevation:	~ 15.5 ft.	Easting:		Drilling Company:	Holt
Vert. Datum:		Station:		Drill Rig Equipment:	LA Rig
Horiz. Datum:		Offset:		Other Comments:	

Hole Diam.:	5 in.
Rod Diam.:	2-5/8" O.D.
Hammer Type:	Automatic

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines represent the approximate boundaries between material types, and the transition may be gradual.*	Depth, ft.	Symbol	PID, ppm	Samples	Ground Water	Depth, ft.
- Becoming fine gravel and coarse sand below 20 feet.	20.6			8		
Medium dense, gray, *Poorly Graded Sand with Silt and Gravel (SP-SM)*; wet; fine to coarse, subrounded gravel; mostly fine to coarse sand.	21.5					22
BOTTOM OF BORING COMPLETED 8/29/2014						24
						26
						28
						30
						32
						34
						36
						38

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: *140 lbs / 30 inches*



◇ % Fines (<0.075mm)
● % Water Content

LEGEND

* Sample Not Recovered
Ground Water Level ATD
2.0" O.D. Split Spoon Sample

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.

Willow Creek Daylight Project
Geotechnical Evaluation
Edmonds, Washington

LOG OF BORING B-2

November 2014 21-1-12393-406

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-3
Sheet 2 of 2

REV 3 - Approved for Submittal

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Geotechnical and Environmental Consultants

LOG OF TEST PIT TP-1

JOB NO.: 21-1-12393-40 DATE: 9-5-2014 LOCATION: See Site and Exploration Plan

PROJECT: Willow Creek Daylight Project, Geotechnical Evaluation

Sketch of Southeast Pit Side — Surface Elevation: Approx. 15.5 Ft.

SOIL DESCRIPTION

1. Gray, chipped gravel over Compacted Sand and Gravel.

2. Brown to gray-brown, *Poorly Graded Sand with Gravel (SP)*; moist; fine to coarse subangular to rounded gravel; fine to coarse sand; trace fines; interbedded with 1- to 2-inch thick fine to coarse gravel layers from 3 to 5 feet. Unit fining downward to fine to medium sand and trace shell below 5 ft.

3. Dark gray to brown with red-brown to yellow-brown locally, *Silty Sand (SM)*; moist; laminated with 1/8- to 1/4-inch thick *Sandy Silt (ML)*; moist; 1/4-inch thick sand layers consist of mostly fine sand; fibrous organics and mica minerals in silt layers; little wood debris throughout unit.

4. Gray, Poorly Graded Sand with Gravel (SP), moist; some fine to coarse, subangular to rounded gravel; fine to medium sand; trace fines.

Ground Water	% Water Content	Samples	Depth, Ft.
		G-1	4
		G-2	7
9.5 ft. ▽		G-3	9

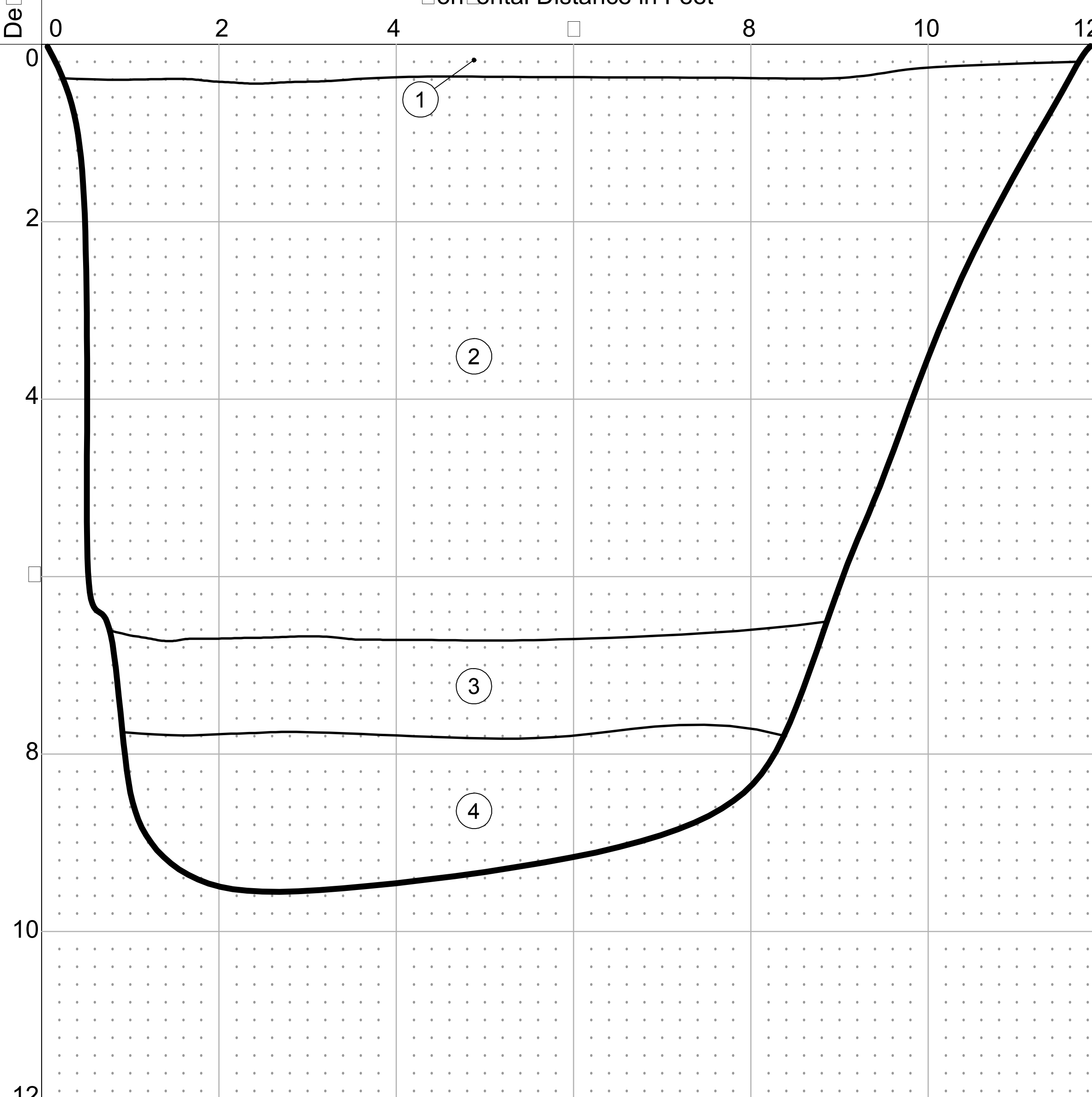


FIG. A-4

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

LOG OF TEST PIT TP-2

JOB NO.: 21-1-12393-40□ DATE: 9-5-2014 LOCATION: See Site and Exploration Plan

PROJECT: Willow Creek Daylight Project, Geotechnical Evaluation

Sketch of Southeast Pit Side Surface Elevation: Approx. 1□ Ft.

SOIL DESCRIPTION	Ground Water	□ Water Content	Samples	Depth, Ft.
(1) Gray, chipped gravel over compacted sand and gravel.	None Observed			0
(2) Brown to gray-brown, *Poorly Graded Sand with Gravel (SP)*; moist, little fine to coarse, subangular to rounded gravel, fine to coarse sand, trace fines. • Sand cross bedded locally from 0.5 to 2.5 feet.				2, 4
(3) Dark gray to brown with red-brown to yellow-brown locally, *Silty Sand (SM)*; moist, laminated with 1/8- to 1/4-inch thick *Sandy Silt (ML)*, moist, 1/4-inch thick sand layers consist of mostly fine sand, fibrous organics and mica minerals in silt layers, little wood debris throughout unit, trace metal debris and iron oxide staining found at top of unit.		3.1	G-1	□
(4) Gray, *Poorly Graded Sand with Gravel (SP)*; moist, some fine to coarse, subangular to rounded gravel, fine to medium sand, trace fines.			G-2	8, 10, 12

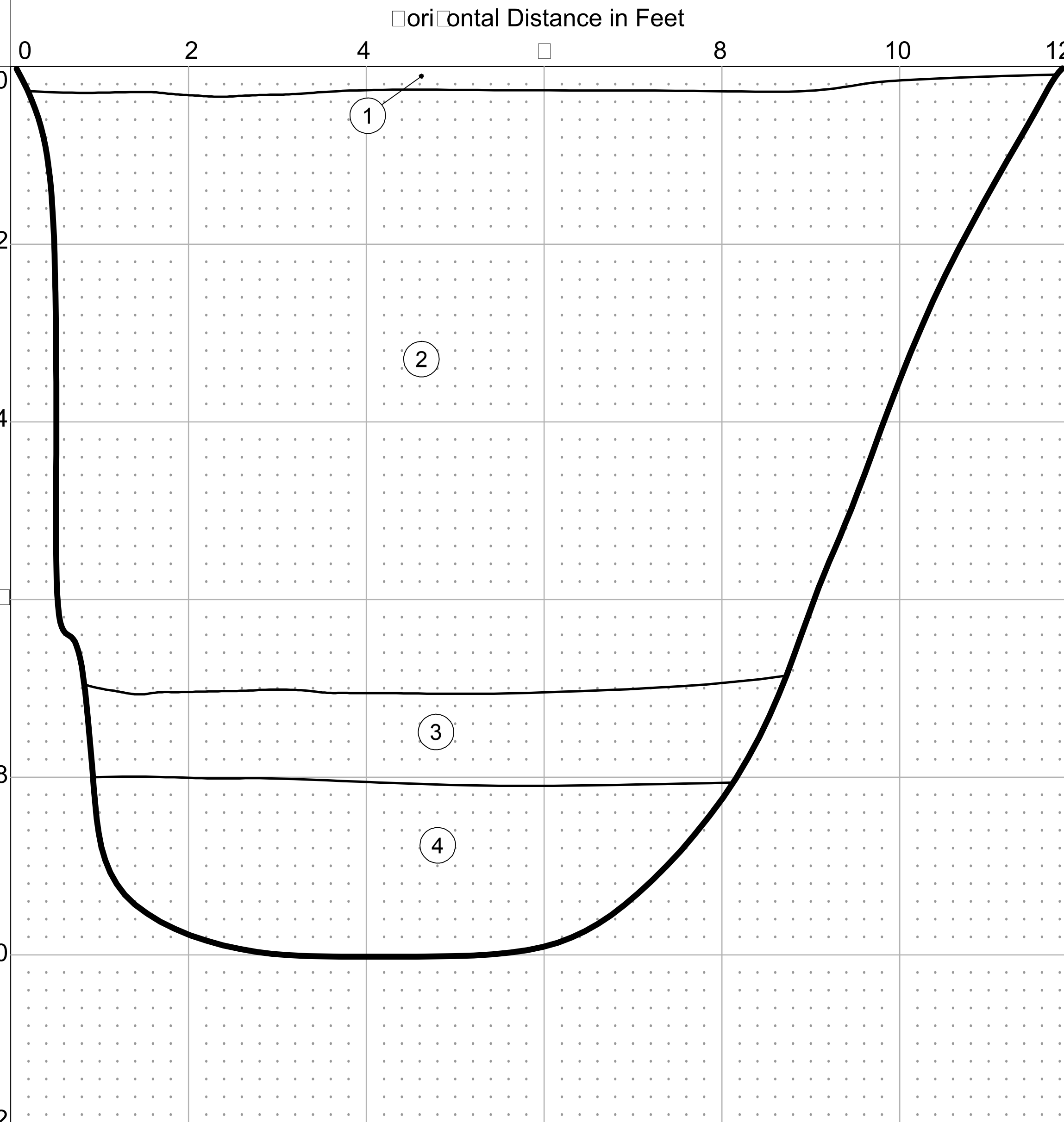


FIG. A-5

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

LOG OF TEST PIT TP-3

JOB NO.: 21-1-12393-400 DATE: 9-5-2014 LOCATION: See Site and Exploration Plan

PROJECT: Willow Creek Daylight Project, Geotechnical Evaluation

SOIL DESCRIPTION	Ground Water	% Water Content	Samples	Depth, Ft.
(1) Gray, chipped gravel.	None Observed			0
(2) Brown, *Poorly Graded Sand with Gravel (SP)*; moist; little fine to coarse, subangular to rounded gravel; fine to coarse sand; trace fines; interbedded with 1- to 2-inch thick fine to coarse gravel about every 1/2 foot from 2.5 to 5 feet.			G-1	2, 4
(3) Dark gray to brown with red-brown to yellow-brown locally, *Silty Sand (SM)*; moist; laminated with 1/8- to 1/4-inch thick *Sandy Silt (ML)*; moist; 1/4-inch thick sand layers consist of mostly fine sand; fibrous organics and mica minerals in silt layers; little wood debris throughout unit; trace metal debris and iron oxide staining found at top of unit.			G-2	6
(4) Gray, *Poorly Graded Sand with Gravel (SP)*; moist; little fine to coarse, subangular to rounded gravel; fine to medium sand; trace fines.				8, 10, 12

Sketch of West Pit Side

Surface Elevation: Approx. 15.5 Ft.

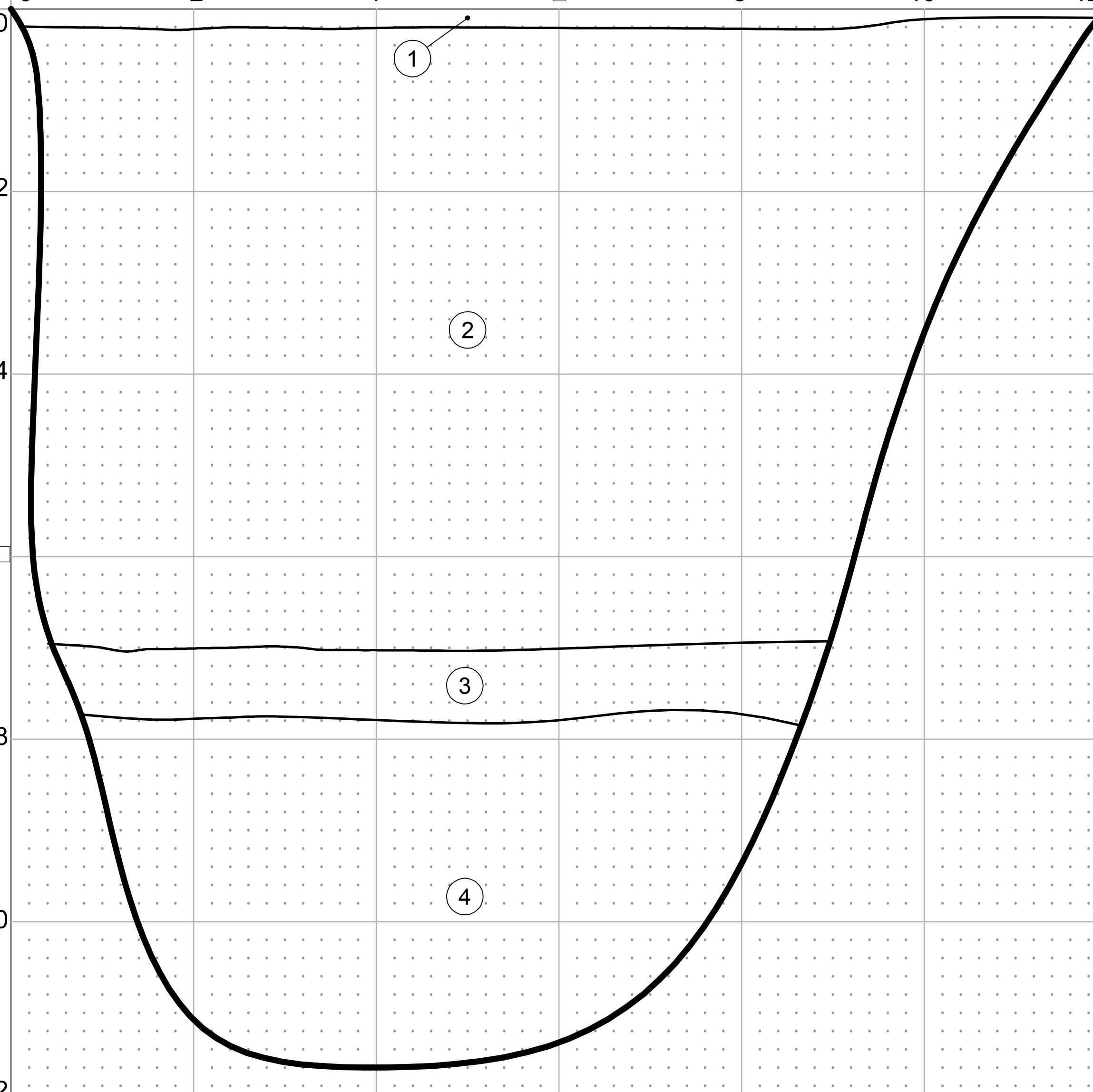


FIG. A-6

Filename: J:\211\12393-40\21-1-12393-40 TPs.dwg Date: 10-21-2014 Login: drtemp

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

LOG OF TEST PIT TP-4

JOB NO.: 21-1-12393-40 DATE: 9-5-2014 LOCATION: See Site and Exploration Plan

PROJECT: Willow Creek Daylight Project, Geotechnical Evaluation

SOIL DESCRIPTION	Ground Water	% Water Content	Samples	Depth, Ft.
(1) Grass sod and brown topsoil. (2) Brown to gray-brown, *Silty Sand with Gravel and Cobbles (SM) to Clayey Sand with Gravel and Cobbles (SC)*; moist; few 3- to 4-inch cobbles; little fine to coarse, subangular to rounded gravel; fine to coarse sand. Fill, possibly from a glacial till source. (3) Gray to gray-brown, *Poorly Graded Sand with Gravel (SP)*; moist; some fine to coarse, subrounded to rounded gravel; fine to coarse sand; trace fines; 1- to 3-inch thick fine to coarse gravel interbeds from □ to 10 feet. • Trace shell fragments below 10 feet. • 1 broken brick found at about 10 feet.	None Observed	2.8	G-1, G-2, G-3, G-4	0–18

Sketch of West Pit Side Surface Elevation: Approx. 20 Ft.

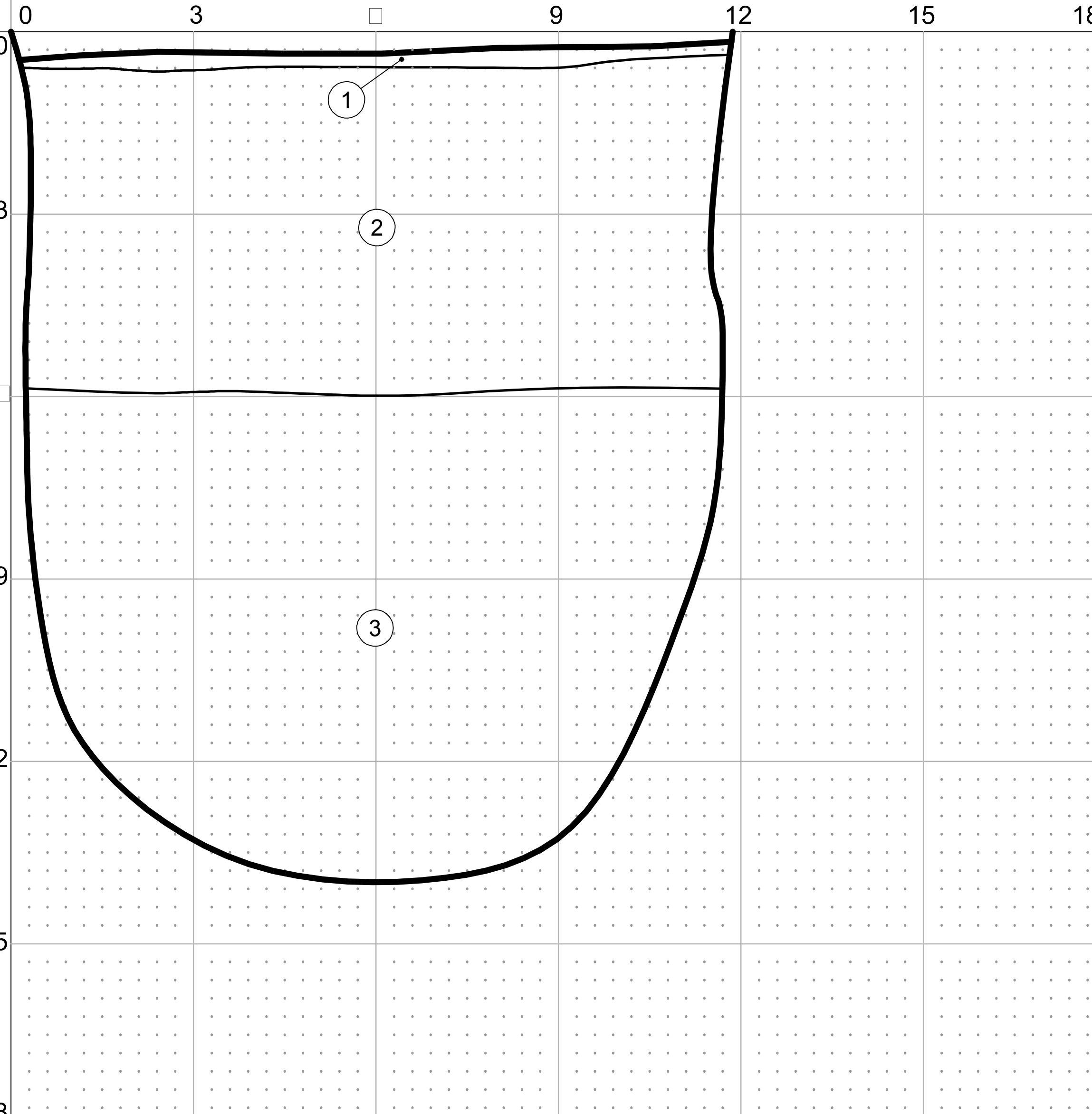


FIG. A-7

Filename: J:\211\12393-40\21-1-12393-40 TPs.dwg Date: 10-21-2014 Login: drtemp

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

LOG OF TEST PIT TP-5

JOB NO.: 21-1-12393-40 DATE: 9-5-2014 LOCATION: See Site and Exploration Plan

PROJECT: Willow Creek Daylight Project, Geotechnical Evaluation

SOIL DESCRIPTION	Ground Water	% Water Content	Samples	Depth, Ft.
(1) Gray to gray-brown, *Poorly Graded Sand with Gravel (SP);* moist, little fine to coarse, subangular to rounded gravel; fine to coarse sand; trace fines; shell fragments; interbedded with 2- to 3-inch thick fine gravel and coarse sand layers about every 1/2 foot from 2.5 to 5.5 feet.			G-1	0–6
(2) Dark gray to brown with red-brown to yellow-brown locally, *Silty Sand (SM);* moist; laminated with 1/8- to 1/4-inch thick *Sandy Silt (ML);* moist; 1/4-inch thick sand layers consist of mostly fine sand; fibrous organics and mica minerals in silt layers; little wood debris throughout unit; trace iron oxide staining in sand.			G-2	6–7
(3) Gray, *Poorly Graded Sand with Gravel (SP);* moist, wet below 8 feet; little fine to coarse, subangular to rounded gravel; fine to coarse sand; trace fines.	8.0 ft. ▽		G-3	7–9

Sketch of South Pit Side

Surface Elevation: Approx. 11.5 Ft.

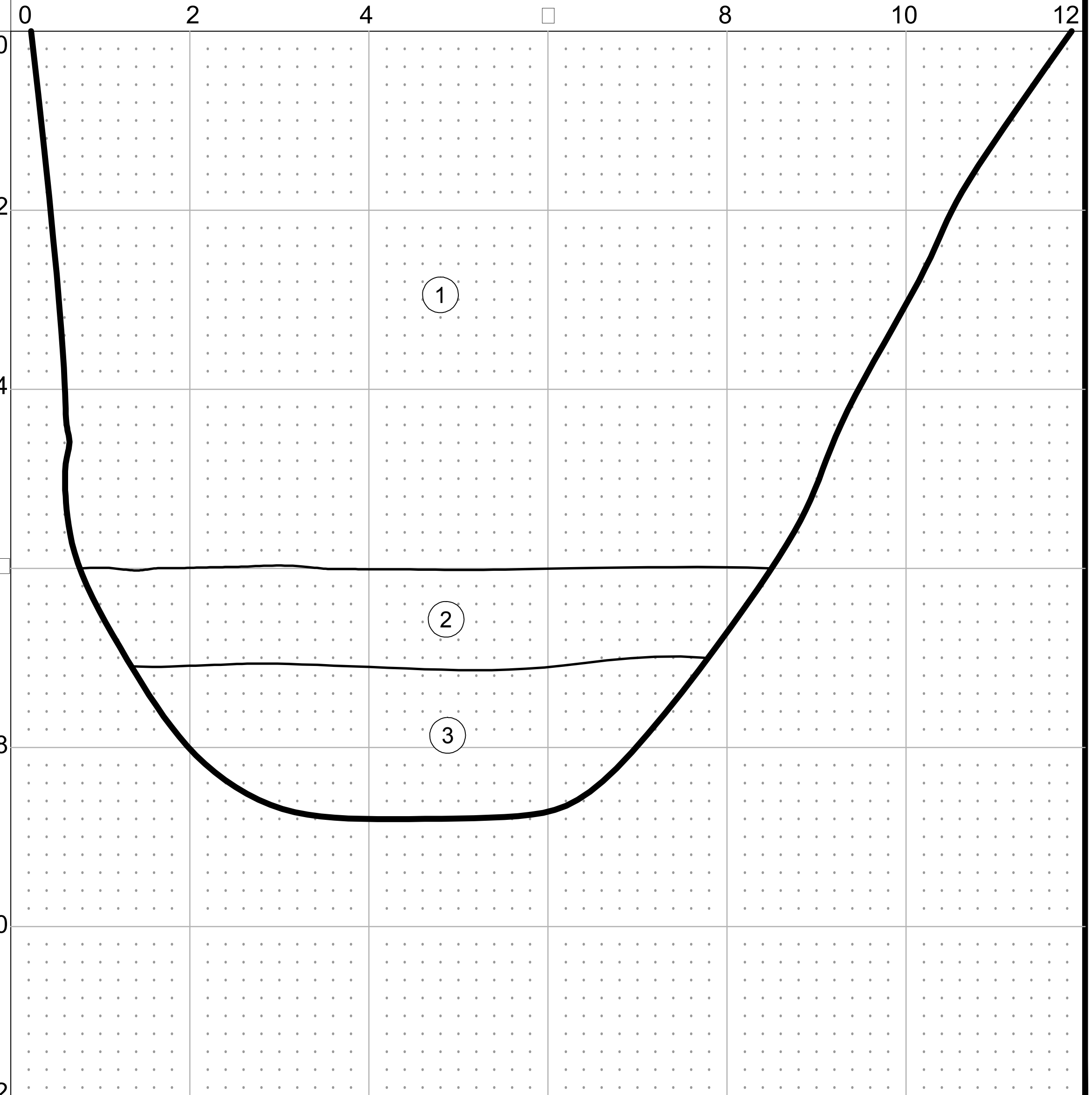
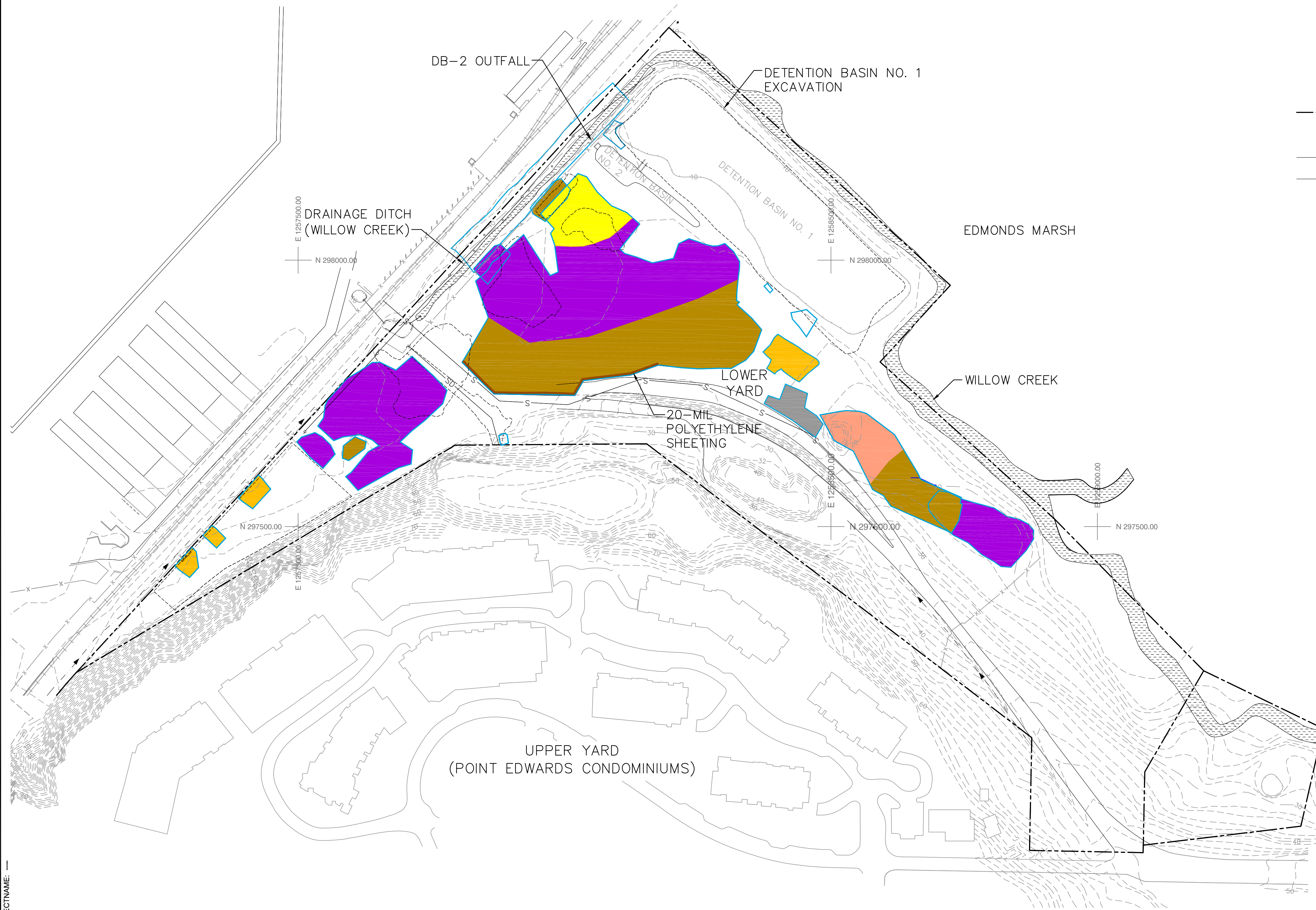


FIG. A-8



LEGEND:

- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- S — WSDOT STORM DRAIN LINE
- SD — POINT EDWARDS STORM DRAIN LINE

TOP OF GRAVEL BACKFILL ELEVATION:

- 2 – 3 FT AMSL
- 4 – 5 FT AMSL
- 5 – 6 FT AMSL
- 6 – 7 FT AMSL
- 7 – 8 FT AMSL
- 9 – 11 FT AMSL

NOTES:

1. MONITORING WELLS MW-129R, MW-139R, MW-8R, AND MW-149R WERE ABANDONED DURING INTERIM ACTION AND REPLACED IN OCTOBER 2008.
2. STAFF GAUGE D-1 RE-ESTABLISHED PRIOR TO JUNE 2009 SAMPLING EVENT.
3. STAFF GAUGE D-4 WAS ESTABLISHED PRIOR TO JUNE 2009 SAMPLING EVENT TO REPLACE STAFF GAUGE D-7 WHICH IS NOT WITHIN THE WILLOW CREEK CHANNEL.
4. STAFF GAUGES WERE RESURVEYED BY OTAK INCORPORATED JUNE 1, 2009. STAFF GAUGES WERE SURVEYED FROM TOP OF GAUGE AND WATER LEVELS ARE NOW MEASURED FROM TOP DOWN TO WATER.
5. 20-MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
6. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
   VERTICAL DATUM: N.A.V.D. 88
   UNITS: U.S. SURVEY FEET
   HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
7. FT AMSL = FEET ABOVE MEAN SEA LEVEL.

0 200' 400'
GRAPHIC SCALE

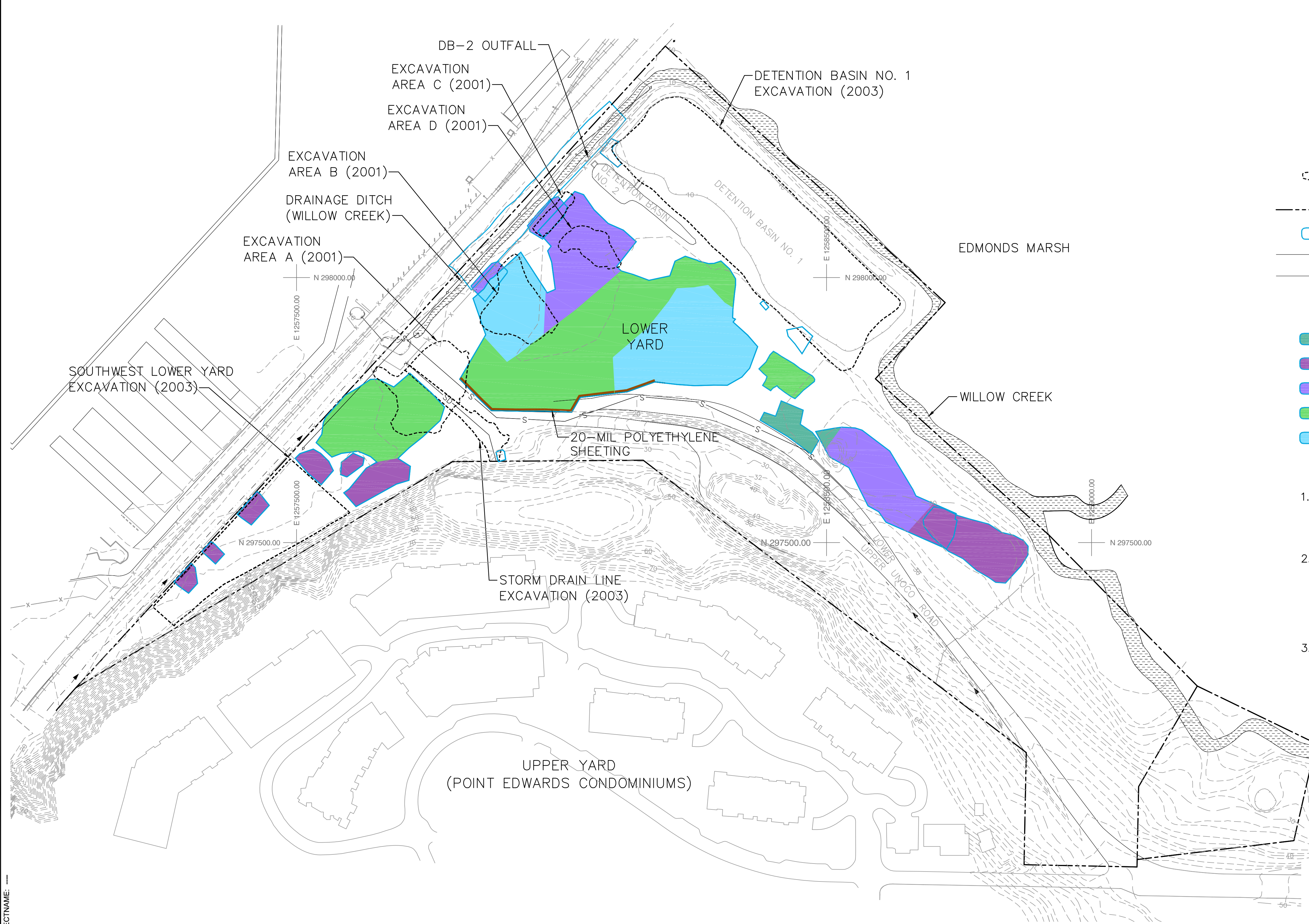
CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL EDMONDS TERMINAL, LOWER YARD
EDMONDS, WASHINGTON
CONCEPTUAL SITE MODEL

TOP OF 2008 GRAVEL BACKFILL ELEVATIONS

ARCADIS

FIGURE
A-9.1

CITY: SYRACUSE, NY DIV/GROUP: ENV/IM-DV DB: K. DAVIS, R. ALLEN, P. LISTER PM/TM: R. ANDRESEN TR: A. PATEL LYR: ON=*;OFF=*REF*
G:\ENVCAD\SYRACUSE\ACT\B0045362\0003\00016\DWG\45362B02.dwg LAYOUT: 10 SAVED: 6/3/2013 10:39 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 6/3/2013 10:40 AM BY: LISTER, PAUL
XREFS: IMAGES: PROJECTNAME: ----
45362X02
45362XDL
45362X03



LEGEND:

- 2001 AND 2003 SOIL EXCAVATIONS BELOW GROUNDWATER TABLE
- LOWER YARD PROPERTY BOUNDARY
- 2007/2008 EXCAVATION BOUNDARIES
- S — WSDOT STORM DRAIN LINE
- SD — POINT EDWARDS STORM DRAIN LINE

BOTTOM OF GRAVEL BACKFILL ELEVATION:

- 8 – 9 FT AMSL
- 6 – 4 FT AMSL
- 4 – 2 FT AMSL
- 2 – 0 FT AMSL
- 0 TO –2 FT AMSL

NOTES:

1. 20–MIL POLYETHYLENE SHEETING INSTALLED UPON COMPLETION OF PHASE I EXCAVATION. SHEETING REACHES TO APPROXIMATELY 7.5 FEET ABOVE MEAN SEA LEVEL.
2. HORIZONTAL DATUM: WASHINGTON STATE COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
   VERTICAL DATUM: N.A.V.D. 88
   UNITS: U.S. SURVEY FEET
   HORIZONTAL AND VERTICAL CONTROL ESTABLISHED BY GPS VIA VERTICAL REFERENCE STATION NETWORK (VRSN).
3. FT AMSL = FEET ABOVE MEAN SEA LEVEL.

0 200' 400'
GRAPHIC SCALE

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
FORMER UNOCAL EDMONDS TERMINAL, LOWER YARD
EDMONDS, WASHINGTON
CONCEPTUAL SITE MODEL

BOTTOM OF 2008 GRAVEL BACKFILL ELEVATIONS

ARCADIS

FIGURE A-9.2

Date Start/Finish: 10/08/08
Drilling Company: Cascade Drilling Inc.
Driller's Name: Andy Flanagen
Drilling Method: Hollow Stem Auger
Auger Size: 8"
Rig Type: CME-75
Sampling Method: 2" Split Spoon

Northing: 297500.80
Easting: 1257354.15
Casing Elevation: 12.18

Borehole Depth: 13.5
Surface Elevation:

Descriptions By: Russ Greisler

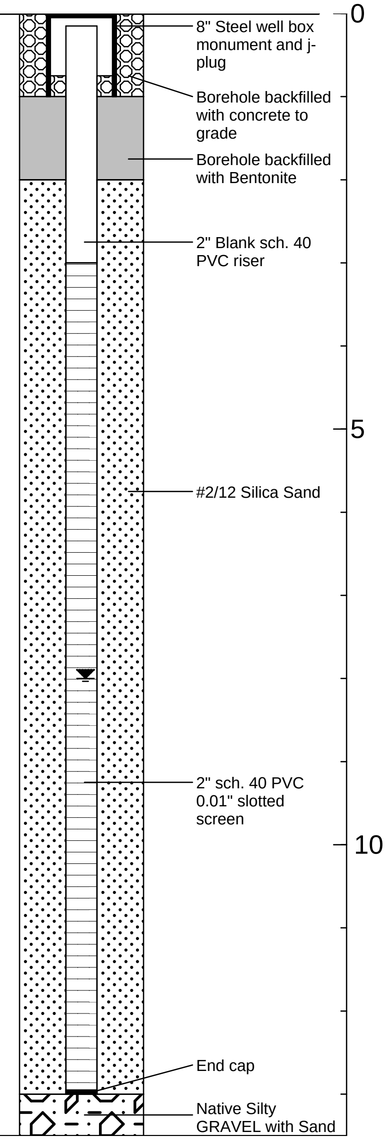
Well/Boring ID: **MW-149R**

Client: Chevron

Location: 11720 Unoco Rd., Edmonds, WA

DEPTH	ELEVATION	Sample Run Number	Recovery (feet)	Blow Counts	N - Value	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description
0								SP		SAND (SP); brown, fine to medium, few fine subrounded to subangular gravels, trace fines. (FILL)
	10	1	1.5			0.0				
5										
	5	2	1.5	5 6 4	10	0.0				
								GW		GRAVEL (GW); brown, subrounded to subangular, trace sand and non plastic fines. (FILL)
10										
	0	3	1.5			0.3		GM		Silty GRAVEL with Sand (GM); dark brown, fine, subrounded to subangular, some non plastic fines, trace sand.

Well/Boring Construction



ARCADIS
Infrastructure, environment, buildings

Remarks: bgs = below ground surface

Project Number:B0045362
Data File:MW-149R.dat

Template:G:\COMMON\Data\Projects\Chevron\Edmonds Terminal\PHASE II Interim Action As-built Report
Date:4/2/2009 AF

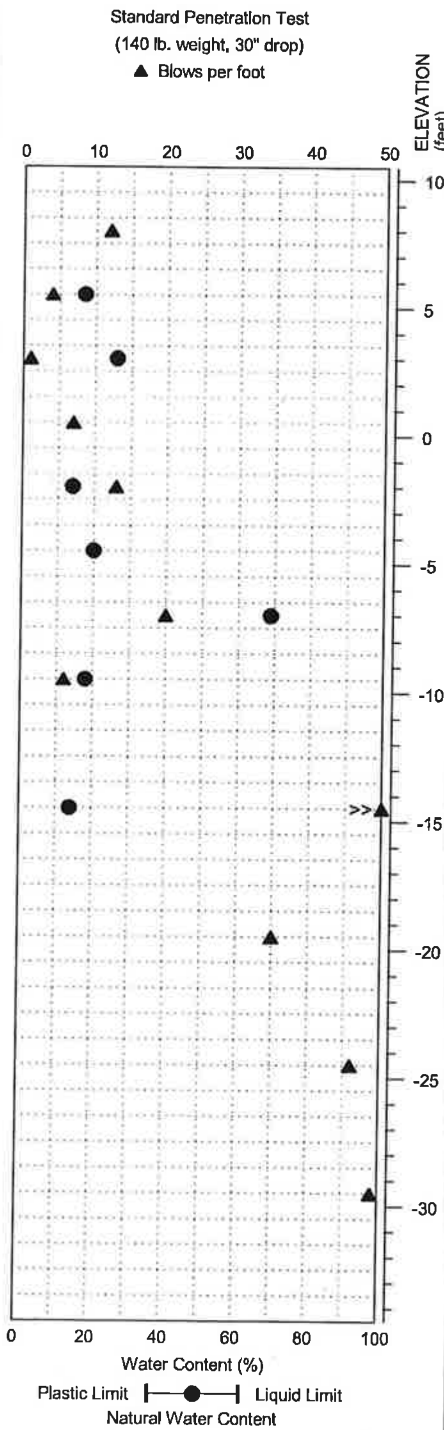
Fig. A-10

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: Hollow Stem Auger, CME-850 track mounted rig
SAMPLING METHOD: SPT with autohammer
LOCATION: See Figure 2: Site and Exploration Plan

DATE STARTED: 07/16/2008
DATE COMPLETED: 07/16/2008
LOGGED BY: J. Speck
SURFACE ELEVATION: 10.5 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE / SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0	ML	Light brown, sandy SILT.				
2.5	SP	Loose to medium dense, dark olive brown, gravelly, fine to medium SAND, moist.	S-1	3-5-7		
			S-2	4-3-1	MC	
7.5	ML SM	Loose, dark olive brown, gravelly, fine to medium silty SAND to sandy SILT, wet.	S-3	0-0-1	MC	∇ (7 ft)
			S-4	1-2-5		
12.5	SM	Loose to medium dense, dark gray, fine to medium silty SAND, wet.	S-5	5-7-6	MC	
		8 inch heave noted, water added.	S-6	5-4-2	GS MC	
17.5	ML	Medium dense, dark olive brown, slightly gravelly, organic SILT, wet.	S-7	14-10-10	MC	
18.5	SM	Dense, dark olive brown, slightly gravelly, fine to medium silty SAND, wet. Trace decomposed wood (black). 2 inch lense of sandy SILT at 20.25 feet.	S-8	6-2-4	GS MC	
		Some siltier lenses 4 inch thick at 25.25 feet, 2 inch thick at 26 feet.	S-9	15-29-36	GS MC	
30	SP	Dense, dark gray, fine to medium SAND with trace fines and gravel, wet.	S-10	1-8-27		
35	SM	Dense, dark olive brown, silty fine to medium SAND with gravel, wet.	S-11	7-17-29		
			S-12	8-16-33		

Borehole completed at TD = 41.5 feet.
Groundwater noted at 7 feet during exploration.



NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

HWA GEOSCIENCES INC.

WILLOW CREEK CULVERT REPLACEMENT
UNDER BNSF MAINLINE

BORING:
BH-1

PAGE: 1 of 1

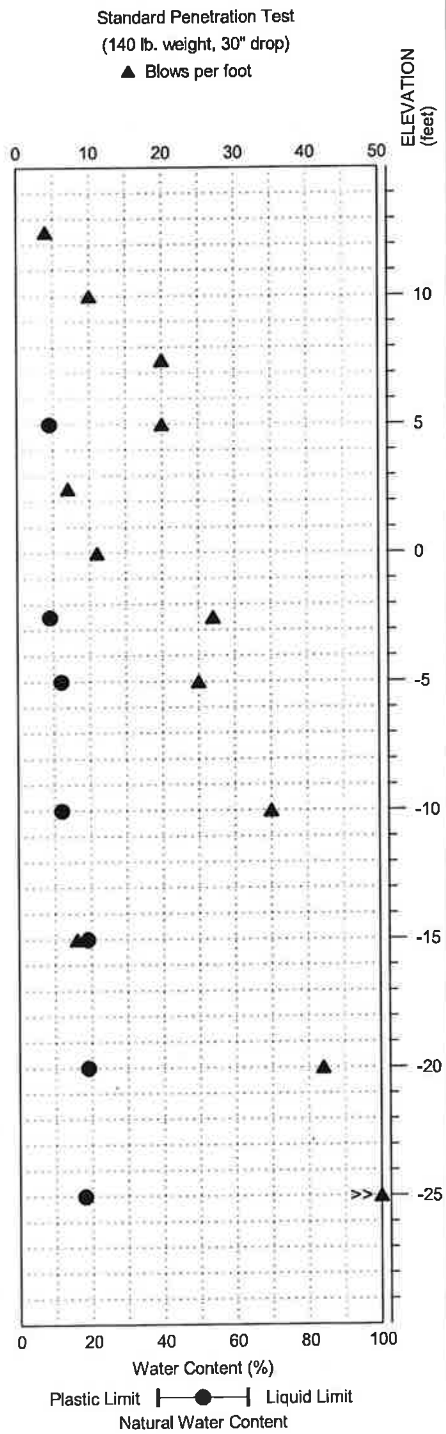
PROJECT NO.: 2007-147-21 FIGURE: 4

BORING-DSM 2007142.GPJ 2/26/10

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: Hollow Stem Auger, CME-850 track mounted rig
SAMPLING METHOD: SPT with autohammer
LOCATION: See Figure 2: Site and Exploration Plan

DATE STARTED: 07/17/2008
DATE COMPLETED: 07/17/2008
LOGGED BY: J. Speck/B. Blanchette
SURFACE ELEVATION: 15.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
0	SM	Cuttings, brown, sandy SILT to fine to medium silty SAND with gravel, moist.			
		No recovery	S-1	4-2-2	
5	SP	Medium dense, olive brown, gravelly, fine to coarse SAND, moist.	S-2	3-4-6	
			S-3	4-8-12	
10		Very gravelly, gravel is fine to coarse. Wet.	S-4	6-9-11	GS MC
			S-5	4-3-4	
15			S-6	2-6-5	
			S-7	8-13-14	MC
20	SP SM	Medium dense, olive brown, gravelly, fine to coarse slightly silty SAND, wet. Gravel is fine. Noticeably more fine sand than above sample.	S-8	11-10-15	GS MC
25	SM	Dense, dark gray, gravelly, fine to medium silty SAND, wet.	S-9	9-15-20	MC
30		Material becomes loose with a 3 inch thick silty sand lense at 31 feet. Color changes to dark gray at 31 feet. Wood fragments noted at 30.5 feet.	S-10	8-3-5	GS MC
35			S-11	13-21 -21	MC
40			S-12	31 -50/3	MC
45		Borehole completed at TD = 41.5 feet. Groundwater was first noted at 9.5 feet during exploration.			



NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

HWA GEOSCIENCES INC.

WILLOW CREEK CULVERT REPLACEMENT
UNDER BNSF MAINLINE

BORING:
BH-2

PAGE: 1 of 1

PROJECT NO.: 2007-147-21 FIGURE: 5

APPENDIX B

GEOTECHNICAL LABORATORY TEST PROCEDURES AND RESULTS

APPENDIX B

GEOTECHNICAL LABORATORY TEST PROCEDURES AND RESULTS

TABLE OF CONTENTS

Page

FIGURES

APPENDIX B

GEOTECHNICAL LABORATORY TEST PROCEDURES AND RESULTS

B.1 INTRODUCTION

This appendix contains descriptions of the procedures and the results of the geotechnical laboratory tests performed on select soil samples obtained from the subsurface explorations completed for the Willow Creek Daylight Project. The samples were tested to evaluate the basic index and physical properties of the native soil. The laboratory test program included visual classifications, water content determinations, and grain size analyses. The laboratory testing was performed by an experienced technician at the Shannon & Wilson, Inc. laboratory in Seattle, Washington.

B.2 VISUAL CLASSIFICATION

The soil samples recovered from the exploratory borings and test pits were visually reclassified in our laboratory using a system based on American Society for Testing and Materials/ASTM International (ASTM, 2000 – 2011) Designation: D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), and ASTM Designation: D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). This visual classification method allows for convenient and consistent comparison of soils from widespread geographic areas. The terminology used and the definition of modifying terms are presented on Figure A-1 in Appendix A. The sample classifications are presented on the individual boring and test pit logs in Appendix A.

B.3 WATER CONTENT DETERMINATION

The natural water content of select samples recovered was determined in general accordance with ASTM Designation: D2216, Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil by Mass. Comparison of the natural water content of a soil with its index properties can be useful in characterizing soil unit weight, consistency, compressibility, and strength. The organic contents are shown graphically on the boring logs in Appendix A.

B.4 GRAIN SIZE ANALYSES

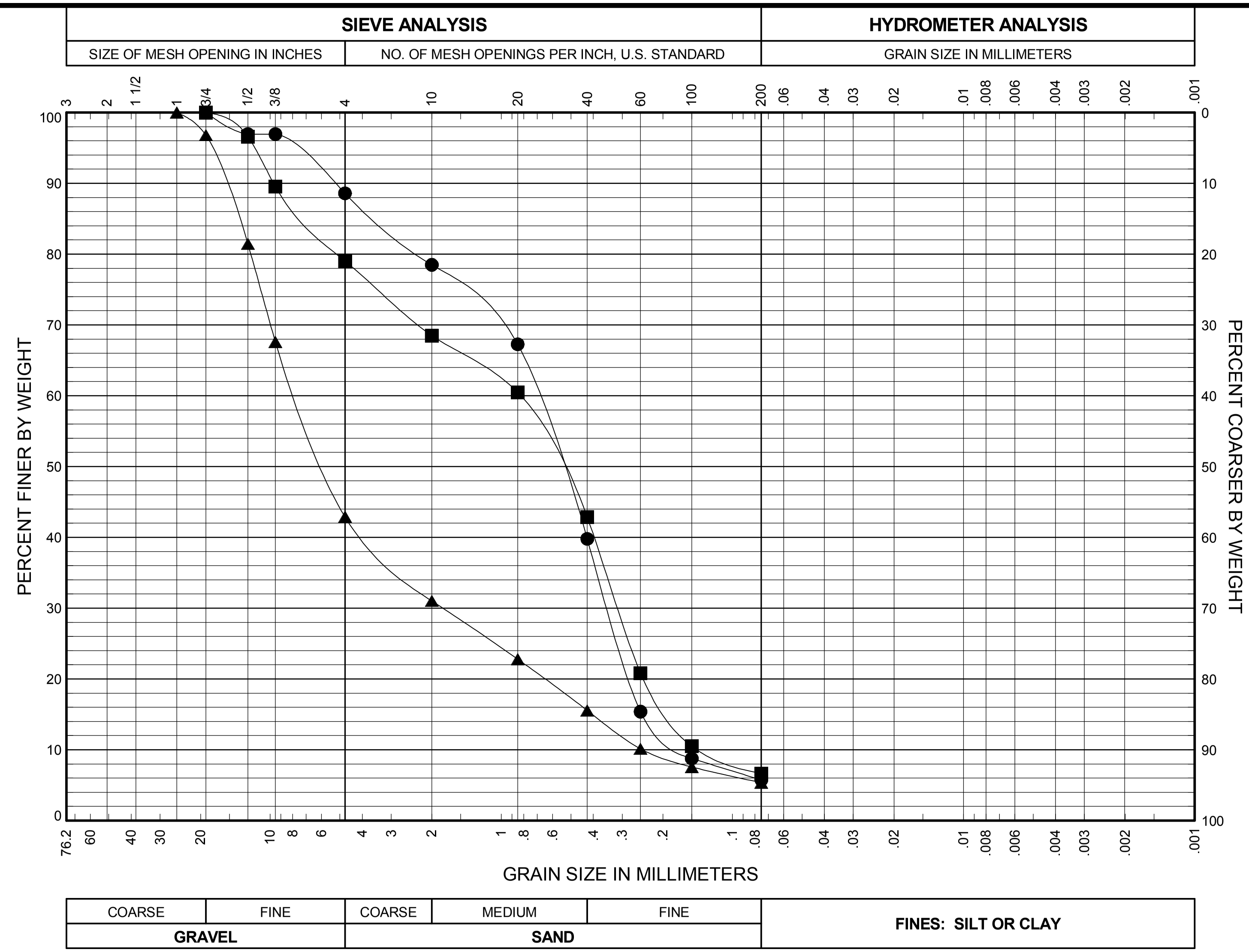
Grain size analyses were performed on selected samples of granular soils in general accordance with ASTM Designation: D6913, Standard Test Method for Particle-Size Analysis of Soils. Results of these analyses are presented as grain size distribution curves in Figures B-1 through

B-3 in this appendix. Along with each grain size distribution is a tabulated summary containing the sample description, Unified Soil Classification System symbol for the soil group, percentage of fines passing the No. 200 sieve, and the natural water content.

Grain size distribution is used to assist in classifying soils and to provide correlation with soil properties, including hydraulic conductivity, capillary action, liquefaction potential, and sensitivity to moisture.

B.5 REFERENCE

American Society for Testing and Materials/ASTM International (ASTM), 2000 - 2011, 2000 – 2011 annual book of standards, construction, volume 04.08, soil and rock (I): West Conshohocken, Penn.



LEGEND

USCS: Unified Soil Classification System

COBBLE REM %: Percentage of cobbles removed from specimen; based on pre-removal total dry mass

< 2 µm %: Percentage of soil particles finer than 2 micrometers (0.002 mm); clay-size fraction

NAT WC %: Natural water content

Cu: Coefficient of uniformity

Cc: Coefficient of curvature

ASTM DES: ASTM International test standard designation

*: ***Sample specimen weight did not meet required minimum mass for ASTM test method.***

BORING AND SAMPLE NO.	DEPTH (feet)	USCS SYMBOL	SOIL CLASSIFICATION	GRAVEL %	SAND %	FINES %	COBBLE REM %	< 2 µm %	NAT WC %	Cu	Cc	TEST BY	REVIEW BY	ASTM DES
● B-1, S-4*	10.0	SP-SM	Poorly Graded Sand with Silt	11	83	5.7			16.1	4.3	1.0	AKV	JFL	D422
■ B-1, S-11*	35.0	SP-SM	Poorly Graded Sand with Silt and Gravel	21	72	6.6			16.3	6.1	0.8	AKV	JFL	D422
▲ B-1, S-13*	45.0	GW-GM	Well-Graded Gravel with Silt and Sand	57	38	5.3			8.9	31.5	1.7	AKV	JFL	D422

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GRAIN SIZE DISTRIBUTION
BORING B-1

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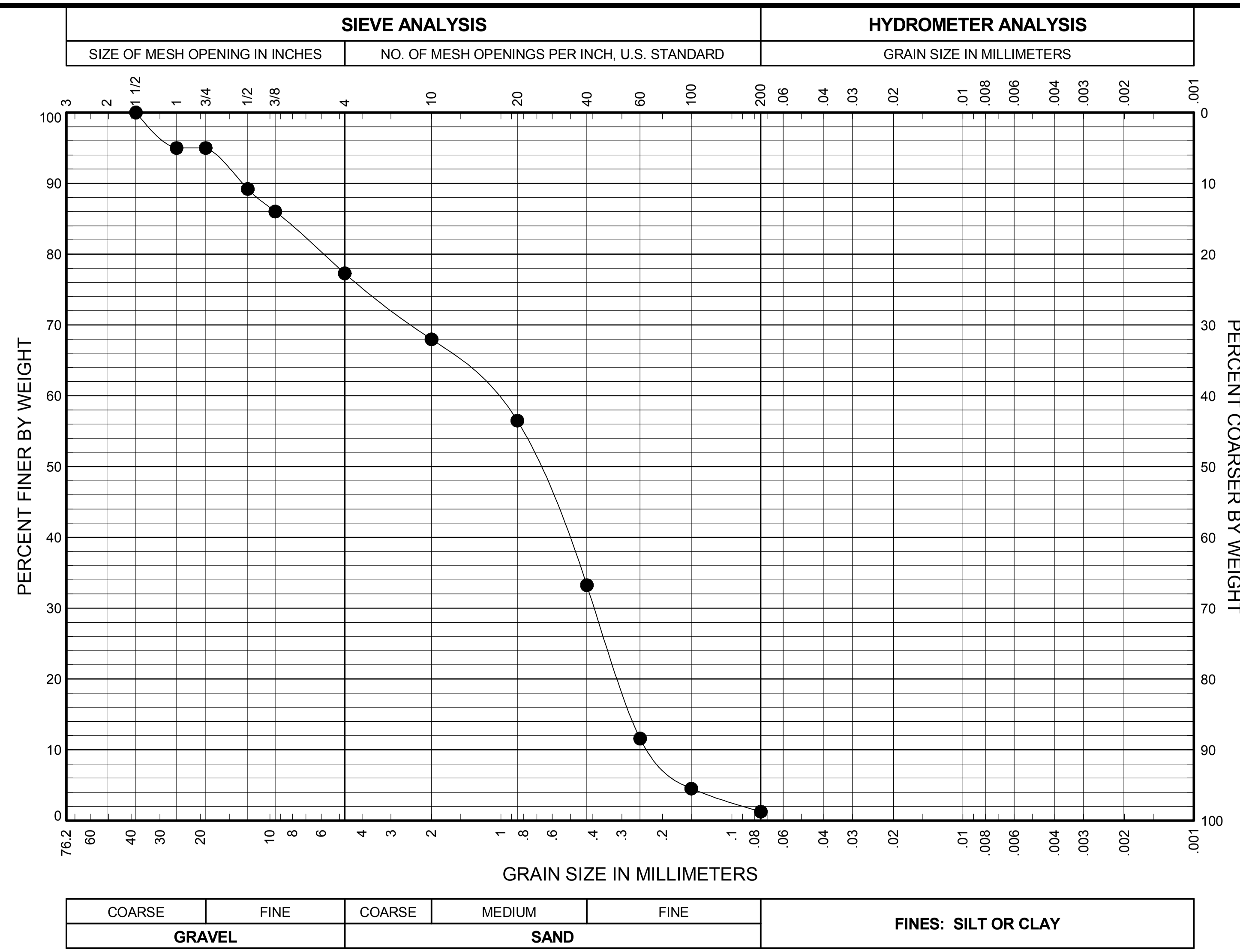
FIG. B-1
Sheet 1 of 1



LEGEND

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BORING AND SAMPLE NO.	DEPTH (feet)	USCS SYMBOL	SOIL CLASSIFICATION	GRAVEL %	SAND %	FINES %	COBBLE REM %	< 2 µm %	NAT WC %	Cu	Cc	TEST BY	REVIEW BY	ASTM DES
● TP-2, G-1*	5.0	SP	Poorly Graded Sand with Gravel	23	76	1.3			3.1	5.0	0.6	AKV	JFL	D422

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GRAIN SIZE DISTRIBUTION
TEST PIT TP-2

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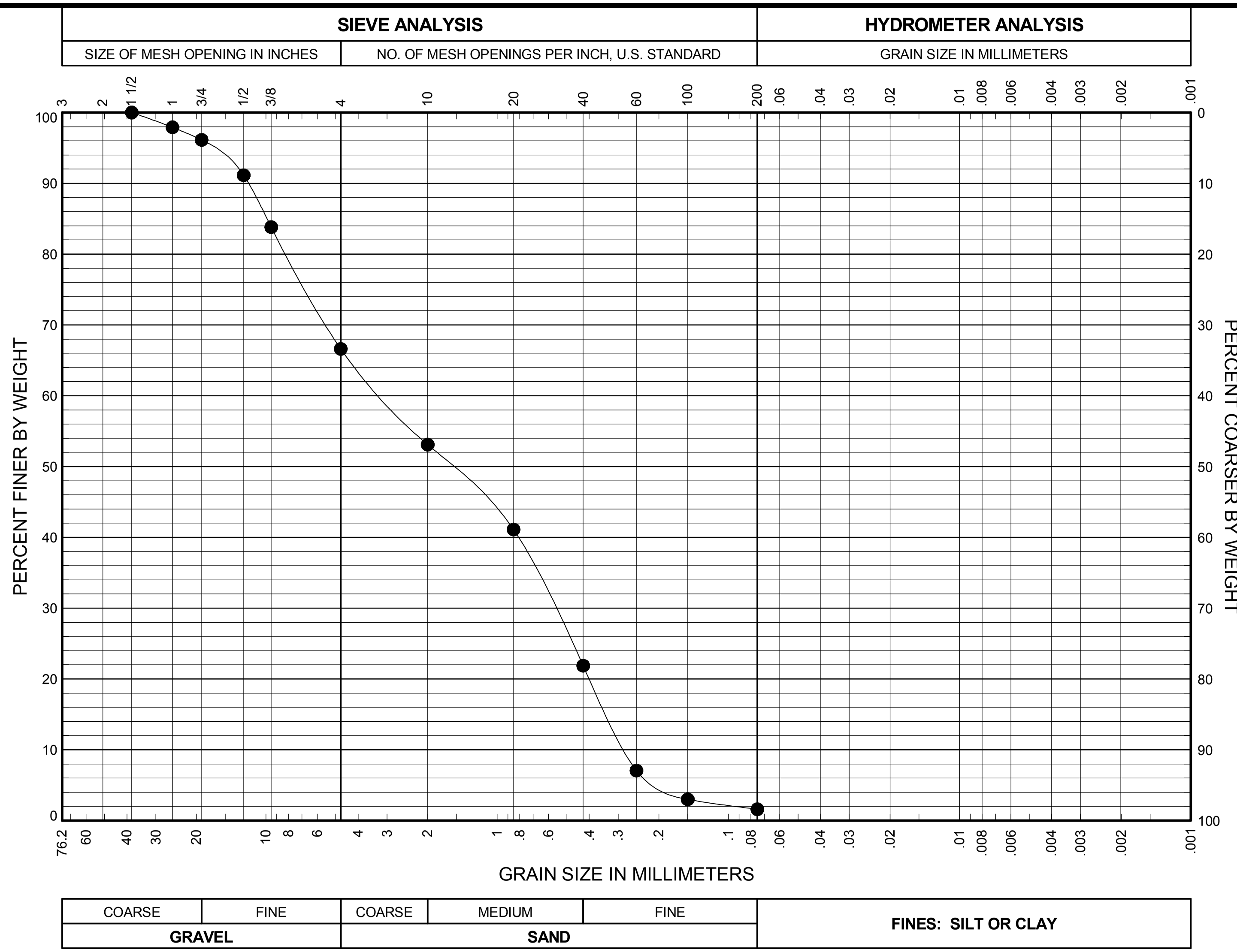
FIG. B-2
Sheet 1 of 1



LEGEND

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< 2 µm %: Percentage of soil particles finer than 2 micrometers (0.002 mm); clay-size fraction

NAT WC %: Natural water content

Cu: Coefficient of uniformity

Cc: Coefficient of curvature

ASTM DES: ASTM International test standard designation

*: ***Sample specimen weight did not meet required minimum mass for ASTM test method.***

BORING AND SAMPLE NO.	DEPTH (feet)	USCS SYMBOL	SOIL CLASSIFICATION	GRAVEL %	SAND %	FINES %	COBBLE REM %	< 2 µm %	NAT WC %	Cu	Cc	TEST BY	REVIEW BY	ASTM DES
● TP-4, G-3*	10.8	SP	Poorly Graded Sand with Gravel	33	65	1.6			2.8	11.2	0.4	AKV	JFL	D422

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GRAIN SIZE DISTRIBUTION
TEST PIT TP-4

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FIG. B-3
Sheet 1 of 1

APPENDIX C

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

Date: November 24, 2014
To: Mr. Jerry Shuster
City of Edmonds

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland