Fir Island Farm Estuary Restoration
Final Design and Permitting
Coastal Engineering Report
Skagit County, Washington

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TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1

2.0 SITE AND PROJECT DESCRIPTION 1

3.0 TIDAL AND SURVEY DATUM 2

4.0 HYDRODYNAMIC, EROSION, AND SEDIMENT PROCESSES 3
- 4.1 Hydrodynamic Modeling Results 3
- 4.2 Sea Level Rise 5
- 4.3 Erosion, Sedimentation, and Vegetation Establishment 6
- 4.4 Wood Transport 14

5.0 COASTAL DIKE DESIGN 15
- 5.1 Natural Resource Conservation Service (NRCS) Dike Design Practice Standards and U.S. Army Corps of Engineers' (Corps') Design Guidelines 15
- 5.2 U.S. Army Corps of Engineers (Corps) PL84-99 Dike Rehabilitation and Inspection Program 16
- 5.3 Federal Emergency Management Agency (FEMA) Floodplain Regulations 17
- 5.4 Level of Protection – Dike Design Elevation 17
- 5.5 Erosion and Scour Protection 19
  - 5.5.1 Wind Waves 19
  - 5.5.2 Tidal Channel and Marsh Flows 20
  - 5.5.3 Scour Toe-down Depth 20
  - 5.5.4 Wood Debris Impacts 21

6.0 SUMMARY OF COASTAL ENGINEERING DESIGN RECOMMENDATIONS 22

7.0 INDEPENDENT TECHNICAL REVIEW (ITR) 23

8.0 LIMITATIONS 24

9.0 REFERENCES 26

TABLES

1 Fir Island Farm – Site-specific Tidal Datums
2 Sea Level Rise Estimates
3 Erosion Shear Stress Literature Values
4 Marsh and Tidal Channel Sedimentation, Scour, and Vegetation Tailwater Effects
5 Dike Design Elevation Summary

FIGURES

1 Project Site Plan
2 Hydrodynamic Modeling Low Tide – Depth/Velocity
3 Hydrodynamic Modeling Flood Tide – Depth/Velocity
4 Hydrodynamic Modeling High Tide – Depth/Velocity
5 Hydrodynamic Modeling Ebb Tide – Depth/ Velocity
6 Hydrodynamic Modeling Low Tide – Shear Stress
7 Hydrodynamic Modeling Flood Tide – Shear Stress
8 Hydrodynamic Modeling High Tide – Shear Stress
9 Hydrodynamic Modeling Ebb Tide – Shear Stress
10 Project Hydrodynamic Effect
11 Hydrodynamic Effect and Without Project Conditions
12 Sea Level Rise Projections – 2000 to 2100
13 Hydrodynamic and Sea Level Rise Effects and Without Project Conditions

APPENDIX

A Independent Technical Review Comment Form
B Important Information About Your Geotechnical/Environmental Report

FIR ISLAND FARM ESTUARY RESTORATION
FINAL DESIGN AND PERMITTING
COASTAL ENGINEERING REPORT
SKAGIT COUNTY, WASHINGTON

1.0 INTRODUCTION

This coastal engineering report accompanies the Hydrodynamic Modeling Analysis report prepared by Battelle for the Fir Island Estuary Restoration Project (Battelle, 2013). The Battelle report provides information on hydrodynamic modeling of the setback dike alternatives, tidal channels, and breach areas, and includes information on the expected maximum water elevation for the project. The purpose of this report is to present hydrodynamic results from the Battelle (2013) study, and to provide design recommendations for the setback dike, marsh areas, and interior drainage system (Figure 1).

Our services were conducted in accordance with the contract and scope of services stated in the Washington State Department of Fish and Wildlife (WDFW) Contract No. 10-1431, Amendment 7, dated May 2, 2013.

2.0 SITE AND PROJECT DESCRIPTION

The Fir Island Farm estuary restoration project (the Project) is located on the WDFW Snow Goose Reserve (the Reserve) site at Fir Island. The site is comprised of 245 acres that are currently farmed, with special farming provisions to meet the Reserve's Snow Goose management objectives. The site is located on the historic Skagit River Delta between Dry Slough and Brown Slough, with Claude O. Davis Slough located near the center of the proposed dike removal and marsh restoration area (Figure 1).

Natural tidal exchange and historical distributary flows to the site have been eliminated and blocked by historic construction of coastal dikes along Skagit Bay and around Fir Island. One-way tidegates installed through the existing dike block inflow of tides and allow for drainage of interior farm lands. The combination of tidegates and dikes protects interior farm drainage areas.

The project will include setting back the existing dike on the Reserve and restoring 127 acres of farmland to tidal marsh. The feasibility study performed in 2011 defined the general setback dike alignment, tidal marsh restoration areas, and pilot tidal channel configurations (Shannon &

Wilson, Inc. [S&W], 2011). This report presents engineering coastal engineering recommendations to be incorporated into the project design, including:

- Interpretation of the Battelle hydrodynamic model with respect to dike and interior drainage design criteria.
- Evaluation of the need for a spur dike to protect the Brown Slough drainage system.
- Analysis of setback dike design alignment, elevations, erosion, and scour protection measures.
- Assessment of tidal hydrodynamic, sediment, and wood transport effects on the interior drainage system and marsh restoration areas.

After permit review by the U.S. Army Corps of Engineers (Corps), the term for the spur dike feature was revised to an "estuarine tidal berm" and the height of the berm was modified to meet Nationwide 27 permit conditions. This report will use the term "spur dike" to describe this feature that has been modified in the 90% design.

3.0 TIDAL AND SURVEY DATUM

The project survey datum is Washington State Plane North, North American Datum 1983, North American Vertical Datum 1988 (NAVD88). Documenting project survey datum and transformations is a necessity, especially in the Skagit River Delta where projects and stakeholders use a variety of survey datum.

The tidal mean lower low water (MLLW) datum published by the National Oceanic and Atmospheric Administration (NOAA) is a common tidal reference. These datum are referred to in NOAA tide prediction and tidal data websites and many tide-prediction handbooks. Conversion from MLLW to NAVD88 datum is often published for each tide gage location on the survey datum reference sheet. This section of the report describes the methods used for calculating tidal datum transformations.

Local NOAA tide gages in the area with published MLLW datum are:

- NOAA 9447592 Crescent Harbor Whidbey Island, Washington
- NOAA 9448576 Sneeoosh Point, Washington
- NOAA 9448558 LaConner – Swinomish Channel, Washington

Review of the Swinomish tide gage datum indicated that there was North Fork Skagit River surge influence on the tidal observations, which can affect MLLW datum transformation calculations. For this study we elected to use the Crescent Harbor and Sneeoosh Point tidal

gages only for calculating MLLW to NAVD88 tidal datum transformations. In coordination with WDFW's professional land surveyor, Al Hammond, a site-specific MLLW-to-NAVD88 tidal datum transformation was estimated by using proportioned scaling based on tide gage latitudes between the Crescent Harbor and Sneeoosh Point. The calculated tidal datum and transformation from MLLW to NAVD88 are summarized in Table 1. Table 1 tidal datum information supersedes previously reported project datum and transformations. The current transformation of MLLW to NAVD88 datum for the project site is:

NAVD88 (feet [feet]) = MLLW (feet) – 2.13 feet

4.0 HYDRODYNAMIC, EROSION, AND SEDIMENT PROCESSES

The Project will affect the local tidal hydrodynamics along the Skagit Bay front area between Brown and Dry Sloughs by setting back the existing dike and allowing for exchange of tidal flows to the restored marsh areas. Potential effects could include changes in hydrodynamic flow patterns, tidal inundation periods, water levels, sedimentation and erosion, tidal channel development, and vegetation patterns. The following section of the report discusses information and findings from the project hydrodynamic modeling study (Battelle, 2013), sea level rise projections, and an overview of erosion and sediment processes and their potential project effects.

4.1 Hydrodynamic Modeling Results

Battelle performed hydrodynamic modeling of the existing (Without Project) and Project conditions (Battelle, 2011a and 2011b, 2013). The Without Project conditions and initial setback modeling results and recommendations were presented in the Fir Island Farm Estuary Restoration Feasibility report (S&W, 2011). Since that time, the Project "spur dike" alternative was analyzed.

The spur dike alternative involves leaving a portion of the existing dike, south of the WDFW parking lot on the west side of the project, in place and extending a section of the dike South 200 feet into the Skagit Bay marsh. This dike configuration isolates the setback dike, and marsh restoration area from secondary inflows and effects from Brown Slough.

We evaluated the hydrodynamic modeling output for the setback alternatives (without and with spur dike) for a typical spring season tidal cycle (Figures 2 through 9). The hydrodynamic modeling output provided tidal flow pattern, velocity, and bed shear stress information, which

were used to evaluate erosion and deposition potential. The following general observations were made regarding hydrodynamic modeling results.

The Project setback, with spur dike, would effectively isolate secondary tidal flows, currents, velocities, and shear stresses in Brown Slough. Without the spur dike, a secondary tidal inflow pathway occurs on the east side of Brown Slough leading into the marsh restoration area. These tidal flows have high enough velocities and shear stresses to increase the risk for erosion and sedimentation that could impact Brown Slough.

The Claude O. Davis main tidal channel inlet "breach" location at the existing dike has predicted velocities and bed shear stresses exceeding tidal channel erosion thresholds, for both the with and without spur dike alternatives. This area is likely to experience considerable erosion of the breach and adjacent areas. Erosion of the main tidal inlet channel is an expected outcome of the project as documented in the Feasibility Study (S&W, 2011). The primary concern is excessive sediment deposition in the Claude O. Davis channel, which could impact interior farm drainage functions.

A majority of eroded material will likely move northward, into the restored marsh areas due to tidal flood dominant velocities and bed shear stresses. To a lesser degree, ebb flow erosion and sedimentation south into Skagit Bay could occur. We recommend excavation of the main tidal inlet breach to a width similar in size to the anticipated extents of erosion and tidal channel equilibrium condition width. Excavation would limit the potential for adverse erosion and sedimentation along the Claude O. Davis and No Name Slough tidal channel(s) that provide interior farm drainage.

Predicted tidal velocities and shear stresses in the marsh area along the setback dike structure are less than the referenced published erosion thresholds (see Section 4.3). Areas with expected erosion are the breach and main tidal inlet channel area, and areas along the excavated pilot channels, with a few locations in the marsh and along the margins of the dike that could have velocities and shear stresses causing localized erosion. Section 4.3 discusses these conditions in further detail.

Shallow ponding will likely occur across much of the marsh restoration area at low tide. The site will not fully drain. Moreover, the hydrodynamic modeling indicates that the marsh, No Name Slough and the excavated tidal drainage pilot channels will not drain to the same extent as the existing tidal drainage channels (Claude O. Davis Slough). Without Project conditions in Claude O. Davis Slough immediately downstream from the current dike and tidegates were compared

with Project conditions in No Name Slough immediately downstream from the proposed dike and tidegates (Figure 10). These are the common tidal tailwater control locations for Without Project and Project conditions. The term "tailwater" refers to the downstream, tidal water surface elevations that "control" the opening, closing, and flow rates through the interior drainage tidegates. The hydrodynamic model predicts low tide tailwater elevations will increase by 0.7 to 1.0 foot at the new upstream No Name Slough location. The predicted increase indicates that the marsh will not drain as much as it currently does, and will reduce the time and the elevations to which the interior drainage system can drain (Figure 10). Tailwater elevations at the existing Claude O. Davis / No Name Slough tidegate outlet (future dike breach location) will be similar for Without Project and Project conditions.

In Figure 10, the hydrodynamic modeling results show the low-tide tailwater elevation is 4.8 feet (NAVD88) for Without Project conditions in Claude O. Davis Slough. The model predicts Project tailwater conditions in No Name Slough at low tide of 5.7 feet (NAVD88); an approximate tailwater elevation increase ranging from 0.7 to 1.0 foot predicted over multiple model tidal cycles.

Our interpretation of the Battelle report hydrodynamic modeling predictions is that the "relative increase" in tailwater elevations is likely representative of Project conditions. It is our opinion that the hydrodynamic model predictions of future tailwater elevations of 5.5 to 5.7 feet (NAVD88) is likely over-predicting low tide water surface elevations. Our justification for this is that observed low tide elevations (Without Project Conditions – Claude O. Davis Slough) at similar Skagit River flows and tidal conditions are nearly 1 foot lower than the low tide water elevations predicted by the model for the Without Project condition predicted by the hydrodynamic model.

Therefore, we interpret the hydrodynamic modeling results as a "relative increase" in tailwater elevations by 0.7 to 1.0 foot. Figure 11 shows how this interpretation was applied for use as tailwater boundary conditions for the Project, interior drainage modeling analyses.

4.2 Sea Level Rise

Sea Level Rise design criteria are not clearly discussed or specified for applicable dike, drainage and habitat restoration guidelines and standards from the Natural Resources Conservation Service (NRCS) Dike Practice Standard (NRCS, 2001), NRCS National Engineering Handbook Section 16. Dikes (NRCS, 1970), the Corps Dike Design Guidelines (Corps, 2000), or habitat restoration guidelines. WDFW, with input and coordination from the project steering committee,

regulatory and funding agencies, decided that a reasonable approach for the project would be to consider Sea Level Rise for a 50-year dike design life cycle (the project design period of 2013 through 2063).

The project Sea Level Rise predictions use information and guidance available from the *National Academy of Sciences (NAS), 2012, Sea Level Rise for the Coasts of California, Oregon and Washington, Past, Present and Future (NAS, 2012).* Sea Level Rise estimates (low, average, and high level predictions based on different models and probabilities of occurring) provided by NAS (2012) for the Seattle area including vertical land mass adjustments associated with the Cascadia subduction tectonics, and glacial isostatic adjustments (isostatic rebound) for the Puget Sound (Table 2). The NAS study land mass adjustments factors were similar to those published by Mote and others (2008) for the Skagit Bay area. Table 2 and Figure 12 summarize the range of estimated Sea Level Rise for the project. The average predicted Sea Level Rise is 0.93 foot in the year 2063, with an uncertainty of ±0.5 foot. Figure 13 shows how the combined Sea Level Rise and project hydrodynamic effects on marsh water surface elevations and culvert tailwater conditions are applied to the interior drainage models.

One method of adaptation or building resiliency associated with potentially higher levels of Sea Level Rise, or other tidal and wave calculations, is to build the dike with additional top width to allow for raising the dike in the future, without needing to build or expand the dike on the landward or waterward slope. For the project, an additional 3 feet top width would allow for raising the dike 0.5 foot, which is similar to the upper confidence boundary of uncertainty for Sea Level Rise in 50 years (i.e., year 2063). For the project, a minimum design top width of 15 feet has been requested by Consolidated Diking District 22 (CDD22), and the 15 feet top width is the current dike design width.

Sea Level Rise and climate change could affect existing and restored marsh area inundation characteristics, sedimentation, and erosion rates. It is likely that the mud and vegetation lines will be increasing in elevation due to Sea Level Rise. Resiliency measures, considering the potential lack of sediment supply to the system discussed in the following section, could be accounted for by building up marsh surfaces using selective fill grading in areas with low shear stresses to improve vegetation establishment.

4.3 Erosion, Sedimentation, and Vegetation Establishment

Erosion and sedimentation are key considerations for the project. These processes are being considered to understand their potential effects on interior drainage functions, as well as the

potential for restoring tidal channels and vegetated marsh areas. The general project approach is to limit the potential for erosion that could result in adverse sedimentation affecting the interior drainage performance. An example of this type of sedimentation would be sedimentation in a tidal channel that could cause increased tailwater elevations and restrict drainage from the marsh. To the extent feasible, the project is evaluating and proposing design and construction methods that reduce these risks to the interior drainage system, while maximizing the benefits of erosion and sedimentation to habitat restoration.

There are several erosion and sedimentation processes that will influence the marsh restoration response:

- Erosion and expansion of the main tidal inlet area and main tidal channel into the marsh.
- Erosion of marsh plain surfaces that are more frequently inundated have higher shear stresses and will not readily establish marsh vegetation.
- Erosion of tidal drainage channels.
- Sedimentation of eroded materials in the new and existing marsh and tidal channel areas.
- External shoreline transport and supply of sediment into the marsh restoration area.

The hydrodynamic modeling results provide predictions of flow patterns, depths, velocities, and shear stresses. This study uses the hydrodynamic modeling predictions in combination with a conceptual framework to evaluate erosion and sedimentation risks, benefits, and to develop strategies for the project. The following simplified sedimentation and erosion framework was developed based studies by Fagherazzi and others (2012), Kirwan and Murray (2007) and Hood (2009).

- Sedimentation is the primary long-term process affecting development of the tidal channel network and vegetation marsh surfaces, not erosion (Hood, 2009).
- Sedimentation rates are likely to be higher in deeper areas that are more often inundated and in areas proximate to tidal channels that deliver sediment (Fagherazzi and others, 2012).
- Areas that are further from tidal channels will have lower sediment supplies and lower sedimentation rates.
- Bare soil areas exposed to tidal flows exceeding critical shear stress thresholds will erode and become local sediment sources. Vegetated areas have much higher critical shear stress erosion thresholds and are less likely to erode. Vegetation establishment

will likely occur above the mudline, which can vary from site to site. The mudline for the existing marsh is between elevation 5.5 and 6 feet (NAVD88), and expected to be somewhat similar for the new marsh area.

- Considering long-term Sea Level Rise, the mudline elevation will likely be increasing over time. If sedimentation rates are not high enough, lower-lying areas may be flooded out and become mudflats. Areas that are inundated for significant amounts of time or exposed to high shear stresses will not likely establish vegetation and will become mudflats, tidal channels, or remain permanently ponded.
- Marsh plant establishment will benefit from quiescent flow conditions (low velocity and shear stress areas) as well as being located in a sedimentary environment. Plant establishment can create a biofeedback that increases sedimentation rates and can promote marsh plain accretion. These quiescent areas are, however, typically further away from tidal channels that supply sediments.
- If the regional sediment supply to the marsh is not high enough to keep up with Sea Level Rise, the mudline advance over time may consume (or limit) vegetated marsh areas.
- Tidal channel and lower-lying marsh areas exposed to coastal waves (near the main tidal inlet) will likely erode and become local sediment sources.
- Establishment of marsh vegetation will focus tidal flows into tidal drainage channels and promote development of these channels, which are considered key habitat for juvenile Chinook.
- Large exposed mud flat and erosion areas are more likely to have erosion and sedimentation that could adversely affect tidal drainage channel functions as it relates to interior drainage.

Using this framework, we reviewed hydrodynamic modeling shear stresses (Figures 7 and 9) to evaluate erosion potential. The hydrodynamic model predictions indicate that the main tidal inlet area, and areas immediately north and south of the inlet, have the highest potential for erosion for both modeling alternatives (with and without spur dike), primarily on the flood and ebb tides. These areas are likely to be exposed to additional wave action, which will also contribute to erosion. Considering the flood tide has elevated shear stresses and velocities, as compared with the ebb tide, eroded sediments will mostly likely transport into the restored marsh area. It is anticipated that sedimentation would occur along the fringes and circumference of the high-shear-stress zones (Figure 7). This observation is based on evaluation of shear stresses exceeding published critical shear stress erosion thresholds. A literature review of published permissible erosion shear stress values was performed and is summarized in Table 3.

Discounting the lowest reported critical shear stress erosion thresholds, a value of 0.1 psf is used to identify likely erosion for bare soil areas. A value of 2.2 psf is used as an erosion threshold for vegetated areas. Both Project alternatives (With and Without Spur Dike) have shear stresses that exceed bare soil and vegetated area critical shear stress erosion thresholds. The With Spur Dike alternative has high shear stresses at the main tidal inlet, extending into the marsh along the pilot channels and adjacent marsh areas. The Without Spur Dike alternative has similar pattern at the main tidal inlet, albeit to a lesser degree, and high shear stresses on the western side of the marsh along Brown Slough. Surface shear stresses for these areas exceed 10 psf, which exceed all of the reviewed permissible shear stress threshold values for bare soil and vegetated surfaces.

The following discussions focus on the recommended spur dike alternative discussed above. The With Spur Dike alternative erosion would primarily occur in the main tidal inlet, along the excavated tidal channels, and adjacent marsh areas nearer the inlet. These areas have blue, green, and yellow colors in Figure 7, showing the highest shear stress conditions during flood tide, which represent shear stresses in excess of 5 psf. Sediment derived from these erosion areas will likely deposit in adjacent low shear stress zones near the tidal channels and sediment sources.

Areas located beyond the high shear stress zones will be less likely to erode and will likely support sedimentation and establishment of vegetation, depending upon inundation and sediment supply characteristics. Based on the marsh process framework from above, we predict sedimentation rates will be lower in these areas as they are less frequently inundated and further away from the tidal channel sediment sources. These areas have no color or are red color in Figures 6 through 9 showing shear stress for a complete tidal cycle. Lower sedimentation rates could indicate that these areas might be at risk for limited establishment of vegetated marsh areas due to long-term Sea Level Rise and mudline elevation increases.

Different methods for mitigating these erosion and sedimentation risks for the both the With and Without Spur Dike Project alternatives include:

- Allow for erosion of the main tidal inlet, the Claude O. Davis channel and adjacent marsh areas, with expectation that eroded sediments will primarily deposit along the margins of the high shear stress zones. The risk is that the fairly quick change in tidal hydrodynamics may create erosion and sedimentation conditions that deposit bars or shoals in tidal channels, which affect tidal channels drainage and tailwater conditions for the interior drainage storage pond. It will be difficult to dredge or maintain the marsh tidal channels in the future. This is the least conservative and least costly approach.

- Allow for erosion of the main tidal inlet and Claude O. Davis channel, and plant areas with a crop cover that will not be consumed by snow geese in marsh restoration areas and along the margins of the high-shear-stress areas. The expectation is that the main tidal inlet area will erode and transport sediment into the new marsh. The cover crop will resist erosion and promote deposition and sedimentation processes similar to natural marsh accretion and vegetation processes. The risk for erosion and sedimentation in the tidal channel remains, but it is likely less than the first method presented. The cover crop would promote sedimentation and limit erosion of adjacent marsh surfaces.
- The third option builds on the second method by adding excavation and dredging of the main tidal inlet and Claude O. Davis channel, and placing dredge spoils and seeding and planting these areas in the new marsh in areas with low shear stresses and low erosion potential. The risk for erosion and sedimentation effects in the main tidal channel and marsh areas will be lower than the first two methods because it will promote more rapid establishment of marsh vegetation. This method requires more construction and work in the existing marsh, rather than allowing for natural erosion processes to modify the main tidal inlet. The excavation of the inlet area will lessen erosion and sedimentation potential, but additional erosion and sedimentation adjustments should be anticipated. This is the most conservative, and costly approach.

We consider erosion and sedimentation framework elements, such as regional (Skagit Bay) erosion and sedimentation conditions to inform our final recommendations.

Shoreline sediment shoaling and littoral drift processes could supply sediment to the marsh restoration areas. The project hydrodynamic forces will likely draw in sediments from Skagit Bay, albeit the central Bay front area is likely limited in sediment supply as compared with the nearby Wiley Slough site near the South Fork Skagit River.

Grossman and others (2011) presents evidence that sediment delivery to the North and South Fork distributaries has increased dramatically since 1850. A combination of land use change (e.g., logging and road building), clearing and dredging in the lower river, and channelization of flow to the North and South Fork distributaries deliver sediments along the forks that would have normally transported through delta distributary channels, and the Skagit River Delta floodplain.

However, the central portion of the Fir Island, Skagit Bay area along the central portion of the Skagit River has had a reduction in sediment supply due to Fir Island diking and channelization of the North and South Forks, and disconnection of the floodplain and river distributaries from levee and dike building. Several studies provide observations of different sedimentation, and

tidal channel pattern characteristics along the central Fir Island Bay front area as compared with adjacent distributaries of the North and South Fork Skagit Rivers.

The Cowles (2012) study of coastal erosion and sediment transport conditions along the Skagit Bay and Skagit Delta, North and South Fork distributaries indicates that the confined river distributaries have higher erosion potential at the mouth of the South Fork distributary (with higher sediment supply) versus areas along central Skagit Bay front. These higher sediment supply and erosion areas of the Skagit River Delta distributaries are likely to be more dynamic and have increased sedimentation and erosion characteristics as compared with the lower-supply, less dynamic areas of the central Fir Island, Bay front area.

Grossman (2014) provided preliminary personal communications regarding long-term, Skagit Bay front sediment transport conditions that may change with climate change and Sea Level Rise. These changes may include increased supply and transport rates along the Bay front, but in-depth studies of these potential changes have not been performed to date. In contrast, Hood (2007) and Phil Williams and Associates (2004) studies document recent trends indicating reductions in sediment supplies to the central areas of Skagit Bay, which have resulted in marsh erosion pedestals along the central Fir Island Skagit Bay front area.

Based on limited hydrodynamic modeling and available sediment studies along the central areas of the Skagit Bay front, we conclude that sediment supply and sources along the central Fir Island Bay front area (Fir Island Farm site) are limited. The project site likely has lower sediment supplies than the neighboring Wiley Slough project, which is near the South Fork Skagit River distributary. Wiley Slough has experienced sediment shoaling conditions affecting interior drainage. Similar conditions could form at the Fir Island site, albeit less likely as the sites are dissimilar because the Wiley Slough site is much closer to the South Fork Skagit River that has higher sediment supply. We provide this information as the project team and stakeholders often compare the Fir Island Farm and Wiley Slough sites.

Another source of information regarding erosion and sedimentation effects of a large scale, coastal setback dike project is the Nisqually Delta Restoration project (the Nisqually project). The Nisqually project is monitoring geomorphologic and sediment effects of a large-scale, more than 700-acre restoration project. Several observations and data sets are presented on the Nisqually monitoring website (U.S. Geological Survey – Western Ecological Research Center San Francisco Bay Estuary Field Station [USGS], 2012). We note that the Nisqually Delta restoration and measurements from the River and tidal channel areas likely have higher sediment

supplies than the central Fir Island Bay front area, because the Nisqually River project likely has higher sediment supply near the river, similar to the Wiley Slough project.

The Nisqually project also monitors marsh sedimentation rates further away from the river. The Nisqually project uses a variety of techniques, for which the website provides sedimentation information on surface elevation table (SET) measurements. These measurements show marsh surface elevations increasing due to varying amounts of sedimentation. For the Nisqually marsh restoration monitoring area, initial sedimentation rates observed were 38 millimeters per year (mm/year) between 2009 and 2010 in the marsh restoration area, and then reduced sedimentation rates from 2010 to 2012, decreasing on average to 9 mm/year in 2010 to 2011 and 2 mm/year in 2011 to 2012.

In contrast, tidal channel monitoring at the Nisqually River and tidal channel monitoring areas showed initial tidal channel sedimentation and elevation increases, likely due to the presence of floating grass and peat mats and sediment waves being transported through the site, Then 40 centimeters of scour occurred between 2010 and 2011 (USGS, 2012).

Early monitoring of the Nisqually project generally showed that larger tidal channels eroded and widened, and nearby marsh surfaces experienced low levels of marsh sedimentation. These empirical observations made at the Nisqually project are likely to occur at the Fir Island site, and are supported by the information provided in the hydrodynamic modeling results above. The data set collected for the Refuge project has a limited time period and limitations regarding the similarity of site characteristics. We interpret the sedimentation results from the Refuge site and applied them as follows:

- Tidal channels will likely erode, scour, deepen, and expand, which will increase drainage and lower tidal tailwater elevations on the project tidegates and interior drainage storage pond system. Changes in tailwater elevations range from -0.1 to -0.4 foot, and use the Nisqually River and tidal channel monitoring data as anecdotes for possible Fir Island project erosion and sedimentation effects.
- Sedimentation will likely occur along the marsh plain areas that will increase tidal tailwater elevations on the Fir Island project tidegates and in interior drainage storage pond system. Changes in marsh for the Nisqually project marsh monitoring areas ranged from 0.1 to 0.5 foot, and were used as anecdotes for possible Fir Island project erosion and sedimentation effects.

Tidal channel erosion and scour and marsh sedimentation rates were compiled from the Nisqually project to provide a range of anticipated erosion and sedimentation rates that may

occur over time at the Fir Island Farm site (Table 4). The values in Table 4 assume that the erosion and sedimentation changes correspond with similar changes in hydrodynamic tailwater elevations on the interior drainage system. The values in Table 4 were used in the interior drainage sensitivity analyses for Erosion, Sedimentation, and Vegetation effects on tidal tailwater conditions.

Considering the low supply of sediment along the central Fir Island Bay front, it is anticipated that the main tidal inlet, pilot channel, and marsh areas adjacent to these features will erode and be the primary sources of sediment supply to the project. In our opinion, these eroded materials will transport toward the marsh restoration area, due to the larger tidal flood shear stress conditions.

In our opinion, the Skagit Bay shoreline sediment supply is not likely large enough to promote actively accreting marsh platforms and establish new high marsh elevations. Also, this lack of sediment supply could be a risk factor associated with increasing inundation levels as Sea Level Rise occurs, and the deeper inundation has the potential of flooding out marsh areas and limiting vegetation establishment.

Considering the limited sediment supply of the central Fir Island Bay front area, and the potential erosion of the main tidal inlet and adjacent marsh surfaces and tidal channels, we recommend the following erosion and sedimentation related aspects of the project design:

- Excavation and dredging of the main tidal inlet channel in high shear stress areas,
- Seeding of disturbed marsh restoration areas and establishing grass on the farm areas prior to breaching to limit erosion potential and accelerate sedimentation,
- Excavation of tidal pilot channels, and
- High marsh fill grading using excavated materials from the interior drainage storage pond, and planting of native salt marsh vegetation in quiescent areas along the margins of the of the new marsh and setback dike in low-shear-stress areas.

The current proposed fill grade, high marsh areas are more broad than were shown in the 2011 feasibility study. The high marsh fill areas have expanded and now locates along most of the setback dike and dike removal areas. High marsh fill grading would raise farm fields up to 3 feet in depth at the margin of the setback dike and dike removal areas and be graded to match the existing grades several hundred feet from the dikes. The high marsh grading areas will have a range of tidal marsh elevations. The benefits of high marsh fill grading include:

- Reduced risk from erosion and sedimentation by pre-excavating the tidal inlet channel and pilot tidal channels and placing materials in the low energy high marsh fill grade areas.
- Increase habitat benefits to juvenile Chinook through establishment of blind tidal channel network in the vegetated high marsh areas that provide food source inputs to the blind tidal channels.,
- Reduce seepage rates underneath and through the dike, and erosion risks to the dike through placement of low permeable material along the toe of the dike, similar to seepage blankets used in dike designs.
- Reduce ponding and improve drainage from the raised marsh elevations and into the tidal channel network.
- Reduce the risks associated with Sea Level Rise and low sediment supply, whereby these areas could be flooded out, making it difficult to establish marsh vegetation.
- Provide a location for onsite disposal with little hauling of excavated existing dike, main tidal inlet, and pilot channel materials.
- Build marsh surfaces in desirable areas rather than allowing natural sedimentation over the long term, which may not be a viable process at the project site due to low sediment supply.

The uncertainties associated with the project restoration design include hydrodynamic, erosion, and sedimentation effects, and their influence on drainage and marsh restoration performance. Sedimentation in the marsh is good for habitat restoration, but may be in conflict with interior drainage functions. These are competing criteria, for which both gravity drainage and pump station drainage features will likely be needed to balance the project objectives and outcomes. An adaptive management and monitoring plan is under development for the project to monitor future project conditions and performance for drainage and habitat restoration conditions. It is likely that long-term, ongoing adaptive management resources will be necessary for the project.

4.4 Wood Transport

Transport of large wood debris from the Skagit River and Skagit Bay into the marsh is likely, as observed with Without Project conditions. Wood transport can damage dikes through direct impact; dragging and scouring of dike materials; and clogging, impacting, and damaging drainage infrastructure.

Without Project conditions along the Skagit Bay front marsh include wood debris that varies in size ranging from small wood debris (typically debris with diameters less than 1 foot), to large wood debris ranging in size from 1-foot-diameter boles and smaller rootballs (less than 3 feet in

diameter) to massive pieces of wood debris that are 3 feet in diameter along the bole and having rootballs (greater than 3 feet in diameter). Patterns of existing wood deposits along the Skagit Bay front and marsh areas indicate that wood transport is a function of wind direction, topography, and tidal water depth. Wind rose data from nearby Whidbey Island naval station shows that predominant wind directions are from the southerly and northwesterly directions (Battelle, 2013).

For the Project the wind will likely push wood debris from the main tidal inlet toward the northernmost section of the dike, and into the southeast corner of the marsh. Site observations indicate that wood debris travels primarily into and along the slough channels. Wood debris may travel across the marsh, but will be limited by tidal depth over the marsh, and the wood debris size, and vegetation density. Elevated topography and grading along the dike toe can limit some wood debris impacts due to shallow water depths that will limit wood transport. Drainage structures (tidegates) in No Name Slough, and the setback dike, will need to be protected with log booms and wood debris racks to prevent wood debris impacts. Significantly large wood deposits could accumulate in the marsh and tidal channels, thereby impacting drainage. This should be monitored and evaluated in the Adaptive Management and Monitoring Plan.

5.0 COASTAL DIKE DESIGN

The dike design is based on a criteria established by dike and dike design practice standards and design guidelines. The following section provides information regarding these design standards and identifies the selected design criteria for the project.

5.1 Natural Resource Conservation Service (NRCS) Dike Design Practice Standards and U.S. Army Corps of Engineers' (Corps') Design Guidelines

The project dike protects WDFW and farm property, roads, infrastructure, and rural residential properties from tidal inundation, flooding, storm surge, wind wave overtopping, erosion, and scour of the dike embankment. Depending up the location, types of areas protected, and type of flood risks, differing design guidelines, regulations, and standards apply, which are summarized herein for the project.

We used the NRCS, 2002, Conservation Practice Standard, Code 356 Dikes and NRCS National Engineering Handbook Section 16, Chapter 6, Dike Design (NRCS, 1970) guidelines to design the project. The Corps dike design guidelines (Corps, 2000) were also used in developing design recommendations, especially when the NRCS guidelines were prescriptive and did not provide engineering methods for evaluating the design. The Fir Island, Skagit Bay dikes are under the

purview of Skagit County Consolidated Dike and Drainage District 22 (CDD22). CDD22 has been involved in the project feasibility study and design development and will ultimately be responsible for maintenance and operation of the dike.

This report focuses on dike design criteria associated with coastal, hydrodynamic, and hydraulic design issues including dike overtopping, scour, and erosion criteria. The dike will be designed to meet seepage, foundation and embankment stability, and interior drainage criteria, which will be presented in further detail in separate interior drainage and geotechnical engineering reports. The following guidelines were referenced in developing design recommendations for the project:

- NRCS, 2001, Conservation Practice Standard, Code 356 Dikes
- NRCS, NEH Section 16, "Drainage of Agricultural Land," Chapter 6: Dikes (NRCS, 1970)
- Corps, 2000, EM 1110-2-1913, "Design and Construction of Dikes"
- Corps, 2009, ETL 1110-2-6-571, "Guidelines for Landscape Planting and Vegetation Management at Dikes, Floodwalls, Embankment Dams, and Appurtenant Structures"
- Corps, 2008, "Coastal Engineering Manual," EM 1110-2-1100

This report addresses the following hydraulic/coastal dike design criteria only, including:

- Level of protection design elevation for a coastal dike based on tide heights, storm surge, wind waves, and Sea Level Rise.
- Erosion protection design based on wave heights, tidal and storm surge wave velocities, and wood debris impacts.
- Dike vegetation based on erosion protection, maintenance, and inspection as stated in NRCS and Corps guidelines (provided in this report).
- Dike top width design based on maintenance and repair accessibility, and related to level of protection uncertainty and future dike raises such as sea level rise.

5.2 U.S. Army Corps of Engineers (Corps) PL84-99 Dike Rehabilitation and Inspection Program

The project dikes do not participate in the Corps' PL84-99 Dike Rehabilitation and Inspection Program, because the Corps PL84-99 program is limited to riverine "levee" systems.

5.3 Federal Emergency Management Agency (FEMA) Floodplain Regulations

The project is located on FEMA FIRM Panel 5301510425C, and shown as a Coastal Zone Flood area V4. The V4 coastal flood elevation is based on waves and velocities, with elevation of 10 feet National Geodetic Vertical Datum of 1929, which translates to a project flood elevation of 13.7 feet (NAVD88). The project dikes are not considered FEMA-accredited dikes providing flood protection under the FEMA National Flood Insurance Program.

The project team consulted with John Graves, FEMA Region 10 (FEMA, 2013), regarding how the FEMA Biological Opinion (Bi-Op) for endangered species would apply for the project. FEMA indicated that because the project is a restoration project, the FEMA Bi-Op provides a safe-harbor provision for Section 7 consultation. Also, the project has a nexus with another federal agency, the U.S. Army Corps of Engineers for the Section 404 permit, and a separate Section 7 consultation will not be necessary for the project.

5.4 Level of Protection – Dike Design Elevation

Using the *NRCS 2002 Conservation Practice Standard*, the Fir Island Farm dikes are considered Class II dikes, reflecting sites where the standard states:

> *"Failure may cause damage to isolated homes, secondary highways, minor railroads, relatively important public utilities, high value land, or high value crops."*

In accordance with the *NRCS 2002 Conservation Practice Standard*, the minimum dike design elevation for a Class II dike should be the sum of:

> *(1) The water elevation (tidal elevation) attained by a highest astronomical tide for the 25-year design frequency event,*
>
> *Plus the larger of,*
>
> *(2.a) The minimum freeboard from the NRCS practice standard Table 1 (which is 2 feet based on a Class II dike that is generally less than 12 feet in height), or*
>
> *(2.b) The wave height caused by wind wave (assuming wind wave includes storm surge and wind wave runup for the specified design event) or boat traffic, and*
>
> *Allowance (addition of material overbuild) for settlement based on geotechnical analysis of fill material, foundation material and condition, and compaction methods.*

The project dike design height used the highest astronomical tide for the current tidal epoch (data period of 1983 to 2001) plus the wave design method (item 1 plus item 2.b, above), as it is larger than the 2 feet of freeboard method (item 2.a, above). The project design analysis did not calculate a 25-year event tidal from the entire historical record; rather, the highest astronomical tide from the current tidal epoch was used. We assume that the highest astronomical tide (HAT) for the current tidal epoch is roughly equivalent to or slightly greater than the 25-year event.

The starting point for dike design elevation is the water elevation HAT elevation. The HAT was calculated by Al Hammond, PLS for the WDFW, by computing proportions of the mean higher high water (MHHW) to HAT at Sneeoosh Point and then extrapolating this ratio to the Crescent Harbor gage for the most recent tidal epoch 1983 to 2001. The project site HAT was then calculated using proportioned scaling based on latitudes between the Crescent Harbor and Sneeoosh Point tidal gages. The project site calculated HAT is 11.28 feet (NAVD88) (Table 1).

Wave height design was interpreted from the NRCS dike conservation practice standard to include storm surge and wind-wave runup components. The NRCS conservation practice standard does not address Sea Level Rise. The project approach to address Sea Level Rise used the methods outlined in Section 4.2, with a 50-year Sea Level Rise prediction.

Storm surge heights were provided in the Battelle report (Battelle, 2013) and based on the 100-year wind storm probability from NOAA's National Climate Data Center station (72797524255) on Whidbey Island. The 100-year storm peak wind speed of 96.8 miles per hour was used in the Puget Sound three-dimensional hydrodynamic model for the complete model simulation period. In our opinion, this approach is considered a conservative estimate of wind-induced storm surge height because the peak wind speed occurs as short burst, and the modeled wind speed was run as a continuous wind speed, allowing full wave setup. The peak wind speed is a 100-year wind storm event, and the guidelines suggest a 25 year event. The model results showed that the water surface elevation near the project site may rise about 2.20 feet at high tide, during a 100-year wind storm with low pressure surge.

Wind wave runup, with breaking waves, was calculated by Battelle (2013) using the methods outlined in the Corps' Coastal Engineering Manual (Corps, 2008), at 0.54 foot (0.166 m). The calculated combined wave height including storm surge wave setup, plus wind wave runup is 2.74 feet.

According to Zervas (2007), tidal heights above MHHW in Puget Sound range from 1.48 feet for a storm with a return frequency of once a year to 3.19 feet for a storm with a return frequency of

once in 100 years. The calculated combined storm surge wave setup and wind wave runup tidal height of 2.74 feet is 0.45 foot less than the 100-year storm tidal height and 1.25 feet higher than the annual tidal heights reported by Zervas.

Using the wave height calculation method plus Sea Level Rise for a 50-year design life, the following equation generates a dike target design elevation of 15 feet, neglecting settlement (Table 6). Settlement design will be included as "overbuild" in addition to the 15 feet elevation in the geotechnical design phases of the project (Table 5).

$$\eta_{Design} = \eta_{HAT} + \eta_{surge} + \eta_{wave} + \eta_{Sea\ Level\ Rise\text{-}2063} = 15 \text{ feet}$$

For comparison purposes, the existing top of dike elevations range from 13 to 14.5 feet, and the setback dike would be 0.5 to 1.5 feet for the Project.

5.5 Erosion and Scour Protection

Using the *NRCS 2002 Conservation Practice Standard*, the slope protection section states:

> *"Slopes of earthen dikes shall be protected from sheet, rill, and gully erosion; erosion from flowing floodwaters; and wave action created by wind and/or boat traffic. Erosion protection measures such as non-woody vegetation, berms, rock riprap, sand-gravel, or soil cement shall be utilized as needed."*

Based on observations and history of the existing dike erosion characteristics, and the hydrodynamic modeling results, the dike will be subject to erosion from wind waves, possible tidal channel development along the dike toe, and impacts from floating large wood debris. The following approach was used to evaluate erosion and scour of the setback dike.

5.5.1 Wind Waves

Riprap size was based on wind wave attack using two methods presented in HEC-23 (Lagasse and others, 2009): the Hudson method (Douglass and Krolak, 2008), and the Pilarczyk method (Pilarczyk, 1998). In the Hudson method, riprap size is a function of the 10 percent wave height (equal to 1.27 times the significant wave height), side slope, and the specific gravity of the riprap and water. In the Pilarczyk method, riprap size is a function of the significant wave height, wave period, and side slope. The following parameters were used to calculate the riprap size:

- Side slopes = 2.5 Horizontal to 1 Vertical (2.5H:1V – based on geotechnical design)
- Rock (riprap) specific gravity = 2.65
- Saltwater specific gravity = 1.03
- Significant wave height = 2.7 feet (Table 5 – Surge and Wind-Wave)
- Wave period = 4.6 seconds (Battelle, 2013)

For the above parameters, the calculated average median particle size (D_{50}) for the two methods is 1.5 feet.

5.5.2 Tidal Channel and Marsh Flows

Tidal channel and marsh flow velocities along the setback dike are low. Tidal channel and marsh flow conditions along the setback dike do not require riprap protection greater than those calculated for wind wave and wood impacts.

5.5.3 Scour Toe-down Depth

Over the long term, formation of new tidal channels and elongation of new and existing tidal channels in the marsh could impact the setback dike. These channels may scour and erode into the dike embankment. The depth of these channels determines the scour protection design depth, which is termed scour "toe-down" depth.

Tidal channel sizes were predicted using methods described by Hood (2007) for the Feasibility Study (S&W, 2011). Consideration of tidal channel development along the setback dike results in an estimated tidal channel top width of 6 feet using Hood's empirical formulas. Assuming tidal channel side slopes of 1.5H:1V, the depth of the tidal channel depth would be 2 feet. Overall, the contributing drainage areas near the dike are small so they would not contribute enough flow to erode a deep tidal channel, near the setback dike.

In the central areas of the marsh and further away from the setback dike, tidal channels up to 35 feet wide and 10 to 20 feet deep, could occur from the increased volume of tidal prism and increased flow velocities. These areas are associated with No Name and Claude O. Davis Sloughs, and the areas immediately upstream from the main tidal inlet. These larger tidal channels are not expected along the setback dike.

There is a potential for localized tidal channel formation of the shallow (2–foot-deep) tidal channels along the setback dike. The project riprap erosion toe-down depth is 3 feet below the waterward (marsh side) final design grade. In the area along the southeast side of the site, the 3-foot toe-down will occur below native grade. In setback areas along the northeast, north, and

northwest, the 3-foot toe-down depth will occur below the high marsh fill grades, so the riprap placement will start near the existing grade elevation. The toe-down depths of 3 feet would be 1 foot below the tidal channel depth calculated above. This does not consider the potential development of a tidal channel running parallel to the toe along a preferential flow path, which is expected to be limited to the southeast corner of the site. The project design includes high marsh fill grading in the southeast to limit development of the preferential flow paths.

Larger localized scour conditions may develop due to larger tidal channel development, scour along preferential flow paths, or large wood debris deposits or impacts. These localized scour conditions may exceed the scour design toe-down depth. The exact location and timing of larger localized scour conditions cannot be predicted. This uncertainty is similar for the existing dike and the proposed setback dike. High marsh fill grading areas will limit this type of erosion and scour. High marsh fill grading in low-shear-stress areas along select areas of the setback dike may reduce localized toe erosion and promote native marsh vegetation establishment, thereby protecting the setback dike from scour and erosion. Annual inspections and maintenance repairs on the dike toe will need to continue to identify localized scour and erosion areas that need repair.

Similarly, filling and grading of borrow ditches, as part of the existing dike demolition, may experience erosion in the areas nearest the main tidal channel entrance near the existing Claude O. Davis Slough tidegates. These areas are preferential flow paths that might erode ditch fills. To reduce the potential for ditch fill erosion, the ditch fill plans are selective and limited to areas beyond the predicted high shear stress zones near the Claude O. Davis, main tidal channel breach area.

5.5.4 Wood Debris Impacts

Large wood transported by the Skagit River and along Skagit Bay will likely impact the dike during storm events. Available information on wood impacts on riprap revetments is limited. FEMA (2011) developed a method for calculating debris impacts to structures in the floodway. Using the FEMA method and the following assumptions, riprap size needed to resist wood impacts was calculated:

- Tree length = 30 feet
- Tree trunk diameter = 2 to 3 feet
- Tree rootwad diameter = 4 to 6 feet
- Unit weight of saturated wood = 50 pounds per cubic feet
- Velocity of water = 0.5 foot per second

- Coefficient of drag for riprap particle = 0.4
- Factor of safety = 1.5

Based on these basic parameters, the minimize size of riprap required to resist wood impacts ranges from 1.8 to 2.6 feet. A separate impact analysis was performed for a smaller piece of wood with a 2 feet bole diameter and a 3 feet rootball diameter that resulted in a required minimum riprap diameter of 1.4 feet. Considering both wind wave and large wood debris conditions along the existing marsh, and the plans for high marsh fill that will limit the size of material that can be transported the full distance to the dike, the following protection measures for wood debris are recommended:

- Erosion protection riprap
  - Minimum size D_{min} > 1.5 feet
  - Average size D_{50} = 2 feet
- Select fill grading along the margins of the setback dike to promote marsh vegetation establishment and protect from wood debris transport, scour, and erosion.
- Installation of log booms in No Name Slough to protect new drainage culverts from large and small wood debris impacts.
- Monitoring and adaptive management wood removal if marsh wood deposits are excessive and effect interior drainage functions.

6.0 SUMMARY OF COASTAL ENGINEERING DESIGN RECOMMENDATIONS

The following is a summary of hydraulic and coastal engineering-related design recommendations contained in this report.

- Alignment Alternative – Spur dike configuration
- Dike Design Elevation – 15 feet plus settlement (based on geotechnical analysis)
- Top Width – 15 feet
- Side Slopes – Assumed 2.5H:1V (based on current geotechnical analysis)
- Dike erosion protection for wind wave and woody debris impacts
  - D_{50} = 2 feet
  - Thickness = 3 feet (typically 1.5 to 2 times the D_{50})
  - Toe-down depth = 3 feet
  - Bedding = Quarry spall bedding and filter layer (could limit animal burrows) or geotextile filter (geotechnical analysis to finalize)

  - Topsoil 1 foot thick with native salt-tolerant grass seed mulch and tackifier, watering and establishment of grass seed prior to breach of the existing dike. No woody shrubs or trees allowed.
  - Use excavated materials as high marsh fill grading in marsh restoration (farm) areas outside high-shear-stress zones along circumference of setback dike to increase marsh restoration potential and reduce scour and erosion, and wood transport potential along setback dike.
- Seepage cutoff – Not included (information is available in the Drainage Engineering Report)
- Drainage protection
  - Limit erosion of tidal channels, inlet areas, and ditch fills to minimize the potential for sedimentation along the drainage channels that could impact drainage tailwater elevations.
  - Excavate main tidal inlet to beyond the predicted edges of high-shear-stress areas at main tidal breach area in order to limit erosion and deposition potential in undesirable areas. Use cut materials as fill in marsh restoration (farm) areas outside high-shear-stress zones.
  - Excavate tidal pilot channels and new channels along preferential flow paths, to limit adverse erosion and deposition potential. Use cut materials as fill in marsh restoration (farm) areas outside high-shear-stress zones.
  - Seed and establish salt-tolerant grasses along margins of high-shear-stress areas to promote deposition and establishment of native marsh species.
  - Limit existing borrow ditch fills to low-shear-stress areas without preferential flow paths, that are less likely to erode.
  - Plant native salt marsh vegetation in select fill grade areas to preserve native salt marsh establishment.
  - Install floating log boom at No Name Slough tidegate outlet to protect tidegates from wood debris impacts and limit maintenance.
  - Analyze interior drainage system considering hydrodynamic effects, Sea Level Rise, erosion/sedimentation/vegetation effects on tailwater conditions presented in this report.

7.0 INDEPENDENT TECHNICAL REVIEW (ITR)

An ITR of this study and report was performed by Moffatt and Nichol and Golder. A copy of the ITR comments and responses are included in Appendix A.

8.0 LIMITATIONS

This report was prepared for the exclusive use of WDFW and other members of the design team for specific application to the design of the project as it relates to the coastal and hydraulic engineering aspects of dike design and marsh discussed in this report. The conclusions contained in this report are based upon site conditions as they existed at the time this report was prepared, and based upon specialized hydrodynamic modeling prepared by others in support of the project. Our analyses and recommendations rely on the modeling predictions. We assume that the data and modeling output provided by others has been accurately developed and calibrated and that it comprises reliable information to perform the analysis. S&W cannot make claims regarding the correctness or accuracy of these models and data, as they are proprietary models. Within the limitations of the scope, schedule, and budget, the data presented in this report were collected and presented in accordance with generally accepted professional engineering practice in this area at the time this report was prepared. No warranty, express or implied, is made.

The scour and erosion types evaluated in this report were limited to those described in this report. Other long-term coastal process and geomorphic changes at the site could influence scour and erosion patterns, but were not specifically evaluated.

Facts and conditions referenced in this report may change over time. Facts and conditions set forth here are applicable as described only at the time this report was written. We believe that the conclusions stated here are factual, but no guarantee is made or implied. More information regarding the limitations of this report is included in Appendix B.

This report was prepared for the exclusive use of WDFW and its representatives and in no way guarantees that any agency or its staff will reach the same conclusions as S&W.

SHANNON & WILSON, INC.

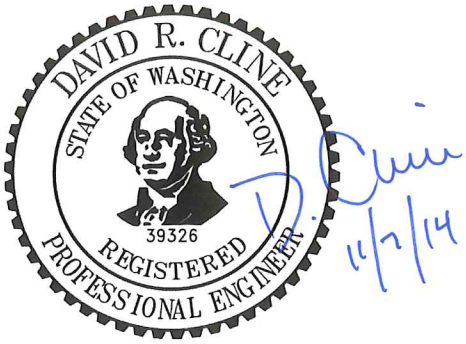

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TABLE 1
FIR ISLAND FARM – SITE-SPECIFIC TIDAL DATUMS

Tidal Elevations[1] (ft)	Mean Lower Low Water (MLLW-ft)	North American Vertical Datum 1988 (NAVD88-ft)
HAT	13.41	11.28
MHHW	11.43	9.30
MHW	10.55	8.42
MSL	6.65	4.52
MTL	6.63	4.50
MLW	2.72	0.59
NAVD88	2.13	0.00
MLLW	0.00	-2.13

Notes:
[1] Abbreviations
ft = feet
HAT = highest astronomical tide
MHHW = mean higher high water
MHW = mean high water
MLW = mean low water
MSL = mean sea level
MTL = mean tide level
MLLW = mean lower low water
NAVD88 = North American Vertical Datum Transformation

TABLE 2
SEA LEVEL RISE ESTIMATES

Year	SLR - Low[1, 2] (ft)	SLR - Avg[1, 2] (ft)	SLR - High[1, 2] (ft)
2000	0.00	0.00	0.00
2013	0.01	0.09	0.17
2030	0.03	0.22	0.40
2033	0.06	0.27	0.47
2050	0.20	0.54	0.89
2063	0.43	0.93	1.44
2100	1.07	2.03	2.99

Notes:
[1] Sea Level Rise (SLR) rates were provided by the National Academy of Science (NAS), 2012, Sea Level Rise for the Coasts of California, Oregon and Washington, Past, Present and Future. Estimates include Cascadia subduction zone tectonics and post-glacial isostatic rebound, vertical land rate adjustments.
2 SLR rates were linearly interpolated for years 2013, 2033, and 2063 from published NAS values in years 2000, 2030, 2050, and 2100.
ft = feet

TABLE 3
EROSION SHEAR STRESS LITERATURE VALUES

Author	Soil Type	Shear Stress Erosion Threshold (psf)
Smeardon and Beasley (1956)	Bare, clayey silt	0.09 – 0.22
vanRijn (1993)	Bare, cohesive (clayey silt)	0.002 – 0.02
Kirwan and Murray (2007)	Bar mudflat	0.01
USBR (2006)	Bare, cohesive soil	0.004 – 0.125
Project selected threshold for bare soils		**0.1**
FHWA (2005)	Grass vegetation	0.4 – 4.0
Project selected threshold for vegetated soils		**2.2**

Note:
psf = pounds per square foot

TABLE 4
MARSH AND TIDAL CHANNEL
SEDIMENTATION, SCOUR, AND VEGETATION TAILWATER EFFECTS

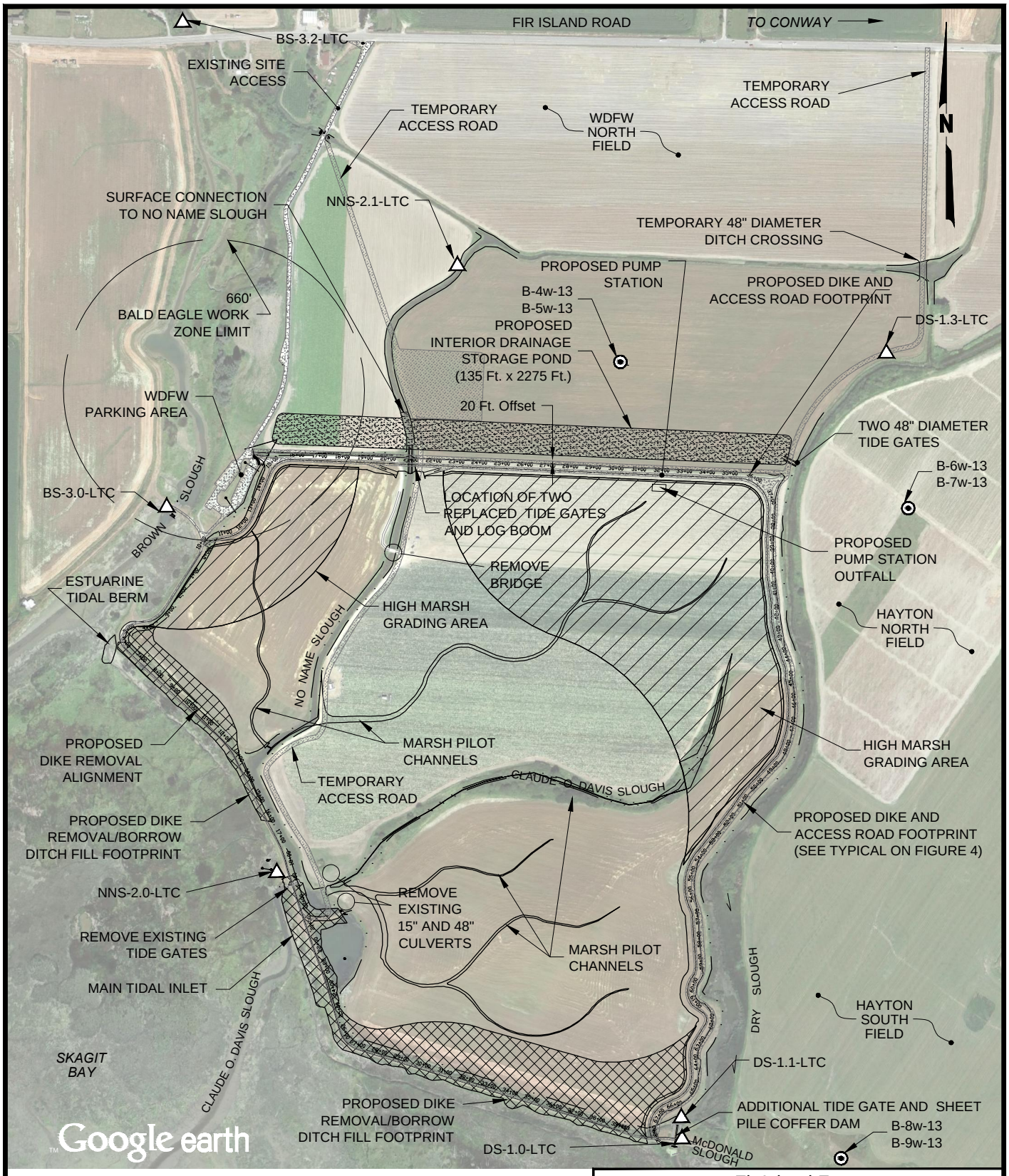
Year	Tailwater Effects - Low (ft)	Tailwater Effects - Average (ft)	Tailwater Effects - High (ft)
2013	-0.1	0.0	0.1
2033	-0.3	0.2	0.3
2063	-0.4	0.3	0.5

Note:
ft = feet

TABLE 5
DIKE DESIGN ELEVATION SUMMARY

Design Element	(ft)[1]
n_{HAT}[2]	11.28
n_{Surge}[3]	2.20
$n_{Wind\text{-}wave}$[3]	0.54
$n_{SLR\text{-}2063}$[4]	0.93
n_{Design}	14.95
Settlement	TBD

Notes:
n = wave design parameter
[1] Final dike design elevation rounded to nearest tenth of foot (15.0 feet [ft]).
[2] Highest astronomical tide (HAT) provided by Al Hammond, P.L.S., Washington Department of Fish and Wildlife.
[3] Surge and wind-wave model and calculations provided by Battelle, 2013.
[4] Sea Level Rise (SLR) estimates provided by National Academy of Sciences 2012 and interpolated for year 2063 SLR estimates referenced in National Academy of Sciences 2012 and interpolated for year 2063 average SLR prediction, including vertical land rate adjustments.
TBD = to be determined



0 600 1200

Scale in Feet

LEGEND

Monitoring Well Designation and Location

Data Logger Designation and Location

NOTE

Map adapted from aerial imagery provided by Google Earth Pro, Image U.S. Geological Survey, Image Island County, reproduced by permission granted by Google Earth ™ Mapping Service.

Fir Island Farm
Estuary Restoration Project
Skagit County, Washington

PROJECT SITE PLAN

NOVEMBER 2014 21-1-12318-217

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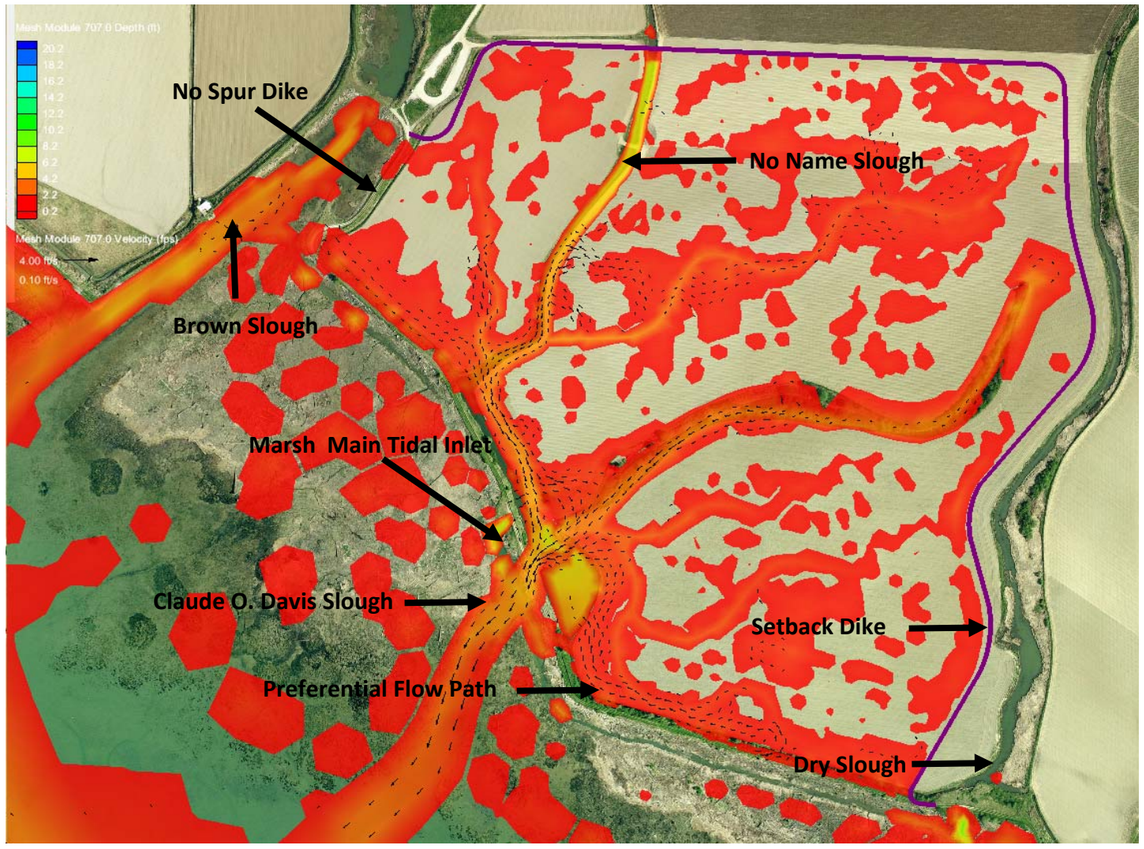
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

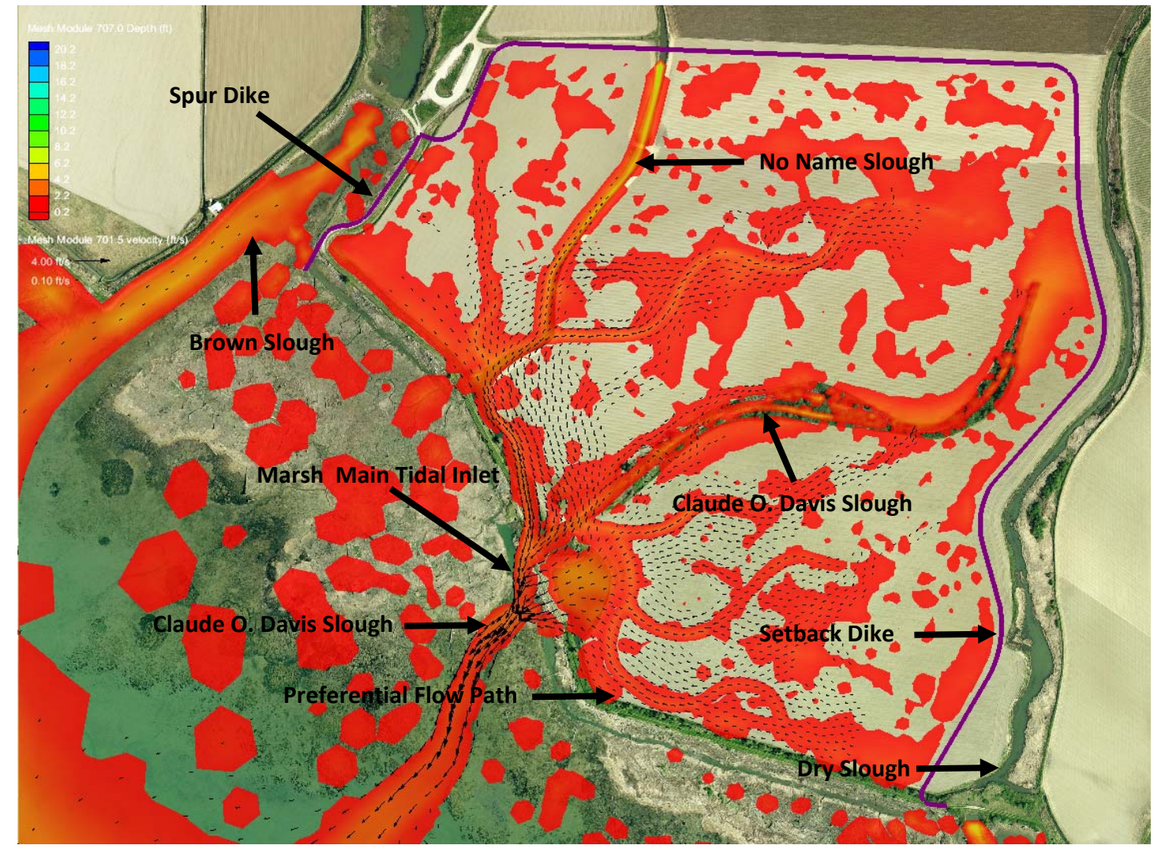
FIG. 1

Filename: I:\WIP\21-1\12318 Fir Island\CAD\FIGURES\-224\21-1-12318-224 60% Design Figure 2.dwg Date: 11-06-2014 Login: cmh



PLAN VIEW - NO SPUR DIKE

Not to Scale



PLAN VIEW - WITH SPUR DIKE

Not to Scale

Legend

Depth (ft)

20.2
18.2
16.2
14.2
12.2
10.2
8.2
6.2
4.2
2.2
0.2

Velocity (fps)

4.00 ft/s →

0.10 ft/s –

N
W E
S

Fir Island Farm Estuary Restoration
Skagit County, Washington

HYDRODYNAMIC MODELING
LOW TIDE - DEPTH/VELOCITY

November 2014 | 21-1-12318-217

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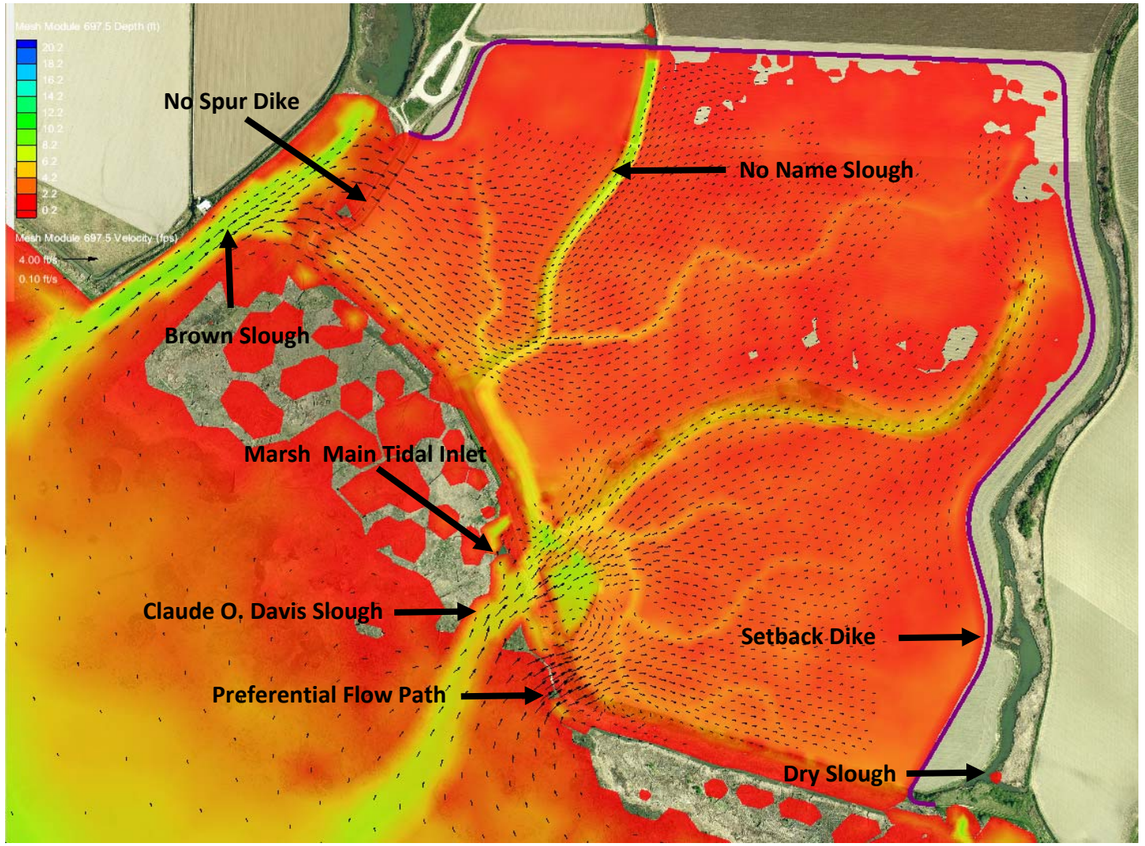
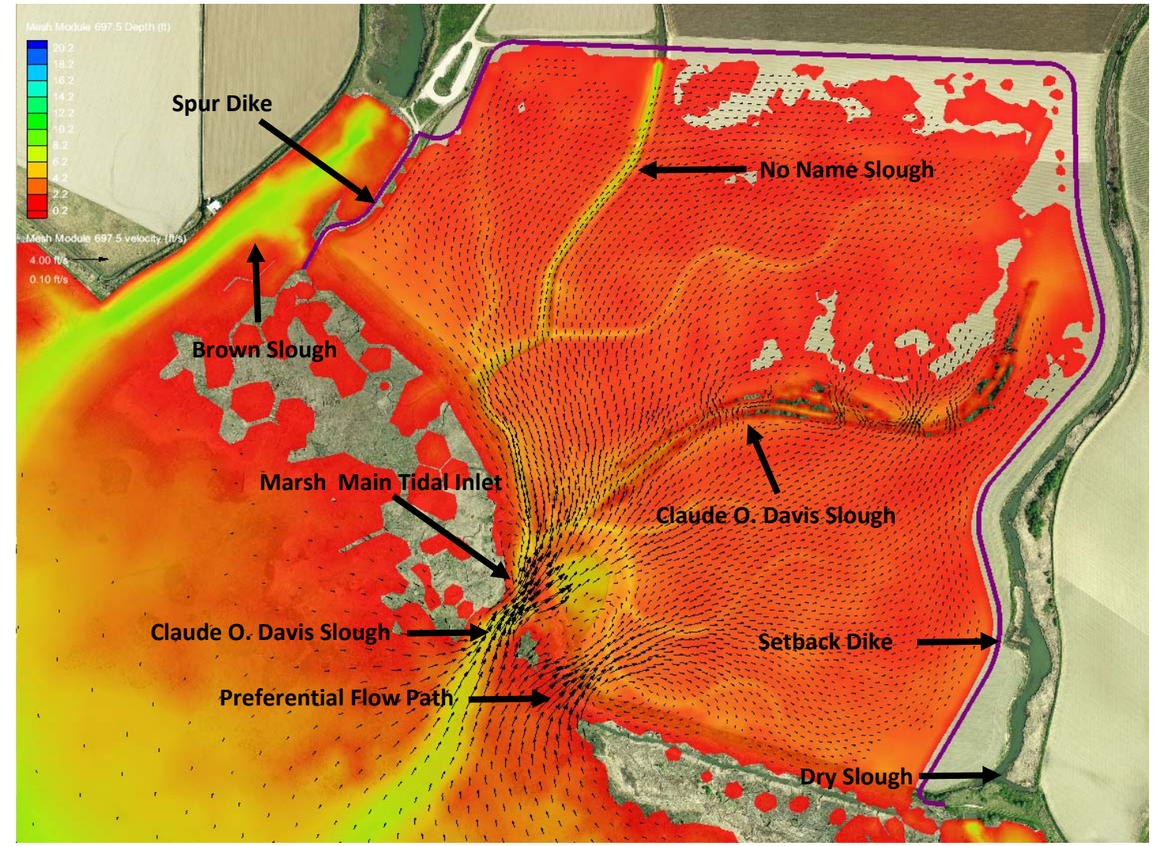
FIG. 2



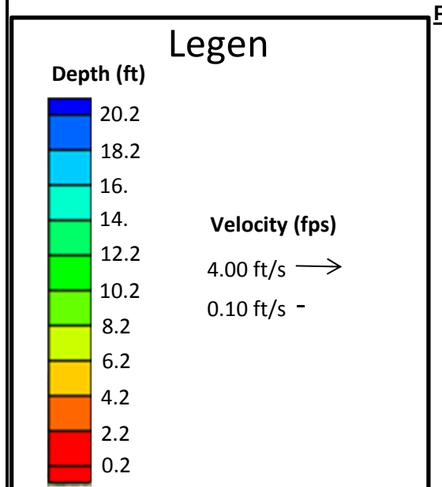
PLAN VIEW - NO SPUR DIKE

Not to Scale



PLAN VIEW - WITH SPUR DIKE

Not to Scale



Fir Island Farm Estuary Restoration
Skagit County, Washington

HYDRODYNAMIC MODELING
FLOOD TIDE - DEPTH/VELOCITY

November 2014 | 21-1-12318-217

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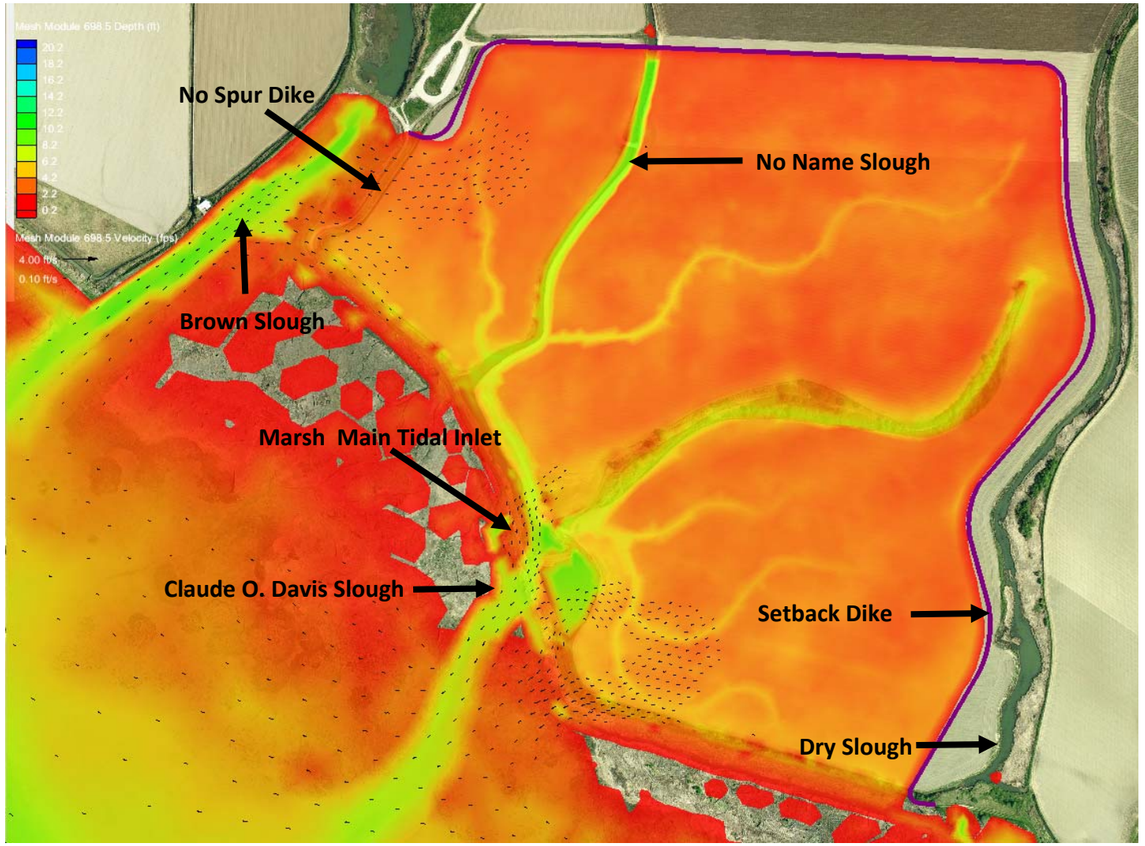
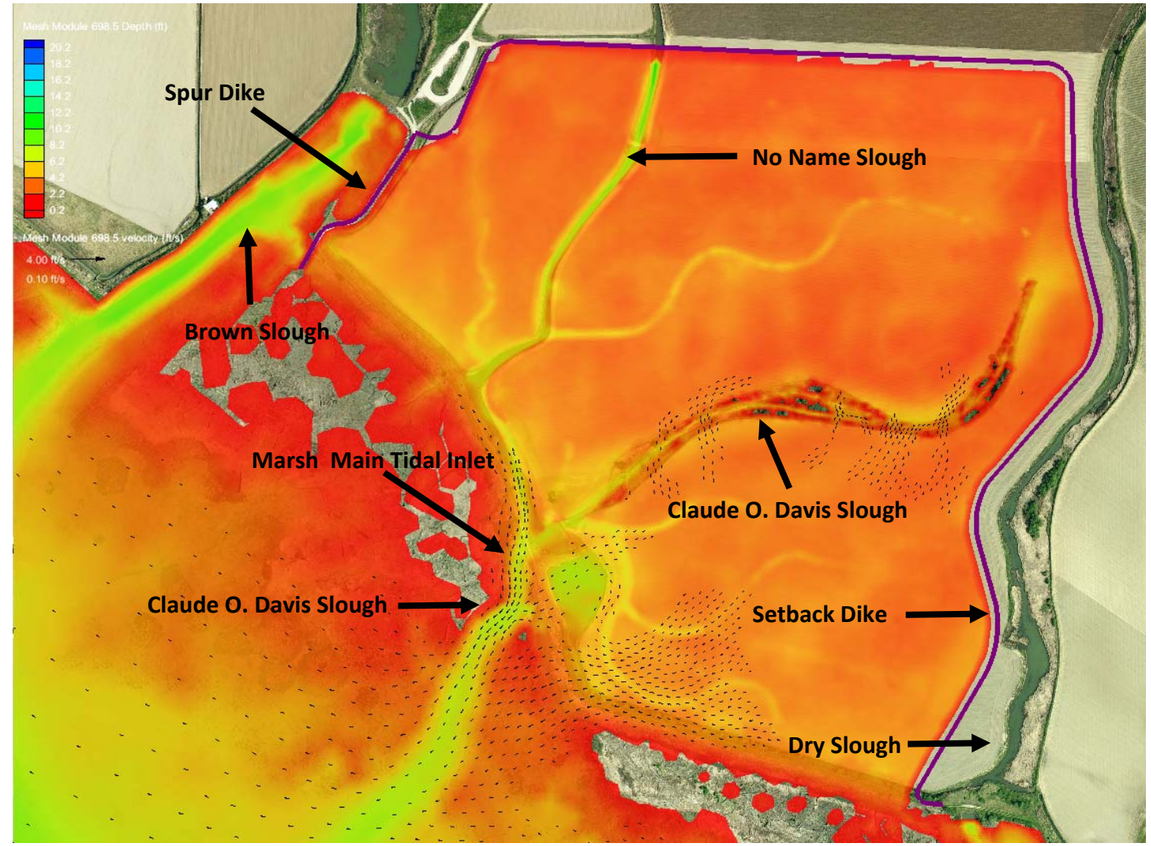
FIG. 3



PLAN VIEW - NO SPUR DIKE

Not to Scale



PLAN VIEW - WITH SPUR DIKE

Not to Scale

Legend

Depth (ft)

20.2
18.2
16.
14.
12.2
10.2
8.2
6.2
4.2
2.2
0.2

Velocity (fps)

4.00 ft/s
0.10 ft/s

N
W E
S

Fir Island Farm Estuary Restoration
Skagit County, Washington

HYDRODYNAMIC MODELING
HIGH TIDE - DEPTH/VELOCITY

November 2014 21-1-12318-217

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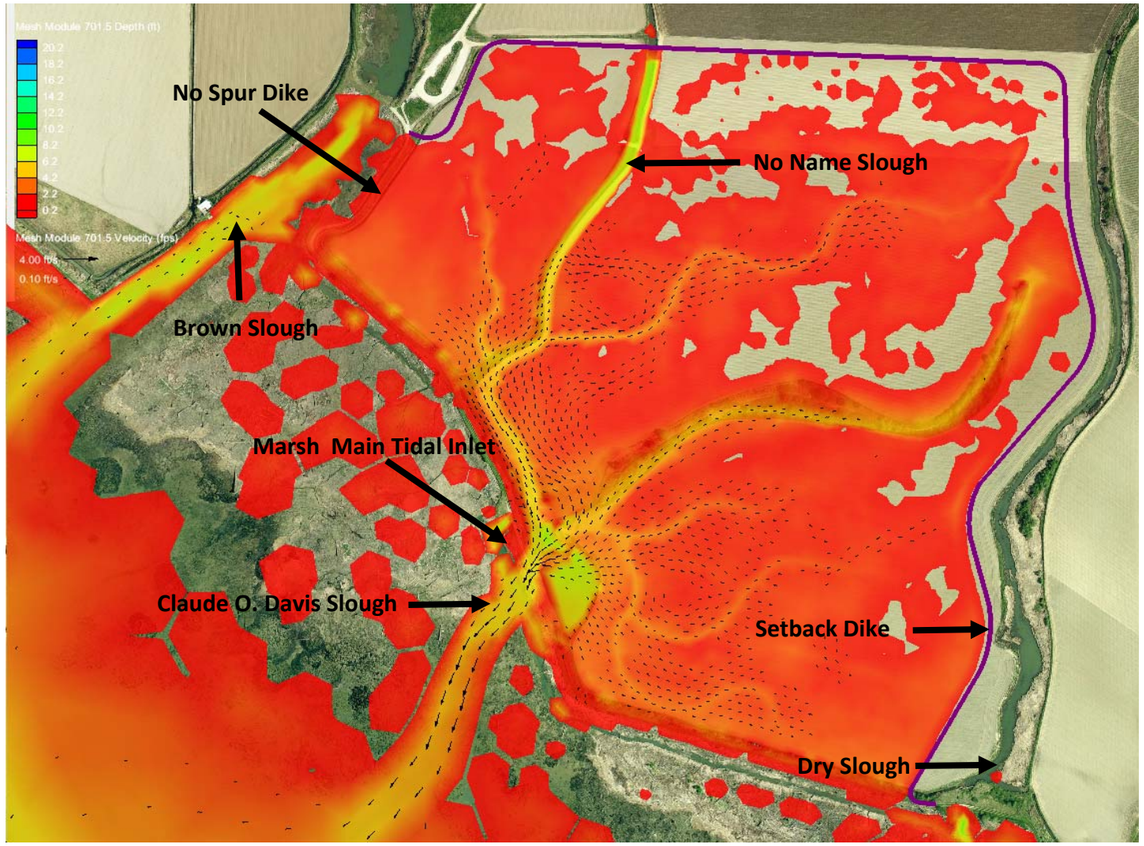
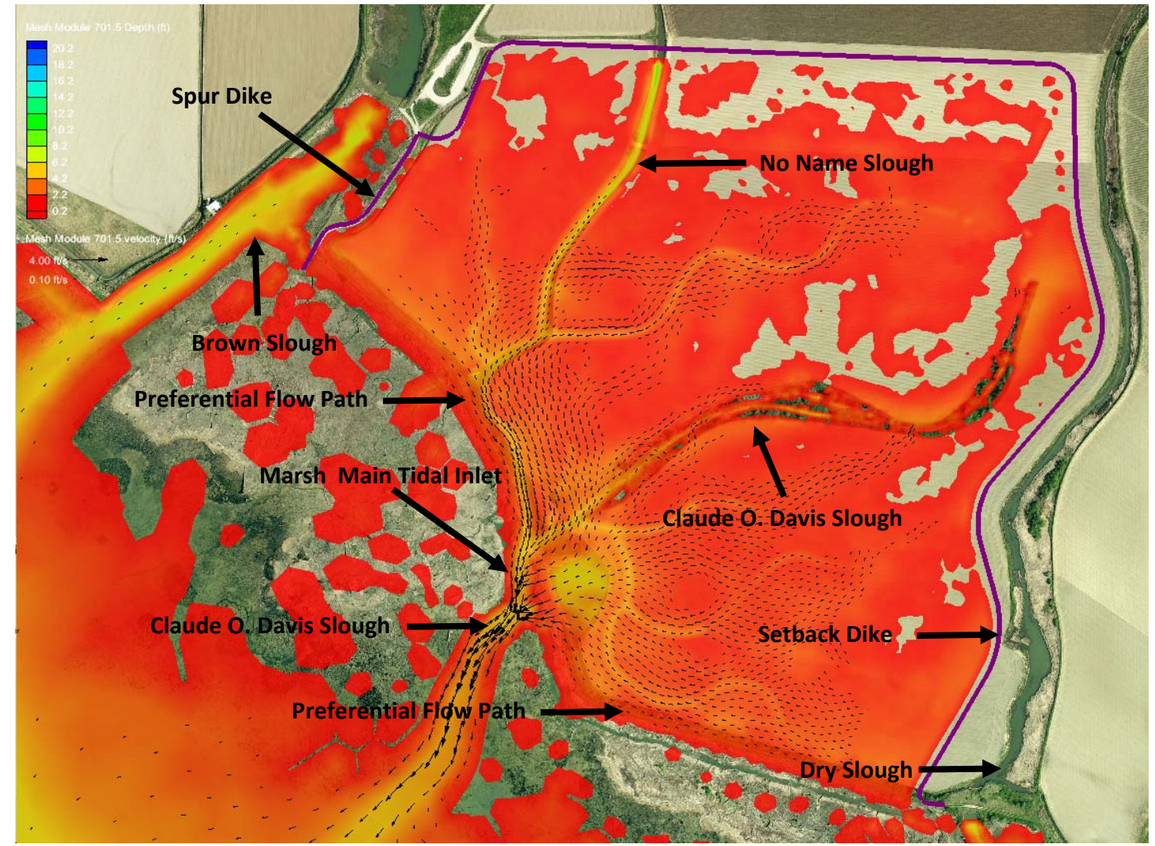
FIG. 4



PLAN VIEW - NO SPUR DIKE

Not to Scale



PLAN VIEW - WITH SPUR DIKE

Not to Scale

Legend

Depth (ft)

20.2
18.2
16.2
14.2
12.2
10.2
8.2
6.2
4.2
2.2
0.2

Velocity (fps)

4.00 ft/s
0.10 ft/s

N
W E
S

Fir Island Farm Estuary Restoration
Skagit County, Washington

HYDRODYNAMIC MODELING
EBB TIDE - DEPTH/VELOCITY

November 2014 | 21-1-12318-217

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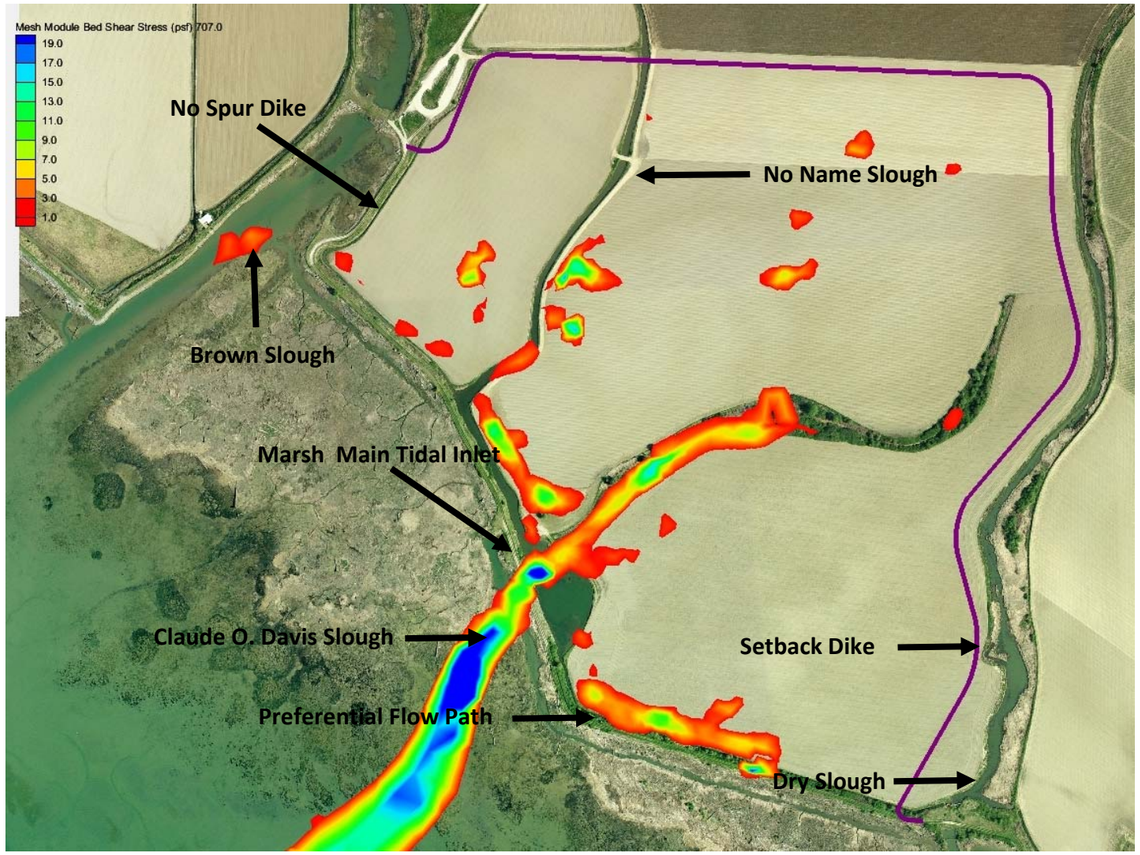
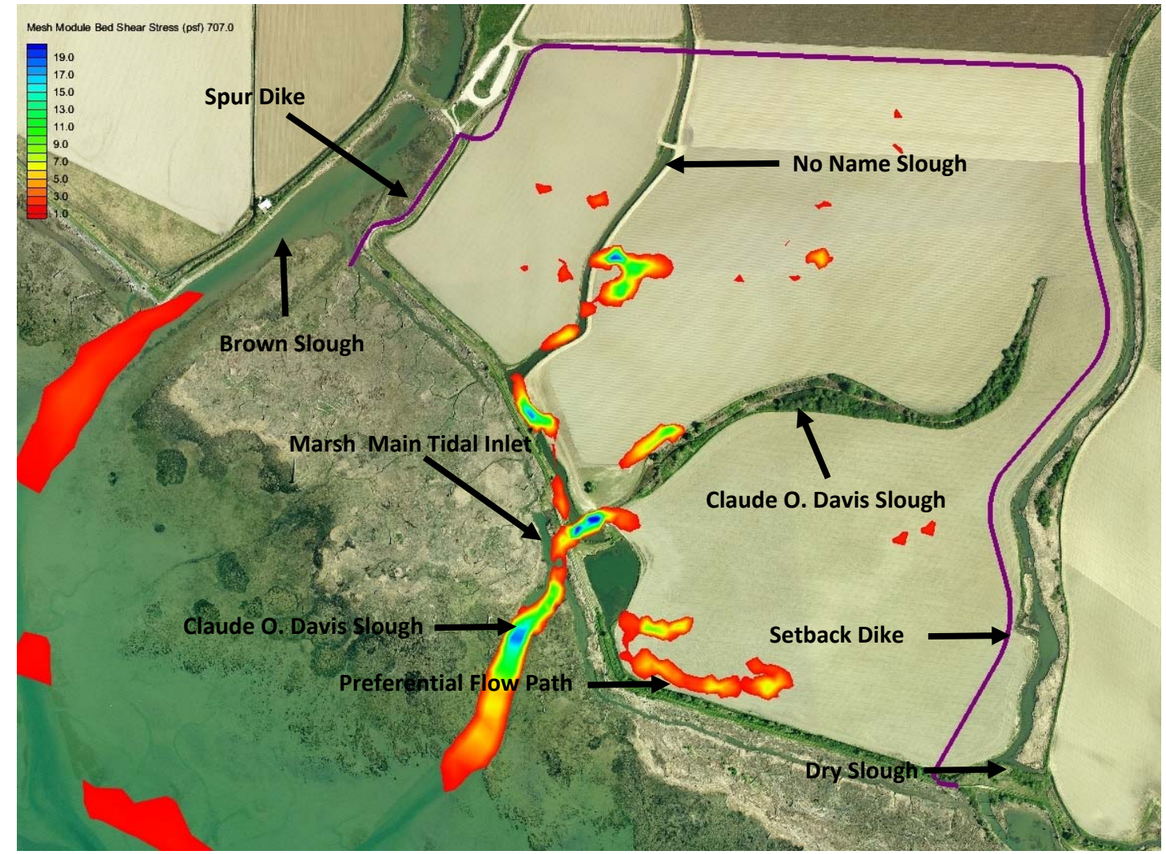
FIG. 5



PLAN VIEW - NO SPUR DIKE

Not to Scale



PLAN VIEW - WITH SPUR DIKE

Not to Scale

Legend

Bed Shear Stress (psf)

19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0

Fir Island Farm Estuary Restoration
Skagit County, Washington

HYDRODYNAMIC MODELING
LOW TIDE - SHEAR STRESS

November 2014 | 21-1-12318-217

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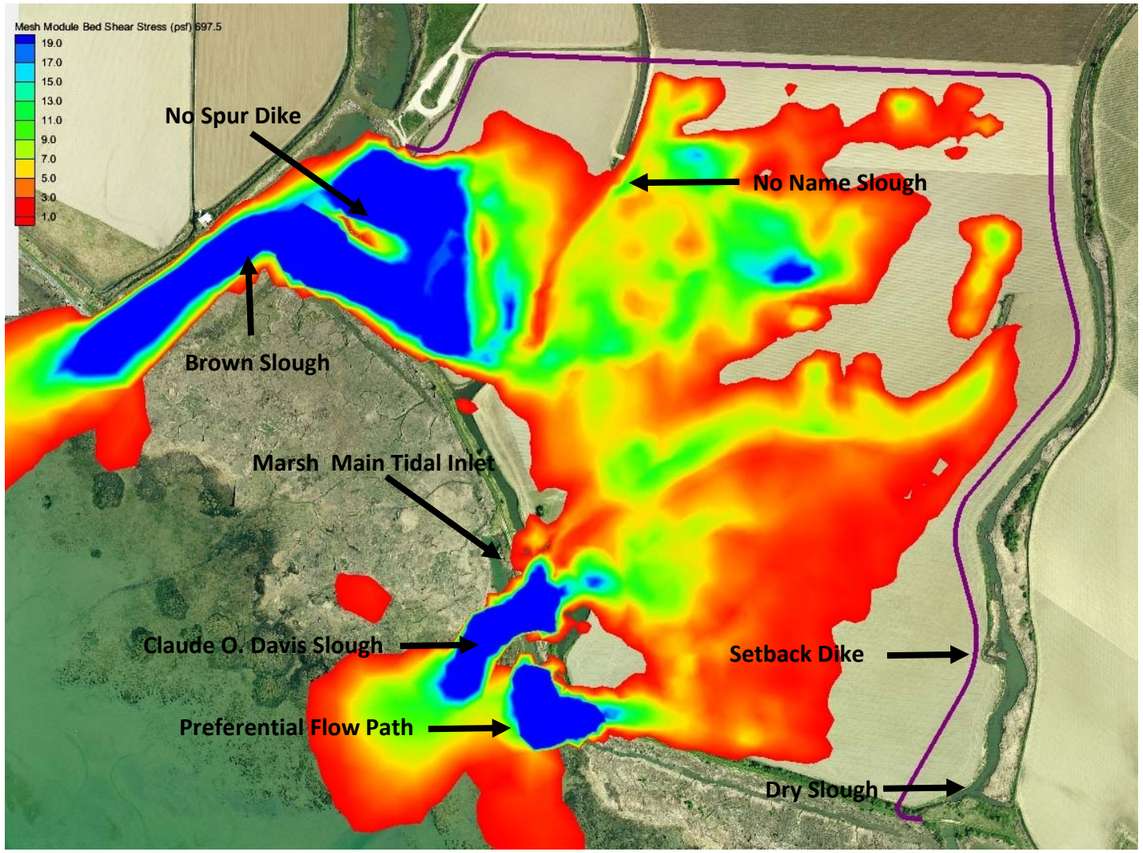
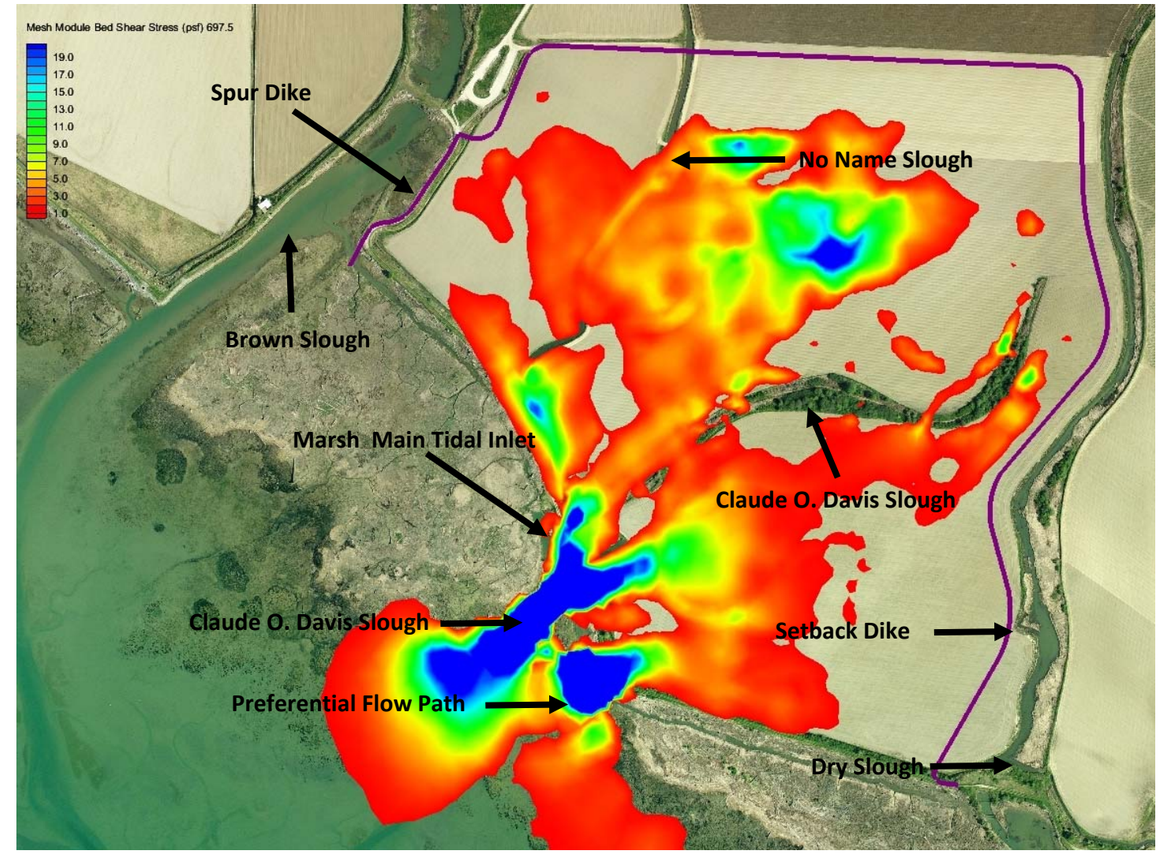
FIG. 6



PLAN VIEW - NO SPUR DIKE

Not to Scale



PLAN VIEW - WITH SPUR DIKE

Not to Scale

Legend

Bed Shear Stress (psf)

19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0

Fir Island Farm Estuary Restoration
Skagit County, Washington

HYDRODYNAMIC MODELING
FLOOD TIDE - SHEAR STRESS

November 2014 | 21-1-12318-217

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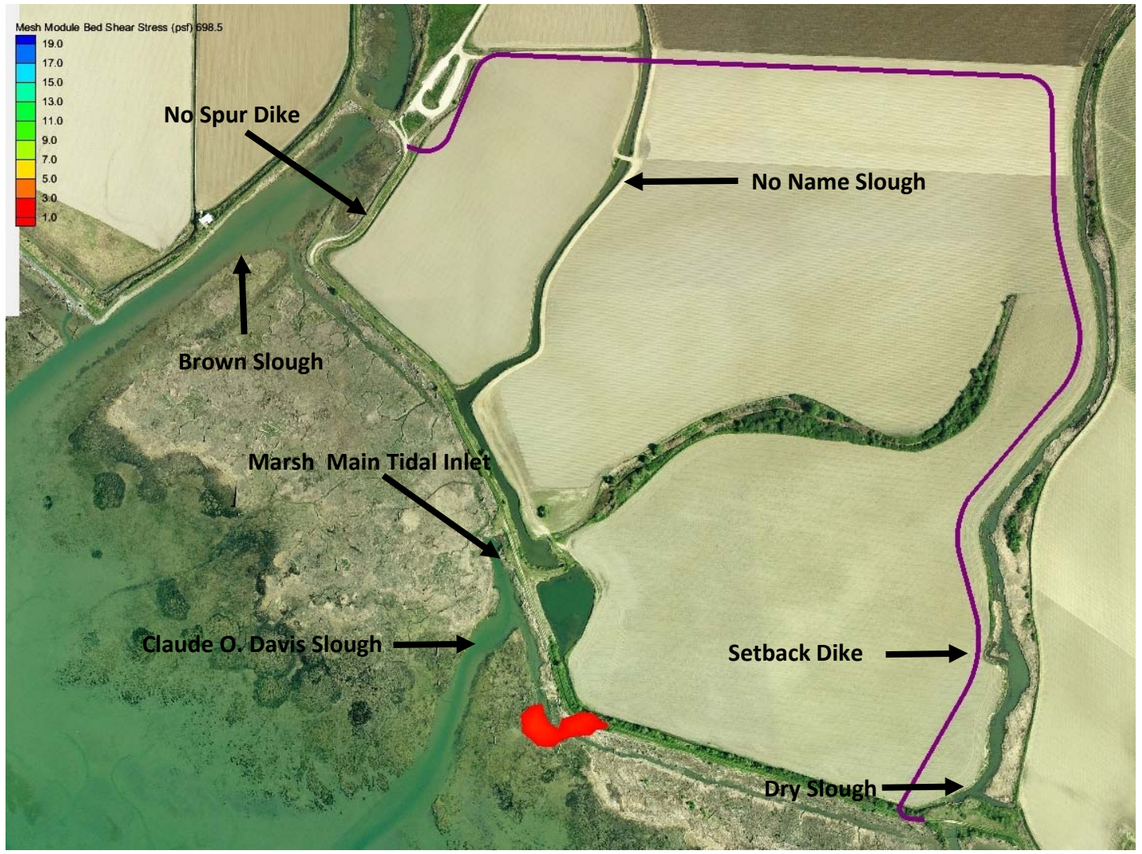
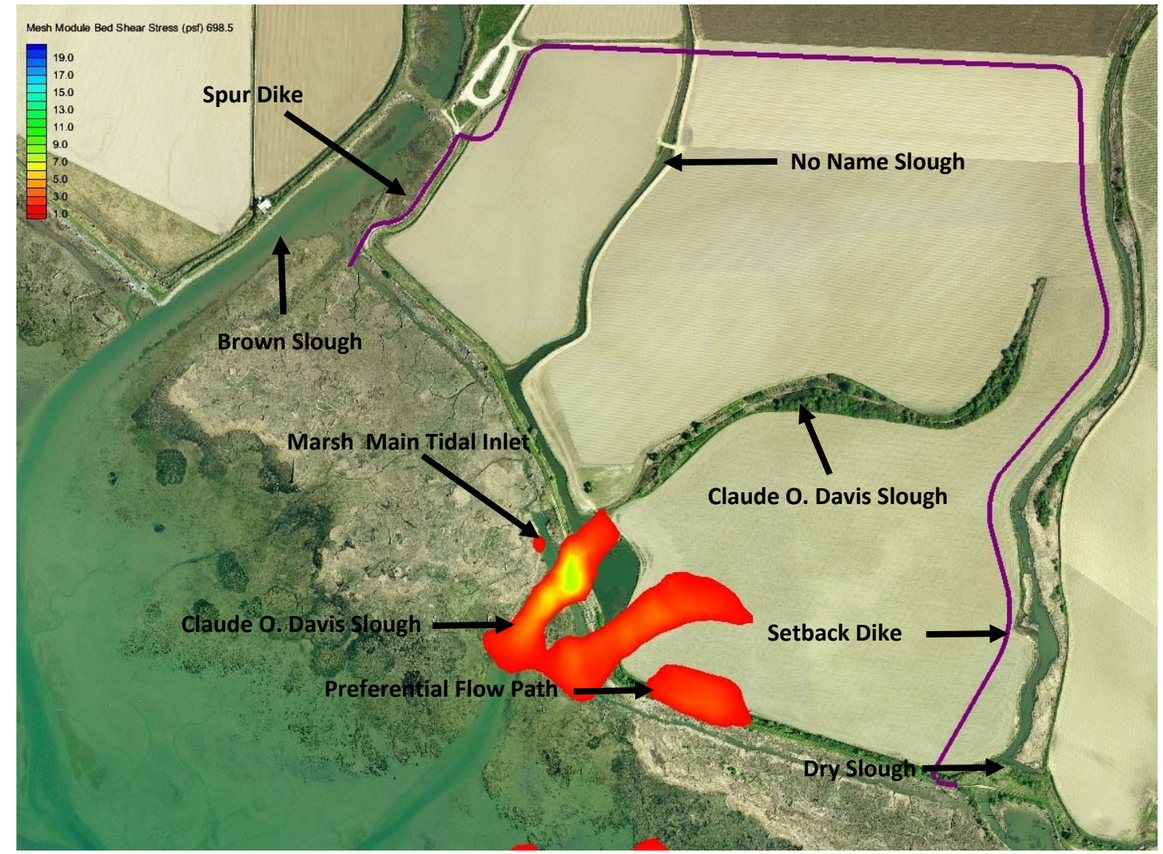
FIG. 7



PLAN VIEW - NO SPUR DIKE

Not to Scale



PLAN VIEW - WITH SPUR DIKE

Not to Scale

Legend

Bed Shear Stress (psf)

19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0

N
W E
S

Fir Island Farm Estuary Restoration
Skagit County, Washington

HYDRODYNAMIC MODELING
HIGH TIDE - SHEAR STRESS

November 2014 | 21-1-12318-217

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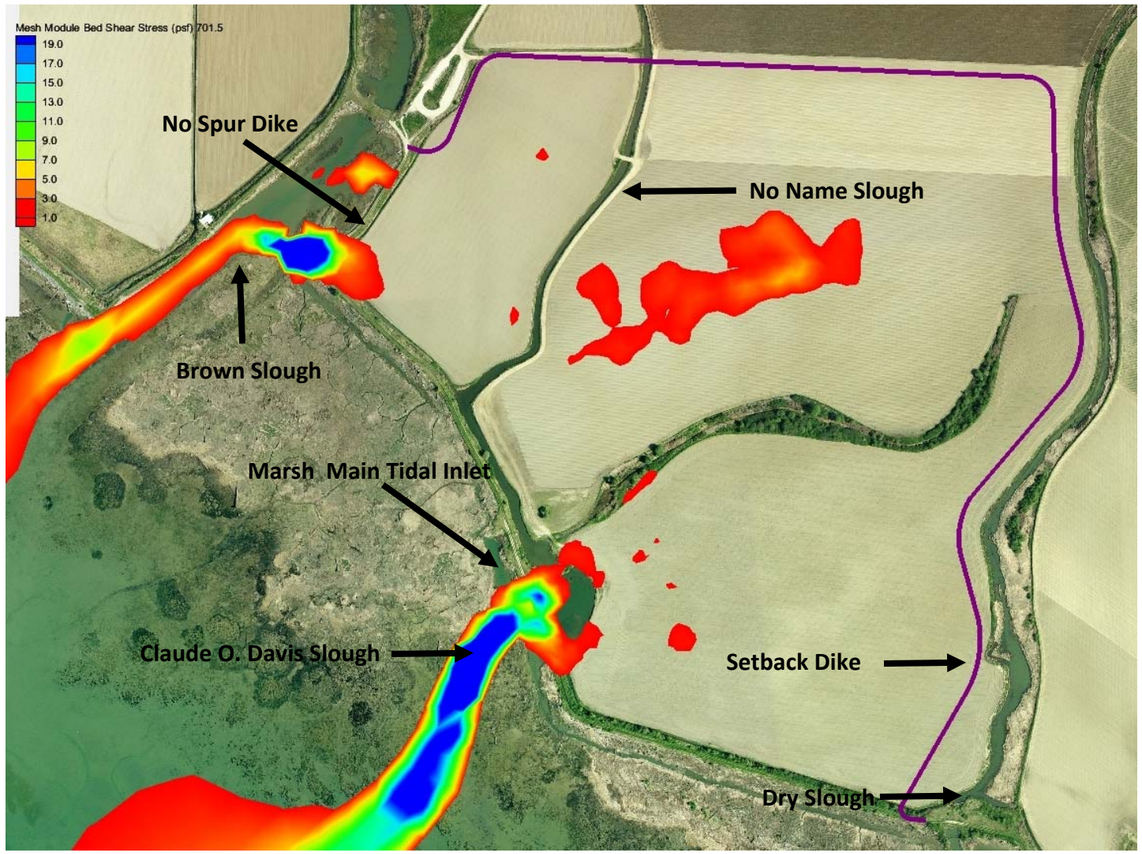
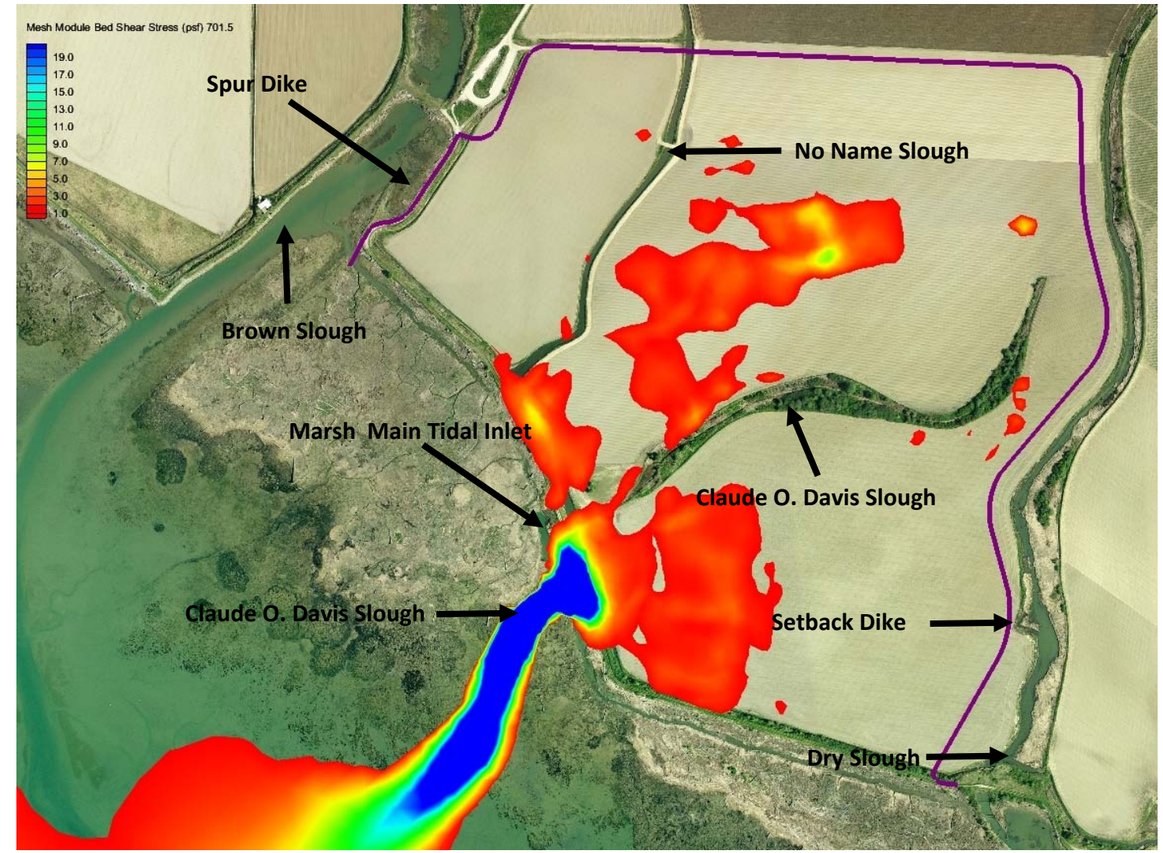
FIG. 8



PLAN VIEW - NO SPUR DIKE

Not to Scale



PLAN VIEW - WITH SPUR DIKE

Not to Scale

Legend

Bed Shear Stress (psf)

19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0

N
W E
S

Fir Island Farm Estuary Restoration
Skagit County, Washington

HYDRODYNAMIC MODELING
EBB TIDE - SHEAR STRESS

November 2014 | 21-1-12318-217

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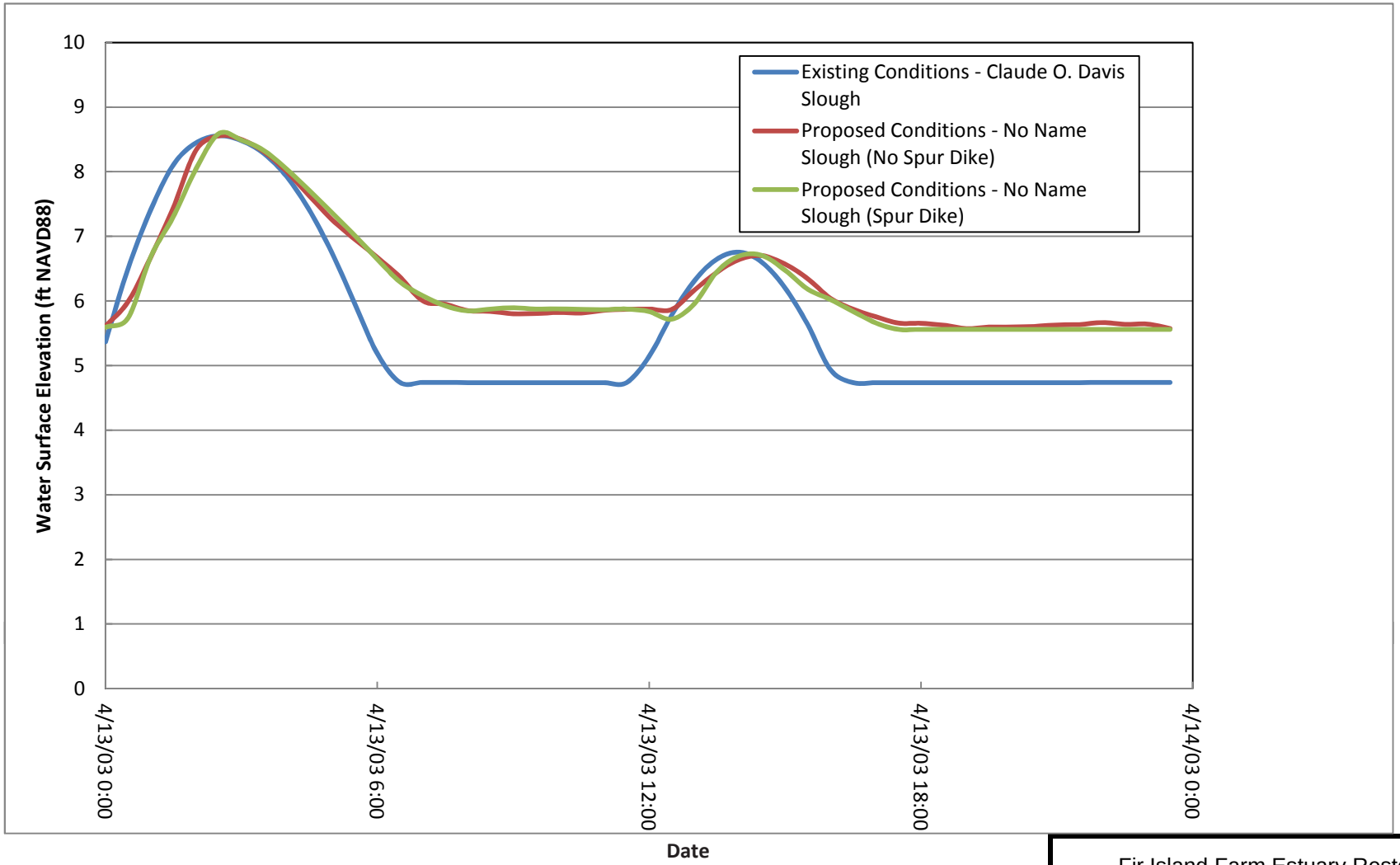
FIG. 9



Note: This figure shows the anticipated increase in low tide tailwater elevations, resulting from the project hydrodynamic effect.

Fir Island Farm Estuary Restoration
Skagit County, Washington

PROJECT HYDRODYNAMIC EFFECT

November 2014 | 21-1-12318-217

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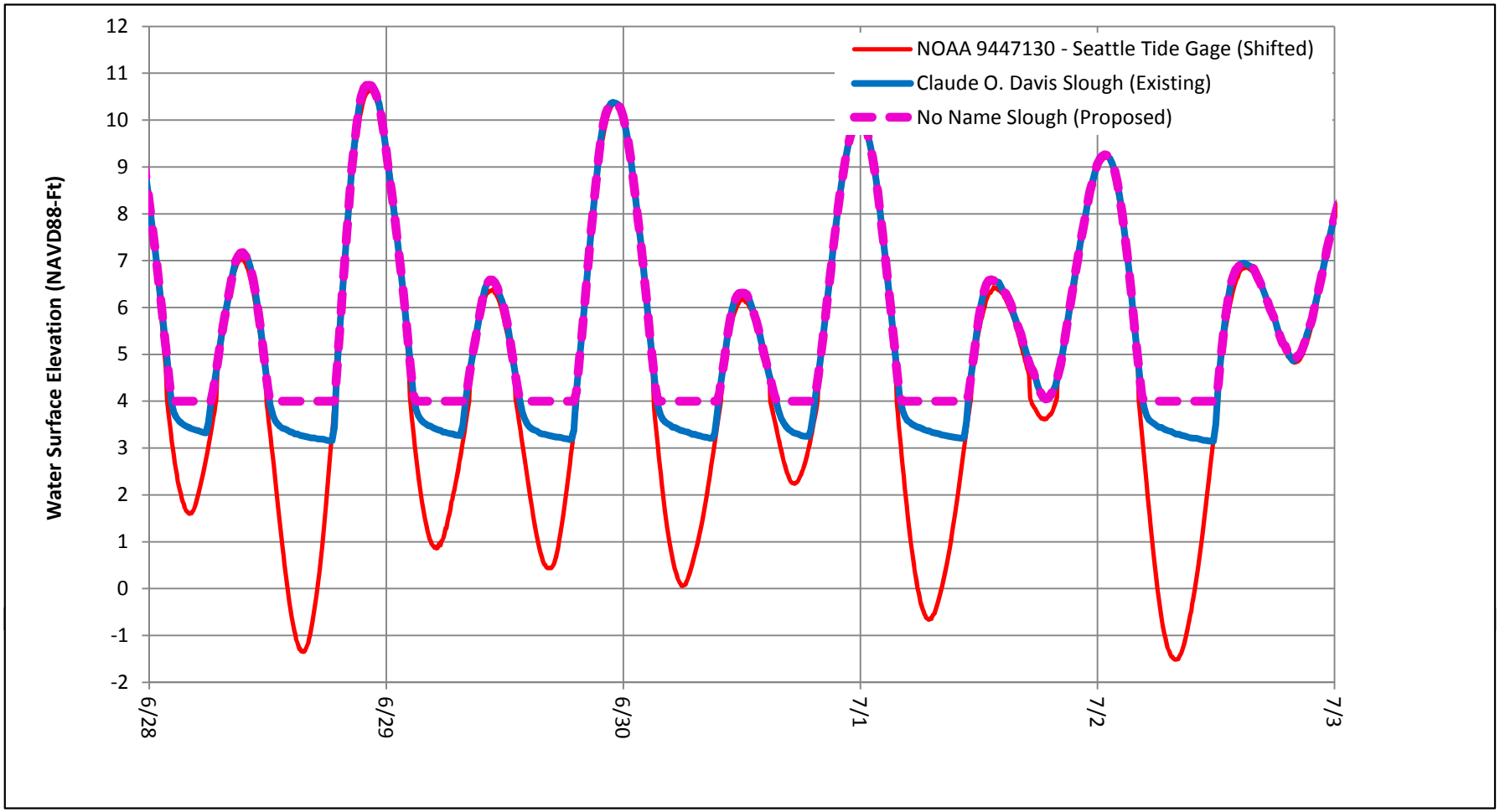
FIG. 10

FIG. 10

I:\WIP\21-1\12318 Fir Island\217_COASTAL_HYD\REPORTS\S&W\1. Native\FIGURES\21-1-12318-217 Figs 2-13.xlsx <FIG10.HYDRO_EFFECT>



Note: Seattle Elliott Bay Gage shifted and scaled to fit Fir Island Farm site data.

Fir Island Farm Estuary Restoration
Skagit County, Washington

HYDRODYNAMIC EFFECT AND WITHOUT PROJECT CONDITIONS

November 2014 | 21-1-12318-217

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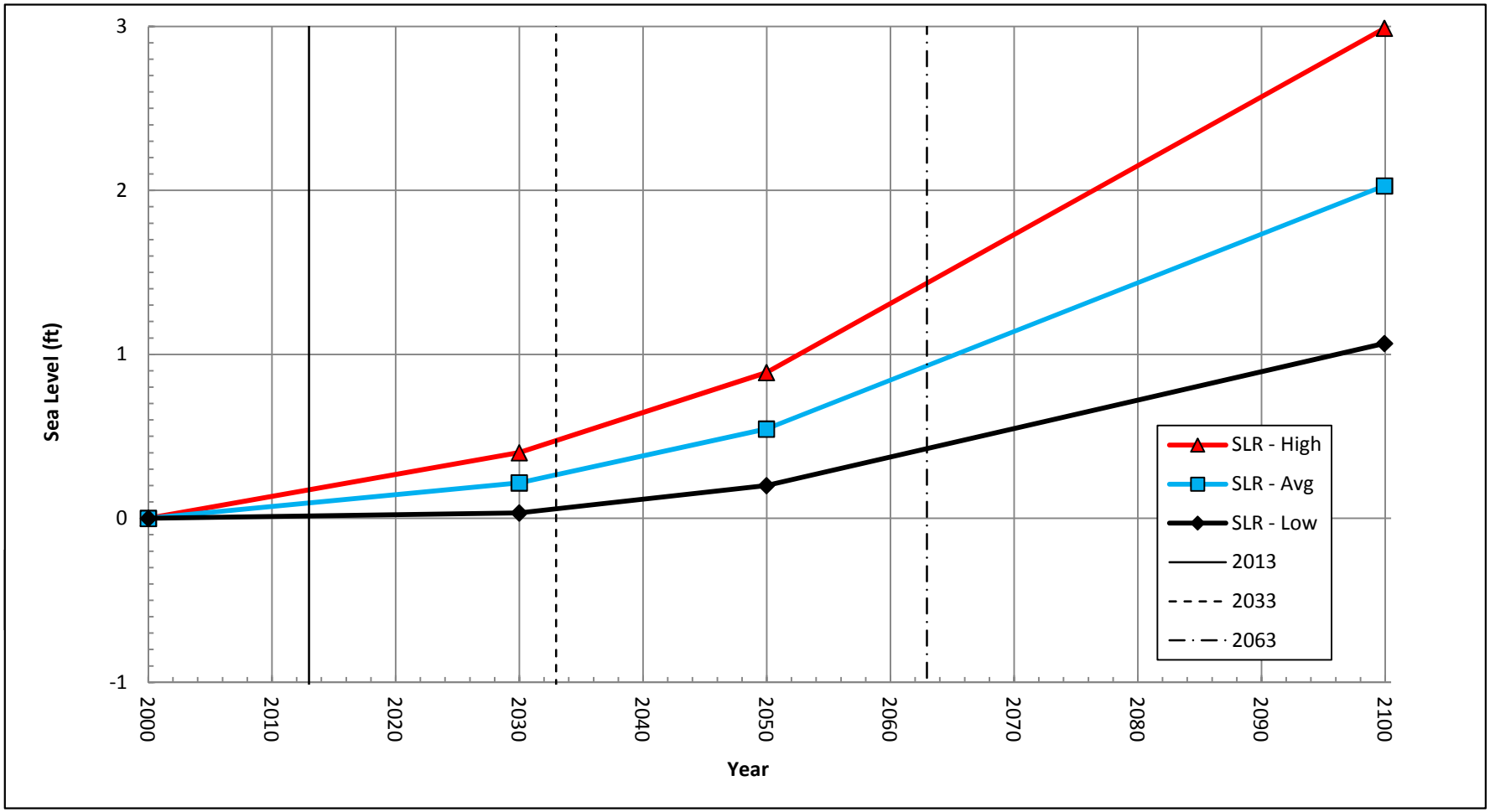
FIG. 11

FIG. 11

I:\WIP\21-1\12318 Fir Island\217_COASTAL_HYD\REPORTS\S&W\1. Native\FIGURES\21-1-12318-217 Figs 2-13.xlsx <FIG11.HYDRO_EFFECT>



Year	SLR - Low (ft)	SLR - Avg (ft)	SLR - High (ft)
2000	0.00	0.00	0.00
2030	0.03	0.22	0.40
2050	0.20	0.54	0.89
2100	1.07	2.03	2.99

Source: NAS, 2013

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

Sea Level Rise Projections
2000 to 2100

November 2014 21-1-12318-217

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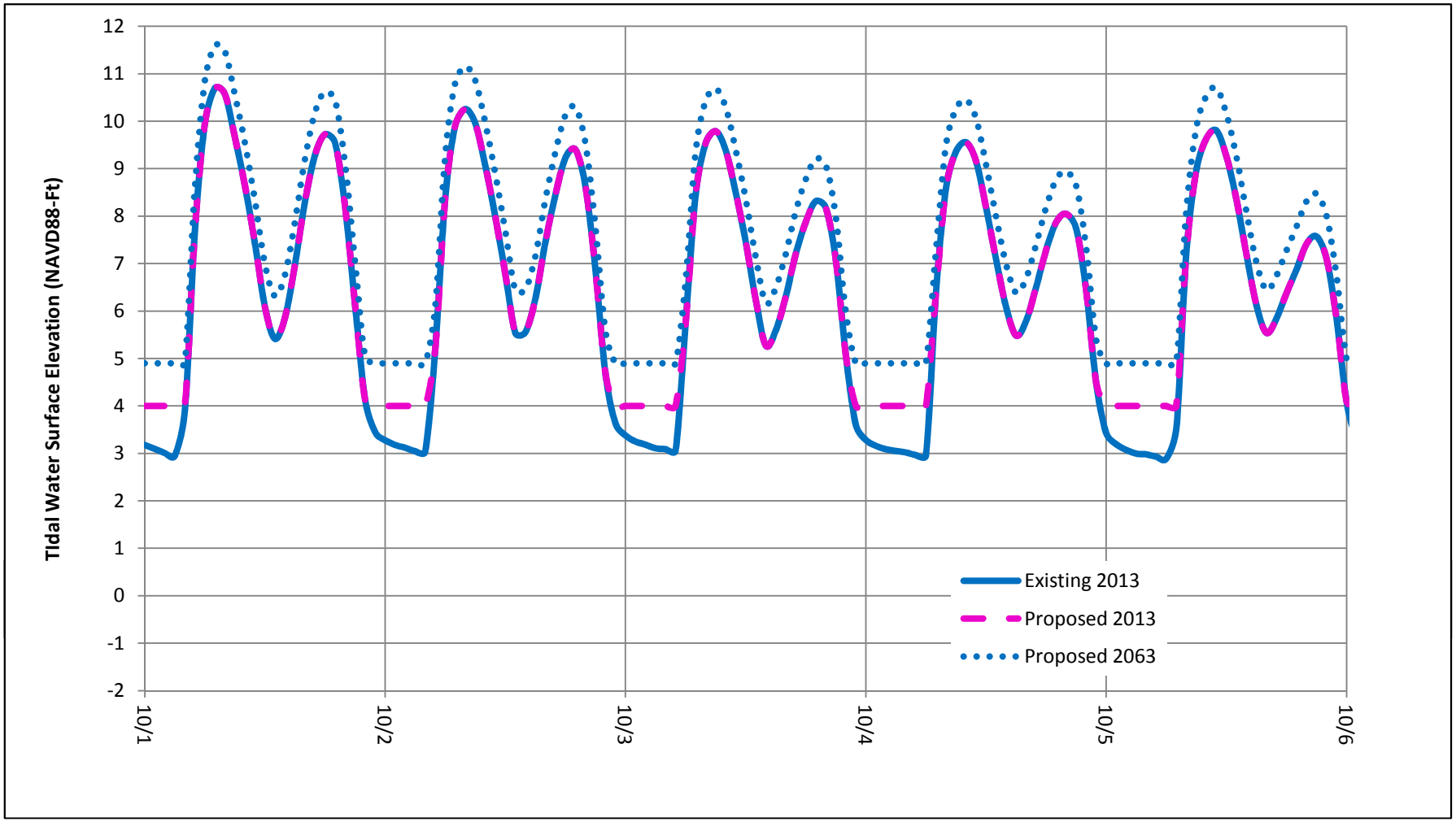
FIG. 12

FIG. 12

I:\WIP\21-1\12318 Fir Island\217_COASTAL_HYD\REPORTS\S&W\1. Native\FIGURES\21-1-12318-217 Figs 2-13.xlsx <FIG12.SLR>



Date

Fir Island Farms Restoration

Skagit County, WA

HYDRODYNAMIC AND SEA LEVEL RISE EFFECTS AND WITHOUT PROJECT CONDITIONS

November 2014 21-1-12318-217

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Fig. 13

Fig. 13

I:\WIP\21-1\12318 Fir Island\217_COASTAL_HYD\REPORTS\S&W\1. Native\FIGURES\21-1-12318-217 Figs 2-13.xlsx <FIG13.SLR+HYDRO-EFFECT>

APPENDIX A

INDEPENDENT TECHNICAL REVIEW COMMENT FORM

Independent Review Technical Comment Form

Owner	**Washington Department of Fish & Wildlife**
Project	**Fir Island Farm - Estuary Restoration Project, Final Design and Permitting**
Reviewer Name	**Susan Tonkin, PhD, PE**
Reviewer Firm	**Moffatt & Nichol**
Reviewer Email	stonkin@moffattnichol.com
Reviewer Phone	206.622.0222
Date of Review:	23-May-14

No.	Report Name	Report Section, Page, Paragraph	Reviewer	Reviewer Comment	Responder	Responder Response	ITR Backcheck Complete
1	Draft Coastal Engineering Report, April 30, 2014	Sect 4.1, p.4, paragraph 4	Susan Tonkin	Editorial: reword sentence starting "Erosion of tidal flows along preferential flow paths".	DRC	Revised sentence.	
2	same	Sect 4.1, p 4, paragraph 5	Susan Tonkin	Editorial: Suggest adding that the with-project and without-project tidal elevations at the same location in Claude O Davis Slough are very similar	DRC	Added sentence describing upstream (further interior marsh area) tailwater effects, and little effect on the outside of dike between existing and proposed conditions.	
3	same	Sect 4.1, p.5, paragraph 3	Susan Tonkin	I reviewed the model grid and observed two relatively high points in the channels - one on the Bay side in Claude O Davis Slough, and one within the project site in No Name Slough . These high points are impeding flow and increasing the tailwater elevations. The high point No Name Slough is responsible for a large part of the increased tailwater effect. This suggests the tailwater effect is overpredicted based the immediate post-construction condition. However, the sediment transport appears to be from the Bay into No Name Slough, so it is feasible that the channel will aggrade in places, impeding the upstream drainage. My conclusion is that the designer's interpretation of the tailwater effect is valid. It may not be apparent immediately, rather developing over time. Taking the increased tailwater into account allows for some sedimentation in the channel, as described in Section 4.3, to occur.	DRC	We believe there will be a releative increase in the tailwater with or without these computational shoals. There will be a hydrodynamic effect regardless because of loss of storage volume. Given that, it has been decided to dredge No Name Slough along the interior farm areas to remove high spots prior to dike removal and breaching.	
4	same	Sect. 4.3, p.12, paragraph 5	Susan Tonkin	I don't see this table - the only one to mention sedimentation is Table 4 and that provides tailwater conditions.	DRC	Table 4 is correct table for Erosion, Sedimentation, Vegetation "tailwater" effects.	
5	same	Sect. 5.1, p.12, last line	Susan Tonkin	Editorial: Check revision date on the Coastal Engineering Manual (there have been a couple of updates since 2008)	DRC	Could only find changes / revisions through 2008 on line.	
6	same	Sect. 6.0, p.22, 5th bullet	Susan Tonkin	The erosion protection thickness corresponds to only one or occasionally two stones thick.We normally use 2 layers of armor stone.	DRC	Erosion protection rock thickness is 1.5D50 and 1xD100. We feel this is acceptable as the potential for LWD transport over the high marsh areas is limited due to increased marsh elevations and decreased tidal depth near the toe of the dike.	

Date: 6/5/2014

WDFW FIR ISLAND FARM FINAL DESIGN PROJECT

COMMENT TRACKING TABLE

Study Sponsor: Washington Department of Fish & Wildlife

Study Parnters: Skagit Conservation District, Seattle City Light, Western Washington Agriculture Association

Study Consultant: Shannon & Wilson Inc., The Nature Conservancy

No.	Date	Party	Report Section, Page, Paragraph	Party Comment	Responder	Responder Response
COASTAL ENGINEERING REPORT						
1	2/7/2014	Jenny Baker		Throughout “levee” and “dike” are both used – maybe choose one for consistency?	DRC	Revised for consistency.
2	2/7/2014	Jenny Baker	Section 4.1	I found Section 4.1 difficult to follow. I think it would be helpful to refer to a specific figure or two that demonstrate particular points being made or features being referenced.	DRC	Revised section to be more clear, especially the end discussing the tailwater effects and the questionable low tide elevation predictions of the hydrodynamic model.
3	2/7/2014	Jenny Baker	Section 4.1	Other comments on section 4.1:		
4	2/7/2014	Jenny Baker	Page 4	Page 4, first paragraph - Excavation of the main tidal inlet breach would limit the potential for adverse erosion and sedimentation in the tidal channels – do you mean on the site? In Skagit bay? Or both?	DRC	Both. Added clarifier.
5	2/7/2014	Jenny Baker	Page 4	Page 4 – second paragraph –a map of preferential flow path locations would be helpful.	DRC	Added preferential flow path identifiers to Figures 2-9.
6	2/7/2014	Jenny Baker	Page 4	Page 4, third paragraph – terminology is confusing - predicted effect? = ponding? = "hydrodynamic effect"?	DRC	Revised for clarification.
7	2/7/2014	Jenny Baker	Page 4	Page 4, third paragraph – "tailwater control" - what does that mean? A feature that controls the level to which the water can drop such as a culvert or ___ is called a "tailwater control"?	DRC	Added description of "tailwater" as the downstream water surface elevation that controls the opening, closing and flow conditions through the tidegate. It is a common hydraulic engineering term for culvert systems.
8	2/7/2014	Jenny Baker	Page 4	Page 4, third paragraph – you make a comparison and refer to figure 1, but figure 1 doesn’t show a comparison – I found this confusing.	DRC	It should be Figure 10, revised.
9	2/7/2014	Jenny Baker	Page 5	Section 4.2, Page 5 - NRCS = Natural Resources Conservation Service	DRC	Not "National"…ooops.
10	2/7/2014	Jenny Baker	Page 5	Page 5, last paragraph - Incorporating additional height to accommodate the average estimates SLR over a 50-year span makes sense. Is it necessary to plan for the higher side of the uncertainty bracket as well? (The average of plus or minus 0.5 ft is 0.)	DRC	The project design uses the average SLR value at year 50 of 0.93ft. The additional 0.5ft height comment has been removed.
11	2/7/2014	Jenny Baker	Page 10	Page 10, paragraph beginning with “Shoreline sediment shoaling…” - Is the sediment supply at the site limited or not?	DRC	It is unknown if the site is sediment limited, and states that likely some sedimentation occur. The amount is unknown.
12	2/7/2014	Jenny Baker	Page 12	Page 12, first and last bullet - multiple truck trips are likely to have a big effect on the marsh plain and can cause logistical issues (trucks getting stuck) - is benefit worth the risk?	DRC	The recommended reuse are for very short hauls. This will be more apparent in the 60% design. As an example, existing dike removal and inlet dredge materials will be placed and dozed directly along the backside of the existing dike removal. The pond excavations will be moved directly south to the farm areas for marsh grade increases. The limited distance should reduce hauling problems/risks.
13	2/7/2014	Jenny Baker	Page 13	Bottom of page 13 - The wind direction will push wood debris that travels through the main tidal inlet toward the northernmost (east-west) section of the dike and into the southeast corner of the marsh. Should this be N-most and SW corner?	DRC	The prevailing winds are from two directions Northwest and South at the Whidbey gage. We note that on Skagit Bay, the predominate wind directions are from the NW and the S and SE. Therefore we anticipate wood transported through the inlet will end up in either corner.
14	2/7/2014	Jenny Baker	Page 14	Page 14 - NRCS = Natural Resources Conservation Service	DRC	Ah! Got it.
15	2/7/2014	Jenny Baker	Section 5.5.3	Section 5.5.3, first paragraph - In a previous section it said shear stresses and velocities are not enough to cause erosion along dikes, and selective fill in low areas could reduce effects further. How likely it is that a 6' wide 2' deep channel will develop along the toe of the dike?	DRC	The probability of a low flow channel developing along the dike is unknown. Another way to think about this is "how likely is the dike district to repair the dike in the future if a tidal channel were to develop?"…very unlikely. I defaulted on the conservative side to reduce future maintenance costs for a 50 year project design.
16	2/7/2014	Jenny Baker	Page 21	Page 21 – Recommendations regarding dike width and toe down depth – see previous comment	DRC	It is very likely that the dike will experience heavy wood debris impacts over its lifetime.
17	2/7/2014	Jenny Baker	Page 21	Page 21 – Recommendations regarding cut, haul and placement of materials – is it possible that some cut materials may be slop and unusable for described purpose? And that travel through marsh plain may have logistical challenges and cause damage and compaction that is difficult to repair?	DRC	See previous response. Cut/fill haul distances are very short. Almost direct cut to fill. We understand the problems with long hauls. The grading plan will reflect this approach.
18	2/7/2014	Jenny Baker	Page 22	Page 22 – misc. recommendations – regarding leaving higher ground for Hit and Miss Gun Club, was this considered in the hydrodynamic modeling? If not, would it affect the results?	DRC	This high ground section was not modeled specifically. It should not affect the results as the high ground that will remain is relatively similar in height to the existing exterior marsh (as seen by tidal flow). The remaining Hunt and Miss Gun club high ground may be impacted and eroded by wind waves. The effects on the modeling results would be minor, if noticeable at all. The modeling grid sizes are only slightly smaller than the high ground, so it would hardly show up in the model geometry.
19	2/7/2014	Jenny Baker	Figure 7	Figure 7 – high shear stress in the middle of the marsh seems odd – I’d like to know more about that.	DRC	The shear stress is water flowing with depth in the excavated pilot channels and spilling onto the marsh plain. We should see erosion, sedimentation occuring in this area.
20	2/7/2014	Jenny Baker	Figure 10	Figure 10 - "project hydrodynamic effect" didn't mean much to me at first glance. Maybe a short caption to explain what's going on would help? My understanding is that the figure shows the water level in Davis Slough under current conditions vs restoration with and without the spur dike over the course of one tidal cycle. Under either restoration scenario, water is expected to pond and not drain to as low a level as it currently does.	DRC	Caption added. I agree with your description about water not draining as low.
21	2/7/2014	Jenny Baker	Figure 11	Figure 11 - showing the Seattle tides added helpful context to the figure (as compared with the previous figure)	DRC	Agree. Did not pull 2003 tidal data to compare with hydrodynamic modeling data.
22	2/7/2014	Jenny Baker	Figure 11	Figure 11 - max water level on previous figure was approx 8'. max water level on this figure is approx, 11' - is this just due to different dates/tides?	DRC	Yes, neap tide vs. spring tide.
23	1/31/2014	B. Williams	Page 4 & 5	The discussion about existing and future tailwater effects is confusing.	DRC	Edited and provided additional explanation of why low tides will not drain as much, described this as the hydrodynamic effect, and described that tailwater is a common engineering term used to describe the flow conditions on the downstream end of a culvert or tidegate controlling opening, closing, flow rates and water elevations.
24	1/31/2014	B. Williams	Page 4 & 5	Why weren’t observed tailwater conditions in Claude O Davis used for the modeling?	DRC	The existing and proposed conditions modeling runs were selected in the Feasibility Study. WDFW and Steering committee agreed that the project would analyze Spring 2003 tides and flows for existing and proposed modeling conditions. This phase of study only added the Spur Dike and compared to model runs that had been performed in the previous feasibility study, otherwise we would have needed to rerun existing, without spur dike and spur dike (three runs vs one).

Date: 6/5/2014

WDFW FIR ISLAND FARM FINAL DESIGN PROJECT

COMMENT TRACKING TABLE

Study Sponsor: Washington Department of Fish & Wildlife

Study Parnters: Skagit Conservation District, Seattle City Light, Western Washington Agriculture Association

Study Consultant: Shannon & Wilson Inc., The Nature Conservancy

No.	Date	Party	Report Section, Page, Paragraph	Party Comment	Responder	Responder Response
25	1/31/2014	B. Williams	Page 4 & 5	If .7-1 increase is more likely a prediction of future changes, then what is the change that is expected in the immediate future?	DRC	The expected immediate change is 0.7ft to 1.0ft increase in low tide elevations. Revised term "future" to "proposed" conditions.
26	1/31/2014	B. Williams	Page 5	1. I think it is appropriate to incorporate the average predicted SLR of .93 feet for the year 2063 into the dike elevation design. However, I do not think WDFW is responsible to CDD#22 for the .5 foot uncertainty around this estimate. I do not think we need to widen the top width of the dike by 3 feet to accommodate a future dike lift of .5 feet.	DRC	Top width recommendation revised to 15.0ft. Removed recommendation for 18ft top width to accommodate additional 0.5ft of uncertainty for SLR.
27	1/31/2014	B. Williams	Page 5	Why does CDD#22 want a 15 foot wide dike top width? The Wiley Slough marine dike has a 12 foot top width. Some of the Port Susan dikes have a 12 foot wide top width. I recommend we build the top of the dike to 15 feet wide which allows a dike footprint wide enough for an additional .5 foot vertical lift while maintaining a 12 foot wide top width.	DRC	Top width recommendation revised to 15.0ft.
28	1/31/2014	B. Williams	Page 5	What does the dike cross section look like when you include all of the recommendations for armoring, i.e. bedding + 2-3 foot rip rap layer + 1 foot thick top soil? Port Susan dike has a 12 foot core top width with an additional 7.2 feet of armoring. Does the dike top width you are recommending include the 5+ feet of armor and top soil dressing?	DRC	Yes, additional width due to armoring and top soil. The 15ft is the "driveable" surface and can accommodate large equipment and haul trucks to repair dike in emergency situations.
29	1/31/2014	B. Williams	Page 8	Report states a value of 2.2 psf is used to identify likely erosion area for vegetated areas. Is this correct?	DRC	Yes, 2.2psf is average of range for vegetated surfaces 0.4psf to 4.0psf.
30	1/31/2014	B. Williams	Page 9	Page 9 – Is there a crop cover that will not be consumed by snow geese?	DRC	Dave Hughes mentioned mustard, but our natural resources people think this isn't a good idea. We should ask others as part of the planting plans.
31	1/31/2014	B. Williams	Page 12	Page 12 – Fill areas – along entire perimeter of new dike on waterward side? Using available onsite materials, is this possible in addition to establishing a range of elevations across site?	DRC	No. Fill zones are limited. More information will be provided in 60% design plans. See responses to Jenny Baker questions about fill zones.
32	1/31/2014	B. Williams	Page 15	This section states that "This report address the following hydraulic/coastal design criteria only." and Bullet 1 states that "design elevation for coastal dike based on tide heights, storm surge and wind waves." What about SLR?	DRC	Added SLR.
33	1/31/2014	B. Williams	Page 18	1. Recommends side slopes 3:1. Why are we building the dike with 3:1 side slopes? Wiley dikes were built with 2.5:1 side slopes. Do all of the dike side slopes need to be 3:1 (potential erosion areas) or are there sections where 2.5: 1 is adequate (landward side of new dike).	DRC	3H:1V was preliminary recommendation. Revised to 2.5H:1V based on geotechnical stability analysis. Factor of safety achieved with geotextile reinforcement. Without reinforcement, a 3H:1V was likely needed.
34	1/31/2014	B. Williams	Page 19	It is unclear whether none, some or all of the existing borrow ditches will be filled? The borrow ditch fill recommendation is good. Include recommendation for borrow ditch filling on Page 19 as well.	DRC	Included statement for select borrow ditch filling. I use the term "selective" as the site is limited in materials and haul distance is a concern.
35	1/31/2014	B. Williams		Dike alignment along Dry Slough maximize restored area while maintaining max 20 foot setback from Dry Slough.	DRC	20ft setback is included in 60% plans.
36	1/31/2014	B. Williams		For comparison, it would be helpful if the section of the report that discusses how the recommended dike top elevation was developed included a discussion of the dike top elevations for CDD#22's existing dikes and the new marine dike at Wiley Slough.	DRC	Added comment about existing dike elevations.
37	2/4/2014	Bob Barnard		Could the fact that the modeled Claude O. Davis main tidal channel inlet "breach" is small enough to cause acceleration account for the reduced drainage at the proposed tide gate? Was the excavated channel recommended in Sec 6 modeled to document improvements? Obviously this would change the tailwater conditions for the interior drainage.	DRC	Overexcavating the inlet channel may have some effect on lowering tailwater conditions. However, by inspection the low tide elevations will be higher, even with a larger inlet, because there is a larger tidal prism (volume of water) filling the area, and longer flow path to drain the area, with the same amount of time to drain on each tidal cycle. Therefore, it will not drain "as much" as current conditions. Additional modeling was not performed to evaluate multiple inlet sizes. The funded modeling scope of work was limited to comparing proposed without spur dike and proposed with spur dike.
38	2/4/2014	Bob Barnard		Did you estimate the volume of material excavated from the main tidal inlet and COD channel? Would this volume provide a meaningful increase in ground elevation in low stress areas (funny how that stuff just disappears when you spread it out)?	DRC	Nearly 80,000cy of excavations from the interior drainage storage pond can provide up to an additional 20 acres of high marsh graded up to three feet deep along the northeastern to northwestern sections of the new setback dike.
39	2/4/2014	Bob Barnard		I found the studies cited concerning sediment supply and dynamics on the bay front somewhat confusing and don't see the connection to your conclusion. I also wonder where you are looking when assessing drainage impacts. This image shows where the problem is at Wiley and the area that I suggest may be a problem for FIF.	DRC	Several studies infer low sediment supplies along the central bay front area, which could impact the long term restoration performance of the Fir Island Farm site. We recommend building higher marsh platforms to the extent feasible to offset these conditions. As far as the potential for adverse sedimentation impacts, such as shoaling in the Wiley Slough channel, channel sedimentation and reduced drainage function has been considered and evaluated in the sensitivity analysis. If sedimentation in these areas occurs, pumping operations may increase and more flow may be shunted to Dry Slough.
40	2/4/2014	Bob Barnard		From a cost and optimal engineering point of view, the levee erosion protection seems excessive. Please consider: Was the significant wave height of 2.7 ft was modeled at the proposed dike or in Skagit Bay? Waves are significantly diminished in enclosed, shallow embayments such as this.	DRC	Lagoons and embayments can provide some protection. The southerly wind wave setup was modeled through the inlet near the setback dike, and the wave setup was shown to be higher on the inside of the dike than the outside, indicating limited wave height attenuation due to bay front marsh effects. As the waves travel over shallower marsh surfaces, the waves become larger, much like a beach.
41	2/4/2014	Bob Barnard	Section 5.4	From a cost and optimal engineering point of view, the levee erosion protection seems excessive. Please consider: Can we clearly associate wood impact with dike failure, especially with a shallow approach like this inside an estuary? Your conclusions in the Sec 4 wood transport section are at odds with Sec 5.5.4 Wood Debris Impacts section.	DRC	My recommendation is to include buried rock protection along the dike to protect from waves and large wood debris impacts. Section 4 describes the anticipated wood transport in the marsh restoration areas. Based on the information contained in Section 4, we downsized rock protection size (based on smaller rootball sizes) listed in Section 5 due to the shallowness of the water depth over the marsh plain. If rock protection is not provided, then the design guidelines suggest flatter slopes (on the order of 5H:1V) which is a significant amount of import material, and also a high cost item. Further reduction in rock protection is related to burial depths. Burial depths are 3feet below marsh grade. For the areas receiving high marsh fill, these toe down depths are being raised 3ft, thereby reducing the volume of rock placed for protection.

Date: 6/5/2014

WDFW FIR ISLAND FARM FINAL DESIGN PROJECT

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No.	Date	Party	Report Section, Page, Paragraph	Party Comment	Responder	Responder Response
42	4/30/2014	J.Wright - NOAA	Section 4.1, page 4,	The text indicates the following: “Shallow ponding will likely exist across much of the marsh restoration area at low tide and the site will not fully drain. Moreover, the hydrodynamic modeling indicates that the marsh and tidal drainage pilot channels (including No Name Slough) will not drain to the same extent as the existing tidal drainage channels (Claude O. Davis Slough).” Does this mean that the site could provide breeding sites for mosquitos? See article on the Bandon Marsh in Oregon where a 400 ac restoration project created standing brackish water and a bad mosquito problem: http://www.cooscountywatchdog.com/1/post/2013/09/the-bandon-marsh-mosquito-farm.html The potential for creating mosquito habitat should be evaluated, and if it appears possible, the design should be altered to drain these areas, or to fill them and prevent this ponding.	DRC	Current plan includes high marsh fill zones and pilot tidal channel excavations which should maximize drainage functions at the site.
43	4/30/2014	J.Wright - NOAA	Section 4.3, page 13, 2nd paragraph, first bullet	This bullet recommends dredging the main tidal inlet channel. Such dredging should be limited near the dike so that the Agricultural Layer is not compromised and the risk of piping increased.	DRC	This section is referring to dredging at the new tidal inlet channel along the existing dike at the breach area. Currently, this section of dike has large quantities of rock placed in the 1990s for repair of the dike. Dredging this area will not have an effect on the setback dike and interior storage pond and farm seepage conditions. Other dredging along No Name Slough from the new tidegates south. The existing ditch and dredge operations both are below the farm soil unit. We have analyzed seepage and stability along the ditch, tidegates and setback dike, and have developed a dike design meeting stability and seepage factors of safety, and interior storage pond design that can withstand seepage rates with ditches and ponds excavated deeper than the farm layers and into the underlying sand unit.
44	4/30/2014	J.Wright - NOAA	Figure 1	A note on this figure says "Dredge and Expand Historic Tidal Channels". As noted in my comments on the Geotechnical Engineering Report, this channel probably should not be dredged close to the new dike as this could remove the Agricultural Layer, and open up a potential avenue for seepage through the Holocene Alluvium that could lead to piping.	DRC	See previous responses regarding dredging and excacavations in farm and underlying sand layers. Seepage modeling and design has accounted for these changes in tidal/groundwater hydrology.
45	5/14/2014	Jenny Baker	s 4.3, p. 7	bullet beginning "Bare soil areas…" includes elevations - are these in NAVD88?	DRC	Reviewed and globally inserted NAVD88 datum reference for reported project elevations.
46	5/14/2014	Jenny Baker	s. 4.3, p 11	first paragraph states that the areas around the Skagit Bay front are "calmer" - this may be misleading. Calmer in terms of less river flooding, large sediment loads, channels eroding, shifting, changing? The FIF site may experience less of these things, but wind wave action and erosion associated with that and tidal currents could make the FIF site not "calm," true?	DRC	Revised to use phrase "less dynamic" in place of calmer.
47	5/14/2014	Jenny Baker	s. 4.3, p 11-12	there is a long discussion of the Nisqually site after acknowledging that sediment supply at the nisqually site is not like sediment supply at the FIF site, but more like the sediment supply at Wiley. If true, please explain why a description of the Nisqually site sedimentation findings are included and what, if anything, they tell us about what is predicted at the FIF site.	DRC	Provided clarification on how Nisqually data was applied. We acknowledge that Nisqually site is not identical, but believe this is the best available monitoring data in the Puget Sound. We contacted Eric Gross at the USGS about Skagit Bay monitoring data, and he indicated that data would not be available for several years.
48	5/14/2014	Jenny Baker	s. 4.3, p 11-12	Are "the Nisqually project" and "the Refuge" used to refer to the same site? I think so but the different terminology is confusing.	DRC	Yes, same project. Revised references to "Refuge" so they are similar throughout document.
49	5/14/2014	Jenny Baker	s. 4.3, p 12	5th paragraph refers to Table 3 - Are you actually refering to Table 4 (not table 3)? Also, Table 4 doesn't appear to contain all that is described in this section of the report (tidal channel erosion and scour and marsh sedimentation rates). This is also the place where you compare Nisqually directly with FIF after saying on Page 11 that the two sites are very different in the amount of sediment available.	DRC	Tables 3 and 4 were out of order. Corrected.
50	5/14/2014	Jenny Baker	s. 4.4, p. 14	Wind direction: previous comment and response assoc'd with draft coastal engineering report indicated that wind direction is from the NW and SE. This report references the Batelle 2013 study as saying winds directions are from the S and NE.	DRC	Corrected statement. Predominate wind directions are from NW and S.
51	5/14/2014	Jenny Baker	s 5.4, p 18	paragraph 5 references table 4, but so you mean table 3?	DRC	Corrected Table numbers and references.
52	5/14/2014	Jenny Baker	s 5.5.3, p. 20	You recommend fill grading in the SE part of the site to limit development of preferential flow paths - this is not shown on the 60% design drawing.	DRC	Fill grading areas have been updated in the 90% Design plans.
53	5/14/2014	Jenny Baker	s 5.5.3, p. 20	last paragraph - you state here that the toe-down depth is 3 feet - elsewhere it says 3-4 feet. Suggest providing the same info in all parts of the discussion.	DRC	Reference a 3ft toe down depth throughout report and in 90% plans.

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54	5/14/2014	Jenny Baker	s. 6.0, p. 22	Erosion protection thickness - no previous discussion of how this was determined.	DRC	Provided reference of erosion blanket thickness typically 1.5 to 2.0 times the D50.
55	5/14/2014	Jenny Baker	s. 6.0, p. 22	topsoil and trees/shrubs - will trees and shrubs be appropriate/allowed on marsh fill grade? If so, how far away from dike prism does this need to be?	DRC	Sentence states... No woody shrubs or trees allowed.
56	5/14/2014	Jenny Baker	s. 6.0, p. 23	Misc. recs: last bullet - access, turnaround and passing lanes assoc'd with construction access? Or permanent public access?	DRC	Provided clarification for construction and maintenance access.
57	5/14/2014	Jenny Baker	table 4	title doesn't match info presented. Is part of the table missing?	DRC	Tables 3 and 4 were out of order. Corrected.
58	5/14/2014	Jenny Baker	general	I'm reading through the coastal engineering report and thinking about LWD. Is it possible that the entire site could fill up with LWD? Or will the change in wind directions and tidal currents circulate LWD around the site and back out? I'm not sure it's a bad thing either way (lots of LWD or just a little), I'm just wondering…	DRC	Looking at LWD along other areas along the Skagit Bay front, pockets of LWD are found. It is unlikely the entire site would fill up with wood (similar to Livingston Bay?) that TNC experienced. I would expect some fairly large wood deposits/rafts similar to those currently observed along Skagit Bay, which could be several hundred feet long and wide. This is small in comparison to the overall site dimensions.

APPENDIX B

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

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