SITKA SEDGE TIDAL WETLAND RESTORATION

90% Basis of Design Report

Prepared for
TILLAMOOK ESTUARIES PARTNERSHIP

Prepared: OCTOBER 2026

ESA



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In Partnership with Oregon Parks and Recreation Department

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1. EXECUTIVE SUMMARY

Tillamook Estuaries Partnership (TEP) and Oregon Parks and Recreation Department (OPRD) are advancing a series of improvements and modifications to the infrastructure at Sitka Sedge State Natural Area (SSSNA) to restore tidal hydrology, aquatic organism passage, and habitat conditions in the area known as Beltz Marsh while maintaining equivalent or better flood protection for the community of Tierra Del Mar (TDM). An earthen levee known as Beltz Dike was constructed in the early- and mid-1900s to separate Beltz Marsh from the adjacent Sand Lake Estuary for the purposes of flood protection and agricultural production. A single undersized concrete box culvert currently provides the only drainage outlet through Beltz Dike. A top-hinged tide gate once prevented tidal waters from entering the marsh through the box culvert, but the tide gate is no longer functional, allowing water to flow both directions through the box culvert. Erosion has occurred along the Beltz Dike, particularly at the inlet and outlet of the box culvert, threatening to undermine the drainage structure and breach the dike in an uncontrolled manner. Furthermore, the existing box culvert is undersized for hydraulic capacity and fish passage, leading to prolonged elevated water levels in the marsh following large storm events and limiting fish passage into the marsh and upstream tributaries.

In 2017-2019, OPRD contracted with consultants to perform a range of site assessments, develop preliminary restoration and infrastructure improvement alternatives, and conduct preliminary hydrologic analysis to select a preliminary preferred alternative including a dike breach to reconnect Beltz Marsh to Sand Lake, coupled with a setback dike near the south end of Beltz Marsh to maintain flood protection for the adjacent community of Tierra Del Mar and Sandlake Road. The results of this previous effort are documented in ***Sitka Sedge State Natural Area Hydrologic Analysis Final Report*** by Pacific Groundwater Group (PGG) and Environmental Science Associates (ESA), (PGG, 2019). This previous effort relied on a hydrologic budget model, referred to as the 'bucket model', to conduct the preliminary surface water modeling in support of a groundwater modeling effort aimed at understanding how potential estuary reconnection would affect groundwater and surface water levels in Tierra Del Mar. Initial dike modification alternatives preliminarily assessed exploratory reference scenarios that included a historical pre-dike or breach hydrological characterization as well as exploration of a range of modern muted tidal regulator systems, compared to the existing conditions configuration. The concept of a setback dike was proposed at the end of the 2019 hydrologic study, and ESA developed a high-level feasibility analysis of a setback dike concept based on a simple comparison of potential storage volume contained upstream of a theoretical setback dike to the estimated volume of water generated during a 100-year storm event. Upon determining that a setback dike was feasible from a stormwater storage perspective, OPRD added this alternative to the other options assessed in a series of technical review team meetings that were open to the public, and later in meetings with County Commissioners, the Oregon Parks and Recreation Commission, and OPRD leadership. OPRD leadership ultimately selected the setback dike concept as part of the preliminary preferred alternative for further design development and

modeling as described in the ***Memorandum of Decision: Selection of a Course of Action for Sitka Sedge State Natural Area Dike Improvement, March 5, 2020*** (OPRD, 2020).

In the two years following the Memorandum of Decision, OPRD partnered with Tillamook Estuaries Partnership (TEP) to seek grant funding for additional hydraulic modeling, alternatives refinement, and stakeholder coordination needed to gain confidence and consensus on the details of a full-project preferred alternative including:

- the optimum location of a potential setback dike for flood protection,
- the size, location, and number of dike breaches through Beltz Dike,
- how best to maintain recreational access to the SSSNA trail network while breaching the dike,
- potential stormwater drainage improvements in TDM,
- potential habitat improvements within Beltz Marsh including filling drainage ditches, excavating sinuous tidal channels, and adding large wood habitat structures,
- potential beaver management strategies or exclusion measures that may be needed to protect the functionality of proposed infrastructure elements, and
- geotechnical engineering considerations for the proposed setback dike, tide gate structure, pedestrian bridge, and other improvements.

In 2022, TEP contracted ESA for the Sitka Sedge Tidal Wetland (SSTW) restoration project to:

- perform additional site analysis and data collection,
- develop and analyze detailed restoration and infrastructure improvement design alternatives,
- conduct additional hydrologic analysis and detailed 2D hydrodynamic modeling,
- assist with stakeholder coordination,
- develop preliminary 30%-level design documents of the preferred alternative,
- advance the design through 60%, 90%, and Final Design iterations, and
- prepare permit applications needed to obtain the necessary local, state, and federal approvals to construct the project.

This Basis of Design Report summarizes the alternatives analysis, hydraulic analyses, and current 90% Design project stage. The proposed design elements depicted in the 90% Design include:

- Constructing an earthen setback dike embankment near the south end of Beltz Marsh located approximately 50 feet north/downstream of the existing primary beaver dam to:
  - Prevent high tide water levels from reaching Tierra Del Mar,

  - Provide sufficient storage volume upstream/south of the setback dike to contain stormwater runoff without increasing water levels in Tierra Del Mar, and
  - Maintain the existing beaver dam/lodge complex and freshwater habitat at the south end of Beltz Marsh to minimize potential beaver conflicts at the setback dike and associated tide gate structure.
- Constructing a new tide gate structure within the proposed setback dike designed hydraulic drainage capacity and fish passage featuring:
  - a 12-foot-wide concrete box culvert, concrete headwalls and wingwalls
  - an 8’ tall x 10’ wide side-hinged aluminum tide gate, with an invert elevation of 5.0’
  - a Muted Tidal Regulator (MTR) control system to operate the tide gate to stay open during the majority of tidal conditions up to an MTR Water Level setting of 8.0’
- Constructing a pair of 36” diameter backup culvert pipes with top-hinged flap gates within the setback dike, set at higher invert elevations of 9.5’ to 10’ to provide relief drainage in the event that the primary tide gate structure is blocked or during extreme storm events,
- Excavating a 140-foot-wide breach opening and channel through the existing Beltz Dike to reconnect Beltz Marsh to tidal processes in Sand Lake, located to connect historical tidal channel alignments and minimize tree removal,
- Removing the existing 4’x4’ box culvert and deteriorated tide gate and reconstructing the dike embankment and overlying trail,
- Constructing a 140-foot-span pedestrian bridge over the dike breach to maintain recreational access along the Beltz Dike Trail to the rest of the SSSNA trail network,
- Installing beaver exclusion and management system at the setback dike drainage structures including:
  - 6” x 6” mesh fencing around the inlets and outlets of the backup culverts
  - 6” x 6” mesh fencing across the upstream and downstream sides of the tide gate structure
  - A Beaver Deceiver flow device including a square filter made of 6”x6” mesh fence panels and a 24” diameter bypass pipe to pass water through the upstream receiver fence
  - Chain link fencing along the tide gate structure’s headwalls and wingwalls with gates to provide access for maintenance
- Filling linear drainage ditches and excavating new tidal channels in the marsh,
- Installing large wood structures in channels and on the marsh plain for habitat complexity and bank stability in select locations,
- Replacing the undersized culvert at Reneke Creek/Sandlake Road to improve fish passage including:
  - Raising approximately 800 feet of roadway to reduce roadway overtopping and constructing a 49-foot span vehicular bridge in place of the existing undersized culvert

  - Realigning the Reneke Creek channel to move the creek out of the roadside ditch and restore a historical channel flow path and alluvial fan/forested floodplain area.

- Revegetating disturbed areas including the setback dike, dike breach area, and Reneke Creek floodplain restoration area.

- A future phase of this project will include the Beltz Creek and No Name Creek culvert replacements at the Sandlake Road crossings

All figures are included in **Appendix A**.

90% Plans are included in **Appendix B**.

90% Preliminary Engineer's Opinion of Probable Construction Cost is included in **Appendix C**.

Additional documents produced to support the 90% Designs include:

- **Appendix D**: **Sitka *Sedge Tidal Wetland Restoration - No Rise Rationale Memo and No Rise Certification*** (ESA, 2026a)

- **Appendix E**: ***Sitka Sedge Tidal Wetland Restoration – Fish Passage and Tide Gate Design Memorandum*** (ESA, 2026b)

- **Appendix F:** Sitka ***Sedge Tidal Wetland Restoration (Bridges and Culvert) Preliminary Geotechnical Engineering Report***. Shannon & Wilson. November 2005. (S&W, 2025)

- **Appendix G:** Sitka ***Sedge Tidal Wetland Restoration (Dike Setback) Preliminary Geotechnical Engineering Report.*** Shannon & Wilson. April 2026. (S&W, 2026)

- **Appendix H:** ***Sitka Sedge Tidal Wetland – Hydraulic Analysis Memorandum.*** (ESA, 2024b)

2. INTRODUCTION AND BACKGROUND

2.1 Introduction

Tillamook Estuaries Partnership (TEP) and the Oregon Parks and Recreation Department (OPRD) are considering a series of improvements and modifications to the infrastructure at Sitka Sedge State Natural Area (SSSNA) to restore tidal hydrology, aquatic organism passage, and habitat conditions in the area known as Beltz Marsh while maintaining existing equivalent or better tidal hydrology at the community of Tierra del Mar. In 2017-2019, OPRD contracted with consultants to perform a range of site assessments, develop preliminary restoration and infrastructure improvement alternatives, and conduct preliminary hydrologic analysis to select a preliminary preferred alternative including a dike breach to reconnect Beltz Marsh to Sand Lake, coupled with a setback dike near the south end of Beltz Marsh to maintain flood protection for the adjacent community of Tierra Del Mar and Sandlake Road (PGG, 2019). At the conclusion of the 2019 study, ESA and PGG recommended additional site assessment, detailed hydrodynamic modeling, and design analysis to advance the design concepts toward implementation.

In 2022, TEP, in partnership with OPRD, contracted ESA for the Sitka Sedge Tidal Wetland Restoration Alternatives Analysis and Preliminary Design project. The current project phase utilizes 2D hydrodynamic modeling to perform a more detailed hydraulic analysis of the proposed design elements, as well as further developing the details of conceptual design elements, to refine the preferred alternative and advance the preferred alternative to a 90%-level design.

2.2 Project Background and Purpose

The Sitka Sedge Tidal Wetland project (SSTW) comprises the southern extent of Sand Lake Estuary nested within the 389-acre Sitka Sedge State Natural Area (SSSNA) and is in unincorporated Tillamook County on Oregon's North Coast. Tidal wetland access is a critical limiting factor for salmonid populations. Sand Lake Estuary is critical habitat for the federally listed Oregon Coast coho salmon. The project area supports 17 federal and/or state species of concern, nine of which are Oregon Watershed Enhancement Board (OWEB) North Coast priority species. Sand Lake Estuary habitat loss is due to diking, ditching, and draining for the purposes of agricultural production. These land modifications altered tidal wetland function and quality, resulting in significant impact to sensitive species and habitats.

In the 1930s, an earthen levee known as Beltz Dike was constructed to separate Beltz Marsh from the adjacent Sand Lake Estuary for the purposes of flood protection and agricultural production. The original tidal channels were filled in, and drainage ditches were excavated to drain the land and create pastures. A single undersized concrete box culvert provides the only drainage outlet through Beltz Dike. A top-hinged tide gate once prevented tidal waters from entering the marsh through the box culvert, but the tide gate is no longer functional, allowing water to flow both directions through the box culvert. Erosion has occurred along the setback dike, particularly at the inboard side of the box culvert, threatening to undermine the drainage structure and breach the

dike in an uncontrolled manner. Furthermore, the existing box culvert is undersized for hydraulic capacity and fish passage, leading to prolonged elevated water levels in the marsh following large storm events and limiting fish passage into the marsh and upstream tributaries.

With funding support from U.S. Fish and Wildlife Service (USFWS), OPRD purchased the property for habitat restoration, preservation, and recreational access, creating the SSSNA.

The primary goals of the project are to:

- restore tidal hydrology and estuarine habitat conditions at SSSNA,
- maintain or improve the current level of flood protection and drainage function for the adjacent community of Tierra Del Mar (TDM) and Sandlake Road,
- restore/improve fish passage from Sand Lake to Beltz Marsh and the upstream tributaries of Reneke Creek and Beltz Creek, and
- maintain recreational access to the SSSNA trail network.

In 2017-2019, OPRD contracted with consultants to perform a range of site assessments, develop preliminary restoration and infrastructure improvement alternatives, and conduct preliminary hydrologic analysis to select a preliminary preferred alternative including a dike breach to reconnect Beltz Marsh to Sand Lake, coupled with a setback dike near the south end of Beltz Marsh to maintain flood protection for the adjacent community of Tierra Del Mar and Sandlake Road. The results of this previous effort are documented in ***Sitka Sedge State Natural Area Hydrologic Analysis Final Report*** by Pacific Groundwater Group (PGG) and Environmental Science Associates (ESA), (PGG, 2019).

This previous effort relied on a hydrologic budget model, referred to as the 'bucket model', to conduct the preliminary surface water modeling in support of a groundwater modeling effort aimed at understanding how potential estuary reconnection would affect groundwater and surface water levels in Tierra Del Mar and adjacent park property. Initial dike modification alternatives preliminarily assessed exploratory reference scenarios that included a historical pre-dike or breach hydrological characterization as well as exploration of a range of modern muted tidal regulator systems, compared to the existing conditions configuration. The concept of a setback dike was proposed at the end of the 2019 hydrologic study, and ESA developed a high-level feasibility analysis of a setback dike was performed based on a coarse comparison of potential storage volume contained upstream of a theoretical setback dike to the estimated volume of water generated during a 100-year storm event. Upon determining that a setback dike may be feasible from a stormwater storage perspective, OPRD added this alternative to the other options assessed in a series of technical review team meetings that were open to the public, and later in meetings with County Commissioners, the Oregon Parks and Recreation Commission, and OPRD leadership. OPRD leadership ultimately selected the setback dike concept as part of the preliminary preferred alternative for further design development and modeling as described in the ***Memorandum of Decision: Selection of a Course of Action for Sitka Sedge State Natural Area Dike Improvement, March 5, 2020*** (OPRD, 2020).

In the two years following the Memorandum of Decision, OPRD partnered with Tillamook Estuaries Partnership (TEP) to seek grant funding for additional hydraulic modeling, alternatives refinement, and stakeholder coordination needed to gain confidence and consensus on the details of a full-project preferred alternative including:

- the optimum location of a potential setback dike for flood protection,
- the size, location, and number of dike breaches through Beltz Dike,
- how best to maintain recreational access to the SSSNA trail network while breaching the dike,
- potential stormwater drainage improvements in TDM that would reduce flooding experienced by residents,
- potential habitat improvements within Beltz Marsh including filling drainage ditches, excavating sinuous tidal channels, and adding large wood habitat structures,
- potential beaver management strategies or exclusion measures that may be needed to protect the functionality of proposed infrastructure elements, and
- geotechnical engineering considerations for the proposed setback dike, tide gate structure, pedestrian bridge, and other improvements.

2.3 Current Project Phase

In 2022, ESA was selected through a competitive proposal process to advance the Sitka Sedge Tidal Wetland Restoration project to a preliminary design level through additional site assessment, data collection, alternatives analysis, hydraulic modeling, and stakeholder coordination.

The current analysis, modeling, and design project builds on previous efforts to gain consensus for improvements at the park by developing more detailed project alternatives and conducting additional hydraulic analysis using a 2-dimensional HEC-RAS model. The 2D model was used to confirm prior conclusions regarding water level conditions that would result from restoration actions and evaluate effects in a more detailed manner than previous modeling efforts.

ESA developed and utilized the 2D HEC-RAS Model to simulate the existing site conditions and potential future conditions under a range of hydrologic scenarios and alternative site configurations including dike breaching, tidal channel creation and ditch filling, culvert replacements, setback dikes/flood protection measures, and drainage system modifications. The model results were primarily used to evaluate:

- the optimum location of a potential setback dike for flood protection *(selected a location approximately 50' north of the main beaver dam to provide sufficient storage capacity during 100-year storm and to maintain the existing beaver dam and freshwater wetland complex at the south end of the marsh)*
- the size, location, and number of dike breaches *(selected a single dike breach, 100-200' wide, located to align with historical tidal channel path, spanned by a pedestrian bridge)*

- anticipated changes in water levels and erosion conditions throughout the project areas *(demonstrated that proposed project would result in lower peak water levels at the southern end of the marsh and interface with TDM, while allowing full tidal fluctuation north of the setback dike)*, and
- the effectiveness of potential drainage system modifications along the Sandlake Road right-of-way and within TDM *(identified a series of stormwater and drainage improvements that could be made in TDM as separate future projects).*

In addition to detailed hydraulic analysis, ESA evaluated and characterized other aspects and feasibility challenges associated with the dike breach and setback dike concepts including wetland and vegetation impacts, geotechnical engineering considerations, and how anticipated beaver activity could influence the functionality and required maintenance in the future.

Following the alternatives development and analysis efforts, ESA presented the results at a Technical Advisory Committee meeting, subsequent discussions with TEP and OPRD staff, and at a public town hall meeting with residents of Tierra Del Mar and other interested parties. Based on the feedback from these meetings, OPRD confirmed their decision to proceed with a preferred alternative that includes a setback dike at the south end of Beltz Marsh north of the existing main beaver dam. The complete preferred alternative also includes a channel breach excavated through the existing Beltz Dike spanned by a pedestrian bridge to maintain access to the SSSNA trail network.

Entering the 30% Design stage, ESA subcontracted with:

- David Evans and Associates, Inc. (DEA) for roadway engineering and structural engineering of the pedestrian bridge and Reneke Creek/Sandlake Road bridge.
- PSE Consulting Engineers (PSE) for structural engineering of the tide gate structure.
- Shannon & Wilson (S&W) for geotechnical engineering to support design of the setback dike, tide gate structure, pedestrian bridge, and Sandlake Road bridges and culverts.
- Beaver Deceivers International (BDI) to assist with design of the beaver exclusion system.
- Statewide Land Surveying (SWLS) to collect additional topographic and bathymetric survey data for use in project base mapping, design, and modeling.

S&W conducted a geotechnical investigation including borings on the existing dike and along Sandlake Road. Due to permits required to access and drill within in the wetland, S&W was unable to collect subsurface borings along the setback dike alignment. Additional borings will be collected at the start of construction anticipated in June 2027, and geotechnical engineering recommendations will be reviewed and adjusted if necessary. S&W prepared two separate preliminary geotechnical engineering reports including:

- ***Sitka Sedge Tidal Wetland Restoration (Bridges and Culvert) Preliminary Geotechnical Engineering Report***. Shannon & Wilson. November 2005. (S&W, 2025)

- ***Sitka Sedge Tidal Wetland Restoration (Dike Setback) Preliminary Geotechnical Engineering Report.*** Shannon & Wilson. April 2026. (S&W, 2026)

DEA utilized the geotechnical engineering recommendations from S&W to develop designs for the foundations of the pedestrian bridge and Reneke Creek/Sandlake Road bridge. DEA also coordinated with pedestrian bridge fabricators to evaluate bridge span options and costs, and worked with ESA, TEP, and OPRD to determine the preferred bridge style and span, resulting in selection of a 140-foot-span prefabricated truss bridge. ESA and DEA also visited the site to review bridge construction logistics, staging areas, and access needs to inform the potential improvements and impacts that may be associated with constructing the pedestrian bridge on the existing Beltz Dike Trail.

PSE utilized geotechnical engineering recommendations from S&W to develop designs for the foundation of the proposed tide gate structure, based on the tide gate structure layout developed by ESA to meet hydraulic and fish passage requirements. This includes a 12-foot-span concrete box culvert with headwalls and wingwalls, with a single 8’ tall x 10’ wide side hinged tide gate with a Muted Tidal Regulator (MTR) control system to be fabricated and installed by Nehalem Marine Manufacturing (NMM).

ESA utilized geotechnical engineering recommendations from S&W to develop designs for the setback dike embankment, including sequencing of preloading the tide gate structure footprint and installing temporary and permanent culvert pipes in the setback dike.

ESA coordinated with BDI and ODFW to develop a beaver exclusion system at the proposed tide gate structure including 6”x6” mesh fencing on the upstream and downstream sides of the tide gate structure, with a Beaver Deceiver flow device consisting of a ‘square fence’ filter and a 24” bypass pipe to convey water through the upstream ‘receiver fence’.

ESA developed additional design detail across the project site including a tidal channel network and ditch filling plan within Beltz Marsh, placement of large wood habitat structures for habitat enhancement and stability in select locations, a channel and floodplain restoration plan for Reneke Creek upstream of Sandlake Road, revegetation plans, and construction access, staging, and logistics plans.

ESA developed 30%-, 60%-, and 90%-level designs of the preferred alternative including Plans, an Engineer’s Opinion of Probable Construction Cost, and this Basis of Design Report which summarizes all work from the current project phase.

3. EXISTING CONDITIONS

3.1 Site Overview and Topography

In 2014, OPRD acquired property north of Pacific City, including and adjacent to portions of Sand Lake Estuary. The property established as Sitka Sedge State Natural Area (SSSNA) consists of approximately 102 acres of marsh, including approximately 70 acres of tidal marsh, sand, and mudflats, 32 acres of freshwater marsh, and 22 acres of forested or shrub swamp. The property includes approximately 78 acres of estuary altered by the half-mile long Beltz Dike which runs east/west across the property.) Tierra Del Mar (TDM) is a residential community located immediately south of Beltz Marsh (**Figure 1**). Relative to surrounding areas, TDM is flat, with elevations of developed portions ranging from around 14 to 23 feet NAVD88. TDM is triangular in shape, narrowing to the south. It is surrounded by the Pacific Ocean and associated foredune to the west, additional vegetated dunes and Beltz Marsh to the north, and forested bedrock hills to the east. A marshy swale referred to as No Name Creek or "East Marsh" occurs between TDM and the bedrock hills to the east (PGG, 2019).

Park property contains 3 major streams: Reneke Creek, Beltz Creek, and "no-name" creek. All of these streams are tributary to the tidal marsh and Sand Lake Estuary.

SSSNA includes a parking lot and trailhead located adjacent to Sandlake Road immediately north of the Reneke Creek area. The trailhead provides recreational access to a network of hiking trails and beach access via the Beltz Dike Trail situated on top of the earthen levee that separates Beltz Marsh from Sand Lake.

Prior to diking, Beltz Marsh was formerly a shallow embayment fully connected to the Sand Lake Estuary via tidal channels and mudflats. Topographic modifications including construction of the Beltz dike, ditching in the marsh, construction of Sandlake Road, quarry activities, and development of the Tierra Del Mar community continue to affect site hydrology (PGG, 2019).

Figure 2 includes an aerial photo of the project area identifying the key site features. **Figure 3** depicts an annotated site topography map derived from OPRD DEM (various dates). Key site features include the Beltz Dike, box culvert and tide gate, remnant tidal channel and ditch network, primary beaver dam in the marsh, Sandlake Road prism, Tierra Del Mar community ditches, east marsh complex, and dunes to the west of the marsh. Areas within the marsh having elevations below 5.0 ft NAVD88 remain inundated most of the time, while areas with elevations above 8.0 ft NAVD88 are rarely inundated. The low point in Sandlake Road has an elevation of approximately 11.6 ft NAVD88. Residential areas within Tierra Del Mar (TDM) have ground elevations ranging from 14.0 to 23.0 ft, or higher. The TDM ditch and culvert network flows north and discharges into the marsh above the direct influence of the tide (PGG, 2019).

FEMA Flood Insurance Rate Maps from the Tillamook County Flood Insurance Study show the 100-year floodplain elevation in Beltz Marsh and the Sandlake Rd/East Marsh crossing of 11.8' NAVD88 (**Figure 4**). This flood elevation inundates the low point in Sandlake Rd and the low-

lying portions of two private properties within TDM. **Figure 5** provides a summary reference of elevations of key site features and water levels in the project area.

3.2 Surface Water Hydrology Characterization

3.2.1 Tides

Tides are the primary driver of surface water level fluctuations in Beltz Marsh. Tidal fluctuations in the Pacific Ocean are transmitted to the marsh via the shallow Sand Lake Estuary and communicated through the existing box culvert and tide gate. The tide gate has deteriorated over time and no longer has a functioning gate flap, but the undersized box culvert still restricts flow into the marsh and mutes the tidal signal resulting in a reduction in peak tidal water levels.

Pacific Ocean tides are influenced by both astronomical (sun & moon) and meteorological factors (storms). Storms and other large-scale atmospheric phenomenon, such as El Niño, tend to elevate the tides above predicted levels during the winter season. These same storm events are also responsible for delivering heavy rain to the area that frequently corresponds with high tide events. Measurements of ocean tides in the immediate vicinity of Sand Lake Estuary are not available. Long-term measurements at South Beach in Newport, OR, and Garibaldi, OR (within Tillamook Bay), provide representative ocean tides offshore of Sand Lake Estuary. As ocean tides enter the Sand Lake Estuary they are affected by the shallow nature of the estuary, constantly changing sand bed forms near the mouth of Sand Lake, and a complex tidal channel network, resulting in a situation where water levels in the estuary near the Beltz Marsh never fully recede to match low tides in the adjacent ocean. Daily low tides are severely muted and never fall below elevation 5.3 ft NAVD88, while ocean tides regularly fall to 0.0 ft NAVD88 or lower.

Fluctuations behind the dike in Beltz Marsh are primarily controlled by the interaction of tides in Sand Lake with the box culvert and tide gate, and secondarily by inflow from creeks and local drainages. Measurements show that under existing conditions, the missing tide gate and undersized box culvert allows a muted tidal flux to fill the marsh on rising tides. Water passes through the box culvert and water levels behind the dike rise more slowly and lag behind those in Sand Lake due to the limited flow through the structure. Tides in Sand Lake peak and begin to fall before the marsh completely fills and as water levels equilibrate on the ebb tide the flow reverses and water slowly drains back into Sand Lake until the minimum low water elevation of ~5.3 ft NAVD88 is reached. In 2017 when the tide gate was still partially intact, high tide elevations behind the dike were approximately 1.9 feet lower than Sand Lake, as shown in **Figure 6**. In 2023, since the tide gate is completely missing, high tide water levels behind the dike were measured to be approximately 1.4 feet lower than Sand Lake and approximately 0.5 feet higher than in 2017, as shown in **Figure 7**.

In the absence of significant freshwater input, low tides behind the dike tend to be similar to those in Sand Lake but are slightly elevated (by a few inches) and of longer duration as the marsh slowly drains. Freshwater inputs from creeks and local drainages that arrive on a rising tide accumulate within the marsh and contribute to elevated water levels behind the dike. Following

heavy rainfall events, it can take multiple tidal cycles for accumulated freshwater to be discharged through the existing box culvert. The leaky/missing tide gate is no longer functional, though the size of the box culvert itself limits flux through the dike and thereby causes lower water levels than in Sand Lake at high tide, and higher water levels than in Sand Lake at low tide and following intense rainfall events.

Existing tidal fluctuations in the south end of the marsh are further impeded by the existing beaver dam that impounds water in the ditches and wetlands near Sandlake Road. Water levels remain relatively constant in time at about elevation 8.0 ft NAVD88 during the wet season and drop down to elevation 7.0 ft during summer low flow period. The beaver dam is approximately 3.0 ft high, based on observations by ESA staff in February 2018. **Figure 8** depicts typical water level fluctuations in the project vicinity during the summer (no rainfall), and **Figure 9** depicts typical water level conditions in the winter during and after a storm event (PGG, 2019).

3.2.2 Freshwater Inputs

Frequent and intense rainfall is common along the Oregon coast, and in the vicinity of the project site. Mean annual rainfall is about 80 inches per year, with a 2-year peak 24-hour rainfall intensity of about 3 inches (USGS, 2018). Other rainfall records are available at Tillamook and Cloverdale, OR. Periods of intense rainfall correspond to both elevated water levels in Beltz Marsh, and photographs of neighborhood rainwater ponding provided by the TDM community from 2016-2017 (pers. com). Given the size of Beltz Marsh, direct rainfall in the marsh may contribute meaningful surface water inflow during high-intensity storm events.

Beltz Creek (0.5 square mile drainage) and Reneke Creek (0.9 square mile drainage) are the primary freshwater sources that discharge into Beltz Marsh under existing conditions. Neither of the creeks has been gaged and few streamflow measurements are available to describe the response of the creek drainages to rainfall events. Therefore, the current understanding of creek hydrology relies on limited observations, comparisons with nearby gaged steams (Tucca Creek), and scaling to approximate discharge from Beltz and Reneke Creeks (PGG, 2019).

Reneke Creek flows west toward Sandlake Road, where it encounters a blocked culvert and then diverts southwest along Sandlake Road. The creek then flows into a partially blocked 38-ft long, 2-ft diameter, culvert that passes beneath Sandlake Road into Beltz Marsh. The culvert invert elevations are low enough to be subject to tidal fluctuations in the marsh during extreme high tides and ESA observed what appeared to be salmonid fish in the pool immediately downstream of the culvert. Upon entering the riparian area west of Sandlake Road, the creek channel meanders through wetlands and then bifurcates into multiple smaller braided channels that separately discharge into the marsh. Signs of erosion and road overtopping indicate that the existing culvert is undersized and does not pass all creek flows beneath the road. Historic photos and ground observations indicate that Reneke Creek was formerly artificially routed through the blocked culvert and then to the north along what is currently a dry swale (PGG, 2019) that historically diverted Reneke Creek flows around the existing dike.

Beltz Creek arrives at Sandlake Road at a higher elevation than Reneke Creek and passes beneath Sandlake Road through an angled 80-ft long, approximately 3-ft diameter, culvert. The

downstream end of the culvert is perched about 2.5 ft above the adjacent creek channel and well above the influence of the tide. The creek channel then flows through a former rock quarry and splits into at least two smaller channels before entering the marsh and ditch network.

The primary drainage ditch from TDM (identified as the East Ditch or Sandlake Road Ditch) flows north through a series of small culverts that parallel Sandlake Road. The final culvert beneath Roma Ave. consists of a 40-foot long 12-inch diameter corrugated smooth interior wall HDPE pipe with an outlet invert elevation of 11.8 ft NAVD88. The ditch continues north and connects with other ditch networks upstream of the existing beaver dam within the marsh. Flows through the ditch along Sandlake Road are limited by the capacity of the culverts and condition of the ditch. A secondary artificial drainage swale within TDM (identified as the North Ditch in **Figure 3**) runs parallel to the dune line and flows northeast through TDM, including beneath roads and structures, before turning in an east-northeast direction north of Roma Ave.

Surface water ponding is a common problem in TDM as evidenced by photographs provided by property owners to OPRD. ESA reviewed these photos and LiDAR topography and found that much of this ponding can be attributed in part to topographic depressions that lack positive drainage. Most side streets have no serviceable roadside drainage ditches or drain structures. Such ponding is likely exacerbated when the soil becomes saturated with groundwater following heavy rains. Figure 10 illustrates ESA's conceptual understanding of frequently ponded areas based on a review of topographic depressions that correlate well with site photographs following intense rainfall events. Ponding depths may vary from a few inches to more than one foot, depending on local topographic conditions (PGG, 2019). During the current project phase, TDM's drainage system was analyzed in more detail to identify specific deficiencies and potential improvements, as described in Section 5.2.

Finally, drainage from the East Marsh located on the east side of Sandlake Road and across from TDM, flows into the south end of Beltz Marsh via a 2-ft diameter culvert beneath Sandlake Road. The East Marsh watershed is approximately 202 acres or 0.32 square miles. Limited measurements in this marsh by OPRD in 2018 indicate that water levels in the immediate vicinity of Sandlake Road are controlled by the backwater created by the beaver dam in Beltz Marsh. Ground levels and surface water levels in the East Marsh continue to rise to the south, likely impounded by relic beaver dams and/or emergent vegetation. Observations by ORPD in spring of 2018 indicated water ponded approximately 1 ft above the ground surface throughout this marsh, with deeper water closer to the Sandlake Road culvert (PGG, 2019).

Groundwater discharge and upwelling are likely to also contribute surface water inputs to the marsh, particularly during the wet season. However, PGG indicated that groundwater discharge flows are likely quite small compared to peak runoff flows during extreme storm events (PGG, 2019).

3.2.3 Hydrologic Characterization Summary

- The Beltz dike tide gate no longer functions properly and allows water to flow into the marsh when water levels are higher in Sand Lake. Still, water levels at high tide are lower

on the inside of the dike under existing conditions (except under extreme stormwater flows) due to limited flux allowed in and out of the existing box culvert.

- The existing box culvert/tide gate is undersized to efficiently drain accumulated freshwater within the marsh following intense rainfall events and thus it currently takes multiple low tide cycles for water levels in Beltz Marsh to drain out and equilibrate with Sand Lake.

- The existing beaver dam at the south end of Beltz Marsh impounds water and creates a backwater area that causes water to pond along both sides of Sandlake Road and within the East Marsh.

- Reneke Creek's northern culvert is completely blocked by gravel, and the southern culvert is undersized for passing peak stream flows. This constriction moderates Reneke Creek flows through the culvert at moderate flows and causes overtopping of the roadway during peak streamflow events.

- The Beltz Creek culvert is perched above the downstream channel and is well above the influence of the tide.

- The upland drainage network in TDM has limited capability to drain TDM following intense rainfall events due to a combination of local topographic depressions with a lack of positive drainage, absence of a drainage network along residential roads, and limited capacity of the culverts along Sandlake Road to transmit flows.

- The East Marsh is affected by the backwater of the beaver dam in Beltz Marsh and is subject to tidal fluctuations during extreme high tides and storm events. Ponded water has been observed in the East Marsh well above the influence of the backwater from Beltz Marsh.

- **Figure 11** shows and describes the major hydraulic control features affecting surface water movement into, out of, and within Beltz Marsh, including the Beltz Dike, culvert and tide gate, and the main beaver dam in the marsh's interior.

- **Figure 5** summarizes elevations of key site features and water levels

- Groundwater hydrology characterization and alternatives modeling are covered in detail in the ***Sitka Sedge State Natural Area Hydrologic Analysis Final Report*** (PGG, 2019) Groundwater modeling of a dike breach scenario without a setback dike predicted insignificant changes in shallow groundwater elevations beneath TDM during average conditions and slightly reduced groundwater elevations during large storm events.

4. HYDROLOGIC AND HYDRAULIC ANALYSIS

To evaluate the site's existing condition and inform and evaluate alternative design concepts, ESA developed and utilized a two-dimensional (2D) HEC-RAS hydraulic model. 2D hydraulic models use a depth-averaged approach to represent flow patterns in the horizontal plane, producing maps of depth and velocity across the simulated landscape. HEC-RAS 2D was used for this project to represent the complex, multi-directional flows within Sand Lake, Beltz Marsh, flood-prone areas, and local infrastructure.

A series of hydrologic scenarios were developed for the site to calibrate the model and analyze design alternatives. Flooding is a concern for TDM and as such, project performance under flood conditions was a priority to analyze. Streamflow inputs for the TDM drainage areas were developed utilizing the Santa Barbara Urban Hydrograph Method. Streamflow inputs for creek watersheds were developed utilizing USGS StreamStats, verified by a watershed scaling of the nearest gaged stream comparable to the project creek. The 2D hydraulic model requires topography, hydrology, and roughness as inputs for the model, which are represented within the model mesh. Alternative design concepts were assessed with model depth, water level, and velocity outputs. Hydraulic model development is discussed in detail in the Sitka Sedge Tidal Wetland – Hydraulic Analysis Memorandum, included in this report as Appendix H. Model results and hydraulic analysis for the Alternatives Analysis and 90% Design are included in Section 5.

4.1 Hydrologic Inputs for 2D Model

There are five hydrologic inputs into the Sitka Sedge marsh:

1. Reneke Creek Watershed
2. Beltz Creek Watershed
3. East Marsh Watershed
4. Tierra Del Mar stormwater subbasin 1 (Sandlake Rd Ditch Subbasin)
5. Tierra Del Mar stormwater subbasin 2 (TDM Northwest Ditch Subbasin)

Reneke Creek, Beltz Creek, and East Marsh watersheds do not have flow gages. A nearby gaged watershed, Tucca Creek watershed, was used to develop inflow hydrographs for these sources. The hydrographs for each watershed were scaled from the Tucca Creek hydrograph using watershed drainage area. (USGS, 2023)

Tierra Del Mar is a residential community south of the marsh. Its landcover is developed and consists mainly of single-family homes, commercial businesses, and roads. A total inflow

hydrograph from this area was developed based on direct rainfall and a total surface area of 190,000 square meters. Rainfall data was filtered with backward-facing 2-day average to simulate the delay between instantaneous and eventual rainfall. The drainage area was then delineated into two subbasins, each draining into the marsh through a small culvert. An inflow hydrograph was scaled from the total hydrograph for each subbasin based on subbasin area. Inflow hydrographs for the February 2017 winter storm used in calibration are shown in **Figure 12**.

Two large statistical storm events were also developed as hydrologic scenarios: the 100-year and 50-year events. The 100-year and 50-year inflow hydrographs for Reneke, Beltz, and East Marsh watersheds were scaled from 100-year and 50-year hydrographs of Tucca Creek. The 100-year and 50-year hydrographs of Tucca Creek were developed by using a flood frequency analysis to find peak flows, following the procedures of Bulletin 17B. (Interagency Advisory Committee on Water Data 1982) The February 2017 Tucca Creek hydrograph was scaled to peak at the 100-year and 50-year peak flows, and the Reneke, Beltz, and East Marsh watershed hydrographs were scaled from that based on drainage area.

The 100-year and 50-year inflow hydrographs for the Tierra Del Mar subbasins were developed using the Santa Barbara Urban Hydrograph method and splicing in its 24-hour hydrograph into the February 2017 hydrograph. This method creates runoff hydrographs based on a 24-hour total rainfall amount, drainage area, and curve number (CN values). Rainfall data (inches per 24 hours storm) from the NOAA Atlas 2 Isopluvials were used in applying this method. The precipitation for the 100-year and 50-year storms at the project site were 6.75 and 6.25 inches, respectively. Inflow hydrographs for the 100-year and 50-year events are shown in **Figures 13 and 14**, respectively.

NOAA Atlas 2 Isopluvials showed precipitation for the 100-year and 50-year storms at the Tucca Creek gage were approximately 10 and 9 inches, respectively. The Isopluvials indicate higher rainfall amounts in the Tucca Creek watershed than in the No Name Creek watershed. 10 inches and 9 inches of rainfall in 24 hours in the No Name Creek watershed area approximately correspond to 1000-year and 500-year 24-hour rainfall amounts, respectively (ODOT, 2008). This indicates that the watershed scaling method from Tucca Creek is conservative, providing an overestimation of risk in the interest of safety and building extra capacity into the setback dike system design. The conservative approach to hydrologic flow development for Reneke, Beltz, and East Marsh Watersheds was maintained to ensure a robust engineering design, avoid underestimating stream flows, and result in extra capacity in the system.

4.2 2D Hydraulic Model Development

4.2.1 Topography and Model Terrain Development

Topography for the hydraulic model was generated from the following sources in order of priority:

1. Statewide Land Surveying Topographic Survey, January 27, 2023. This surface was developed following a survey conducted on January 27, 2023, to support the project. It

includes small areas around culvert structures. This survey also surveyed the culvert materials, shapes, and invert elevations. (SWLS, 2023)

2. "PhoDAR" photogrammetric/LiDAR hybrid elevation model. This DEM is a combination of a photogrammetrically derived elevation model and LiDAR (Light Detection and Ranging) data with manual adjustments. The aerial photography used in the photogrammetrically derived model was taken on September 18, 2015. The LiDAR is dated to 2009. Manual adjustments were made in some areas of dense vegetation. However, the PhoDAR includes some artificially elevated artifacts outside of the vegetation zone adjustments. (OPRD, 2017).

Additional terrain edits were performed in HEC-RAS to enforce low ground in channels as well as high ground elevations along roadways, the Beltz Dike, and alternative setback dikes where vegetation and other obstructions caused artifacts of apparent higher elevation in the bare ground model.

4.2.2 Model Boundary Conditions

HEC-RAS requires flow as input at the upstream model boundaries and river stage at the downstream boundary. Streamflow estimates were developed as detailed in section 3.1. The downstream boundary of the model is located in Sand Lake approximately 2,000 feet downstream of Beltz Dike. This downstream boundary condition is tidal. The tides data used was water level data measured outside of the Beltz Dike February 1-13, 2017. This data is appropriate for use for all three hydrologic scenarios (Calibration, 100-year, and 50-year) because of the high tides (11.9 ft NAVD and 11.3 ft NAVD) included in the dataset that are concurrent with the hydrograph peak. Tidal water level data used is shown in **Figure 15**.

HEC-RAS includes Gate functions (opening and closing of gate structures) in model boundary conditions. Tide gates were coded using the HEC-RAS Rules feature to close when the simulated outboard water levels exceed inboard water levels and to open otherwise.

4.2.3 Model Layout

The full model extent, along with hydrologic inflow and boundary conditions locations, are shown in **Figure 16**. For 2D hydraulic models, the model domain is divided into a mesh composed of cells. In HEC-RAS, the water surface elevation is calculated at each model cell, and velocity is calculated at the faces between cells. As such, cell size and cell face orientation are important to consider to accurately represent flow patterns within channels and the floodplain. Break lines were added to the mesh to ensure that roads, berms, Beltz Dike, channels, and swales were properly captured within the model mesh. Additionally, the mesh resolution was assigned to 20 ft inside the Beltz Dike to appropriately capture flows within channels and across the floodplain. Existing culvert structures within the model domain were included using culvert materials, shapes, and invert elevations as surveyed by Statewide Land Surveying, Inc. (SWLS, 2023)

4.2.4 Roughness

HEC-RAS requires an estimation of the roughness of the landscape as characterized by the parameter Manning's *n*. For the 2D hydraulic model, the National Land Cover Database (NLCD) 2019 Land Cover was used (**Table 1**). (MRLC, 2021) Manning's n for culvert structures ranged from 0.01 to 0.035.

TABLE 1. ROUGHNESS CATEGORIES AND FINAL MANNING'S *N* VALUES

Type	Manning's *n*
Open Water	0.035
Barren Land Rock-Sand-Clay	0.03
Evergreen Forest	0.15
Developed, Open Space	0.035
Woody Wetlands	0.07
Developed, Low Intensity	0.08
Grassland-Herbaceous	0.04
Developed, Medium Intensity	0.12
Shrub-Scrub	0.05
Mixed Forest	0.12
Deciduous Forest	0.1
Emergent Herbaceous Wetlands	0.045
Developed, High Intensity	0.15
Pasture-Hay	0.045

4.2.5 Model Calibration

Model calibration requires on-site data to be compared against modeled outputs. Water levels are not regularly monitored in Sitka Sedge State Natural Area. Therefore, water level loggers were installed to record site data inside and outside of the Beltz Dike at the existing culvert. Water level was recorded from November 2016 to June 2017 and again from January 2023 to March 2023. During these periods, a representative winter storm that caused flooding occurred between February 1-13, 2017. This storm event was used to calibrate the existing conditions 2D model.

4.2.6 Model Sensitivity

A sensitivity analysis was conducted to evaluate the impact of including precipitation-based inflows directly on the marsh behind the setback dike and downstream of the Tierra Del Mar inflows. This was done on the 90% Design model under the 100-year event. Resulting water levels behind the setback dike only resulted in an increased peak 100-year water level of 0.04 feet and maintained a peak water level below 11 ft NAVD. Therefore, a precipitation-based inflow directly on the marsh in this area was not included in the 90% design hydraulic analysis. Sensitivity analysis resulting water levels are shown in **Figure 17**.

Model results and hydraulic analysis for the Alternatives Analysis and 90% Design are included in Section 5.

5. ALTERNATIVES ANALYSIS AND REFINEMENT OF DESIGN ELEMENTS

5.1 Alternatives Development

ESA developed a series of design alternatives for restoring tidal connectivity and fish passage between Sand Lake and Beltz Marsh, while maintaining or improving drainage and flood protection for Tierra Del Mar and Sandlake Road and maintaining recreational access to the trail network at SSSNA.

Development of alternatives and design variations focused on the following key project elements:

Setback Dike -

- the optimum location of a setback dike for flood protection and storm drainage function,
- minimizing wetland impacts associated with a setback dike
- potential stormwater drainage improvements in TDM that would reduce flooding experienced by residents or improve the functionality of a setback dike
- potential beaver management strategies or exclusion measures that may be needed to protect the functionality of proposed infrastructure elements, and
- geotechnical engineering considerations for the proposed setback dike, tide gate structure, pedestrian bridge, and other improvements.

Dike Breach and Maintaining Recreational Trail Access -

- the size, location, and number of dike breaches through Beltz Dike,
- how best to maintain recreational access to the SSSNA trail network while breaching the dike,

Interior Marsh Habitat Enhancements –

- potential habitat improvements within Beltz Marsh including filling drainage ditches, excavating sinuous tidal channels, and adding large wood habitat structures,

5.2 TDM Stormwater Drainage System Assessment

5.2.1 TDM Stormwater Drainage System Assessment

In order to understand how the SSTW project will affect the function of TDM's stormwater drainage system, specifically how a setback dike in a given location would perform, or how high tide levels could affect TDM's drainage, it is important to characterize the stormwater drainage network and facilities within TDM and the East Marsh watershed. Most of the land in TDM sits above maximum tidal or flood levels of Sand Lake, but the flat terrain and depressional areas

within TDM hold water during storm events due to a lack of positive drainage pathways for water to escape. While the ditch along Sandlake Road and an existing swale at the northwest end of TDM have some ability to convey water downstream to Beltz Marsh, many areas, particularly in the western half of TDM, have no drainage connection to these conveyance features. Furthermore, culverts and ditches along Sandlake Road have limited conveyance capacity and regularly clog with sediment and debris. These conditions lead to real drainage problems and exacerbate residents' perception of flooding in TDM and their concern that modifications to the dike and tide gate system could make these conditions worse. While changes in tidal connectivity in Beltz Marsh could potentially influence drainage and flooding conditions in TDM locations that are below the highest measured tide elevation of approximately 12' NAVD88, the surface water flooding experienced in TDM further away from the marsh is unrelated to conditions in the marsh and would not be affected by the proposed restoration actions.

This assessment of TDM's drainage system is aimed at:

- defining drainage patterns within TDM and estimating stormwater runoff rates and volumes that contribute to the East Marsh and Beltz Marsh for incorporation into the 2D HEC-RAS modeling,
- identifying the deficiencies within the system that cause or contribute to flooding and ponding of water within TDM,
- differentiating between flooding caused by localized stormwater drainage issues within TDM versus any potential for flooding that could be influenced by restoration actions at SSSNA, and
- identifying potential drainage improvements in TDM that could alleviate flooding conditions experienced by residents or reduce runoff volumes draining into the area behind the proposed setback dike (such as redirecting runoff to a separate outfall on the beach).

ESA used a combination of LiDAR and survey data, site reconnaissance and interviews with TDM residents, and winter-time storm observations and water level data to define drainage patterns/flow routing, sub-catchment areas, stormwater discharge points/connections to SSTW, and system deficiencies that could be improved. **Figures 18a and 18b** show an overview of the existing TDM Drainage System with aerial photo and LiDAR backgrounds, respectively.

5.2.2 Potential TDM Drainage System Improvements

While improvements to TDM's stormwater system are outside of the scope of this project, ESA identified a series of potential improvements that could be undertaken as a separate project to alleviate some of TDM's drainage and perceived flooding issues. Improvements are grouped by drainage basin, including actions related to areas that drain to the Sandlake Road ditch and actions related to areas that drain to the TDM Northwest Ditch.

Potential infrastructure improvements and priority maintenance actions within the Sandlake Road Ditch subbasin include:

- Frequently maintain culverts and ditches to clear blockages that constrict flow, reduce drainage, and cause backups in the system
- Upsize culverts along Sandlake Road ditch for increased drainage capacity (especially at Roma Ave)
- Excavate swales or ditches along side streets to drain water to the Sandlake Rd ditch, similar to recent improvements at the east end of Guardenia Ave. and Coats Ave.
    - Opportunities range from subtle grading or potential hand excavation to more extensive and deeper ditching
    - Requires driveway culverts and raising driveways in some locations,
    - Requires managing conflicts with existing utilities (water, telecommunications, overhead electrical lines/poles) and potentially adjusting, deepening, and protecting utility lines,
    - Could include catch basins/inlets and storm pipes to collect and convey water from low points that lack positive drainage,
    - Could include perforated pipe underdrains ('French Drains') to intercept and convey shallow groundwater,
- Daylight (convert culverts to open ditches) sections of Sandlake Road ditch where long culverts prevent side street drainage (such as at Holly Ave) and are susceptible to clogging,

Potential infrastructure improvements and priority maintenance actions within the TDM Northwest Ditch subbasin include:

- Replacing and upsizing culverts at Pollock Ave and Jasmine Ave to increase conveyance capacity within the Northwest Ditch,
- Excavate to enlarge the ditch/swale feature in select locations to remove fill and blockages
- Consider catch basins and new outfall pipes to the beach to drain areas that are not feasible to connect to the Sandlake Road ditch (such as the depressional area at the west end of Austin Ave)
- Enhance flow paths within the Northwest Ditch subbasin that have been lost or blocked due to infill developments and localized fill placement, likely with subsurface drains or swale grounding around existing structures.

5.2.3 TDM Drainage System Interaction with Setback Dike

During large storm events, runoff from TDM and the East Marsh watershed would drain into the storage basin behind the setback dike. During high tides when the water level in Sand Lake and the reconnected portion of Beltz Marsh is elevated, the setback dike's tide gate would be closed, and runoff would accumulate to begin filling the storage basin and cause water levels behind the dike to rise. When the tide recedes, or the inboard water level exceeds the outboard water level, the tide gate would open and allow the storage basin to drain out.

For analysis of the setback dike alternatives described in Section 5.4, it is important to understand the runoff and streamflow contributions that enter the south end of Beltz Marsh in the area that would be upstream of each potential setback dike alternative alignment. Depending on the chosen location for the setback dike and potential re-routing of stormwater, some of the runoff could be routed to flow outside of the setback dike and therefore not occupy storage volume behind the setback dike.

ESA identified three separate drainage basins within TDM including:

- East Marsh/No Name Creek watershed – approximately 202 acres (0.315 square miles) including portions of TDM that lie east of Sandlake Road and the forested hillslopes east of TDM

- Sandlake Road Ditch subbasin – approximately 30 acres including most of the residential area of TDM that lies west of Sandlake Road. These areas generally drain toward the Sandlake Road ditch where water is conveyed through a series of culverts at each side street intersection.

- TDM Northwest Ditch subbasin – approximately 12 acres including a smaller portion of the TDM residential area situated between the Pacific Ocean foredune and a topographic rise that separates this area from the Sandlake Road Ditch subbasin to the east. This area drains northward through swales that have been partially blocked by infill development, becoming a channel that flows through culverts at Jasmine Ave, Pollock Ave, and Roma Ave and toward Beltz Marsh.

In alternatives analysis for 30% design stage before a precise location for the setback dike was selected, ESA noted that a setback dike located near the existing beaver dam would be downstream of all TDM and East Marsh runoff contribution points, and all runoff and streamflow from these areas would drain into the marsh upstream of the dike. Therefore, a setback dike in this location would need to include sufficient storage volume to contain all runoff from TDM and the East Marsh subbasin.

The pre-decision 30% design stage alternatives analysis also determined that it could be possible to orient a new setback dike alignment such that the TDM Northwest Ditch would drain directly into Beltz Marsh downstream or outside of the setback dike. Furthermore, it could be possible to intercept flows from the TDM Northwest Ditch subbasin and reroute these flows to a new outfall on the beach. These actions could reduce the amount of runoff draining into the storage basin

upstream of the proposed setback dike and could reduce the amount of storage capacity needed. These modifications were considered and analyzed as described in Section 5.4.3. However, the TDM Northwest Ditch subbasin contributes three times less runoff to Beltz Marsh than the Sandlake Road Ditch subbasin, and the East Marsh watershed is five times larger than both subbasins combined. Hydraulic modeling determined that re-routing flows from the Northwest Ditch subbasin to the outside of the setback dike would not substantially influence the performance of a setback dike or required storage volume. Capturing runoff within the TDM Northwest Ditch Subbasin and the west end of Austin Ave, and rerouting flows to a new outfall on the beach, could improve localized flooding in the subbasin by providing a more efficient way to drain water out of these flat depressional areas.

5.2.4 TDM Drainage Considerations for SSTW Final Design

ESA identified a series of drainage deficiencies and potential stormwater improvement projects that may be implemented in the future as separate projects by the County, TDM community, or individual property owners. Most notably, regular cleaning of the Sandlake Road Ditch and associated culverts beneath side streets in TDM, minor grading to help convey stormwater runoff to the Sandlake Road Ditch and upsizing the culvert conveying the Sandlake Road ditch flows beneath Roma Ave could alleviate stormwater backups and drainage in TDM.

ESA demonstrated that the proposed improvements associated with the SSTW project will not affect stormwater drainage in TDM, and the proposed setback dike and tide gate operations will result in lower peak water levels during storm events compared to existing conditions.

No specific stormwater or drainage improvements within TDM are included in the SSTW project final designs.

5.3 Dike Breach and Trail Accommodations Alternatives Assessed

5.3.1 Size, Location, and Number of Dike Breaches

During the 2019 hydrologic study, ESA estimated the minimum dike breach dimensions that would allow for full equilibration of tidal water levels between Sand Lake and Beltz Marsh based on a combination of Tidal Channel Design Guidelines (PWA, 1995), hydraulic geometry (Williams, 2002), and analysis of nearby reference tidal channels. Using the parameters of contributing marsh surface area and tidal prism volume (the potential volume of water contained within the marsh between mean higher high water and mean lower low water datum elevations), ESA estimated the dike breach tidal channel should have a minimum bottom width of 37 feet, with a top width (at the top of the dike breach) of approximately 80 feet. However, a larger dike breach opening may be beneficial for:

- restoring more natural circulation patterns and sediment transport/accretion processes,
- reducing water velocities through the dike breach to reduce erosion and facilitate fish passage, and

- reducing shear stress on the banks of the dike breach channel to minimize potential for erosion at potential pedestrian bridge abutments.

Full removal of the earthen levee known as Beltz Dike would restore tidal connectivity closest to the conditions that would have existed prior to the construction of Beltz Dike allowing for unconstrained flow of tidal water across the marsh surface. However, if the dike were fully removed, the Beltz Dike Trail which provides access from the trailhead to the rest of the SSSNA trail network would be severed. An alternate trail connection could be provided by constructing a boardwalk across the marsh or by establishing a new trail around the perimeter of Beltz Marsh and across the south end of the marsh. These options for maintaining recreational access are discussed herein. TDM residents have also raised concerns about removing the full dike.

Number of Dike Breaches

ESA considered whether it would be beneficial to construct multiple dike breaches, or if it would be better to focus on a single dike breach. Multiple breaches could provide additional fish passage pathways between Sand Lake and Beltz Marsh. However, including multiple breaches would have several disadvantages including:

- requiring additional pedestrian bridges or culverts to maintain trail access,
- splitting tidal flow and tidal prism volume between multiple breaches/inlets, rather than focusing tidal prism volume through a single breach to help maintain the channel width and depth in the future,
- reducing predictability due to splitting flow through multiple breaches that could evolve/enlarge over time and cause damage to bridges or culverts. For example, if one large breach and one small breach were constructed, it is possible that the larger breach could be blocked by sediment or other means, causing the smaller breach to enlarge and undermine bridge abutments. All breaches and associated access infrastructure would need to be sized to handle all flow in case it became the preferential flow path.

Additionally, natural tidal channel networks in similar settings along the Oregon Coast typically exhibit a fractal dendritic planform resembling a tree trunk that branches into many smaller channels. **Figure 19** shows an example of a dendritic tidal channel network where multiple small first-order channels combine to create a 2nd order channel, 2nd order channels combine to create a 3rd order channel, and 3rd order channels combine to create a 4th order channel, all funneling tidal flows to a single inlet/outlet point (Hughes, 2012). This dendritic channel network planform can be observed in the northeastern portion of the Sand Lake Estuary (**Figure 20**), and in many other locations along the Oregon Coast and low-gradient marshes across the world.

For these reasons, we recommend focusing on constructing a single dike breach that is generously sized large enough for flood conveyance capacity, fish passage, and to accommodate some channel adjustment in the future.

Location of Dike Breach

To determine the ideal location for a dike breach, ESA analyzed historical aerial photos along with current-day aerial photos and onsite observations of existing flow paths and relict channel features. In the oldest available historical aerial photo from 1939 shown in **Figure 21** (University of Oregon Libraries, 2020), two large channels appear near the midpoint of Beltz Dike, and it appears that the drainage structure was also near this location at the time. In the historical aerial, as well as recent aerial photos (**Figure 22**), it appears that these large central channels upstream of the dike generally align with the largest channel features downstream of the dike in Sand Lake. This central area appears to be the most logical location to construct a new dike breach channel to restore historical flow patterns and connect the prominent channel features observed upstream and downstream of the dike.

Two other potential locations were considered for a dike breach. A breach could be excavated near the current location of the existing concrete box culvert and tide gate, near the eastern end of the dike. However, while the existing culvert drains out into Sand Lake and into downstream channel forms, the upstream channel network within Beltz Marsh does not align well with this location. The existing box culvert has large scour holes upstream and downstream of the culvert. The upstream scour may be partially caused by the location of the culvert relative to the upstream channel, which causes water from Beltz Marsh to funnel into this area and form a large eddy. Allowing for more tidal exchange in this location could continue causing erosion of the adjacent banks and dike embankment. At the west end of Beltz Dike, a dike breach could be excavated to connect the northwestern lobe of Beltz Marsh to a small tidal subbasin observed outside of the dike. The 1939 aerial does not show any evidence of a historical channel connection in this location, and the small tidal subbasin observed today appears to have formed within the borrow ditch excavated outside of the dike.

These four potential dike breach locations considered are identified in **Figure 23**.

We recommend locating a new single dike breach near the midpoint of Beltz Dike to restore connectivity between the large channel features visible in historical and current aerial photos inboard and outboard of Beltz Dike.

Sizing a Dike Breach

ESA utilized the 2D model to analyze dike breach and removal alternatives including:

- 100-Foot Breach - A single dike breach with a 40-foot bottom width and 100-foot top width
- 200-Foot Breach – A single dike breach with a 200-foot top width allowing for a wider marsh plain bench through the opening
- Full Dike Removal – Full removal of the entire Beltz Dike lowered to match the existing adjacent marsh plain elevations with a breach channel

Factors for evaluating the performance, benefits, and disadvantages of each dike breach or removal option include:

- Changes or differences in water levels in Beltz Marsh or behind a setback dike
- Circulation patterns of water moving between Sand Lake and Beltz Marsh, across the marsh plain, and within channels
- Velocities and shear stresses through the dike breach openings, across the marsh, and within channels to inform fish passage, erosion potential, and sedimentation/accretion responses

Water Levels

Because the 100-foot breach is large enough to allow for full equilibration of water levels inside the marsh, the model showed no difference in water levels generated inside the marsh under the dike breach scenarios compared to the full dike removal alternative. The model also showed negligible differences in water levels behind the setback dike between the dike breach or full dike removal alternatives. **Figure 24** shows a comparison of modeled water levels behind a setback dike under a 100-foot dike breach or full dike removal compared to the existing dike configuration and water levels in Sand Lake.

Circulation Patterns

While there was no discernable difference in water levels modeled under the dike breach and full dike removal scenarios, there are differences in the circulation patterns of how water moves in, out, and across the marsh surface.

Under the dike breach scenarios, water moving between Sand Lake and Beltz Marsh is funneled to and concentrated through the dike breach opening. Low velocities are present on the marsh plain, with relatively higher velocities in the concentrated flows within the channels. With full dike removal, tidal flux is distributed more evenly across the marsh and interface between Sand Lake and the marsh, particularly at higher water levels. During lower water levels under the full dike removal alternative, water is still generally funneled into the channel and the proposed dike breach location, concentrating flows with higher velocities observed in the channels.

100-foot dike breach compared to full dike removal – tidal circulation during high tide drain out: **Figure 25** shows a comparison of water circulation patterns and flow directions under the 100-foot dike breach and full dike removal alternatives during drain out while water levels are still high (above 9’ NAVD88). **Figure 26** shows the same comparison after water levels have fallen below 9’ NAVD88 and flows are concentrated in channels under both conditions.

Under the 100-foot dike breach condition, an eddy is visible in Figure 25 just inside of the marsh near the dike breach. This eddy was not observed in modeling under the 200-foot dike breach condition. An eddy has potential to cause erosion on the banks of the dike breach if shear stresses are high enough to erode the soils and could require scour countermeasures such as armoring with rip rap or other means.

Velocity/Shear Stress

The 100-foot breach results in water velocities through the breach that are less than 2 feet per second (ft/sec) for most of the time (ODFW's threshold for fish passage peak velocities in fishway transport channels). Short-duration peak velocities of approximately 3 ft/sec occur during peak drain out during the 100-year storm scenario. **Figure 27** shows modeled water velocities through the 100-foot breach throughout the 100-year storm hydrologic scenario compared to the 2 ft/sec fish passage velocity threshold. During the moments of peak velocity, the peak shear stress through the dike breach reaches approximately 0.19 pounds per square foot (lb/sf), which has the potential to erode medium to coarse gravels and may require light armoring to prevent erosion in the vicinity of potential bridge abutments. **Figure 28** shows a 2D model output of peak shear stress through the 100-foot dike breach compared to a table for limiting shear stress for uniform noncohesive sediments (Fischenich, 2011).

The 200-foot dike breach would result in even lower velocities through the dike breach opening with peak velocities across the breach at approximately 1 ft/sec. Slightly higher velocities occur in tidal channels near the breach. **Figure 29** shows a comparison of peak velocity through 100-foot and 200-foot dike breaches during the 100-year storm hydrologic scenario. The lower peak velocities and shear stresses through a 200-foot dike breach would likely not require any armoring to protect potential bridge abutments. For comparison, the nearby Whalen Island road bridge has an upstream contributing marsh area of 180 acres, more than twice that of the Beltz Marsh. The Whalen Island Bridge has an 80-foot span and channel opening, but the velocities and shear stresses through that bridge section require extensive rip rap armoring and deep sheet pile walls to protect the bridge abutments as seen in **Figure 30**.

It is unclear how these differences in circulation patterns and velocity distributions would influence sedimentation or accretion within Beltz Marsh. Once the marsh is fully reconnected to tidal flows, accretion rates may be more dependent on sediment supply within the water than peak tide circulation patterns. The remaining portions of the dike after breaching would act as berms which can slow water on the marsh plain and increase sedimentation by reducing wind/wave erosion. The remnant dike may act as a 'wave break berm' and serve this function. However, areas where water is funneled back into channels and through the dike breach would likely experience more erosion than deposition.

Advantages, Disadvantages, and Risks of Full Dike Removal

While a 100-foot or 200-foot dike breach would allow for a much-improved connection between Sand Lake and Beltz Marsh, this opening would still be a constriction compared to historical conditions prior to the construction of Beltz Dike. Full dike removal would represent the maximum restoration and reconnection by removing the artificial fill that bisects the south end of the Sand Lake estuary. Removing the full dike would also allow for 3 acres of wetland restoration within the footprint of the existing dike. Fill from the existing dike could possibly be used to build a setback dike, though construction sequencing could be logistically challenging as the setback dike would need to be substantially complete prior to removal of the outer dike.

The 2D model shows that there would be a negligible difference in water levels in the marsh, or behind a setback dike, between full dike removal and the dike breach scenarios. There are notable differences in the circulation patterns between the dike removal and breach options, particularly at higher water levels. However, it is unclear how these differences in circulation patterns would influence sediment dynamics or marsh accretion. As noted above, the existing dike or remnant dike sections after breaching may act as wave-break berms during high water levels. Fully removing the dike could increase wind-wave erosion at the edges of the marsh by increasing wave fetch distance.

Full dike removal would require removal of the Beltz Dike Trail and require major trail modifications to maintain recreational access, such as 2000 feet of boardwalk and small bridges, or rerouting the trail through the Reneke Creek and Beltz Creek areas where dense vegetation, braided channels, and wetland conditions would make trail construction difficult and costly. Additionally, dike removal would require removing many mature spruce trees and extensive shrub vegetation along the dike.

5.3.2 Maintaining Recreational Access to Trail Network

The Beltz Dike currently provides recreational access from the SSSNA parking lot and trailhead to the SSSNA trail network and beach. Breaching or removing the existing dike would sever the trail connection. ESA considered design alternatives for maintaining recreational trail access under the proposed dike breach scenarios, including spanning the dike breach with a pedestrian bridge, constructing a new boardwalk across Beltz Marsh, and rerouting the trail around the perimeter of the marsh to cross the marsh on the setback dike. **Figure 31** shows a conceptual depiction of the pedestrian bridge and boardwalk alternatives.

ESA subcontracted David Evans Associates (DEA) to provide preliminary structural engineering support in developing and evaluating bridge and boardwalk alternatives. Foundation Engineering provided preliminary geotechnical engineering input to inform the bridge and boardwalk alternatives.

Pedestrian Bridge(s) Alternative and Bridge Selection Considerations

Figure 32 depicts the pedestrian bridge option, with a 100-150-foot-span pedestrian bridge over a 140-foot-wide dike breach channel.

A dike breach with a top width of 100-200 feet could reasonably be clear spanned with a pedestrian bridge. Spans of up to 300 feet are possible but can be quite expensive and require deep/tall girders or trusses. Prefabricated bridges are the most cost-effective alternative, providing some cost savings compared to traditional steel or concrete girder bridges. Signature bridges such as custom trusses, arches, or suspension bridges could add aesthetic value and character to the park but would be expected to more than double the bridge cost. Modern prefabricated truss or arch options can provide a similar feel of a signature bridge design while also realizing the cost savings of a pre-manufactured product (DEA, 2023). **Figure 33** shows examples of prefabricated pedestrian bridges in this span range.

While it may be tempting to select the shortest span bridge that would allow reconnection of the marsh to Sand Lake, it is important to not undersize the bridge and channel opening. A lesson can be taken from the Nisqually National Wildlife Refuge where a boardwalk was constructed across a restored tidal marsh. At one of the main channel crossings, a 40-foot span pedestrian bridge was constructed in 2011. In the decade following construction, the channel beneath the bridge began to evolve by enlarging in response to the new hydrologic conditions causing bank erosion beneath the bridge. After attempts to stabilize the banks with armoring, the small bridge was eventually replaced by a 90-foot pedestrian bridge as shown in **Figure 34**.

Pedestrian Bridge Material and Style Options and Considerations

Being close to the ocean and salt conditions in the water and air, some materials such as timber and unprotected steel would not fare well in the long run and would require extensive maintenance. Timber bridges are highly prone to degradation in such a corrosive environment. It would likely take only a few decades for the timbers to start showing substantial wear and require attention. With the proposed span ranges, a timber bridge would likely be a timber arch or truss bridge, which would be difficult to replace in pieces as rot develops. A timber girder bridge, while requiring significant maintenance can often be addressed without major costs. However, given the location, proposed span lengths, and anticipated conditions, a timber bridge should be avoided due to potential long-term maintenance costs.

Weathering steel is often a good choice for avoiding long-term costs for maintenance such as repainting, but in high salinity environments where chloride concentrations are too high, weathering steel doesn't effectively form its protective patina. The wet salt air constantly breaks down the patina and prevents it from sticking to the steel.

For a steel bridge option, stainless or painted steel would resist corrosion. Painted steel would be effective but would require ongoing maintenance to repaint the bridge approximately every 30 years or so. Repainting costs can also be significant, especially in this location where extensive containment systems would be required to contain the old paint and apply new paint. Stainless steel is a better solution for minimizing long-term maintenance, but it would come at a substantial increase in upfront costs. Stainless steel would also require monitoring of the conditions and potential maintenance, as near-ocean conditions are damaging to all materials in the long run.

A concrete bridge structure is a potential option, but concrete would be better suited to bridge girders that would sit beneath the bridge deck and occupy cross-sectional flow area or require raising the trail profile by several feet. A concrete arch structure would likely be cost-prohibitive. Reinforcing steel within the concrete should be stainless steel, and additional concrete thickness would be required to protect the rebar and preserve the structure.

Girders - From a materials standpoint, girders are typically the most economical option. Two girders could support the path decking and would provide for a very straightforward construction solution. The biggest drawback of this type of bridge is that the girders need to be below the path. With a relatively long span for girders, this could present issues from the bridge substructure encroaching on the hydraulic opening beneath the bridge. A general rule is that the depth of a girder bridge is about 3.5%-4.5% of its length. This would result in an approximately 6ft deep

bridge. This amount of structure below the path may present an issue with path grades requiring significant raising and would impact the trail approaches for long distances in each direction to avoid steep trail gradients.

Arches/Trusses - A custom-designed arch or truss bridge is likely uneconomical for this project. However, there are many prefabricated arch and truss-style bridges manufactured specifically for pedestrian bridge applications. These are most commonly steel or timber. Concrete arches are available, but they are often more expensive to manufacture and ship due to their heavy weight. An arch or truss structure would address the path profile issue as most of the structure is located above the travel path. This would substantially increase the hydraulic opening beneath the bridge without the need for substantial raising of the trail grade. Arch and truss bridges also provide an added aesthetic structural element.

Suspension/Cable Stay – While visually similar to the arch or truss alternative in that the structure is above the pathway; this system is different primarily in how it's supported. Suspension or cable stay structures use high-strength wires that support the path and extend back to an anchoring tower. The tower typically resists the forces coming from the wires by using an additional cable/tendon that is tied into the ground beyond the end of the bridge/tower. This may present a substantial construction challenge at this site, as the area around the bridge is all imported fill. This is not likely to be suitable for anchoring cables without substantial underground improvements like a large deadman anchor that could hold the tendons in place. Suspension structures are also not a common premanufactured system. This would increase the design cost for the project. The viability of this kind of alternative would likely hinge on the viability of the substructure to carry the large lateral loads carried by a suspension bridge compared to the lower lateral forces from an arch or truss (DEA, 2023).

Boardwalk Alternative

ESA evaluated alternatives to spanning a dike breach with a pedestrian bridge including abandoning the Beltz Dike Trail as a connection to the rest of the SSSNA trail network and constructing a new boardwalk across the marsh. **Figure 35** shows a potential alignment for a new boardwalk, traveling through the Reneke Creek confluence wetland area and crossing the marsh where the open water channel features are narrower and connecting to the existing trail network near the Elk Knoll viewpoint. This option would allow for full dike removal or a larger breach opening without the need for a long-span pedestrian bridge over the dike breach. However, this alignment would still require 50 to 100-foot span boardwalk bridges over the tidal channels. This alignment would include approximately 2,000 linear feet of boardwalk, including the channel-spanning bridges.

Other boardwalk alignments or variations could be considered, such as constructing a boardwalk within the footprint of the existing dike coinciding with dike removal excavation. This alignment would also require a bridge over the new primary tidal channel.

As described under the pedestrian bridge alternative, designing a boardwalk and associated bridges would also need to overcome challenging geotechnical conditions. The boardwalk and bridges would require specialized foundation elements that could include Diamond Pier footings

similar to the boardwalk system at Nisqually National Wildlife Refuge. The bridge spans and potentially other portions of the boardwalk would likely require deep foundations such as driven piles. Micropiles may also be an option and would require smaller installation equipment compared to conventional pile-driving equipment (Foundation, 2023).

Reroute Trail to Cross Marsh at Setback Dike Alternative

The trail could also be rerouted around the eastern perimeter of the marsh, traveling across the Reneke Creek and Beltz Creek confluence areas toward the proposed setback dike location. Depending on the setback dike alternative selected, the trail could cross the marsh where it is narrower than the conceptual boardwalk alignment, or it could be connected to the dike top access road to cross the marsh. **Figure 36** shows a potential trail alignment for rerouting the trail southward toward the setback dike area. This option would also allow for full dike removal, or a larger-sized dike breach without the need for a long-span pedestrian bridge.

This option would require small bridges or boardwalk sections where the trail crosses Reneke and Beltz Creeks. Where the creeks enter the marsh, the channels braid into multiple flow paths. The Reneke Creek area is forested with dense understory and wet/soft conditions. The middle portion of the trail could utilize the higher ground between the creeks, and vegetation impacts would be minimal as this area is currently pasture. Beltz Creek's main channel could be crossed with a pedestrian bridge, but south of Beltz Creek the hillslope rises steeply out of the marsh and boardwalk sections, or hillslope grading could be needed to continue traveling southward toward the proposed setback dike alignments. The trail could also cross the marsh west/southwest from the Beltz Creek area where the marsh is much narrower than the previously described boardwalk alignment.

Pedestrian Bridges, Boardwalk, and Trail Rerouting Cost Comparison

ESA developed concept-level estimates of construction cost for four alternatives for breaching or removing Beltz Dike in combination with pedestrian bridge, boardwalk, and trail rerouting alternatives for maintaining recreational access to the SSSNA trail network and beach. Table 2 below provides a comparison of estimated construction costs for each alternative.

5.3.3 Summary of Dike Breach and Trail Access Alternatives Analysis

Dike Breach Sizing and Comparison to Full Dike Removal

- Single dike breach would be much more predictable than multiple breaches and would be consistent with typical dendritic tidal channel planforms that funnel flows from smaller first-order channels into progressively larger tidal channels.

- Single dike breach would require only one pedestrian bridge rather than multiple structures

- 100-foot breach is a ‘constriction’ compared to historical conditions, but peak modeled velocities (and shear stresses) are modest ~3 ft/sec (0.19 lb/sf) within the breach (much lower on marsh plain)
- No difference in water levels in marsh or behind setback dike between 100-foot dike breach, 200-foot dike breach or full dike removal.
- Difference in circulation patterns at higher water levels (still funnels flow to channel at most water levels)
    - Not clear if this difference would influence sedimentation/accretion
    - “Berms” can slow water and increase sedimentation by reducing wind/wave erosion. Remnant dike may function as a ‘wave break berm’ and serve this function
    - More dependent on sediment supply and inundation duration than peak tide circulation (not affected by dike breach size)

Dike Breach - Location/Dimensions/Trail Accommodations

- Considered 100’ breach, 200’ breach, and Full Dike Removal (multiple breaches)
- Dike breaches can be spanned by pedestrian bridges
- Full dike removal would require ~2,000 LF boardwalk to replace dike trail
- Full removal would restore most natural condition, but significantly more expensive
- 100’ dike breach sufficient to equalize water levels with moderately low velocities, but peak shear stresses could cause erosion and may require bank armoring to protect bridge abutments
- 200’ dike breach results in even lower peak velocities and shear stresses, would not require bank armoring and would provide more space for channel evolution/adjustments
- Unclear/mixed whether full dike removal would benefit sediment dynamics/accretion

5.3.4 Final Dike Breach Sizing and Pedestrian Bridge Selection to 90% Design

Following the 30% design stage, ESA and DEA’s bridge engineers met with OPRD and TEP staff to discuss the information outlined above. OPRD agreed that a prefabricated steel truss bridge was likely the preferred bridge material type. OPRD would like the ability to drive a pickup truck across the bridge and not have unreasonable restrictions on the number of people standing on the bridge at once. DEA proposed a 90 pounds per square foot (psf) pedestrian live load and a H-10 vehicular loading. DEA presented a planning-level cost comparison of pedestrian bridges ranging

from 100- to 200-foot spans. It was apparent that bridges in excess of 140-foot spans for the recommended loading requirements become significantly more expensive on a per square foot basis.

ESA developed updated hydraulic modeling for a 140-foot dike breach option to compare against the previously modeled 100- and 200-foot breach sizes. A comparison of the modeled peak velocities and shear stresses for all three breach sizes is shown in **Figure 37**. The 140-foot-wide dike breach resulted in peak velocities during the 100-year drain out below 2 fps, with 0.08 psf peak shear stress, and the eddy circulation pattern visible in the 100-foot breach model results was not present. These combined factors led the team to commit to the 140-foot-span pedestrian bridge size. **Figure 38** shows the 90% design dike breach grading plan, and **Figure 39** shows the channel cross section and select bridge details.

DEA and S&W coordinated on the bridge foundation design, and S&W's provided geotechnical engineering design criteria and recommendations (S&W, 2025). The proposed pedestrian bridge foundation includes two concrete abutments, each with three PP20x0.625 pipe piles to be driven to a nominal resistance of 170 kips, with a minimum pile tip elevation of -60' and a cutoff elevation of 11' within the concrete pile cap. S&W recommends preboring holes to -60' elevation prior to driving pile. More detailed information is available in the geotechnical engineering report and on the pedestrian bridge plans notes and details.

The pedestrian bridge is designed in accordance with the 9th edition of the AASHTO LRFD Bridge Design Specifications, with H10 load and/or 90 psf pedestrian load. Seismic design is performed in accordance with the AASHTO Guide Specifications for LRFD Seismic Bridge Design. The horizontal peak ground acceleration coefficient (PGA) for 1000-year return (no collapse) earthquake is 0.755G, based on 2026 USGS seismic hazard maps. The bridge site is defined as a site Class E with site factor (FPGA) of 1.10.

5.4 Setback Dike

Following the 2019 hydrologic study, stakeholder coordination, and subsequent technical advisory committee meetings, OPRD selected a preferred alternative concept that included breaching the outer Beltz Dike while constructing a new setback dike closer to TDM to maintain or improve flood protection for the adjacent community and Sandlake Road. This alternative provided the compromise that best met all the diverse goals of the project (OPRD, 2020).

At this time, a setback dike was conceived to be located approximately at or near the location of the existing primary beaver dam, approximately 700 feet north of the TDM/SSSNA boundary. In 2019, ESA performed a preliminary feasibility assessment to determine if a setback dike located near the beaver dam could have sufficient storage volume upstream of the setback dike to contain stormwater runoff from a 100-year storm event without resulting in higher peak water levels than under existing conditions (**Figure 40**).

The 30 and 60% design stage phase refined the location of a potential setback dike to provide sufficient stormwater runoff storage capacity while minimizing wetland impacts and maximizing

the area of marsh that could be reconnected to the Sand Lake estuary. Additionally, it is important to consider other aspects and challenges associated with constructing a new earthen dike across the marsh and maintaining functionality of a new tide gate and drainage structure that would prevent high tides from reaching TDM and drain stormwater runoff away from TDM and toward Sand Lake.

Key challenges associated with construction and long-term performance of a new earthen setback dike are centered around the subsurface conditions in the area and geotechnical engineering investigations, analyses, and design measures that would be needed for final design. Several feet of settlement would likely be expected to occur when placing fill across the marsh due to deep, soft marsh soils and estuarine deposits underlying the proposed setback dike area.

Additionally, due to heavy beaver activity at the south end of the marsh, including an active beaver dam and lodge near the proposed setback dike location, it is important to consider how beavers may interact with the new setback dike and associated drainage structure/tide gate system. Beavers are known to intentionally block culverts with mud and debris when it is beneficial for them to do so, and blockage of the drainage structure or tide gate associated with the new setback dike could require significant long-term maintenance and/or worsen flooding conditions at the south end of the marsh and low-lying properties within TDM.

Geotechnical engineering, dike embankment design, tide gate hydraulic capacity and fish passage, and beaver activity considerations are discussed in subsequent sections.

5.4.1 Initial Setback Dike Design Dimensions and Characteristics

Based on previous setback dike designs in similar settings, for the setback dike alternatives analysis, we assumed the following setback dike design dimensions and characteristics that were refined in the 30-90% design stages and informed by geotechnical engineering recommendations:

- Minimum top width of 12 feet to accommodate vehicular and equipment access for monitoring and maintenance of the setback dike and tide gate structure
- Maximum side slopes of 3H:1V (Horizontal:Vertical) on the inboard/protected side and 5H:1V on the outboard/flood side of the setback dike, vegetated to provide erosion control and habitat value
- Long-term minimum top elevation of 15 ft NAVD88 to provide approximately three feet of freeboard above peak water levels, which could require overbuilding the dike to a top elevation of approximately 17 ft NAVD88 to accommodate long-term settlement of the earthen embankment and underlying soils
- An approximate footprint width of 80-100 feet where the side slopes meet the existing marsh surface

- Eastern embankment tie-in to Sandlake Road with driveway connection to allow for vehicular and equipment access onto a dike-top access road

- Western embankment tie-in to the existing forested dune with a vehicle turnaround for maintenance

- Removal of existing vegetation and soft saturated soils within the setback dike footprint and subgrade stabilization measures to mitigate differential settlement that could damage the embankment

- One or more drainage structures/culverts with tide gates to limit tidal inundation while providing drainage of stormwater runoff from TDM, likely including a Muted Tidal Regulator (MTR) to maximize fish passage through the setback dike.

Figure 41 shows a preliminary conceptual cross section view of a proposed setback dike with these assumed dimensions and side slopes.

5.4.2 Optimizing Location/Alignment of Setback Dike

Constructing a new setback dike across the south end of Beltz Marsh will result in wetland impacts including wetland fill within the footprint of the setback dike as well as limiting the area of marsh that can be reconnected to full tidal interaction with Sand Lake. The further south that a setback dike can be located, the smaller the dike's footprint would be and the smaller the portion of wetland remaining disconnected from Sand Lake would be. However, shifting the setback dike southward would also reduce the potential storage volume available to contain stormwater runoff from TDM during high tides when a new tide gate would be closed. **Figure 42** shows a conceptual plan of potential setback dike locations relative to TDM, Sandlake Road, and the channels/ditches that would contribute runoff to the area behind a setback dike.

In an effort to minimize wetland impacts and maximize estuary restoration, while protecting upstream infrastructure and private property, ESA developed a series of four setback dike alignment alternatives for detailed hydraulic modeling and analysis including:

- **Alternative 1** – located at or near the existing primary beaver dam and approximately 700 feet north of TDM (similar to the preliminary setback dike location evaluated in 2019). This alternative would provide the greatest potential storage volume to contain stormwater runoff from TDM. If this storage volume was determined to be insufficient, additional setback dike alternative locations further north would be considered.

- **Alternative 2** – located approximately 300 feet south of the existing primary beaver dam and 300 feet north of TDM. This alternative would reduce runoff storage volume and wetland impacts.

- **Alternative 3** – located at the southern park boundary and configured to allow the TDM Northwest Ditch to flow directly to the marsh outside of the setback dike thereby not contributing runoff to the setback dike's upstream storage basin. This alternative would

significantly reduce wetland impacts and runoff storage volume but would route a portion of TDM's runoff outside of the setback dike, possibly reducing the necessary storage capacity.

- **Alternative 4a** – located along Sandlake Road and Roma Avenue, raising these roadways to a minimum elevation of 15' NAVD88 to function as the setback dike with a new culvert and tide gate at the Sandlake Rd/East Marsh crossing. Under this scenario, the NW Ditch and Sandlake Rd Ditch would flow directly to the marsh, while the East Marsh and adjacent TDM properties would be protected from the highest tides, and the East Marsh would function as the runoff storage basin. Properties between Roma Avenue and Beltz Marsh would have no protection from the elevated roadway based "dike". This option would nearly eliminate wetland impacts associated with the project.

- **Alternative 4b** – similar to 4a but without a new tide gate at the Sandlake Rd/East Marsh crossing. This alternative would allow full peak tide levels at the south end of Beltz Marsh and in the East Marsh but not retain any stormwater runoff upstream of the elevated embankment. This alternative would essentially be a non-setback dike alternative while raising Sandlake Road and Roma Ave above current and expected future peak water levels. This alternative could maintain roadway access during the highest expected water levels but would expose portions of the lowest-lying private properties in TDM to increased frequency of tidal inundation.

All setback dike alternatives assume the setback dike would have a 12-foot span box culvert fitted with a tide gate controlled by a muted tidal regulator (MTR) system, and the MTR would be set to stay open until upstream water levels exceeded 8.0' NAVD88. All alternatives also assume that the culvert at the Sandlake Rd/East Marsh crossing is replaced with a 12-foot span box culvert so that the water levels behind the setback dike freely propagate upstream into the east marsh.

Figure 43 shows the approximate locations of Setback Dike Alternatives 1 through 4 as described above. Table 2 below shows a comparison of wetland impacts associated with each of the four setback dike alternatives.

TABLE 2. WETLAND IMPACT COMPARISON FOR SETBACK DIKE ALTERNATIVES

Alternative	Setback Dike Location	Wetland Impact Area (dike footprint) (acres)	Wetland Area Behind Setback Dike (acres) [a]
Existing Conditions	None (outer Beltz Dike)	0.0	82.1
Alternative 1	Near Existing Beaver Dam	1.5	10.9
Alternative 2	300' South of Beaver Dam	0.9	5.1
Alternative 3	At Park Boundary (NW Ditch Outside)	0.7	1.2
Alternative 4	At Sandlake Rd/Roma Ave	0.1	0.0

NOTES:

a. Wetland Area Behind Setback Dike within SSSNA and not including East Marsh.

5.4.3 Hydraulic Performance of Setback Dike Alternatives

Using the 2D HEC-RAS Model setup discussed in Section 4, ESA evaluated the performance of each setback dike alternative under a range of hydrologic conditions. For the purposes of understanding how each setback dike alternative would affect water levels at the south end of the marsh/north end of Tierra Del Mar, this analysis focused on modeling combinations of high tides and large storm events, including:

- High tides ranging from average high tide levels of 7-8' NAVD88, to frequently occurring peak high tides of 10' NAVD88, to maximum observed high tides or King Tides reaching approximately 12' NAVD88.

- Stream flows and stormwater runoff ranging from wintertime base flow conditions to peak stream flows under 50-year storm events and an extreme 100-year storm event.

This full range of potential wintertime conditions were combined into a single 14-day hydrologic scenario that includes:

- 3 days of typical wintertime conditions with base flow from the East Marsh, Beltz Creek, and Reneke Creek, and no runoff from the TDM subbasins combined with average tide conditions,

- 5 days of a 'first storm' that includes moderate peak stream flows (approximating a 2-year peak stream flow) and stormwater runoff rates, combined with high tides reaching 10' NAVD88, and

- 6 days of a 'second storm' that includes 100-year peak stream flows and stormwater runoff rates, combined with King Tides reaching 12' NAVD88.

This longer-duration hydrologic scenario is intended to allow for a single alternative model run to capture a wide range of anticipated wintertime conditions and provide a realistic but conservative starting point for the extreme tide/storm event (with water already in the system). Water level plots shown in the following sections may include the full 14-day hydrologic scenario or focus in on one of the three periods described above (typical wintertime conditions, first storm/2-year storm, and 100-year storm).

Modeled Water Levels Inside Beltz Dike:

As a baseline for understanding the water levels that would occur outside of the setback dike under a dike breach scenario, ESA used the 2D model to compare water levels inside Beltz Dike (north end of Beltz Marsh) after dike breaching to existing conditions. Confirming conclusions made during the 2019 hydrologic study, the 2D model results show that after dike breaching, water levels in Beltz Marsh would match the water levels occurring in Sand Lake. During typical wintertime conditions, dike breaching would allow for higher, short-duration peak water levels that are higher than water levels under existing conditions. However, under existing conditions, the existing undersized box culvert prevents efficient drain out of water and leads to higher water levels that take several tide cycles to drain out. During multi-day storm events, stormwater

accumulates behind Beltz Dike creating higher water levels with each successive high tide event. During the simulated extreme storm event of 100-year stream flows, 100-year stormwater runoff, and king tides, the existing condition results in the highest peak water level, and it takes more than five days for water levels in Beltz Marsh to drain out to pre-storm levels. These modeled water level conditions inside Beltz Marsh under the 100-year storm scenario are shown in **Figure 44**. The 2019 hydrologic study concluded that these prolonged elevated water levels would contribute more to elevated groundwater levels than the short-duration peak tide levels that would occur under a dike breach alternative (PGG, 2019).

If no setback dike were constructed, these modeled peak tides under the dike breach scenario would occur at the south end of the marsh/north end of TDM. However, due to the presence of the existing beaver dam, water levels at the south end of the marsh would never fall below approximately 8' NAVD88.

Modeled Water Levels at South End of Marsh Under Setback Dike Alternatives:

ESA utilized the 2D model to simulate water levels at the south end of Beltz Marsh (at the north end of TDM) under each setback dike alternative compared to existing conditions. **Figure 45** shows predicted water levels at the south end of the marsh during the 100-year storm hydrologic scenario. **Figure 46** zooms in on results from the 'first storm' (approximately 2-year flows with 10' tides), and **Figure 47** zooms in on the 100-year storm event (100-year flows with King Tides). As previously described, the existing conditions result in the highest peak water level and slow drain out of water leading to prolonged elevated water levels. As shown in Figures 13 and 14, the hydrologic inputs for the 50-year event are not that much lower than the hydrologic inputs for the 100-year event. The resulting modeled water levels under existing and proposed conditions during the modeled 50-year storm scenario and the 100-year storm scenario. For this reason, the analysis of the setback dike performance focuses on the results of the 100-year storm scenario, and output plot figures for the slightly less extreme 50-year event were not included in this report. Demonstrating that the proposed system performs adequately during a 100-year storm scenario indicates that the system will also perform adequately during a less extreme 50-year storm scenario.

Setback Dike Alternative 1 has the largest upstream storage capacity of all setback dike alternatives and results in lower water levels than existing conditions during almost all points in the 14-day simulation period. Alternative 1 results in higher peak water levels than existing conditions during the first two high tides of the 2-year storm event, but these peaks are 8.5' and 8.9' NAVD88 respectively which would not be problematic. In addition to lower peak water levels, Alternative 1 also provides rapid drain out after the peak of high tide.

Setback Dike Alternative 2 similarly provides rapid drain out after the peak of high tides. However, the reduced storage capacity compared to Alternative 1 results in higher peak water levels than existing conditions during all high tides within the 2-year storm and only marginally reduces the peak water levels during the 100-year storm event.

Because Alternative 2 would generally be an improvement over existing conditions during large storm events but would not be as effective as Alternative 1, ESA tested a variation of rerouting flows from the TDM Northwest Ditch to a new outfall on the beach to determine if this modification would reduce the amount of stormwater runoff entering the storage basin behind the setback dike and result in lower water levels behind Setback Dike Alternative 2. However, model results show that this modification would have a negligible effect on water levels behind the setback dike because the relative proportion of runoff from the TDM Northwest Ditch subbasin is very small compared to the Sandlake Road Ditch subbasin (both of which are dwarfed by the streamflow contribution of No Name Creek/East Marsh watershed). These model results are shown in **Figure 48**. While this modification would not improve the performance of a setback dike, rerouting flows from the Northwest Ditch subbasin could still be beneficial for relieving localized ponding in depressional areas within the subbasin such as at Austin Ave, Pier Ave, and Jasmine Ave. However, establishing a new beach outfall could have other challenges including optimizing the pipe elevation and slope, protecting the pipe from exposure to waves and shifting sand, outfall erosion, and permitting.

Setback Dike Alternative 3 also provides rapid drain out, but because of the minimal storage capacity behind the setback dike, peak water levels are only marginally lower than unrestrained water levels in Sand Lake.

Setback Dike Alternative 4, which raises Sandlake Road and Roma Ave to function as the setback dike for areas upstream, would have no influence on water levels at the south end of Beltz Marsh. Under this alternative, peak water levels at the south end of the marsh would match water levels in Sand Lake. Because this alternative is coupled with dike breaching, this configuration would also provide rapid drain out after the peak of high tide and would also be an improvement compared to existing conditions during a 100-year storm event with King Tides. This alternative would allow tides to regularly enter private properties north of Roma Avenue under both variants 4A and 4B. Certain low-lying private properties along east marsh would be exposed to regular saltwater tidal water under variant 4B. Low-lying private properties along east marsh would be exposed to regular stormwater back up approximately equal to outboard tide levels under variant 4A.

Modeled Water Levels in the East Marsh/Upstream of Sandlake Road:

ESA also evaluated modeled water levels upstream of Sandlake Road in the East Marsh under all setback dike alternatives. Because Tillamook County Public Works and other stakeholders are planning to replace the existing culvert in this location, all modeled alternatives assume this culvert is upsized to a 12-foot span box culvert. This culvert upsizing generally results in similar water levels upstream of Sandlake Rd as are predicted downstream of Sandlake Rd for all setback dike alternatives. **Figure 49** shows modeled water levels in the East Marsh for all setback dike alternatives compared to existing conditions during the 2-year storm with 10’ tides. **Figure 50** shows modeled water levels in the East Marsh during the 100-year storm with King Tides.

Setback Dike Alternatives 4a and 4b (with and without a tide gate, respectively) result in similar water levels within the East Marsh due to the minimal storage capacity available within the East Marsh.

5.4.4 Setback Dike Alternatives Analysis Summary and Recommendations

Based on the results of the alternatives analysis, 2D hydraulic modeling, and stakeholder coordination, we recommended proceeding with Setback Dike Alternative 1. Setback Dike Alternative 1 is the only setback dike alternative location evaluated that has sufficient storage capacity to reduce peak water levels at the south end of the marsh/north end of TDM during extreme storm conditions. Coupled with a dike breach, this proposed configuration provides the best compromise for meeting restoration goals for restoring estuarine processes to the majority of the marsh and improving fish passage from Sand Lake into the marsh and tributaries.

The following sections describe additional design details for the setback dike and tide gate structure including geotechnical engineering recommendations, determining the exact alignment and tie in locations of the setback dike embankment, final proposed dimensions, and beaver management.

5.4.5 Geotechnical Engineering Recommendations for Setback Dike and Tide Gate Structure

Following the 30% Design, Shannon & Wilson conducted a geotechnical engineering investigation in the project area including a series of borings around the perimeter of the site on Beltz Dike at the proposed pedestrian bridge and at the Sandlake Road crossings of Reneke, Beltz, and No Name Creeks. Due to cultural resources and environmental permitting restrictions, and weather conditions, it was not feasible to collect borings in the marsh along the proposed setback dike alignment. S&W utilized the borings around the site perimeter and boring data from a previous project at Whalen Island, to develop conservative preliminary geotechnical engineering recommendations for the setback dike and tide gate structure. S&W will collect additional borings within the wettest portions of the marsh from the initial pre-loading settlement setback dike fill course during the first year of construction of the setback dike and update their recommendations as needed to address any important new data relevant to initial conservative settlement and stability design criteria.

S&W's ***Sitka Sedge Tidal Wetland Restoration (Dike Setback) Preliminary Geotechnical Engineering Report*** detailing their analysis and recommendations is included in **Appendix G**.

S&W conducted settlement analysis, seepage and slope stability analyses, and analyses related to the tide gate structure. S&W provided recommendations related to:

- clearing, grubbing, and stripping the surface prior to fill placement,
- subgrade preparation and stabilization measures,
- geogrid and geotextile placement,
- fill placement on the slopes at the eastern and western tie ins,
- dike embankment materials,
- potential trench drains on the inboard side of the dike,

- fill placement and compaction requirements,
- temporary cut slopes,
- wet weather earthwork and erosion control,
- vegetation and planting considerations, temporary construction drainage, pipe penetrations,
- settlement monitoring during construction, and
- geotechnical support during construction.

Notably, S&W recommend using 5H:1V side slopes on both the inboard and outboard sides to improve slope stability and allow for shrub planting on the side slopes without allowing deeper rooting plants to penetrate the setback dike's structural core (a 2H:1V prism within the larger dike embankment.

S&W's recommendations have been incorporated into the 90% Plans and Specifications and will be reviewed by S&W again prior to finalizing bid documents to ensure recommendations have been implemented.

5.4.6 Final Setback Dike Design

Based on Setback Dike Alternative 1, located immediately downstream of the existing main beaver dam, ESA refined the exact alignment location, setback dike footprint, tie-in locations, and channel reconfiguration to facilitate drainage during construction.

ESA sited the setback dike's location north of the beaver dam far enough away to accommodate channel excavation to avoid physically disturbing the beaver dam during construction and to maintain 50 to 100- feet of channel between the beaver dam and the tide gate structure. The eastern tie in location was moved southward to tie into Sandlake Road at a lower elevation than the previously shown alignment cutting straight across the marsh. The exact location of the eastern tie in was selected to preserve specific large, healthy trees on the Sandlake Road embankment slope. The western tie-in location was similarly selected to minimize tree impacts and specifically protect a very large, mature, multi-trunk spruce tree. Some tree impacts on both ends are unavoidable, but removed trees will be used in large wood habitat structures elsewhere in channels and on the floodplain. The resulting setback dike alignment and grading plan is shown in **Figure 51**. The setback dike design profile, including recommended layers of geogrid are shown in **Figure 52**. The setback dike typical sections, incorporating most of S&W's geotechnical recommendations are shown in **Figure 53**. Additional details from the geotechnical engineering recommendations will be included in the final specifications for construction.

The setback dike will be constructed over two years of construction, with an initial build phase to construct the majority of the embankment and preload the footprint of the tide gate structure to induce primary settlement of the underlying soils. In the second year, and after analyzing settlement monitoring data and subsurface boring data collected during Year 1, the embankment will be built to its final height, correcting any areas of settlement and overbuilding the height to

account for the amount of settlement predicted for the next 50 years to maintain a long-term target crest elevation of 15' NAVD88.

S&W recommends utilizing all imported fill meeting their suggested specifications for soil type, fines content, and plasticity index for the structural core (identified on ESA's plans as "Zone B"). The outer portions of the embankment, to the 5:1 side slopes may consist of onsite excavated material if it meets specifications for soil characteristics and does not contain organics. The outer 24 inches of the embankment may utilize native topsoil excavated from onsite from tidal channel excavations or subgrade preparations. This will allow for use of onsite soils and provide topsoil suitable for revegetating with native shrubs and herbaceous plants.

Updated Hydraulic Modeling for Final Setback Dike Design

Compared to the modeled Setback Dike Alternative 1, the eastern end of the setback dike was moved further south, but the central portion was moved slightly to the north. The 2D hydraulic model was updated to reflect the grading plan depicted in the 90% Plans to demonstrate that the setback dike as designed will perform very similarly to Setback Dike Alternative 1. Additional refinements of the 2D model include incorporating the channels to be excavated upstream and downstream of the tide gate structure, including excavating a continuous sinuous channel network through the center of Beltz Marsh while filling segments of the linear central drainage ditch. The backup culverts were assumed to be closed, to analyze the tide gate functioning solo.

Sample point locations within the 2D model used for water level and velocity plots are shown in **Figure 54**, and updated water level model results for the 100-year storm scenario are shown in **Figure 55**. The final setback dike and channel configuration performs very similar to the modeled Setback Dike Alternative 1, resulting in peak water levels south of the dike at a maximum of 11.0' during the 100-year storm with King Tides (more than 1 foot lower than the peak water level that occurs under the modeled existing conditions), with rapid drain out matching the receding tide in Sand Lake (compared to prolonged high water levels under the existing condition that takes more than 4 days to return to pre-storm levels). For a more moderate flood scenario, specifically an approximately 2-year storm with 10' tides, the project is predicted to result in water levels to peak approximately 0.5 feet below existing conditions, with rapid drain out matching the receding tide in Sand Lake. This would be a pronounced drying effect of private properties at elevations above 9'.

The main tide gate was designed to convey flows over 1,200 cfs, far exceeding the combined 100-year flows (which is less than 120 cfs). This was confirmed by testing a simulation with a maximum 15 ft inboard water level during February 2017 tides, to predict maximum tide gate drainage without overtopping of the setback dike. The backup culverts were not included in this model simulation to estimate the maximum capacity of the main tide gate structure independent of the backup culverts, but the backup culverts would provide additional capacity during such conditions when water levels exceed 10.5' and activate the backup culverts. In this extreme case simulation, the inboard volume drained out to an elevation of 8 feet within approximately 3 hours of simulation time, during which the outboard tide remained below 8 ft allowing water to drain out through an open tide gate. This scenario is unlikely but could occur under tsunami conditions. In the unlikely event that the setback dike and tide gate remain intact and can still hold water

following a tsunami event, the expected drain out time from a 15' water level to 11' water level (the low point of Sandlake Road) is approximately 1.5 hours following tsunami recession. The additional drainage capacity of the backup culverts could further reduce this time to approximately 1 hour. By contrast, the existing Beltz Dike and undersized tide gate would likely take many more hours, or even days, to drain out under an equivalent tsunami-driven full reservoir situation.

5.4.7 Tide Gate Structure Fish Passage Analysis and Design

ESA conducted additional hydraulic modeling and statistical analysis of tidal water level data to demonstrate compliance with ODFW fish passage criteria for tide gates. This work is documented in ESA's ***Sitka Sedge Tidal Wetland Restoration – Fish Passage and Tide Gate Design Memorandum*** (ESA, 2026a), which is included in **Appendix E.** This memo includes characterization of existing hydrology, description of the proposed restoration measures, summary of water level monitoring data and NOAA tide station data used, hydraulic modeling results including modeled velocities inside the tide gate structure, proposed operations of the tide gate's Muted Tidal Regulator (MTR) control system, a water level management plan, monitoring and maintenance plans, and descriptions of the proposed beaver exclusion measures and flow device.

ESA conducted hydraulic modeling and statistical analysis of tidal water level data, following guidance in the Tidal Areas Restoration Program (TARP) programmatic biological opinion prepared by the National Marine Fisheries Service (NMFS) (Corps of Engineers, 2018), to demonstrate that the proposed tide gate structure will meet ODFW fish passage criteria for velocity, water depth, and % of time the gate is open throughout the year and in a given month.

For the proposed conditions as depicted in the 90% Plans (a tide gate structure with a 12-foot-span box culvert and a single 8' tall x 10' wide side-hinged tide gate, with a 5.0' invert elevation, controlled by a Muted Tidal Regulator system operated with an MTR water level setting of 8.0'), the modeling results show that velocities through the tide gate structure will remain below 2 feet per second during all typical tidal conditions. Short duration peak velocities exceed 2 feet per second (fps) only when passing 1-year and 2-year stream flows and stormwater runoff, with peak velocities reaching as high as 2.3 fps through the fishway and up to 2.8 fps through the gate threshold transition. During extreme flood conditions (100-year flows and stormwater runoff coupled with 12' King Tides), modeled peak velocities through box culvert and tide gate threshold reached 3.7 fps and 4.5 fps, respectively.

Figures 56 and 57 show water levels immediately inside and outside of the tide gate structure, as well as modeled velocities inside the box culvert/fishway and at the tide gate threshold/transition during the February 2017 model calibration event that included typical winter tide conditions followed by a 1-year storm event. **Figure 58** shows water levels and velocities at the tide gate structure during the extreme flood model scenario including a 2-year storm followed by a 100-year storm event coupled with King Tides.

ESA utilized MATLAB modeling and performed a statistical analysis to estimate the tide gate open and close time for the full year. Using 10-years of NOAA tide data adjusted to the relative

location and specific conditions at the project site show that a tide gate with the proposed MTR water level setting of 8.0' NAVD88 would be open for 90.7% of the time (for the full year), with monthly values ranging from 83.5% in January, up to 93.6% of the time in June and July. Hydraulic modeling of water depth and velocity indicates that fish passage criteria will be met at all times during typical tidal conditions and stream flows lower than the 1-year flow, when the tide gate is open. ODFW fish passage criteria for tide gates requires the tide gate meet fish passage criteria at least 51% of the time.

The final design of the tide gate structure layout is shown in **Figure 59**, using a plan view excerpt from the 90% Plans. **Figure 60** shows a profile view of the tide gate structure and drainage channel through the structure, including beaver exclusion measures and fencing along the structure's headwalls and wingwalls. Additional structural engineering design drawings, notes, and details developed by PSE Consulting Engineers are included in the 90% Plans. PSE utilized geotechnical engineering recommendations from S&W, and tide gate layout information from ESA to develop structural designs. Final stamped structural calculations will be provided prior to final design.

5.4.8 Beaver Management and Exclusion Measures at the Tide Gate

With the proposed location of a setback dike and associated culvert/tide gate structure being in an area of heavy beaver activity, it is important to consider how beaver activity could affect the functionality and anticipated maintenance requirements of the proposed infrastructure. Beavers will likely remain at Sitka Sedge following dike breaching and reconnecting the marsh to Sand Lake. While beavers are typically associated with freshwater environments, growing research across the Pacific Northwest and beyond indicates that beavers utilize brackish water habitats more than once believed (Goldfarb, 2019). The Wetlands Conservancy has observed beavers in estuarine habitats in the Yaquina River near Newport, Oregon, and is conducting additional surveys to understand the extent of beaver use in Oregon's estuaries (Lipp, 2021). Furthermore, because the missing tide gate at Beltz Dike already allows water to enter the marsh from Sand Lake, significant changes in salinity conditions are unlikely to occur after dike breaching.

Beavers are well-known to plug culverts when they are able to and it is beneficial to their habitat conditions, by creating or expanding ponded water conditions, for example. King County, Washington's guidance document "Anticipating Beaver When Designing Restoration Projects" states "If there is a culvert within your project site, you should assume beavers will eventually try to plug it." (King County, 2022). At Smuggler's Slough within the Lummi Nation in Washington, a similar tide gate system located in brackish waters has experienced blockages caused by mud placed by beavers. That system has required dewatering and vacuum excavation to restore functionality, and fencing has been installed in attempts to exclude beavers from the tide gate and culvert structure (Rice, personal com. 2023).

If beavers are able to block a culvert/tide gate structure associated with a setback dike at Sitka Sedge, the functionality of the system could be compromised. Debris or mud could prevent the tide gate from closing during extreme high tides and allow these high-water levels to reach the

south end of the marsh. If the tide gate were blocked such that it didn't open properly, water could back up in the area behind the setback dike and lead to elevated water levels behind the setback dike. For these reasons, it is critical to consider how beavers would behave around the new infrastructure, what design features could make it less likely for beavers to affect the structure, and what long-term maintenance could be required to relieve blockages or debris accumulation in the vicinity of the setback dike and tide gate structure.

Beaver Management and Design Features to Minimize Risk of Blockage

Several creative systems have been developed across the country to manage beaver activity around culverts and drainage structures. These measures range from exclusionary fencing around culverts to prevent beavers from accessing the inlet or outlet, to more complex systems such as the 'Beaver Deceiver' invented by Skip Lisle of Beaver Deceivers International, which includes exclusionary fencing and flow devices that drain water from an upstream beaver pond to the culvert inlet. These systems are often custom designed to fit the specific characteristics and conditions of a site.

Other design features can be used to mitigate the impacts of beaver activity, or make it more challenging for beavers to block a structure including:

- Selecting the exact location of a culvert relative to existing beaver dams/lodges or pinch points,
- Increasing the culvert width, a minimum of 10 feet wide for example, to make it harder to dam,
- Over-widening or deepening the channel at the culvert inlet or outlet to make it harder to dam, or to provide extra clearance to avoid interference with opening or closing a tide gate,
- Providing a smooth concrete bottom of culvert structure with no substrate to make it more challenging to establish the foundation of a beaver dam.
- Allowing or encouraging dam building in acceptable locations
- Providing additional, redundant culverts that can maintain drainage if one of the culverts is blocked.

Beaver removal has occurred in many locations where conflicts arise between beavers and infrastructure, but removal is often only temporary. Furthermore, habit restoration specialists recognize the value of beavers for creating and improving habitat conditions for fish and other wildlife (ODFW, 2023). Beaver removal would be counterproductive to the project's habitat restoration goals.

Beaver exclusion devices can cause challenges for fish passage and are regulated in Oregon by ODFW requiring a fish passage plan and consultation with ODFW biologists. ODFW's fish

passage criteria require minimum spacing for fencing or mesh depending on the anticipated species and life stages of fish expected to be present at a given site (Apke, 2020).

Proposed Beaver Exclusion System and Fish Passage Documentation

The final proposed beaver exclusion system and flow device is discussed in great detail in the Sitka Sedge Tidal Wetland Restoration Fish Passage and Tide Gate Design Memo (ESA, 2026) and summarized here.

The proposed setback dike and tide gate structure are located in an area of existing beaver activity. The main beaver dam located approximately 50 feet south of the proposed tide gate structure has been present and persistent for the last 10 years or more, since the early stages of project planning and hydraulic analysis. Other smaller beaver dams have been observed throughout the project area, including beaver dams in the central ditch north of the proposed setback dike and beaver dams in the Reneke Creek, Beltz Creek, and No Name Creek flow paths. We expect that the main beaver dam and other beaver activity in the project area will persist after the dike breach and other restoration actions are completed.

In order to protect the proposed setback dike tide gate structure and MTR control system, and to prevent the tide gate structure from being blocked by beaver activity or debris from a beaver dam blow out, we propose to construct a beaver exclusion system at the tide gate structure consisting of:

- a 6”x6” mesh fencing across the channel downstream of the tide gate structure (downstream exclusion fence), with 6”x6” mesh fencing on the channel bottom to prevent beaver from digging under the fence,
- a 6”x6” mesh fencing across the channel upstream of the tide gate structure (upstream receiver fence)
- a 6”x6” mesh box with internal 6”x6” mesh baffles (square fence filter) to allow water to pass through and into a 24-inch diameter bypass pipe that penetrates the upstream receiver fence, and
- chain link fencing along the top of the tide gate structures headwalls and wingwalls (at the top and side slopes of the setback dike embankment), with gates to provide human access into the fenced area for maintenance.

The proposed beaver exclusion system at the tide gate structure is depicted in **Figures 61 and 62.** Additional details and notes describing the beaver exclusion system are shown on Sheet D4.1 of the 90% Design Plans.

ODFW has communicated that No Name Creek is a cutthroat-only stream. Based on fish use data and on-the-ground observations, No Name Creek and the beaver-impounded wetland area south of the setback dike and upstream of Sandlake Road are not suitable for adult salmon use.

Therefore, 6-inch spacing of vertical and horizontal members of beaver exclusion elements/fencing may be used at this site.

The beaver exclusion system is designed to be easily maintained with access to both sides of the exclusion fencing. The setback dike will have a gravel access road on top, providing vehicular access to the tide gate structure for monitoring and maintenance, including access by an excavator or vacuum truck in the event that such equipment is needed to perform maintenance or removal of mud or debris.

OPRD staff are present at the SSSNA most of the time, with the Park Manager's residence located within the park. OPRD staff will frequently monitor and maintain the tide gate and beaver exclusion system to maintain hydraulic function and fish passage.

5.4.9 Backup Overflow Culverts at Setback Dike

In addition to the main tide gate structure through the proposed setback dike, the project design includes two 36" diameter culvert pipes passing through the setback dike to provide emergency relief in the event that the main tide gate structure was blocked by beaver or other reasons. Each backup overflow culvert is designed to carry over 80 cfs which collectively exceeds the combined peak 100-year flows from No Name Creek and stormwater runoff from Tierra Del Mar during a 100-year storm event. The main tide gate structure is designed to have adequate hydraulic capacity to provide drainage flow capacity 10 times the collective peak flows from No Name Creek and stormwater runoff from Tierra Del Mar during a 100-year storm event.

The main tide gate structure has an invert elevation of 5.0'. Modeling of peak flood events indicate that water levels south of the setback dike will rarely exceed 10.0' except during extreme events such as a 100-year storm/streamflow event, which would lead to short-duration peaks up to 11.0'. The backup culverts are designed with invert elevations of 9.5' (downstream end) and 10.5' (upstream end), such that they will only convey flow during the largest or storm events or under emergency conditions if water levels in the upstream marsh exceed 10' elevation.

The backup culverts are designed in accordance with US Army Corps of Engineer's Engineering Manual EM1110-2-1913 Design and Construction of Levees, for pipes penetrations through a levee embankment, including appropriate bedding and backfill. The upstream and downstream ends of the culvert pipes will include concrete headwalls with riprap armoring around the headwalls and at the pipe outfalls. The upstream culvert inlet headwalls will include metal trash racks. Based on consultation with Beaver Deceivers International, we do not expect beavers would attempt to block the backup culverts because they would almost never convey any water and therefore would not attract beavers to block them. The backup culverts will only convey flow during extreme storm events or if the main tide gate structure were blocked for some reason.

The downstream ends of the backup culverts will include traditional top-hinged flap gates to allow for one-way drainage of water, from upstream to downstream. The top-hinged flap gates would reliably prevent tide water from flowing upstream through the backup culverts into the area upstream of the setback dike. **Figure 63** shows the plan view locations of the two backup culverts and a profile view of one of the backup culverts.

Due to the infrequent conditions when water will pass through the backup culverts and their intended function as emergency backup drainage features, we are seeking an exemption or waiver for meeting fish passage criteria at these crossings. Rationale for providing an exemption or waiver is outlined below.

OAR 635-412-0025 - Fish Passage Waivers and Exemptions states:

(1) The Commission (or Department as applicable) may grant exemptions from fish passage requirements at an artificial obstruction if it is determined that:

(a) A lack of fish passage has been effectively mitigated;

(b) The owner or operator has received a legal waiver for the artificial obstruction from the Commission or the Department; or

(c) There is no appreciable benefit to providing fish passage.

The lack of fish passage through the two backup culverts through the setback dike is mitigated by the establishment of an effective fish passage route through the setback dike via the main tide gate structure described in detail in Section 5. As documented herein, the main tide gate structure will provide fish passage approximately 91% of the time throughout the year by allowing fish passage at all times when tidal water levels are at or below 8' NAVD88 (just below MHHW) and only closing during peak tides exceeding this elevation.

The backup culverts are designed with invert elevations of 9.5' (downstream end) and 10.5' (upstream end), such that they will only convey flow during heavy storm events or under emergency conditions if water levels in the upstream marsh exceed 10.5' elevation. Furthermore, the area upstream of the setback dike, including No Name Creek which is characterized by ODFW as a cutthroat-only stream, is not suitable for adult salmon use. We do not believe providing fish passage through these elevated backup culverts would provide any appreciable benefit to fish passage through the setback dike.

5.5 Interior Marsh Habitat Enhancements

In addition to the primary project elements of dike breaching and setback dike construction, ESA considered additional habitat enhancements that could be implemented in the site's interior. Historical aerial photos show a progression of land conversion that occurred along with dike construction including filling historical channels, excavating linear drainage ditches, and removal of forest vegetation. Logs were likely removed from channels and the marsh as the land was converted for pasture use. Today linear drainage ditches are present on both inboard and outboard sides of the Beltz Dike. Parallel linear drainage ditches convey water through the center of the marsh's northern half, and a manifold network of drainage ditches is present at the southern end of the marsh. These southern drainage ditches are currently impounded by the main beaver dam which backwaters the ditches and maintains a nearly static water level at the south end of the marsh.

Interior marsh habitat enhancements featured in the final design include filling linear drainage ditches, excavating a network of sinuous tidal channels draining to the dike breach, and installing large wood habitat structures in the channels and on the marsh plain. Large wood is used in select locations for bank stabilization, including at the ends of filled ditch segments and on the banks near the proposed pedestrian bridge. Accessing the site's interior with heavy construction equipment will have some impact to the existing high-quality native plant communities and compact the marsh surface soils. We propose to use low-ground pressure or amphibious excavation equipment, use of wood or geotextile mats, and limiting access routes to the channel alignments and footprints to the extent feasible.

The proposed tidal channel network planform was designed using a combination of reference natural tidal channels, situating channels to follow existing low-lying or depressional areas to allow water to drain from the marsh plain into the channels, and avoiding specific areas of existing vegetation. Channel locations may be adjusted in the field during construction to avoid impacting specific plant communities or site features on the ground. Tidal channel sizing, dimensions, and depth are based on tidal channel design guidelines and hydraulic geometry relationships between tidal channels in reference marshes in west coast estuaries (Williams, et al., 2002).

Grading plans and cross sections of proposed tidal channels and filled ditches, as well as large wood placement locations and details are shown in the 90% Plans. Excerpts from the tidal channel grading plans are shown in **Figures 64 and 65**.

5.6 Reneke Creek Culvert Replacement and Floodplain Restoration

The culvert crossing at Reneke Creek and Sandlake Road is undersized and the roadway frequently overtops during high flow events on the creek. Replacing this culvert is a high priority for TCPW. Reneke Creek is also the largest of the three tributaries draining into Beltz Marsh and is this highest priority for fish passage improvement.

Under separate contract with TCPW, ESA conducted a geomorphic assessment of the Reneke Creek and developed a proposed concept for realigning the creek away from the roadside ditch across its historical floodplain to the natural low point in the landscape where the current culvert crossing is located (ESA, 2024a). ESA conducted hydraulic modeling to develop preliminary designs for replacing the existing culvert with a clear-span bridge crossing to improve fish passage and flood conveyance. This memorandum is included in Appendix I: *Reneke Creek Culvert Replacement – Hydraulic and Geomorphic Analysis Memorandum, May 29, 2024*.

ESA provided recommended channel dimensions, anticipated peak water levels, and suggested freeboard requirements to DEA's bridge and roadway engineers. DEA prepared a Type, Size, and Location Report, recommending a 49-foot span, 2-lane roadway bridge, while raising approximately 600 feet of Sandlake Road up to 2 feet to an elevation of 18' (DEA, 2024). ESA and DEA prepared 30% Design Plans and Engineer's Estimate of Probable Construction Cost for the bridge, roadway, and stream realignment/floodplain restoration work.

At 60% and 90% Design, the Reneke Creek design was incorporated into the Sitka Sedge Tidal Wetland Restoration project plans. ESA refined the channel realignment plan to include a new sinuous main channel and two side channel branches, with each of the channel paths terminating at the edge of the forested wetland to tie into the existing remnant channels present within the forested wetland area. The main channel is sized to match the active channel width of Reneke Creek of 12 feet, with a depth that would overtop its banks during approximately 1-year stream flows, allowing for frequent side channel and floodplain activation. The design also includes using logs salvaged from onsite tree removals to add large wood habitat structure in the channel and on the floodplain to create fish habitat, streambed heterogeneity, and restore roughness to the floodplain that would have existed prior to deforestation, clearing, and grading to use the area as pasture. The channel realignment grading plan from the 90% Plans is shown in **Figure 64**.

Downstream of the stream diversion point, the existing Reneke Creek channel would be filled at least to the top of bank, with additional berms to block and redirect flows away from the existing flow path and roadside ditch. In conjunction with road raising, the roadside ditch would be filled to prevent the stream channel from migrating back to this location. The roadside drainage from the area to the north (from the park host camping area) would be redirected southward, away from the roadside ditch area and into the existing wetland where water would eventually drain to the low point and channel/road crossing.

Due to funding limitations and the estimated construction costs of the project, we anticipate that the Reneke Creek bridge and roadway work will be built separately in a future construction project in 2029 or later. However, the Reneke Creek channel realignment and floodplain restoration work will remain included in the SSTW project anticipated for construction in 2027 or 2028.

5.7 Revegetation

ESA developed revegetation plans in collaboration with OPRD and TEP staff. Revegetation zones and associated plant communities were developed based on anticipated conditions and elevation relative to tidal inundation frequency, soil saturation, and salinity exposure. Species were selected based on site observations and documentation of existing vegetation in the Vegetation Inventory and Botanical Resource Assessment for Sitka Sedge State Natural Area (Bacheller, 2016), with subsequent refinement of the species lists through coordination with OPRD and TEP.

Planting areas and plant communities include:

- Setback dike side slopes:
    - Two zones of shrub planting (Upper: 12’-15’ and Lower: 8’-12’) on the majority of the setback dike slopes
    - 10-foot horizontal clear zone along the dike-top access road, to be seeded only with the “Upper Seed Mix” at elevations between 12’-17’.

    - Seeded areas (no shrubs) around the proposed tide gate structure to maintain clearance for inspections. Supplemental herbaceous plug planting is being considered in lower areas and channel banks that will be disturbed by construction and will be inundated too frequently for seeding to be effective.

- Dike breach area and disturbed side slopes of the existing dike:

    - Two zones of shrub planting (Upper: 12'-15' and Lower: 8'-12')

    - Tidal marsh planting zone from 6'-8' on the banks and marsh plain bench between the channels and toe of the existing dike embankment

- Reneke Creek floodplain restoration area:

    - Upland Riparian Forest plant community of trees, shrubs, and a seed mix in floodplain and riparian areas expected to have upland conditions following construction

    - Swamp Forest plant community of trees, shrubs, and seed mix in areas expected to be wetland following construction

Detailed plant lists, notes, planting plans, and details are included in the 90% Plans.

5.8 Stakeholder Input on Alternatives Analysis

This project phase builds upon an extensive stakeholder engagement process including town hall meetings, technical advisory team meetings, and coordination with interested parties including local residents, government agencies, and non-profit organizations. OPRD, interested parties, and partners have been working for the last 9 years to find a solution to issues related to Beltz Dike at SSSNA, including as many as 20 meetings open to the public.

The current project phase has included two technical advisory team meetings and three public townhall meetings to keep stakeholders informed on the alternatives analysis and design process, and to solicit feedback from stakeholders on the alternatives analyzed.

Townhall Meeting 1 and Technical Advisory Meeting 1 were held in October 2022 to provide an update to stakeholders that the project was starting back up again with project management and funding secured by Tillamook Estuaries Partnership. ESA presented at Townhall Meeting 1 to provide an overview of the project phase ahead and the restoration alternatives being considered. TDM residents were also notified that ESA was conducting a stormwater drainage system assessment and TEP provided contact information for TDM residents to share photos and accounts of drainage and flooding issues. ESA subsequently met onsite individually with many interested residents to discuss flooding and drainage issues within TDM.

In April 2023, Townhall Meeting 2 was held as a hybrid in-person and virtual event. ESA provided a summary of the TDM stormwater drainage system assessment. No design conclusions or restoration alternatives analyses were presented at this meeting.

Following the conclusion of ESA's alternatives analysis and hydraulic modeling effort, ESA presented the results at Technical Advisory Team Meeting 2 in May 2023. Technical experts and agency representatives participated in a discussion on each of the proposed alternative design elements. The group discussed the need to balance ecological restoration, wetland impacts, and protection of infrastructure and private property. This virtual meeting was recorded and made available to the public on TEP's website.

In June 2023, ESA presented the results of the alternatives analysis and hydraulic modeling effort to the public at Townhall Meeting 3. This meeting was held in person at Kiawanda Community Center in Pacific City, Oregon, with an option for people to watch online. ESA presented the results of the TDM drainage system assessment including a series of potential improvements to improve drainage and flooding conditions in TDM that are unrelated to the SSTW restoration project. ESA also presented the alternatives and hydraulic modeling results for the dike breach and optimizing the location of the setback dike. Stakeholder feedback at Townhall Meeting 3 largely focused on the proposed setback dike alternatives.

In an effort to minimize wetland impacts associated with the project, as well as to consider all reasonable options for meeting the project goals and addressing the challenges associated with building a setback dike across the south end of the marsh, ESA developed Setback Dike Alternative 4 which raises Sandlake Road and Roma Ave above 15' NAVD88 (the proposed minimum elevation for a setback dike). This alternative was developed as a book-end scenario for pushing the setback dike as far south as possible and included a tide gate at the East Marsh crossing. However, 2D modeling showed minimal differences in resulting water levels at the south end of Beltz Marsh or in the East Marsh whether a tide gate was included or not. Setback Dike Alternative 4b, without a tide gate, essentially functions as a non-setback dike alternative that simply raises up the roadways that would be affected by the higher tides at the south end of Beltz Marsh caused by breaching Beltz Dike. While some stakeholders saw potential merit for considering Setback Dike Alternative 4, this alternative was not received favorably by the TDM Neighborhood Association representatives who felt this alternative was back-tracking on OPRD's previous decision to pursue a setback dike alternative.

In August 2023, OPRD issued a letter to Sitka Sedge State Natural Area neighbors and friends summarizing the steps along the way that led to OPRD's 2020 decision to pursue the setback dike alternative for further analysis, the reasons ESA developed and evaluated Setback Dike Alternative 4, and OPRD's decision to reject Setback Dike Alternative 4 and stay focused on a traditional setback dike alternative like Setback Dike Alternative 1 (OPRD, 2023).

Additional tech team meetings and public townhall meetings were held to present the 30% and 60% Design updates, and one additional set of tech team and town hall meetings is planned for fall 2026.

6. 90% DESIGN

6.1 90% Design Drawings

Upon selection of the preferred alternative and with subsequent refinements of design details described herein, ESA prepared a set of 30%, 60%, and 90% Design Drawings advancing the suite of proposed design elements towards bid-ready construction documents.

90% Plans include the following list of sheets:

- Cover
- General Construction Notes
- Existing Conditions and Survey Control
- Site Plan and Overview
- Access, Staging, Demolition, and Protection Plan
- Construction Logistics Plans
- Dike Breach Plan, Profile, and Cross Section (with pedestrian bridge)
- Pedestrian Bridge Structural Plans and Details
- Channel and Ditch Fill Grading Plan (with Wood Habitat Structures)
- Channel Grading Profiles and Sections
- Habitat Details
- Setback Dike Plan, Profile, Sections, and Tie-In Grading Details
- Tide Gate Structure Plan
- Tide Gate Structural Engineering Details
- Reneke Creek Bridge and Roadway Plans and Details
- Revegetation Plans, Notes, Schedules, and Details

The 90% Plans are submitted with the County Land Use Applications, Joint Permit Application (JPA), Fish Passage Applications, and 1200-C Permit Application. Final Designs will address comments received on the 90% Designs, include a level of detail appropriate for advertising the

project for bidding by qualified construction contractors, and will be accompanied by technical specifications that provide additional detail on materials and construction requirements.

6.2 90% Engineer's Opinion of Probable Construction Cost

90% Design Preliminary Engineer's Opinion of Probable Construction Costs are included in **Appendix C**. The full project as depicted in the 90% Design Drawings, including the Reneke Creek stream, roadway, and bridge elements, is estimated to cost approximately $14.7 Million to construct. Table 3 provides a summarized cost estimate for the SSTW elements and the Reneke Creek project elements. TEP and OPRD are raising funds for construction, and the final packaging of the project will be determined by the level of funding obtained in time for initial bidding. The final design stage will include cost estimates corresponding to the bid package plans and remaining work items to be constructed at a later date.

These estimates include the primary design elements of:

- setback dike and associated drainage/tide gate structure(s)
- dike breach and pedestrian bridge, and removing the existing box culvert/tide gate and reconstructing the embankment
- Reneke Creek realignment, bridge, and roadway work
- ditch filling, tidal channel excavation, and large wood habitat structures

General construction work activities required to accomplish the project include:

- mobilization
- work zone traffic control, site access, and staging
- water management and work area isolation
- erosion and sediment control/pollution control
- construction surveying
- clearing and grubbing
- subgrade stabilization
- seeding/revegetation of setback dike and disturbed areas

Estimated lump sum costs and unit prices in the 90% Cost Opinion are based on a combination of resources including Oregon Department of Transportation (ODOT) Bid Item Prices/Bid

Tabulations from projects in 2022-2026 and actual construction contractor bids for similar types of projects in Oregon and Washington.

TABLE 3. SUMMARIZED ENGINEER'S ESTIMATES OF PROBABLE CONSTRUCTION COST FOR SSTW AND RENEKE CREEK PROJECT ELEMENTS

Sitka Sedge Tidal Wetland Restoration - 90% Design - Estimated Construction Cost

Construction Category		*Cost*
Mobilization/Demobilization	$	886,000
Access, Traffic Control, Water Mangement, Survey	$	847,000
Demolition, Clearing, and Grubbing	$	205,000
Tidal Channel and Ditch Fill Earthwork	$	584,000
Setback Dike Embankment, Imported Fill, Access Rd	$	2,555,000
Setback Dike Drainage Structure, Tide Gate, MTR	$	1,841,000
Backup Drainage Culverts and Flap Gates	$	113,000
Seeding and Revegetation	$	210,000
Wood Habitat Structures	$	100,000
Prefabricated Pedestrian Bridge and Foundations	$	2,407,000
15% Contingency for 90% Design Stage	$	1,462,000
Sitka Sedge TWR Total Construction Cost	**$**	**11,210,000**
Construction Engineering and Permit Compliance Services (20%)	**$**	**2,242,038**

Reneke Creek Bridge and Stream Realignment - 90% Design - Estimated Construction Cost

Construction Category		*Cost*
Mobilization/Demobilization	$	276,927
Access, Traffic Control, Water Management, Survey	$	314,695
Demolition, Clearing, and Grubbing	$	83,235
Roadway Improvements	$	403,119
Roadway Bridge and Pile-Supported Foundation	$	755,430
Stream Channel and Ditch Fill Earthwork	$	550,449
Wood Habitat Structures	$	127,500
Seeding and Revegetation	$	534,844
15% Contingency for 90% Design Stage	$	456,930
Reneke Creek/Sandlake Road Total Construction Cost	**$**	**3,503,129**
Construction Engineering and Permit Compliance Services (20%)	**$**	**700,626**

Total Estimated Construction Cost for SSTW and Reneke Creek	**$**	**14,713,129**
Total Recommended Funding Amount for Construction and Consultant Services:	**$**	**17,655,793**

7. REFERENCES

Apke, Greg. 2020. Beaver Working Group Meeting. Presentation by Greg Apke, ODFW Fish Passage Program Leader. February 12, 2020. https://www.dfw.state.or.us/wildlife/living_with/docs/2020_beaver_wg/6%20Fish%20Passage_Apke_BWG%20Feb%202020.pdf

Bacheller, Noel. 2016. Vegetation Inventory and Botanical Resource Assessment for Sitka Sedge State Natural Area. Oregon Parks and Recreation Department. September 2016.

Corps of Engineers, Federal Emergency Management Agency, and Federal Highways Administration. 2018. Endangered Species Act – Section 7 Programmatic Biological Opinion, Letter of Concurrence and Magnuson Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. Prepared for Tidal Area Restoration Authorized, Funded, or Implemented by the Corps of Engineers, Federal Emergency Management Agency, and Federal Highways Administration in Oregon and the Lower Columbia River.

Corps of Engineers, 2023. HEC-RAS River Analysis System: Hydraulic Reference (Version 6.4.1). U.S. Army Corps of Engineers Hydrologic Engineering Center.

David Evans Associates, Inc. 2023. Sitka Sedge Bridge Alternatives Memo. D202200434.00 (DEA Proj: ESCI-0003) Sitka Sedge Tidal Wetland Restoration. Prepared for ESA. May 30, 2023.

FEMA / Federal Emergency Management Agency. 2018. The Flood Insurance Study for Tillamook County, Oregon and Incorporated Areas. Effective dated September 28, 2018. FIS Number 41057CV001A. https://map1.msc.fema.gov/data/41/S/PDF/41057CV001A.pdf?LOC=12f4f7d2caaf6077e0b665a469f254af

ESA, 2024a. Reneke Creek Culvert Replacement – Hydraulic and Geomorphic Analysis Memorandum. Prepared for Tillamook County Public Works, May 29, 2024.

ESA, 2024b. Sitka Sedge Tidal Wetland – Hydraulic Analysis Memorandum. April 30, 2024.

ESA, 2025. Sitka Sedge Tidal Wetland Restoration 30% Basis of Design. Revised January, 2025.

ESA, 2026. Sitka Sedge Tidal Wetland Restoration – No Rise Rationale Memo and No Rise Certification. March 9, 2026.

Goldfarb, Ben. 2019. The Gnawing Question of Saltwater Beavers. Hakai Magazine. January 19, 2019. https://hakaimagazine.com/features/the-gnawing-question-of-saltwater-beavers/

Hughes, Z.J. (2012). Tidal Channels on Tidal Flats and Marshes. In: Davis Jr., R., Dalrymple, R. (eds) Principles of Tidal Sedimentology. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-0123-6_11

Interagency Advisory Committee on Water Data 1982. Guidelines for determining flood flow frequency: Bulletin 17B of the Hydrology Subcommittee, Office of Water Data Coordination, U.S. Geological Survey, Reston, VA., 183 p.

King County. 2022. Planning for Beavers Manual: Anticipating Beavers when Designing Restoration Projects. King County Department of Natural Resources and Parks, Water and Land Resources Division. November 2022.

Lipp, Kenneth. 2021. Coastal Beavers Found in Lincoln County. Newport News Times. November 26, 2021. https://www.newportnewstimes.com/news/coastal-beavers-found-in-lincoln-county/article_cbe0eaca-4d8f-11ec-9635-db72f29519c9.html

Multi-Resolution Land Characteristics Consortium (MRLC). 2021. NLCD 2019 Land Cover (CONUS). https://www.mrlc.gov/data/nlcd-2019-land-cover-conus.

National Oceanic and Atmospheric Administration (NOAA). 2023. Tides and Currents – South Beach OR (9435380). https://tidesandcurrents.noaa.gov/datums.html?datum=NAVD88&units=0&epoch=0&id=9435380&name=South+Beach&state=OR

National Oceanic and Atmospheric Administration. 2021. Tides and Currents – Garibaldi (9437540). https://tidesandcurrents.noaa.gov/noaatidepredictions.html?id=9437540&legacy=1

ODFW/Oregon Department of Fish and Wildlife. 2021. Oregon Fish Habitat Distribution and Barriers Web Map. https://nrimp.dfw.state.or.us/FHD_FPB_Viewer/index.html

Oregon Department of Fish and Wildlife (ODFW). 2023. Living with Wildlife: American Beaver. May 2023. https://www.dfw.state.or.us/wildlife/living_with/docs/beaver.pdf

ODOT/Oregon Department of Transportation. 2008. Regional Precipitation-Frequency Analysis and Spatial Mapping of 24-Hour Precipitation for Oregon. January 2008. https://digitalcollections.library.oregon.gov/nodes/view/209058

ODOT/Oregon Department of Transportation. 2023. Average Bid Item Prices. 2018-2023. https://www.oregon.gov/odot/Business/Pages/average_bid_item_prices.aspx

ODOT/Oregon Department of Transportation. 2023 Bid Tabulations. https://www.oregon.gov/odot/Business/Procurement/Pages/BT.aspx

Oregon Department of Transportation (ODOT). 2014. Hydraulics Design Manual. April 2014. https://www.oregon.gov/odot/hydraulics/pages/hydraulics-manual.aspx

Oregon Parks and Recreation Department (ORPD). 2017. PhoDAR DEM. Provided to ESA via email December 18, 2017.

Oregon Parks and Recreation Department (OPRD). 2020. Memorandum of Decision: Selection of a Course of Action for Sitka Sedge State Natural Area Dike Improvement. March 5, 2020.

Oregon Parks and Recreation Department (OPRD). 2023. Memorandum to Sitka Sedge State Natural Area neighbors and friends. August 15, 2023.

Pacific Groundwater Group (PGG). 2019. Sitka Sedge State Natural Area Hydrological Analysis Final Report. June 4, 2019.

Philip Williams & Associates (PWA), 1995. Design Guidelines for Tidal Channels in Coastal Wetlands. The U.S. Army Corps of Engineers Waterways Experiment Station.

Shannon & Wilson, Inc., 2015. Whalen Island Sand Lake Bridge Replacement. Geotechnical Report. August 2015.

Shannon & Wilson, Inc., 2025. Sitka Sedge Tidal Wetland Restoration (Bridges and Culverts). Preliminary Geotechnical Engineering Report. 2025

Shannon & Wilson, Inc., 2026. Sitka Sedge Tidal Wetland Restoration (Dike Setback). Preliminary Geotechnical Engineering Report. April 2026.

Statewide Land Surveying, Inc. (SWLS). 2023. Sitka Sedge Conditions Survey. January 30, 2023.

University of Oregon Libraries. 2020. Aerial Photography Collection. 1939, 1953, 1972 Aerial Photos for Tierra Del Mar, Oregon. Obtained in 2020. https://library.uoregon.edu/digital-library-services/aerial-photography-collection/aerial-photography-collection-details

US Army Corps of Engineers (USACE). 2000. Design and Construction of Levees. Engineering Manual. EM 1110-2-1913. April 30, 2000.

US Army Corps of Engineers (USACE). 2020. Conduits, Pipes, and Culverts Associated with Dams and Levee Systems. Engineering Manual. EM 1110-2-2902. December 31, 2020.

USGS 2023. USGS Peak Streamflow for the Nation USGS 14303200 Tucca Creek Near Blaine, OR. https://nwis.waterdata.usgs.gov/nwis/peak?site_no=14303200&agency_cd=USGS&format=html. Accessed April 20, 2023.

Washington Department of Transportation (WSDOT). 2023. WSDOT Hydraulics Manual. May 2023. https://www.wsdot.wa.gov/publications/manuals/fulltext/m23-03/hydraulicsmanual.pdf

Waterways Consulting, Inc., 2017. Sitka Sedge Natural Area, Summary of Work Completed to Date. Final. April 7, 2017.

Williams, P., M. Orr, and N. Garrity. 2002. Hydraulic Geometry: A Geomorphic Design Tool for Tidal Marsh Channel Evolution in Wetland Restoration Projects. Restoration Ecology, 10:3, pp. 577-590. September 2002.

Appendix A.
Figures

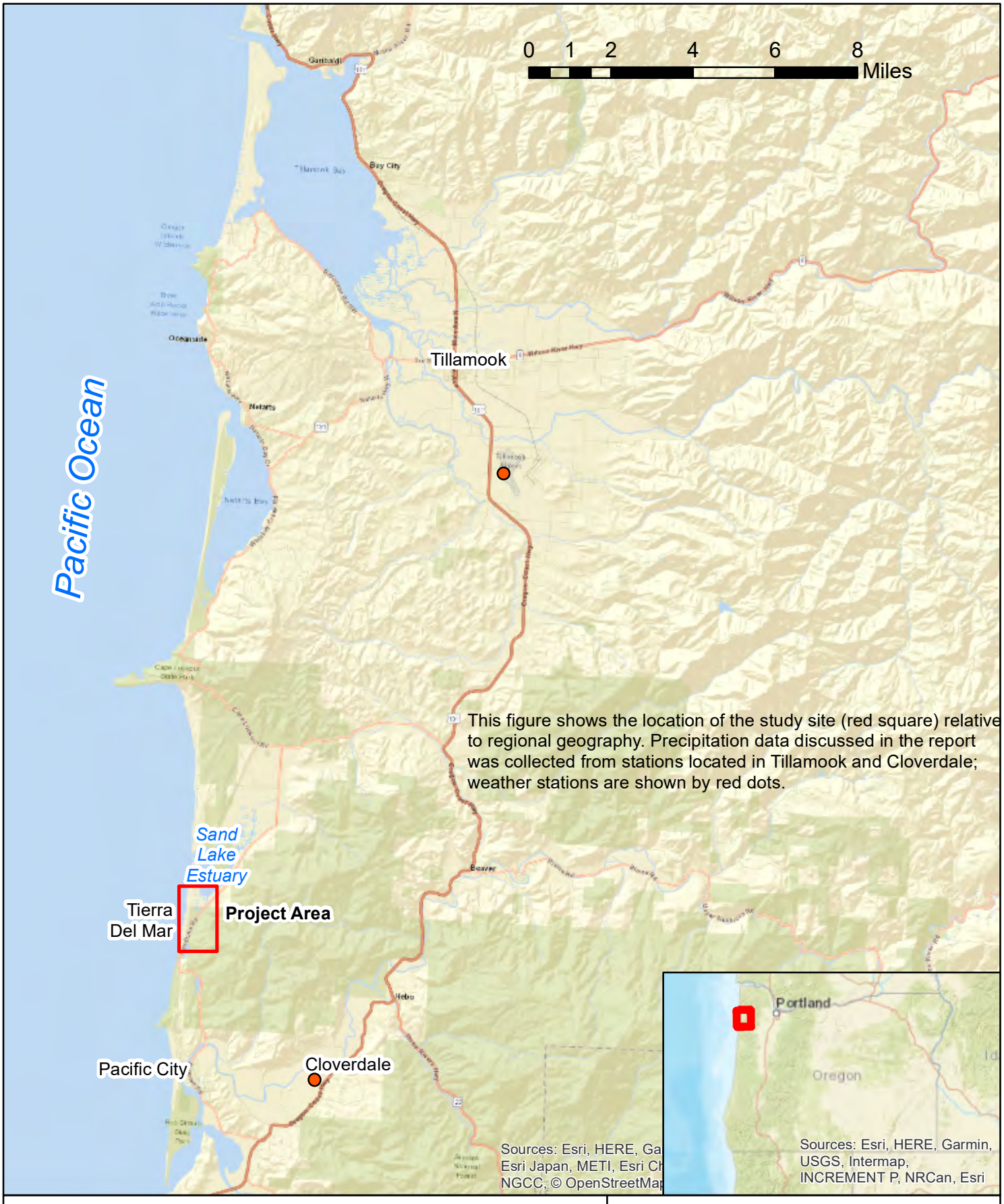


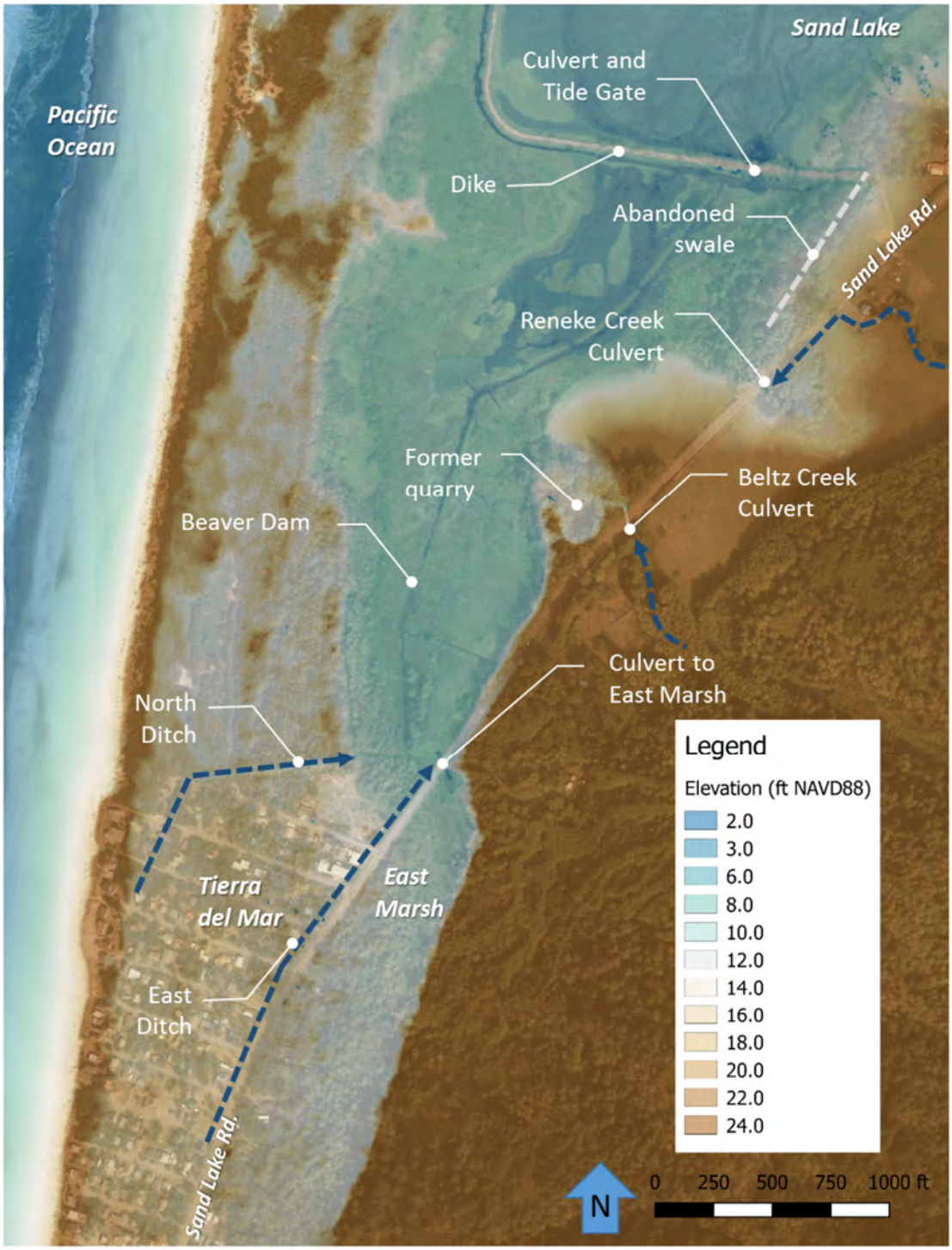
Figure 1
Project Location Map

Sitka Sedge Tidal Wetland Restoration
90% Basis of Design Report



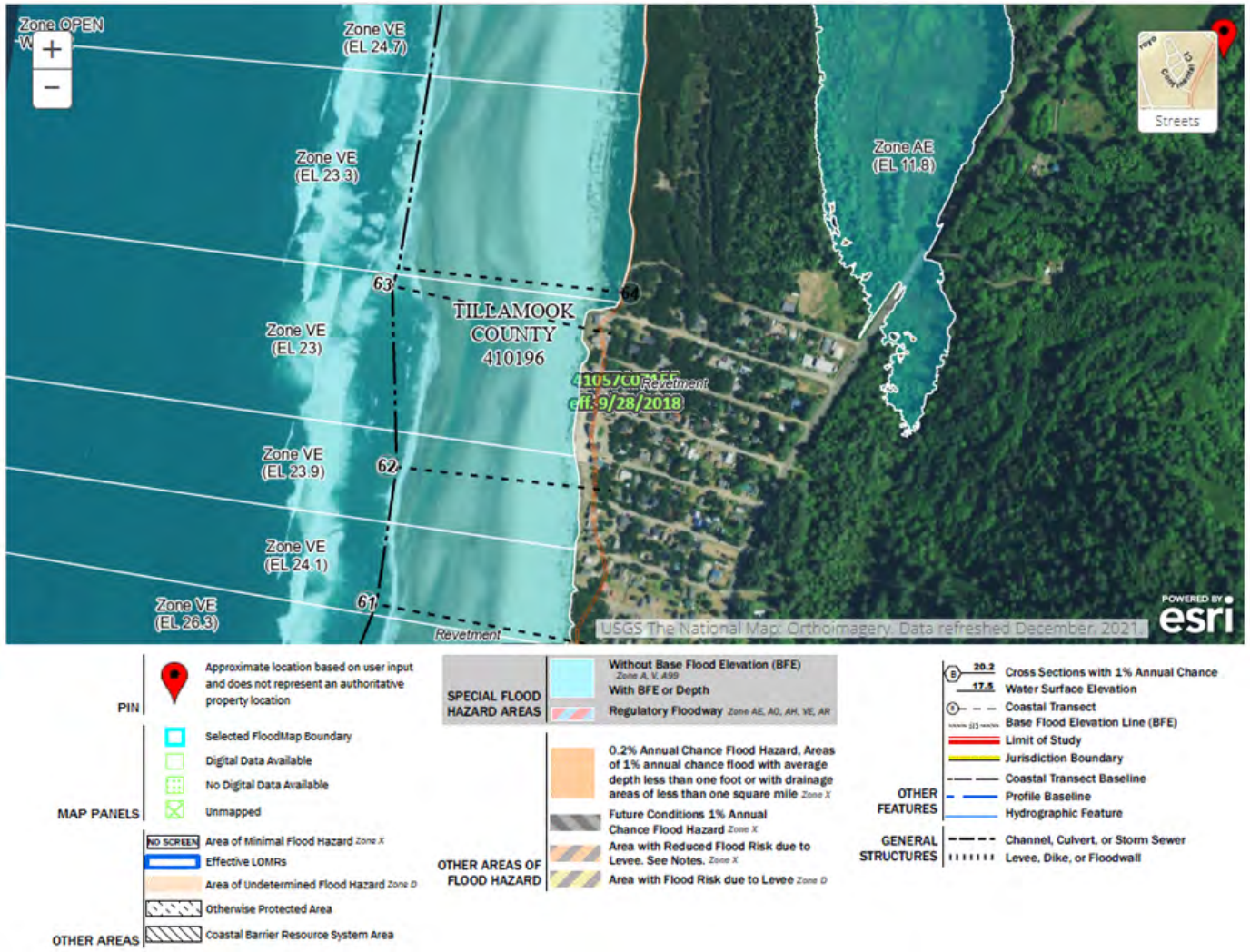
Note: *This figure is an aerial photo* identifying key site features of the project area.

Figure 2
Annotated Site Map and Aerial Photo



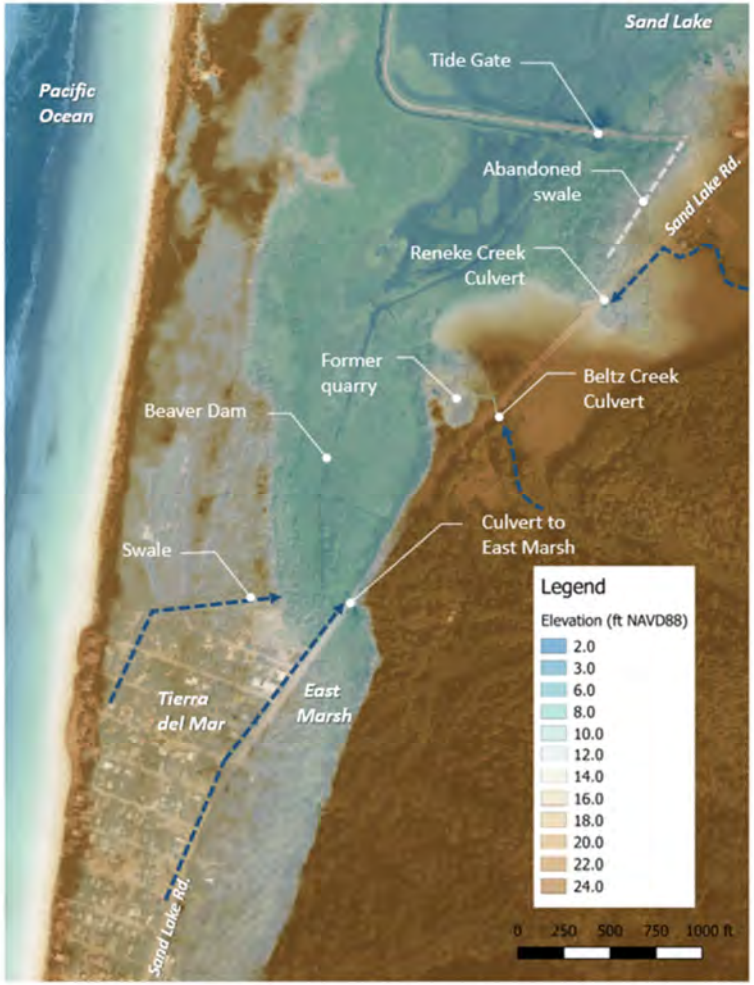
Note: *This figure is an aerial photo with a LiDAR elevation data overlay. Key site features are labeled for reference.*

Figure 3
Annotated Site Topographic and Hydrologic Map



Note: *This figure shows* the FEMA Flood Insurance Rate Map of the project area, including the mapped 100-year floodplain boundary which inundates the lowest lying portions of Tierra Del Mar and overtops the low point in Sandlake Road at the East Marsh crossing. The road low point elevation is 11.6' NAVD88 compared to the 100-year floodplain elevation of 11.8'.

Figure 4
FEMA Flood Insurance Rate Map Excerpt from North End of TDM



FEMA Base Flood EL. +11.8 ft

Low top of Dike EL. +12.8 ft
Bottom of Tide Gate EL. +1.3 ft
Scour hole EL. -4.5 ft

Low tide in Sand Lake EL. +5.5 ft
MSL in Ocean EL. +3.8 ft

Reneke Ck. Culvert Invert. EL. +9.6 ft

Beltz Ck. Culvert Invert. EL. +20.7 ft

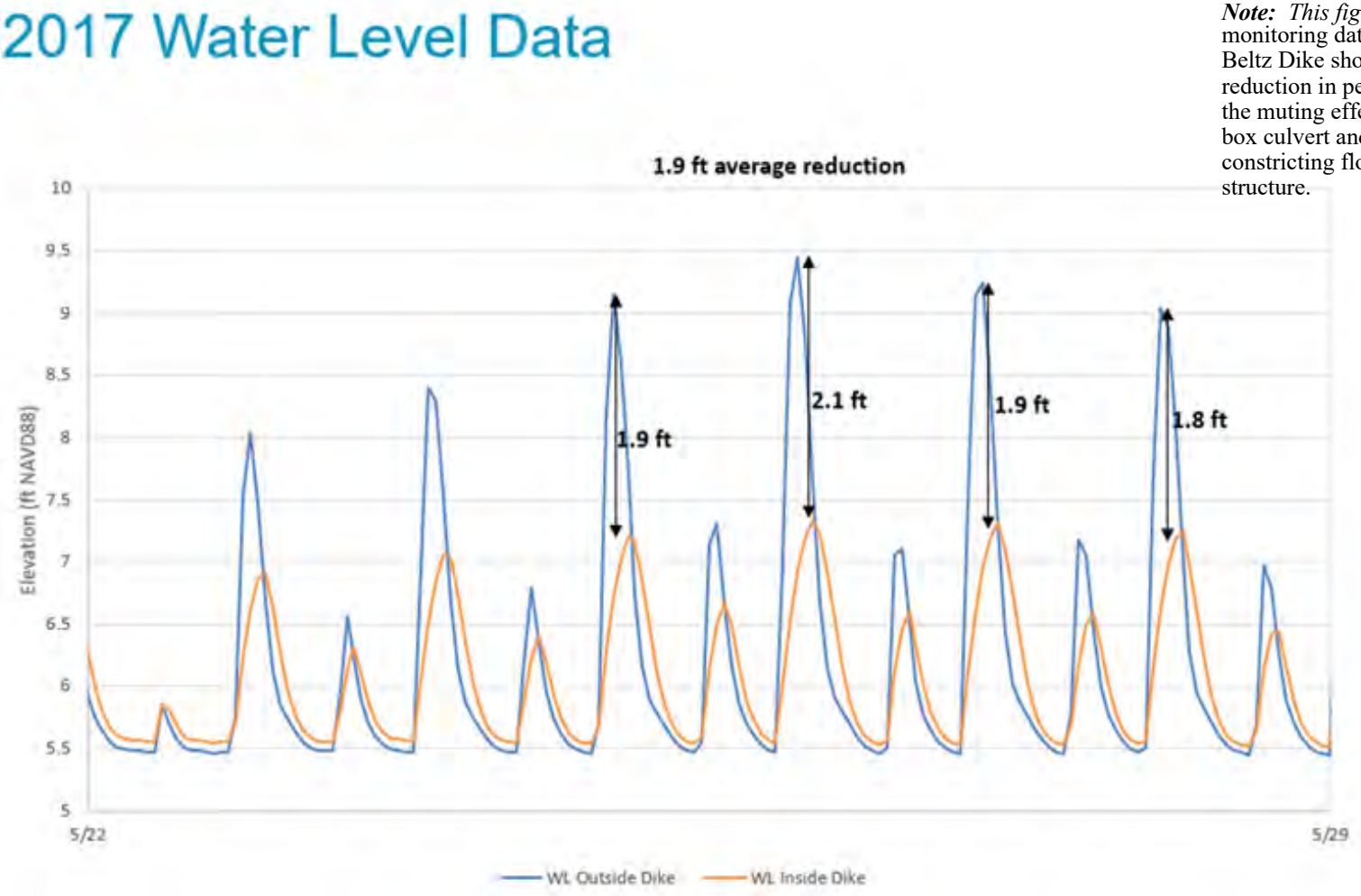
Top of Beaver Dam EL. ~8.0 ft

Culvert to East Marsh Invert EL. 5.15 ft
Low Point in Sand Lk. Rd EL. ~11.6 ft

Culvert Invert at Roma Ave = +11.7 ft
Land in Tierra del Mar EL. +14 to 22 ft

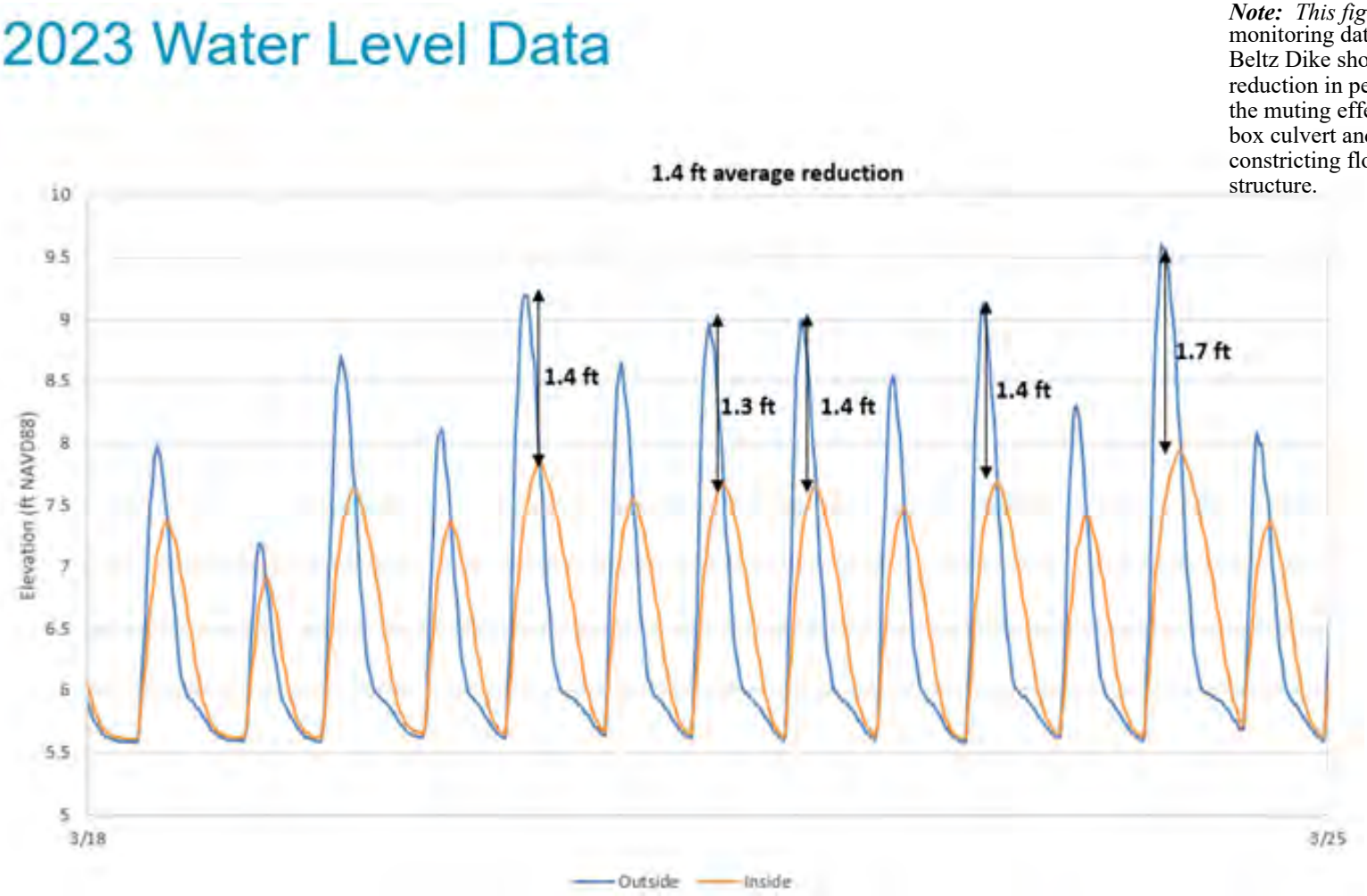
Note: *This figure summarizes the elevations of key features within the project area. All elevations are referenced to North American Vertical Datum 1988 (NAVD88).*

Figure 5
Elevations of Key Site Features and Water Levels (NAVD88)



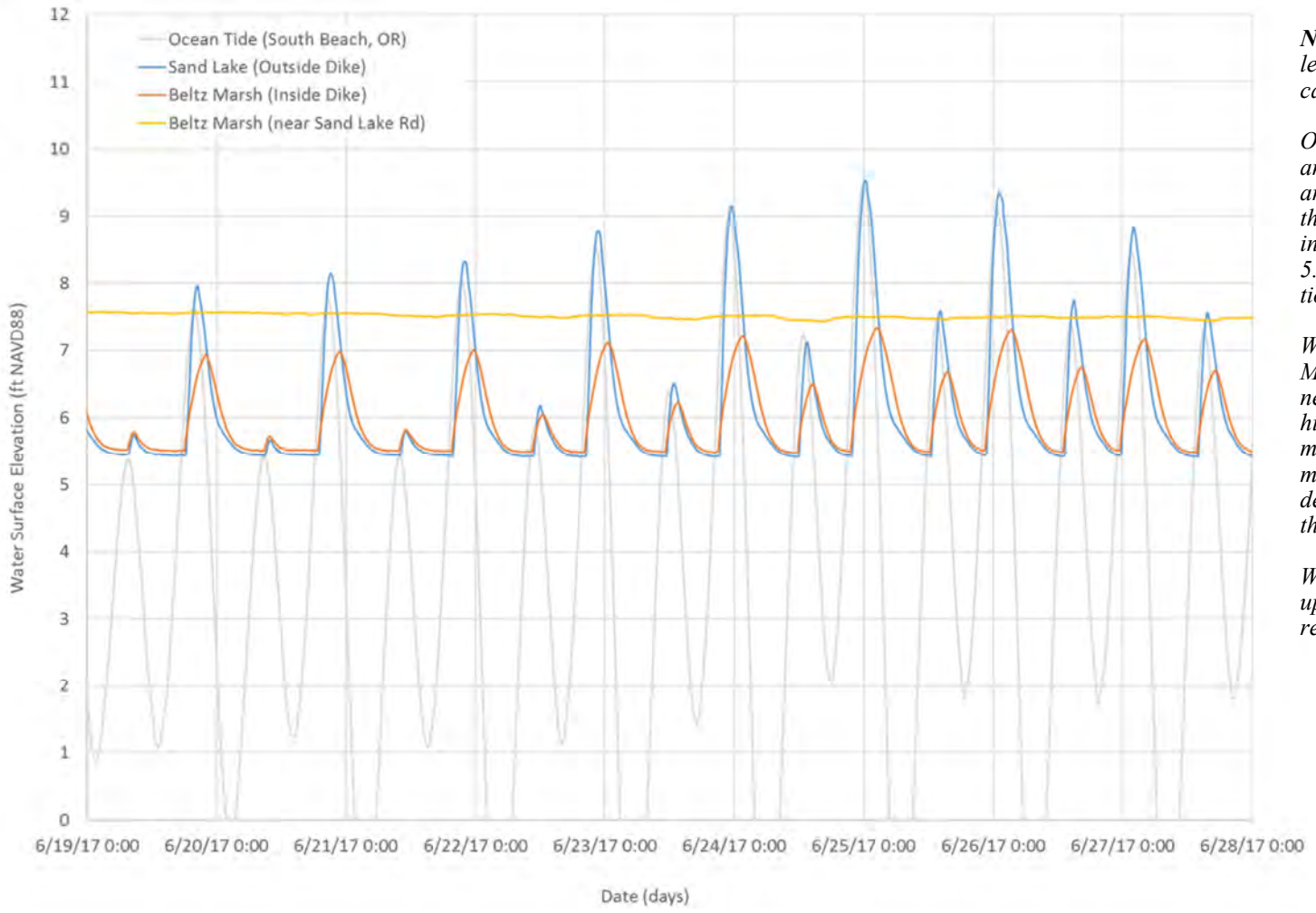
Note: *This figure shows* water level monitoring data inside and outside of Beltz Dike showing the typical reduction in peak tide levels caused by the muting effect of the undersized box culvert and and partial tide gate constricting flow through the drainage structure.

Figure 6
2017 Water Level Data Inside and Outside of Beltz Dike



Note: *This figure shows* water level monitoring data inside and outside of Beltz Dike showing the typical reduction in peak tide levels caused by the muting effect of the undersized box culvert and and partial tide gate constricting flow through the drainage structure.

Figure 7
2023 Water Level Data Inside and Outside of Beltz Dike



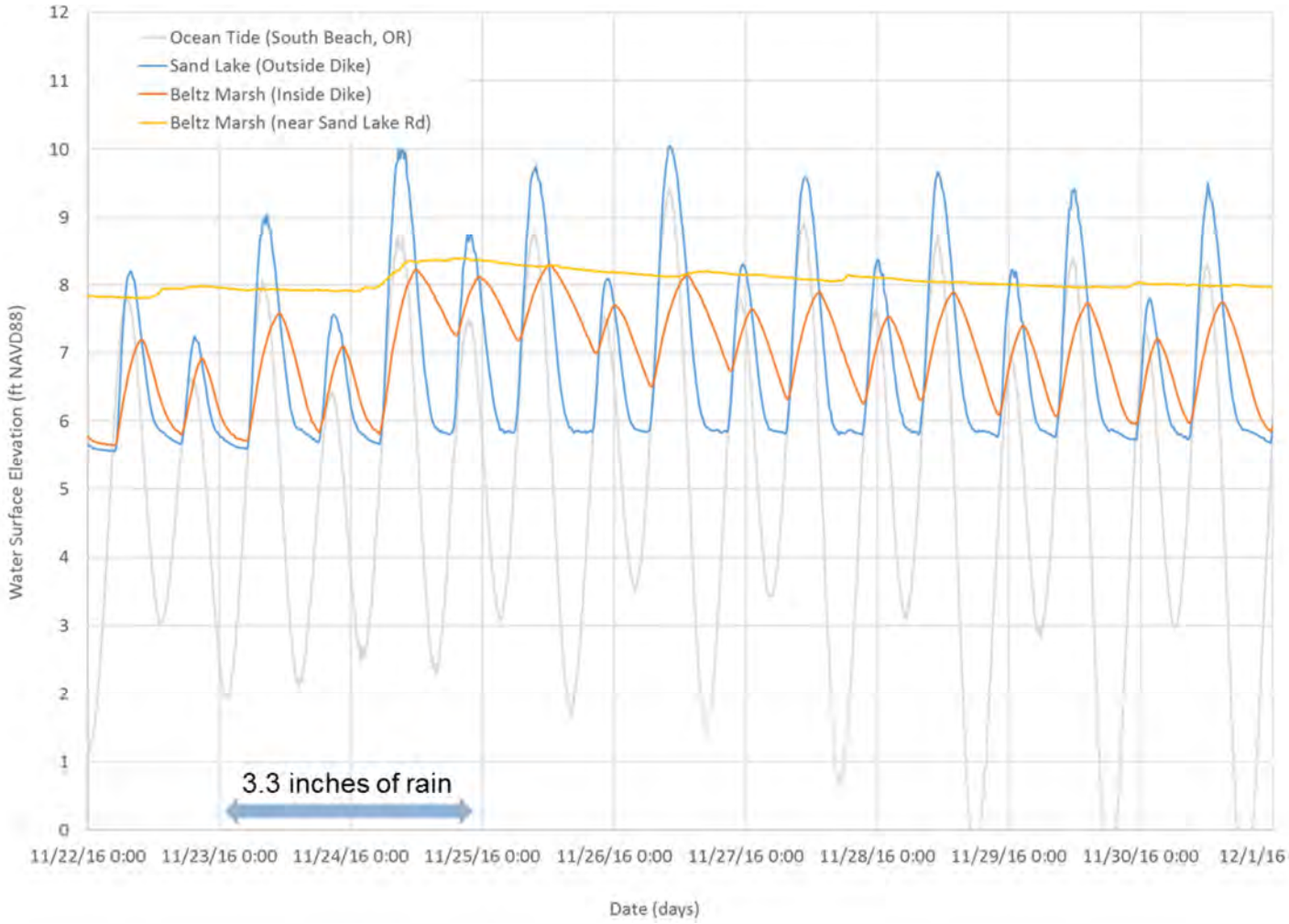
Note: *This figure shows water level data collected during a typical period during the dry season..*

Ocean tides fluctuate between 0' and 9.5'. Sand Lake water levels are typically slightly higher than the ocean at high tide. Low tides in Sand Lake never fall below 5.5' due to controlling bed elevations.

Water levels inside the dike/ Marsh show a muted tidal connection. The tide gate prevents high tides from entering the marsh. Water drains out of the marsh as tides recede, slightly delayed due to limited capacity of the culvert.

Water levels at Sand Lake Road upstream of the beaver dam are relatively constant at 7.5'.

Figure 8
Typical Water Level Fluctuations in Beltz Marsh During the Dry Season



Note: *This figure shows water level data collected during a typical period during the wet season..*

Ocean tides fluctuate between 0' and 9.5'. Sand Lake water levels are typically slightly higher than the ocean at high tide. Low tides in Sand Lake never fall below 5.5' due to controlling bed elevations.

Water levels inside the dike/ Marsh show a muted tidal connection and low capacity for drainage. The tide gate prevents high tides from entering the marsh. After a rainfall event, water accumulates within the marsh, and the undersized culvert prevents efficient drainage. Accumulated water takes several days, and several low tides, to drain.

Water levels at Sand Lake Road upstream of the beaver dam are relatively constant at 8', with a slight increase following a rainfall event.

Figure 9
Typical Water Level Fluctuations in Beltz Marsh During the Wet Season



Recent Events	48-Hr Rainfall (inches)
Dec. 18, 2015	4.1
Nov. 24, 2016	3.3
Dec. 20, 2016	2.3
Feb. 9, 2017	3.1
Feb. 16-19, 2017	2.4 + 1.6
Mar. 7, 2017	1.3
Mar. 15, 2017	2.9

Note: *This figure shows areas of surface-water ponding observed following rainfall events.*

These ponded areas generally correspond to depression areas without positive drainage.

Figure 10
Areas of Surface-water Ponding in Tierra Del Mar

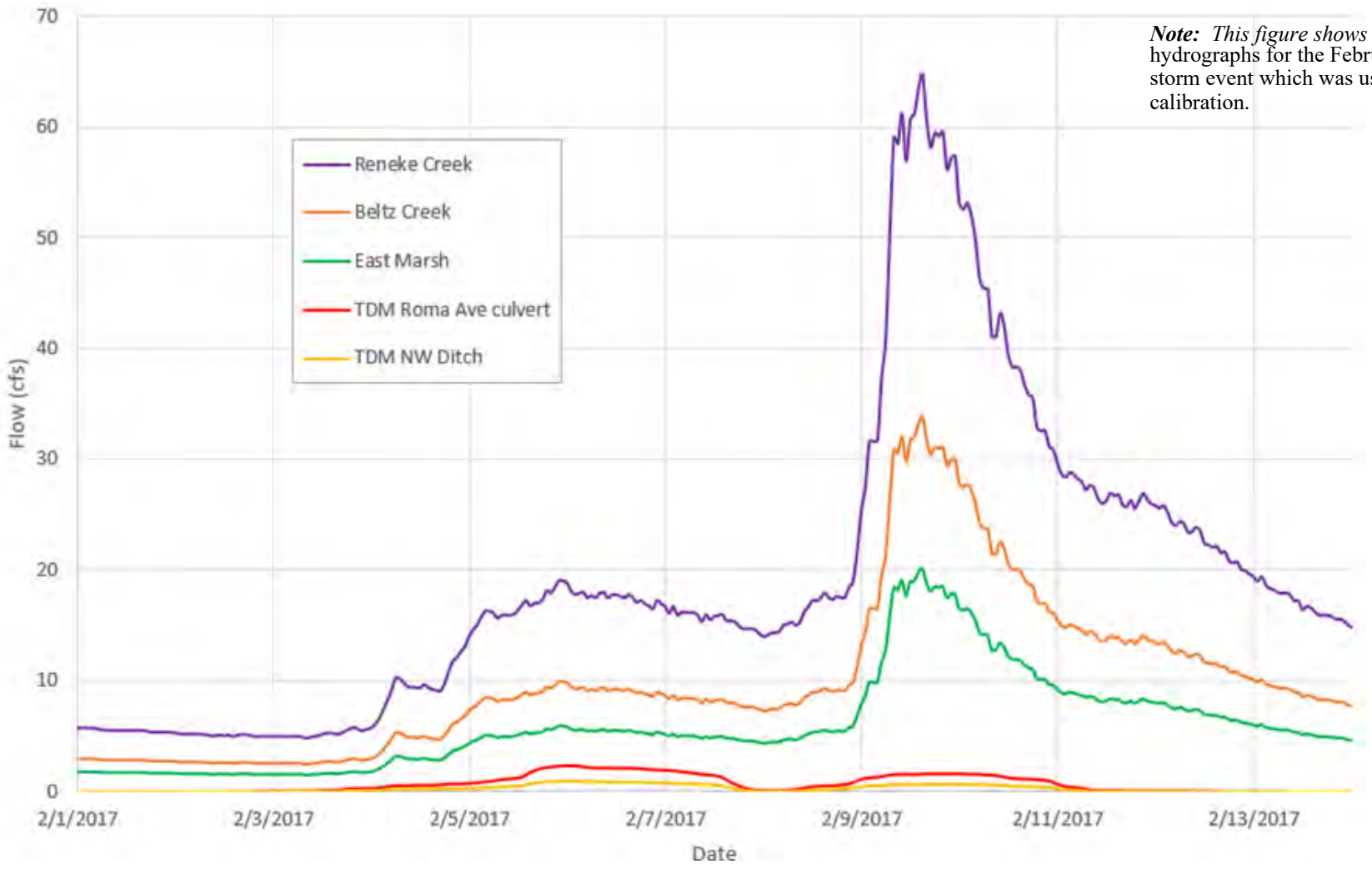




- Beltz Dike and tide gate
  - Limited tidal flux in/out of marsh
  - High tides behind dike are 1-2' lower than Sand Lake
  - Water still flowing into marsh when tides begin to fall
  - Culvert limits draining of marsh
  - Heavy rainfall events can take several tide cycles for freshwater to drain out of marsh
- Beaver Dam within marsh
  - About 3 feet tall
  - Limits tidal fluctuation at south end of marsh
  - Steady water levels 7 to 8' NAVD88
  - Backwater at culvert and east marsh
- Multiple Culverts (not shown)

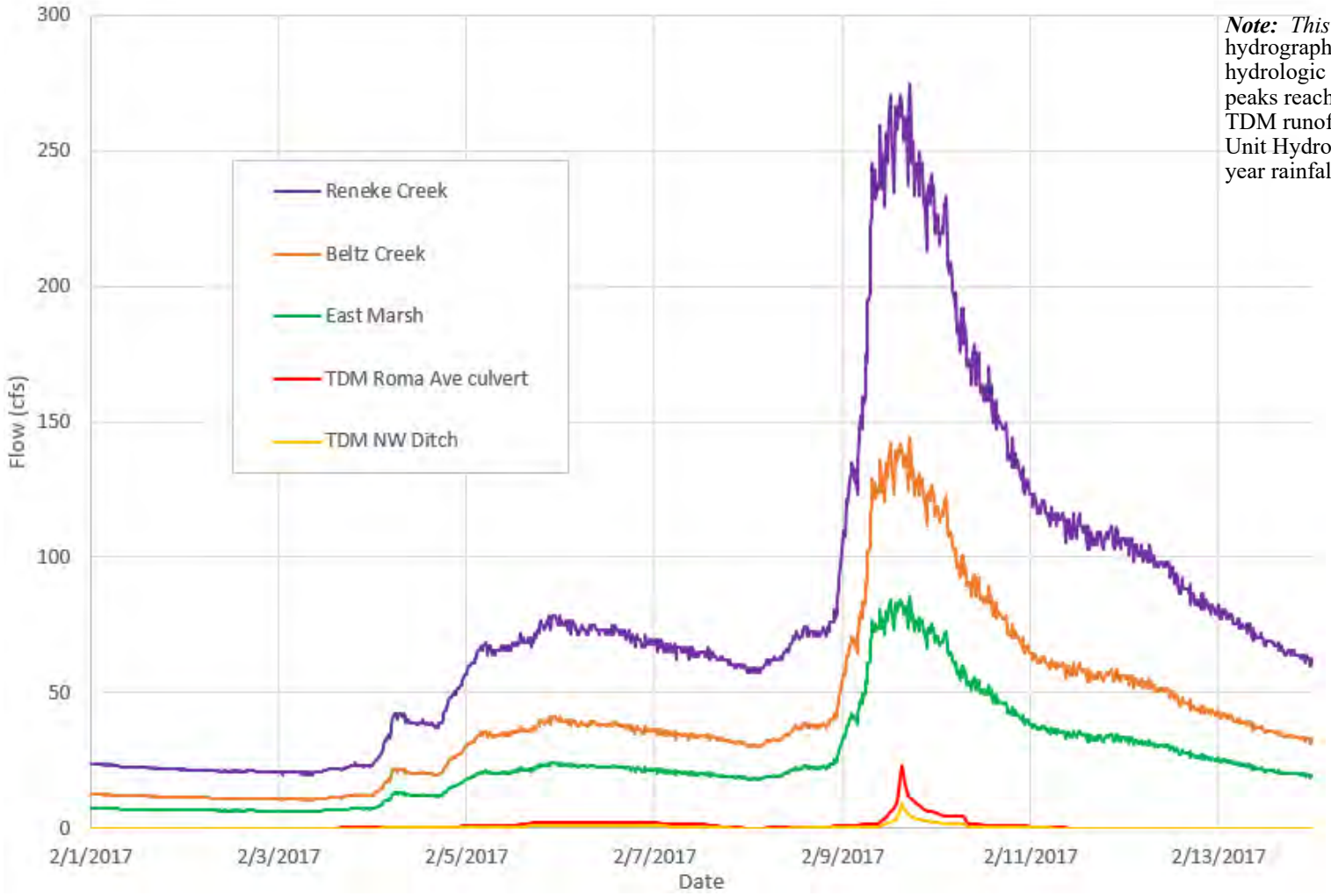
Note: *This figure provides summary information on the primary features that control surface-water movement into, out of, and within Beltz Marsh.*

Figure 11
Hydraulic Control Features Affecting Surface-water Movement



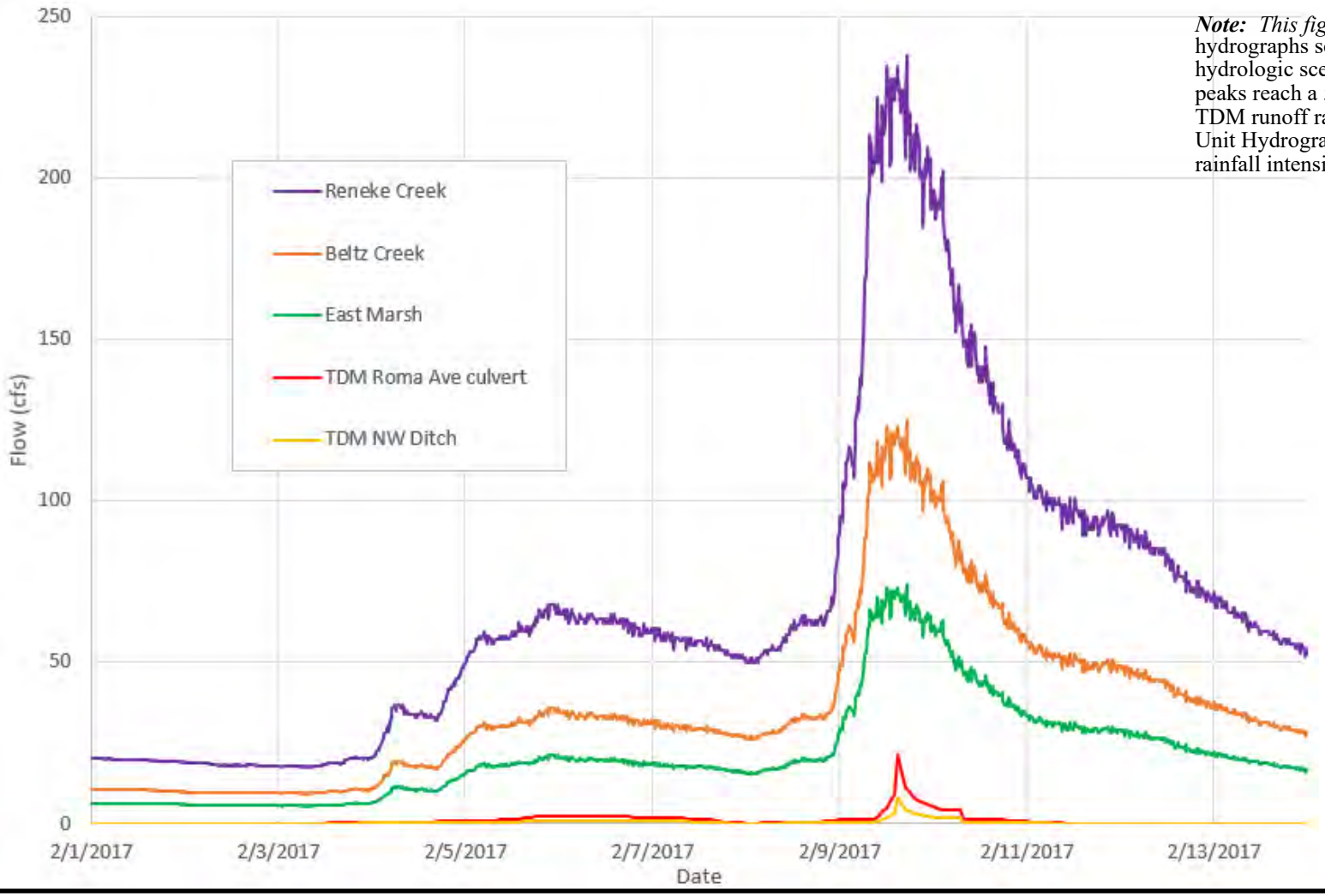
Note: *This figure shows* stream hydrographs for the February 2017 storm event which was used for model calibration.

Figure 12
2D Model Inflow Hydrographs, February 2017 Calibration Event



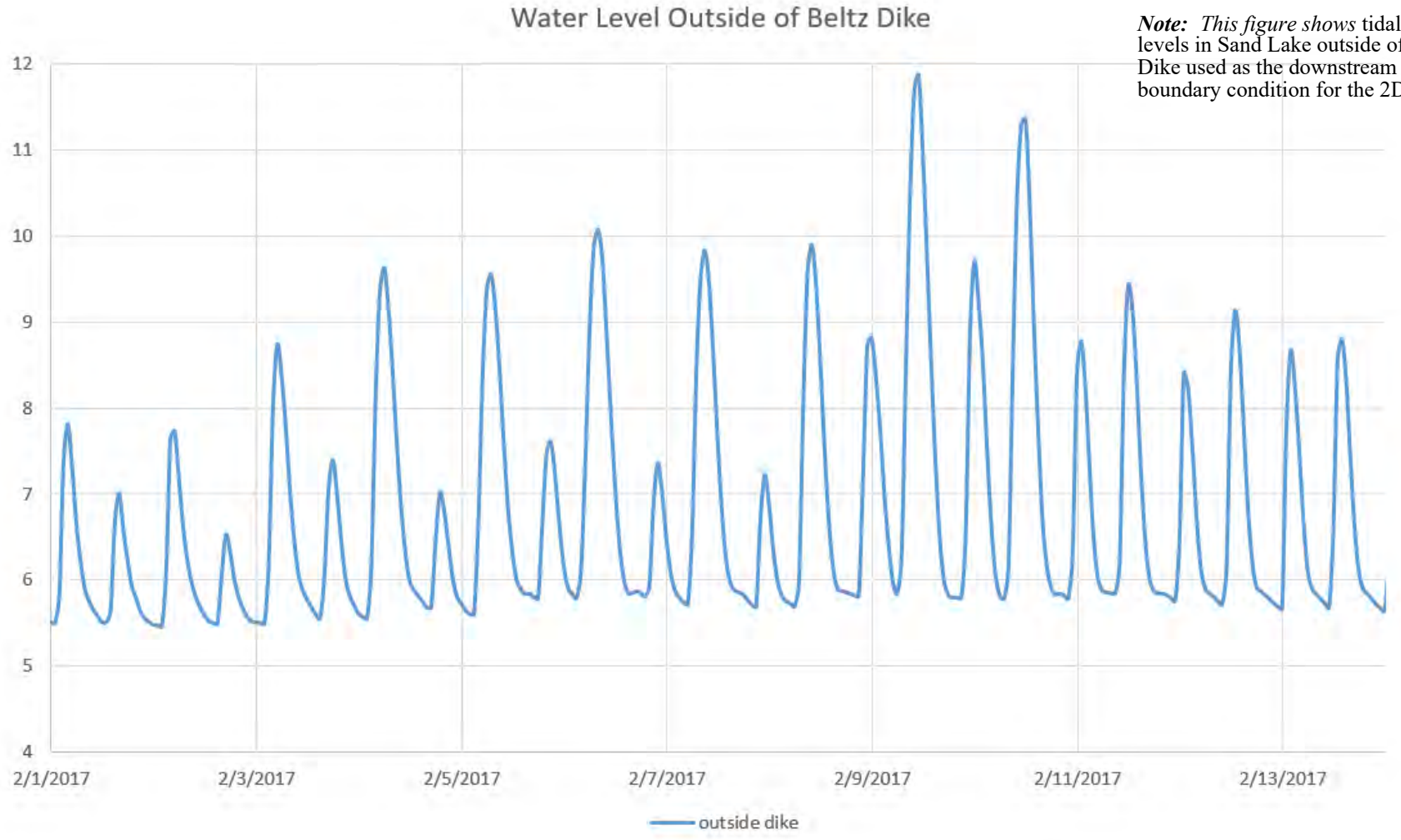
Note: *This figure shows* stream inflow hydrographs scaled for a 14-day hydrologic scenario where streamflow peaks reach a 100-year storm event. TDM runoff rates use a Santa Barbara Unit Hydrograph method with 100-year rainfall intensity.

Figure 13
2D Model Inflow Hydrographs for the 100-year storm even



Note: *This figure shows* stream inflow hydrographs scaled for a 14-day hydrologic scenario where streamflow peaks reach a 50-year storm event. TDM runoff rates use a Santa Barbara Unit Hydrograph method with 50-year rainfall intensity.

Figure 14
2D Model Inflow Hydrographs for the 50-year storm event



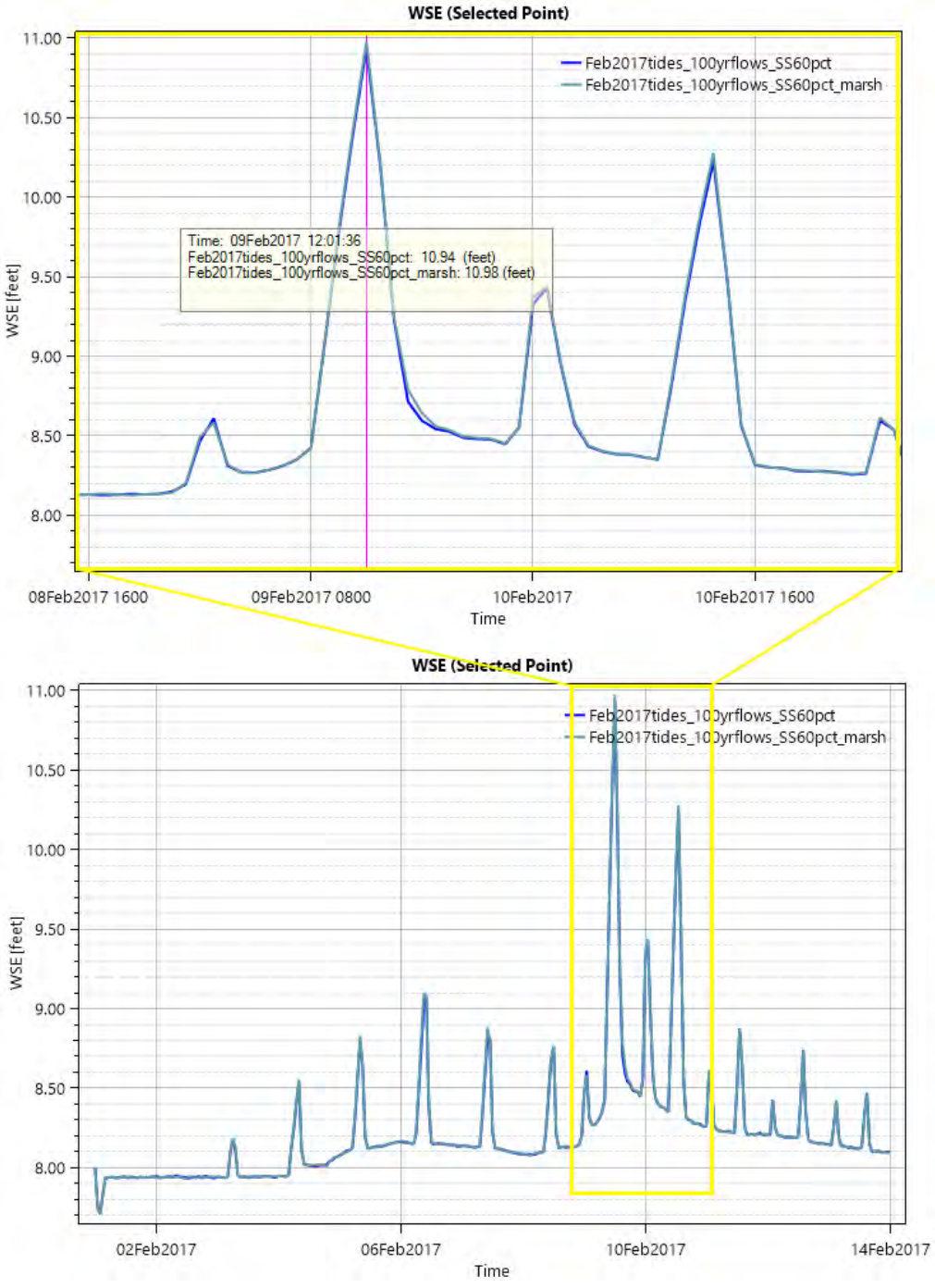
Note: *This figure shows* tidal water levels in Sand Lake outside of Beltz Dike used as the downstream boundary condition for the 2D Model.

Figure 15
2D Model Downstream Boundary Condition



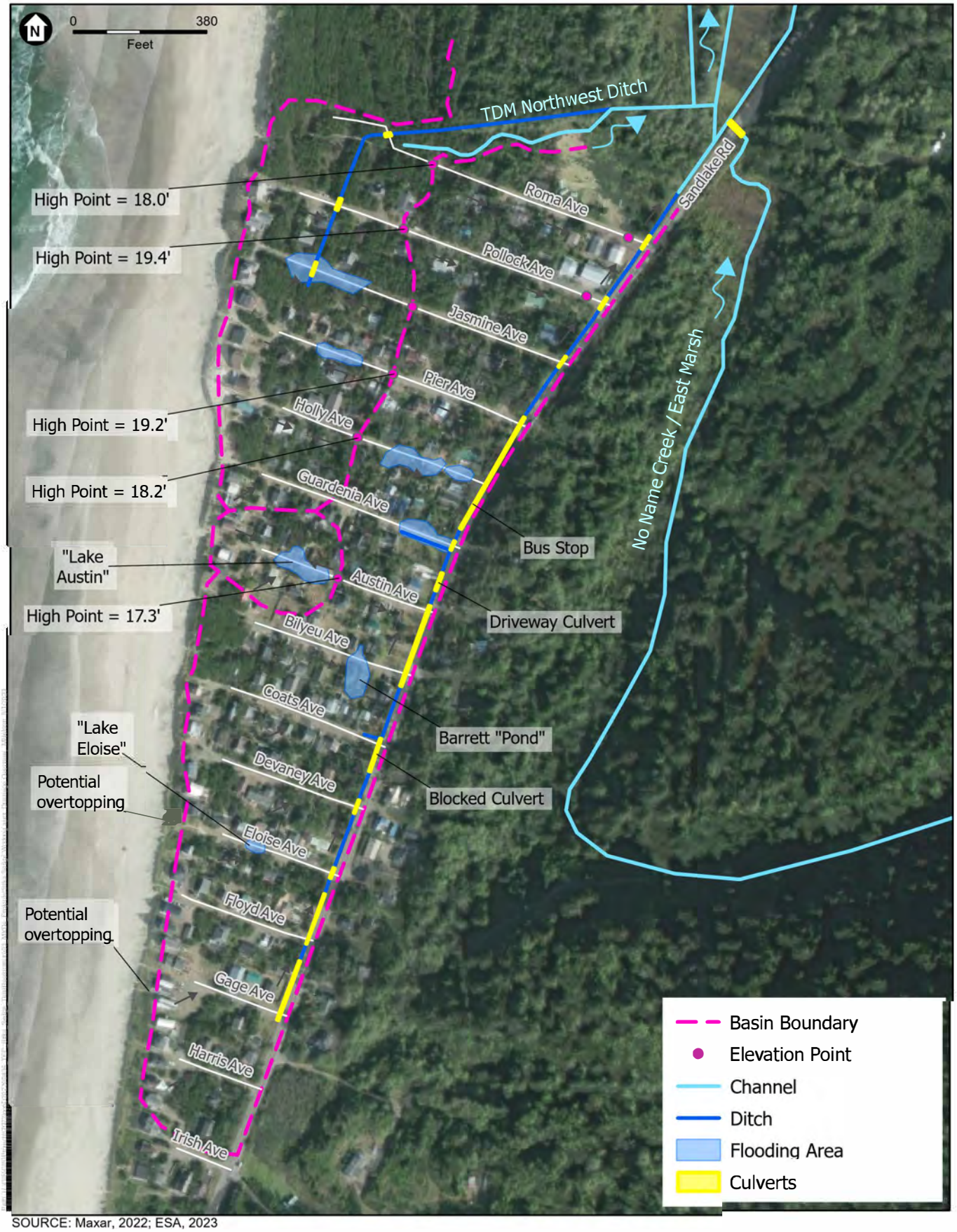
Note: *This figure* shows the extent of the 2D HEC-RAS Model, hydrologic inputs, and downstream boundary.

Figure 16
2D Model Extents, Downstream Boundary, and Hydrologic Inputs



Note: *This figure shows* that including precipitation-based hydrologic inputs directly on the marsh behind the setback dike and downstream of the Tierra Del Mar inflows results in an increased peak 100-year water level from 10.94 ft to 10.98 ft (an increase of 0.04 ft). This maintains a peak 100-year water level below 11 feet.

Figure 17
Hydrologic Input Sensitivity Analysis

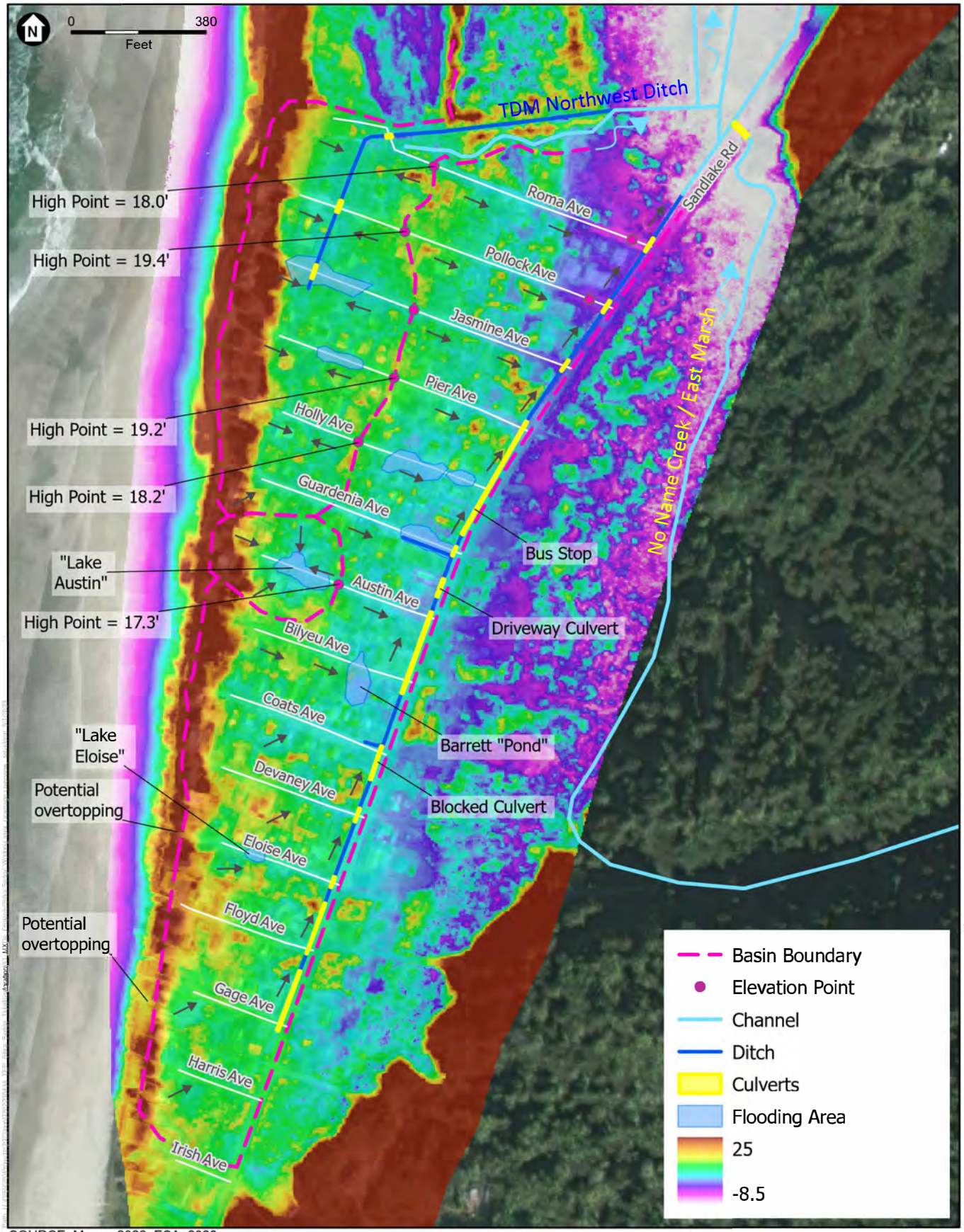


SOURCE: Maxar, 2022; ESA, 2023

Figure 18a

Tierra Del Mar Drainage System Analysis - Aerial Photo

Sitka Sedge Tidal Wetland Restoration
90% Basis of Design Report



SOURCE: Maxar, 2022; ESA, 2023

Figure 18b
Tierra Del Mar Drainage System Analysis - LiDAR



Note: *This figure shows* an example of a fractal, dendritic tidal channel network, a planform that commonly occurs in low-gradient tidal marshes where many small tidal channels drain individual subbasins and funnel water into progressivly larger channels that all drain to a single outlet.

This typical tidal channel planform supports a justification to focus dike breaching on a single dike breach channel rather than multiple dike breaches.

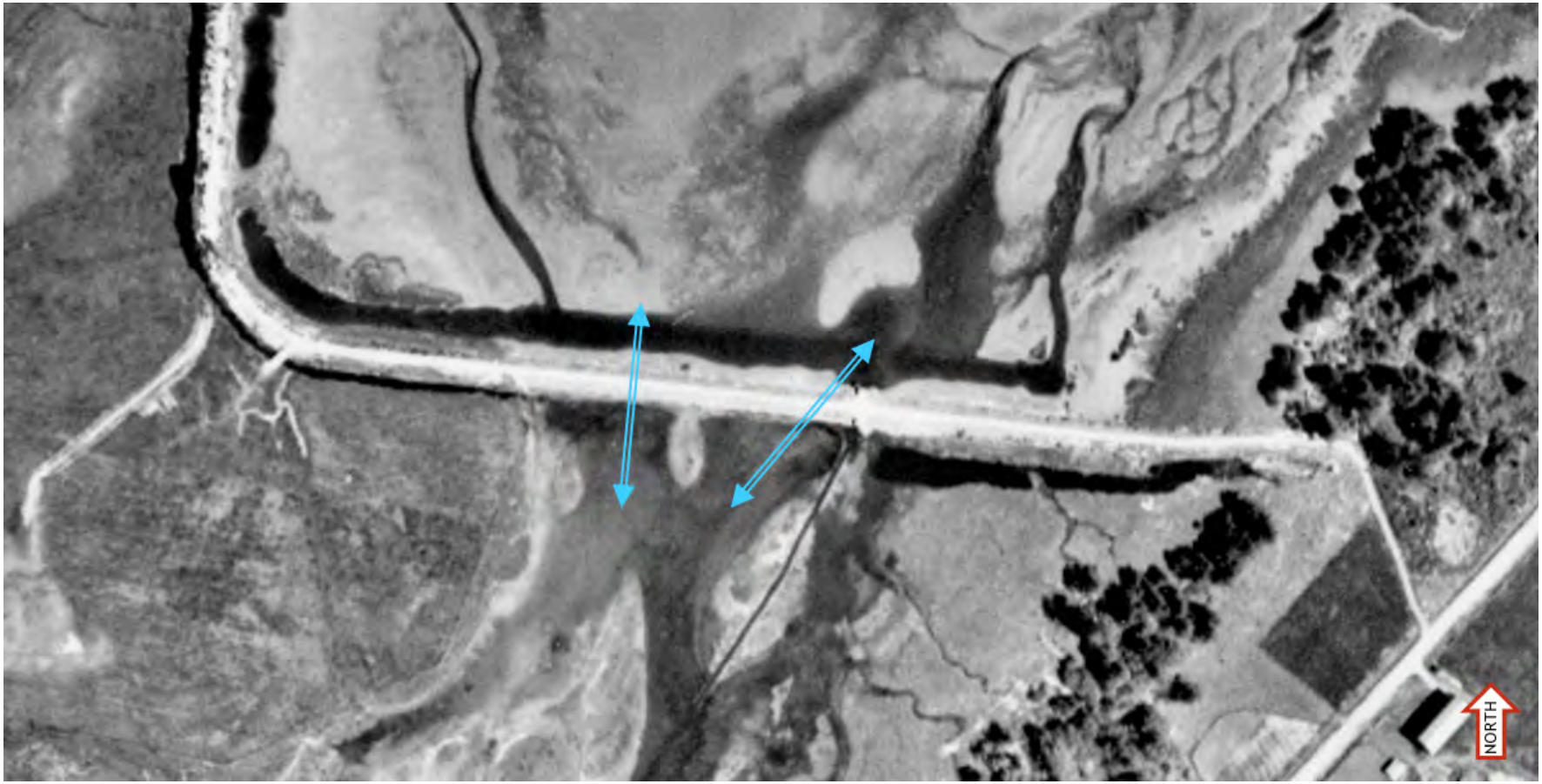
Figure 19
Example of Dendritic Tidal Channel Network Draining to Single Outlet



Note: *This figure shows* an example of a dendritic tidal channel network that exists nearby in the northeastern portion of the Sand Lake Estuary, a planform that commonly occurs in low-gradient tidal marshes where many small tidal channels drain individual subbasins and funnel water into progressivly larger channels that all drain to a single outlet.

This typical tidal channel planform supports a justification to focus dike breaching on a single dike breach channel rather than multiple dike breaches.

Figure 20
Example of Dendritic Tidal Channel Network in Sand Lake Estuary



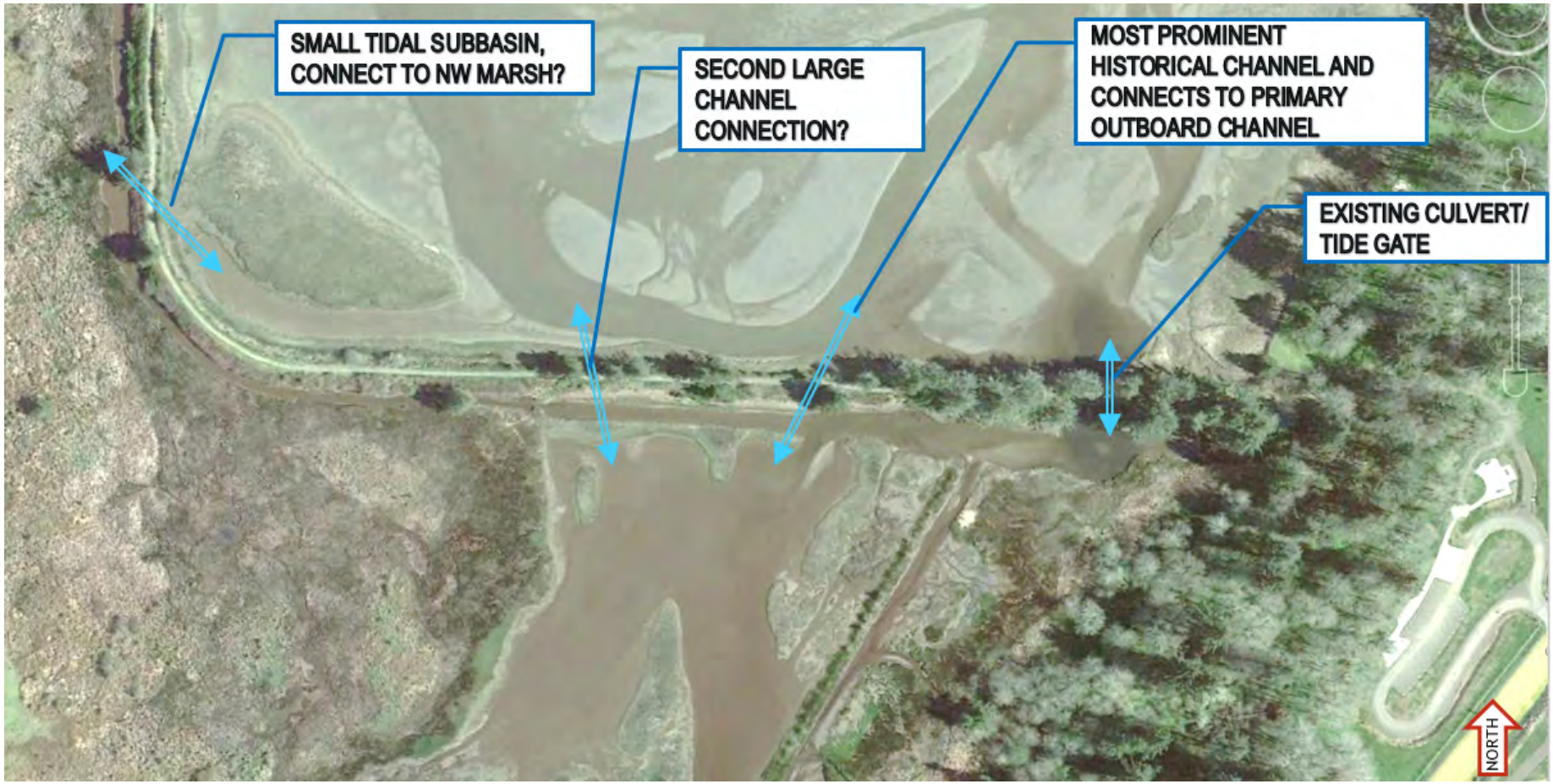
Note: *This figure shows* a historical aerial photo from 1939 (UofO Libraries, 2020), highlighting the apparent location where two large tidal channel forms cross Beltz Dike. This analysis is used to identify the appropriate location for a dike breach to restore tidal connectivity between Sand Lake and Beltz Marsh.

Figure 21
1939 Aerial Photo of Beltz Dike and Large Tidal Channel Planforms



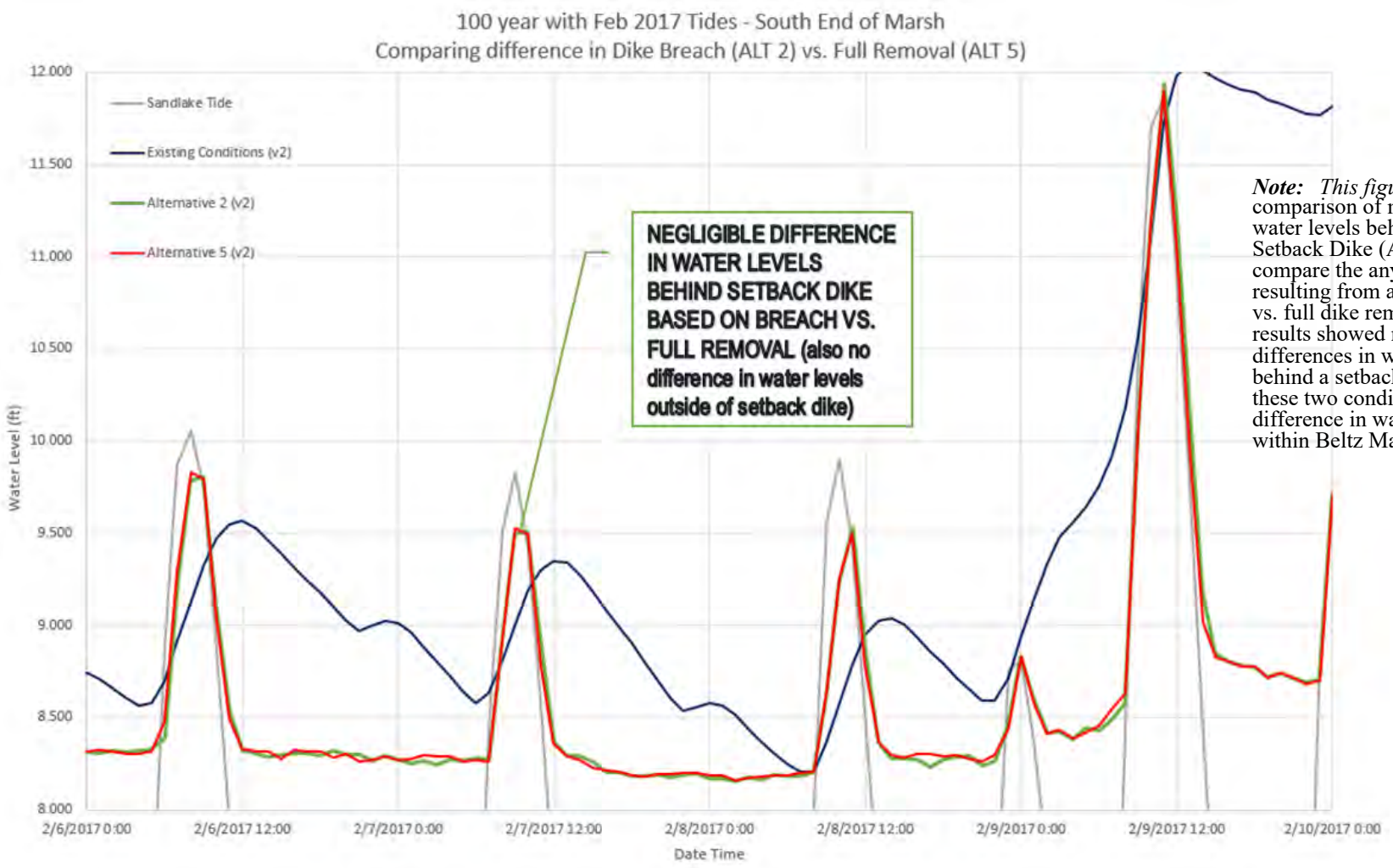
Note: *This figure shows* a current aerial photo (NS Consulting, 2022), showing the central historical flow path connecting channels inboard and outboard of Beltz Dike, as well as the existing box culvert/tide gate location which is not aligned with historical flow paths.

Figure 22
2022 Aerial Photo of Beltz Dike, Existing Culvert, and Historical Flow Path



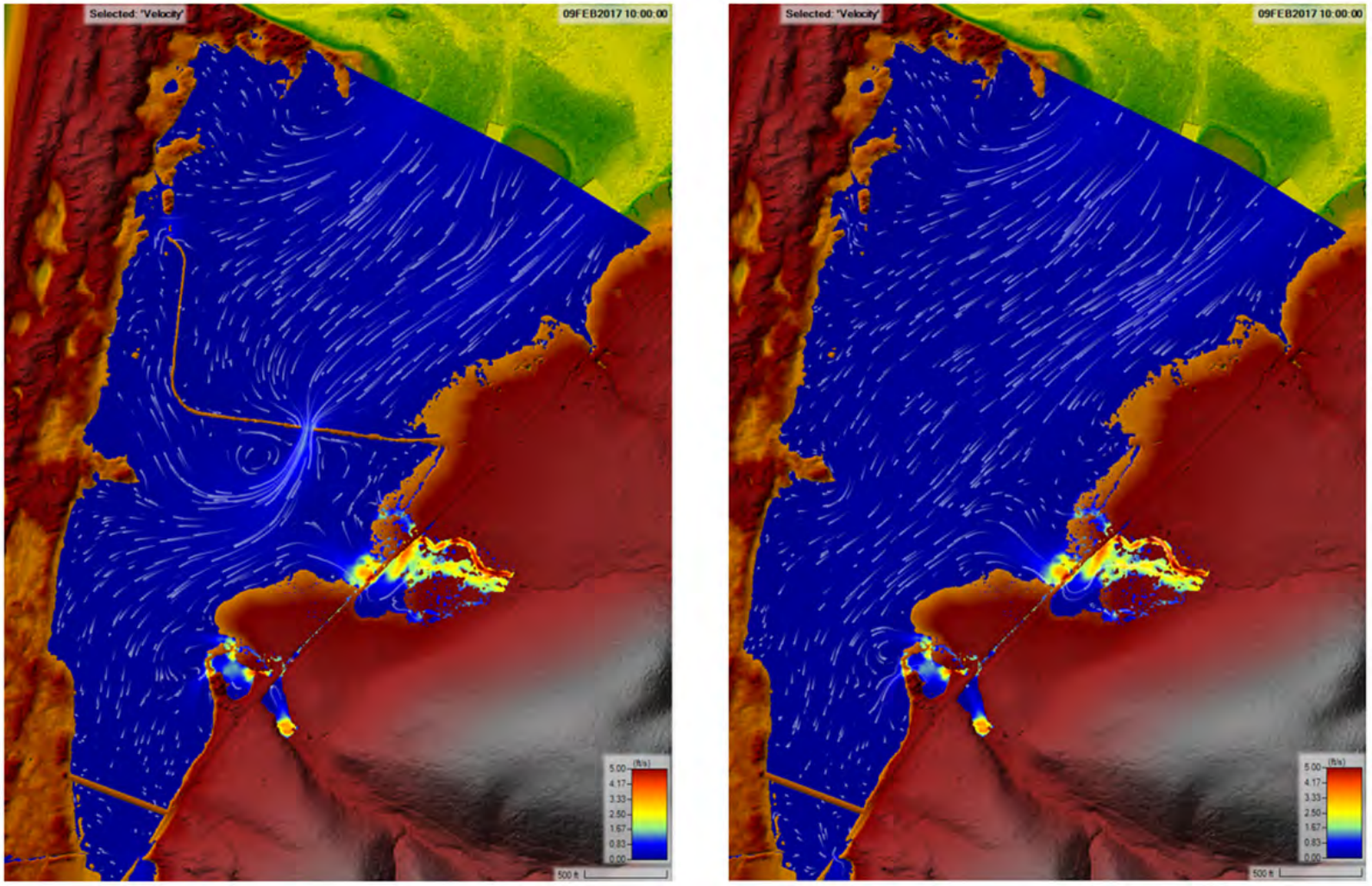
Note: *This figure shows* four potential dike breach locations under consideration.

Figure 23
Four Potential Dike Breach Locations Considered



Note: *This figure shows* a comparison of modeled water levels behind a Setback Dike (Alt 2) to compare the any difference resulting from a dike breach vs. full dike removal. Model results showed negligible differences in water levels behind a setback dike under these two conditions (and no difference in water levels within Beltz Marsh).

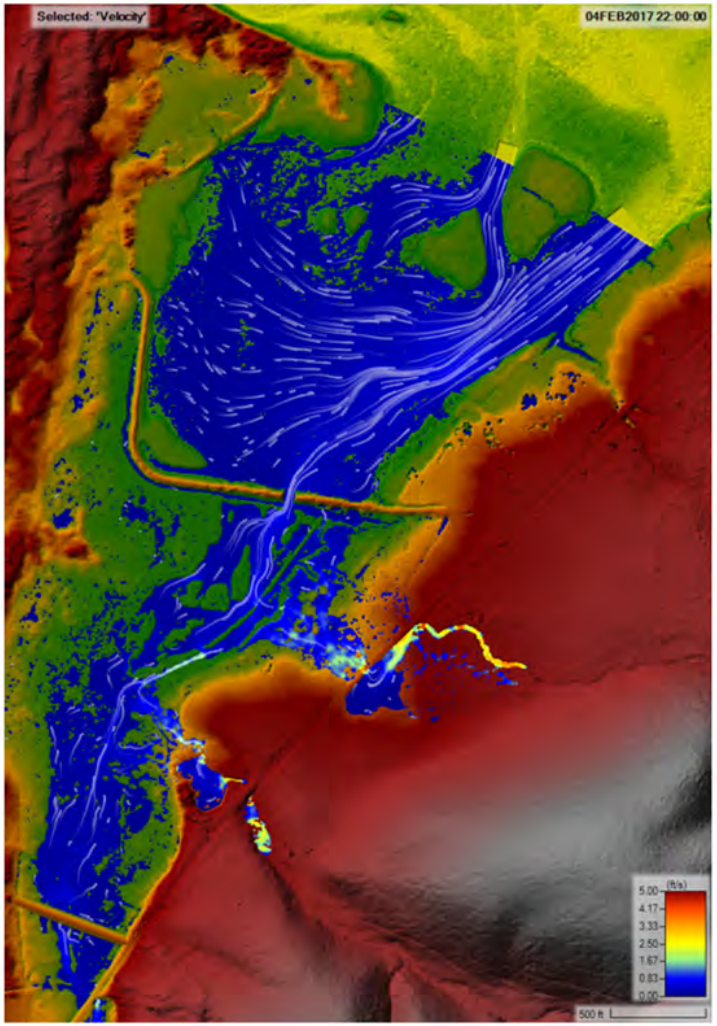
Figure 24
Comparison of Modeled Water Behind a Setback Dike Under Dike Breach and Full Dike Removal

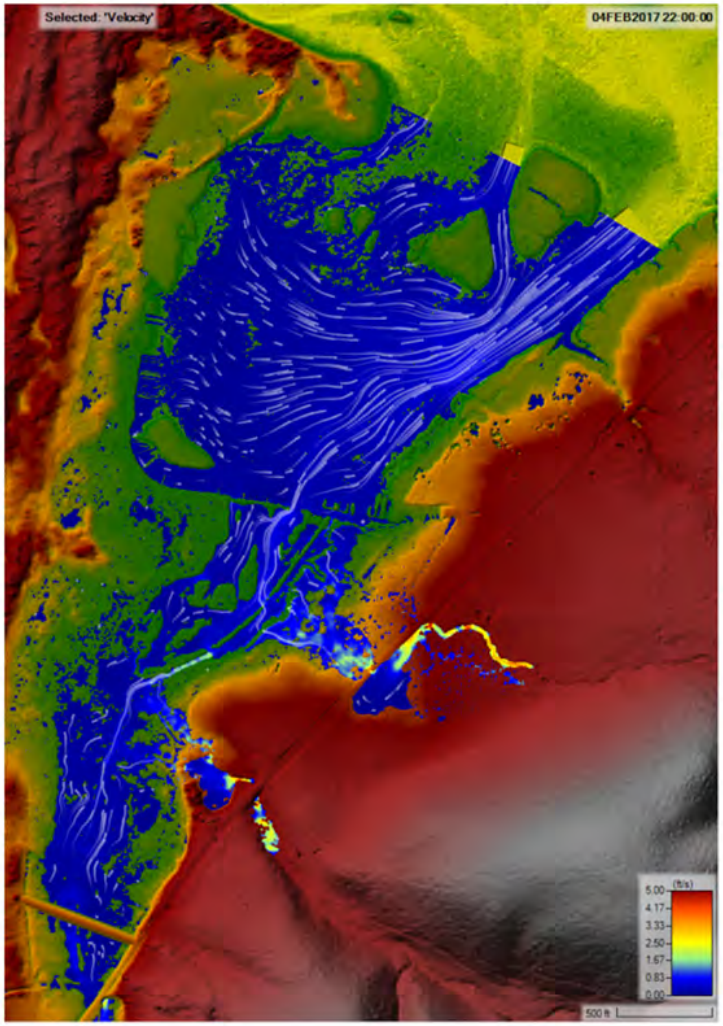


Note: *This figure shows* a comparison of water circulation patterns and flow directions under a dike breach vs. full dike removal during drain out while water levels are still high (above 9' NAVD88).

When water level are high, water in Beltz Marsh is funneled to the center of the marsh towards the dike breach where velocities are higher and a small eddy is visible upstream of the dike breach. Under full dike removal, water flux is evenly distributed across the marsh.

Figure 25
Comparison of Circulation Patterns Under Dike Breach Vs. Full Dike Removal (High Water)





Note: *This figure shows* a comparison of water circulation patterns and flow directions under a dike breach vs. full dike removal during drain out after water levels have fallen below 9' NAVD88.

When water level are low, water in Beltz Marsh is funneled to the center of the marsh under both dike breach and full dike removal conditions, where water is more confined to the channels.

Figure 26
Comparison of Circulation Patterns Under Dike Breach Vs. Full Dike Removal (Low Water)

PEAK VELOCITY DURING 100-YR STORM RUN (MAX TIDE SWING)

Peak velocity ~ 3ft/sec (short duration peak, majority of time is less than 2 ft/sec: fish passage velocity threshold)

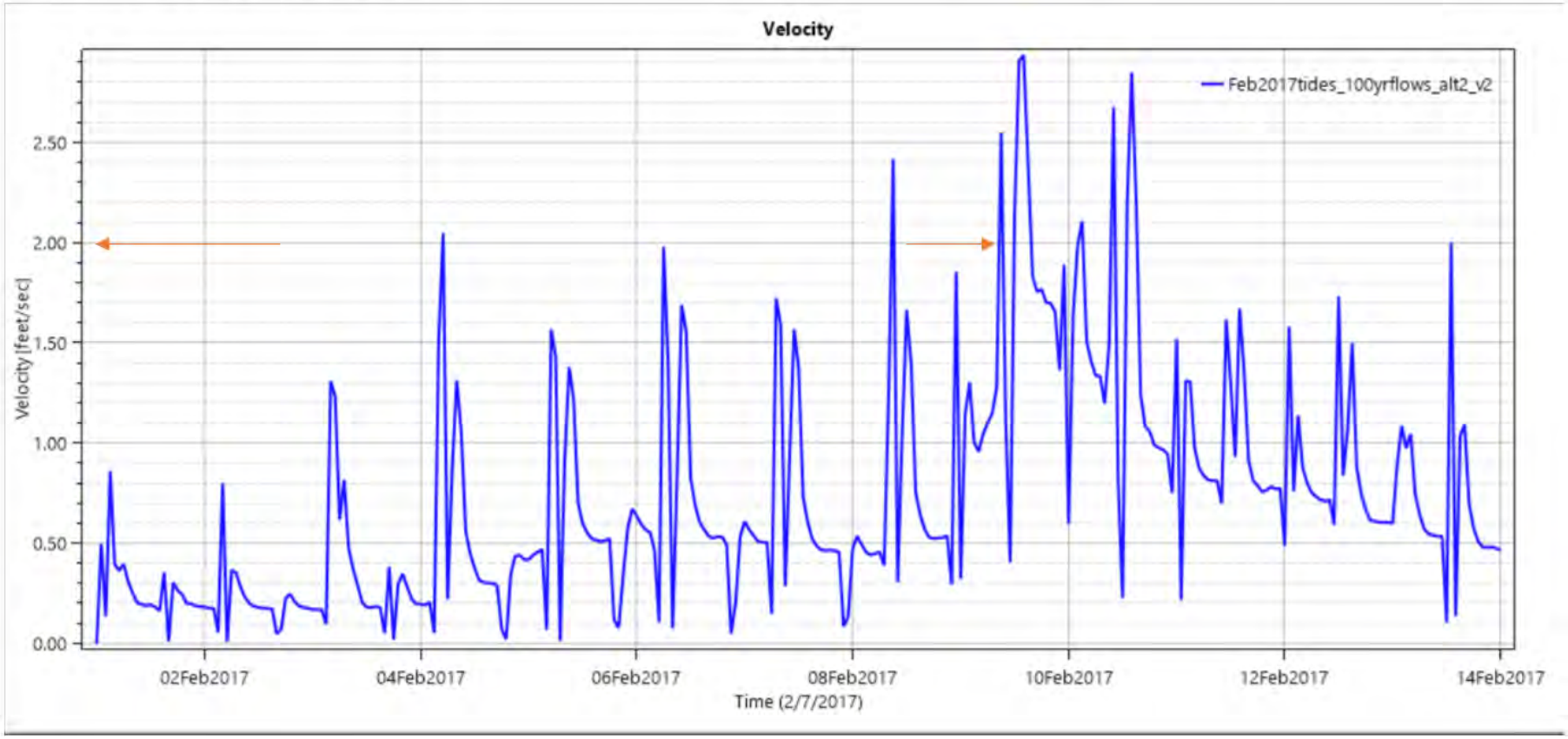


Figure 27
Water Velocity Through a 100-Foot Dike Breach During the 100-Year Hydrologic Scenario

100-Foot Dike Breach – Peak Shear Stress (lb/sf):

Alt 2 – 100-year run at the time step with the highest shear stress and velocity at the Beltz dike breach

Peak Shear Stress = 0.19 lb/sf (able to erode medium to coarse gravels. May need light armoring)

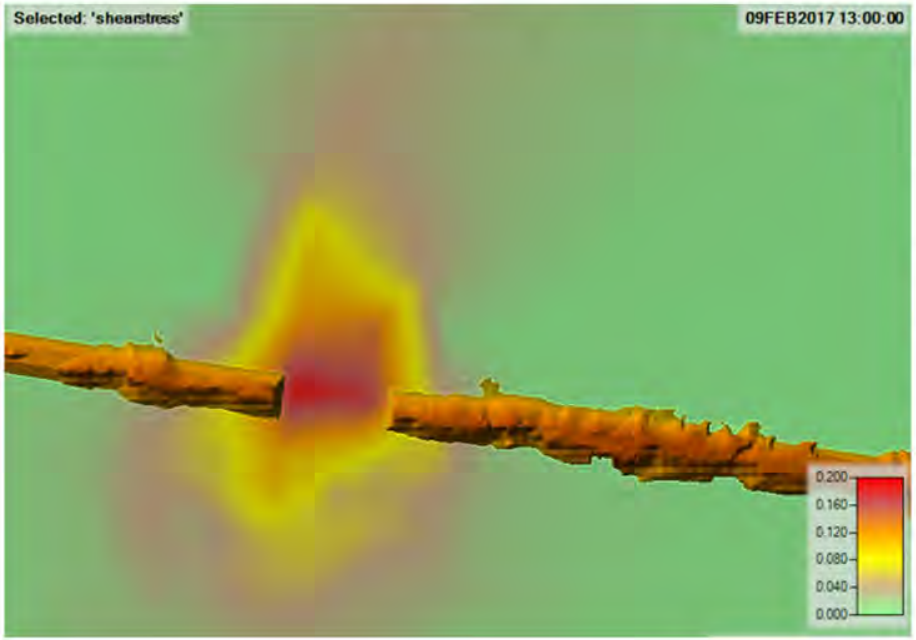


Table 1. Limiting Shear Stress and Ve locity for Uniform Noncohesive Sediments

Class name	d_s (in)	ϕ (deg)	τ_c	τ_{cr} (lb/sf)	V_c (ft/s)
Boulder					
Very large	>80	42	0.054	37.4	4.36
Large	>40	42	0.054	18.7	3.08
Medium	>20	42	0.054	9.3	2.20
Small	>10	42	0.054	4.7	1.54
Cobble					
Large	>5	42	0.054	2.3	1.08
Small	>2.5	41	0.052	1.1	0.75
Gravel					
Very coarse	>1.3	40	0.050	0.54	0.52
Coarse	>0.6	38	0.047	0.25	0.36
Medium	>0.3	36	0.044	0.12	0.24
Fine	>0.16	35	0.042	0.06	0.17
Very fine	>0.08	33	0.039	0.03	0.12
Sands					
Very coarse	>0.04	32	0.029	0.01	0.070
Coarse	>0.02	31	0.033	0.006	0.055
Medium	>0.01	30	0.048	0.004	0.045
Fine	>0.005	30	0.072	0.003	0.040
Very fine	>0.003	30	0.109	0.002	0.035
Silts					
Coarse	>0.002	30	0.165	0.001	0.030
Medium	>0.001	30	0.25	0.001	0.025

Stability Thresholds for Stream Restoration Materials

by Craig Fischenich[1]

May 2001

Figure 28

Peak Shear Stress Through 100-Foot Dike Breach Compared to Stability Thresholds of Sediments

PEAK VELOCITY DURING 100-YR STORM RUN (MAX TIDE SWING)

100-Foot Breach : Peak velocity ~ 3ft/sec (short duration peak, majority of time is less than 2 ft/sec: fish passage velocity threshold)

200-Foot Breach: Peak velocity ~ 1ft/sec (slightly higher velocities in site's internal tidal channels)

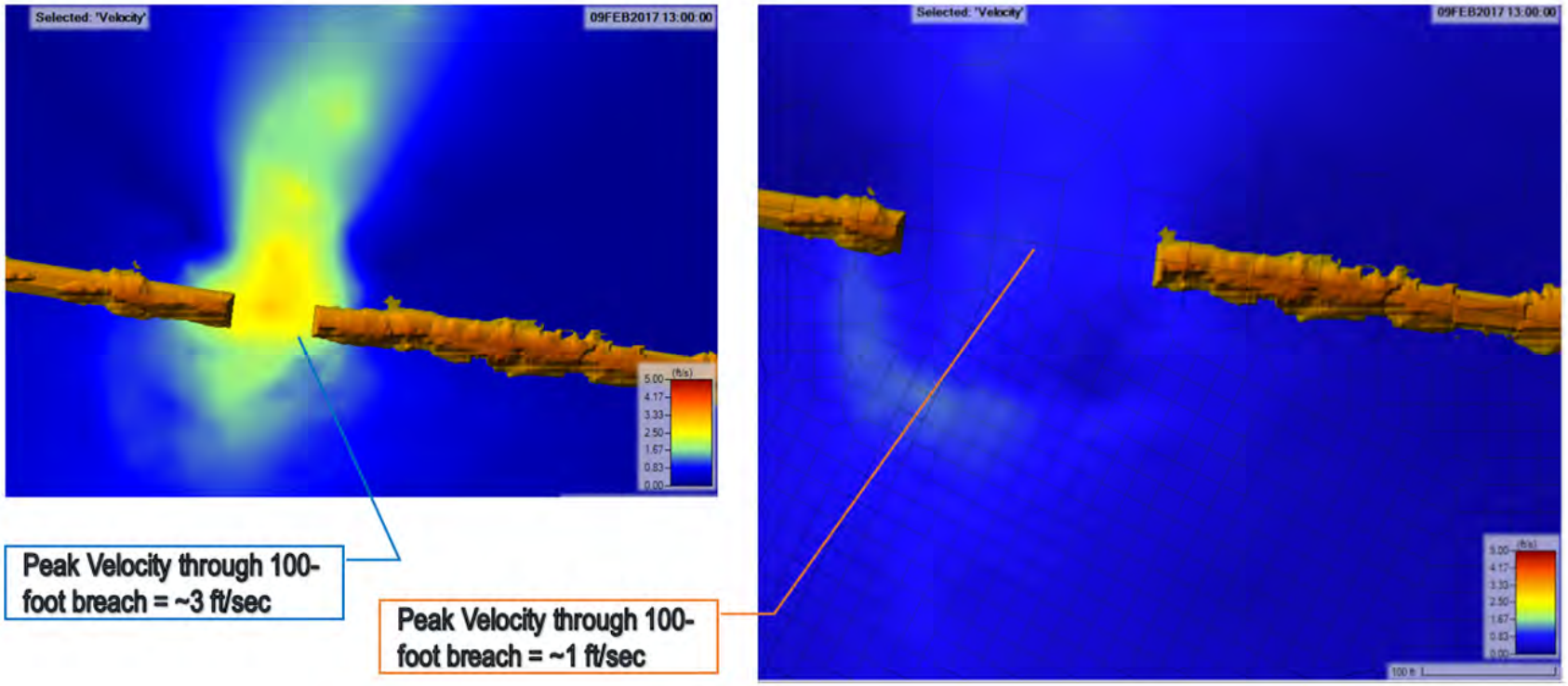


Figure 29
Comparison of Peak Velocity Through 100-Foot and 200-Foot Dike Breaches

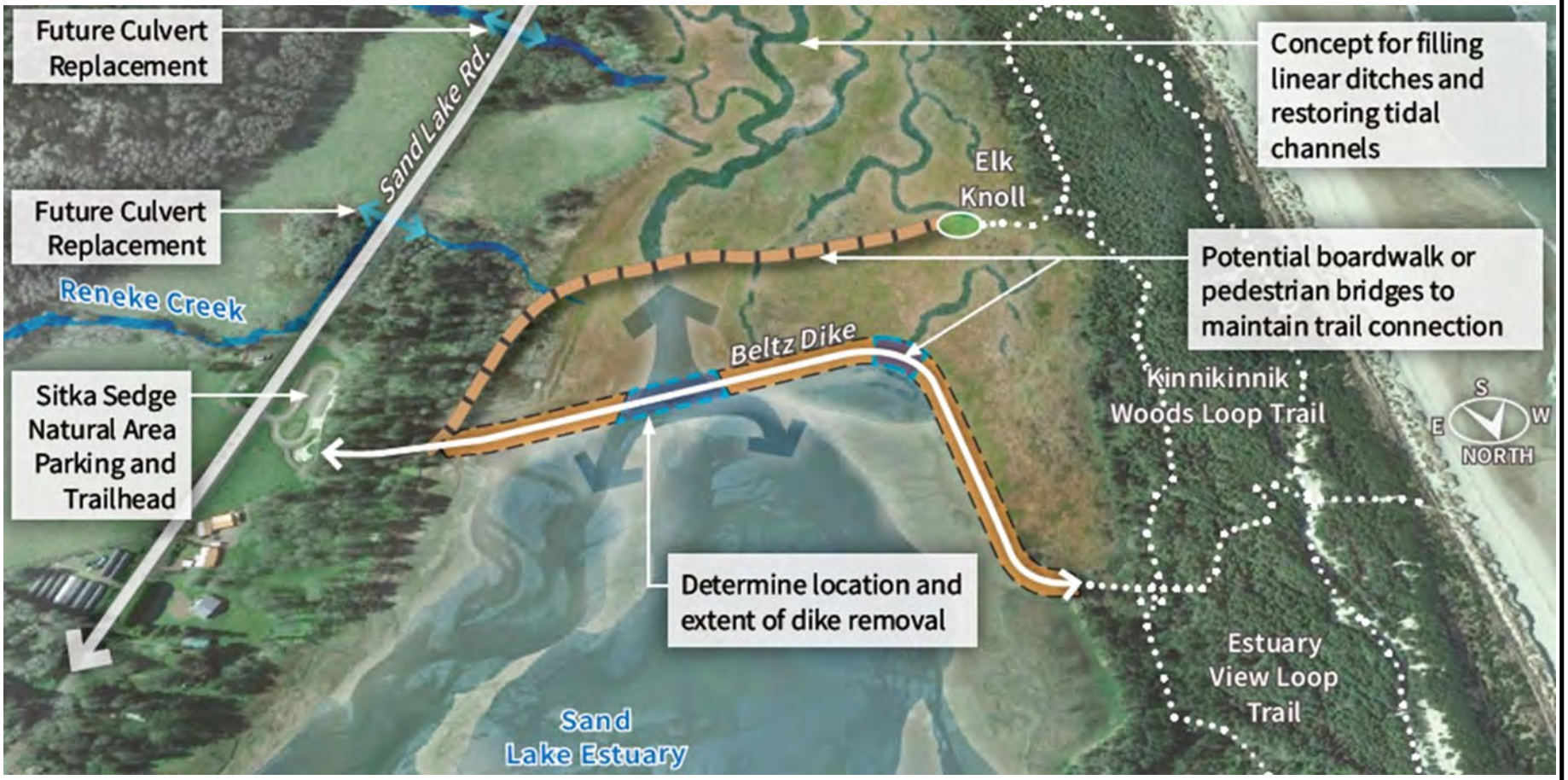
Whalen Island Rd Bridge

- 180-acre contributing marsh area (80 acres at Sitka Sedge)
- 80-foot span
- Heavily armored opening/banks with riprap



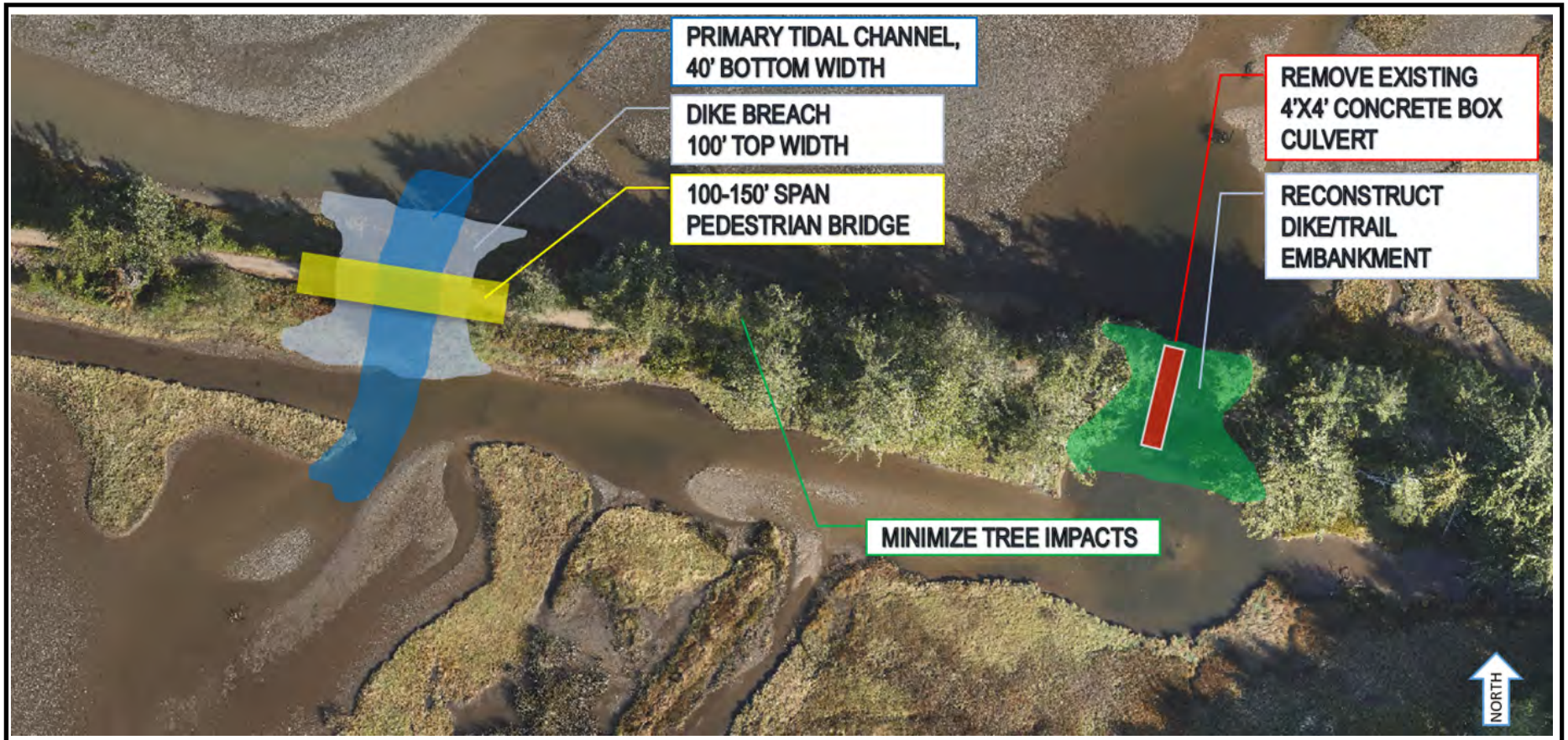
Note: *This figure shows* the nearby Whalen Island Road bridge as a point of comparison of span length compared to upstream contributing marsh area and required armoring due to constriction and high velocities/shear stresses.

Figure 30
Whalen Island Bridge



Note: *This figure shows* a conceptual plan for maintaining recreational access from the Sitka Sedge parking lot and trail head to the SSSNA trail network and beach, while breaching or removing Beltz Dike. The Beltz Dike Trail currently provides access but would be severed by a dike breach or removal. Options include spanning the dike breach with a pedestrian bridge, constructing a boardwalk across the marsh, or rerouting the trail southward to the setback dike.

Figure 31
Conceptual Plan For Maintaining Recreational Access While Breaching Dike



Note: *This figure shows* a conceptual plan for maintaining recreational access by constructing a pedestrian bridge over a dike breach, as well as removing the existing failing box culvert and reconstructing the eroding embankment to provide long-term trail stability.

Figure 32
Concept Plan for Constructing a Pedestrian Bridge Over a Dike Breach



Note: *This figure shows* examples of prefabricated pedestrian bridge designs in the 100-200-foot span range including structures from Contech and Western Wood Structures.

Figure 33
Examples of Prefabricated Pedestrian Bridges



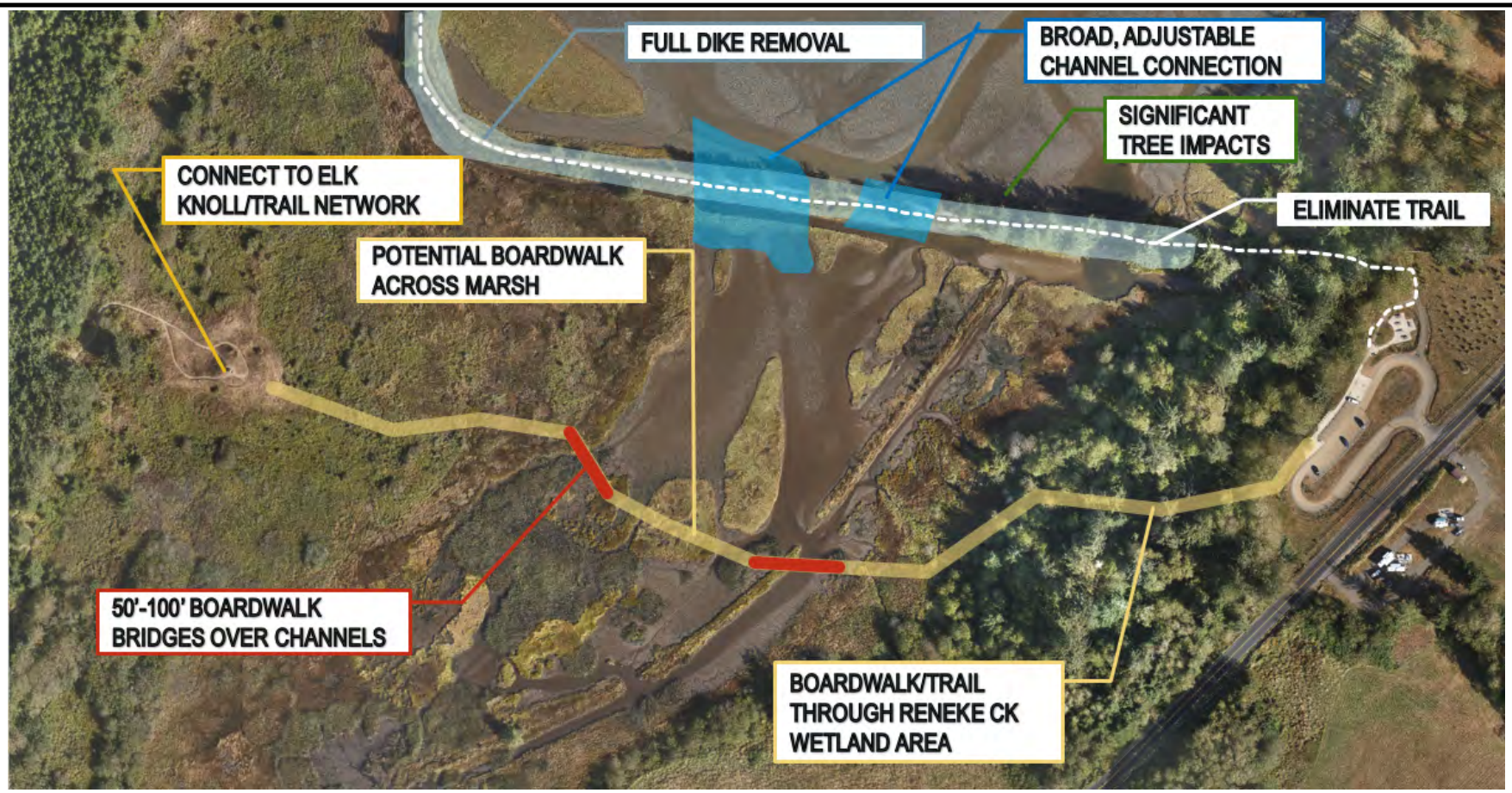




Note: *This figure shows* a boardwalk pedestrian bridge located at the Nisqually National Wildlife Refuge near Olympia, Washington. A 40-foot span bridge was originally constructed in 2011, but in the follwing years the channel began to enlarge and erode the banks. After attempts to stabilize the banks, the bridge was evenutally replaced by a 90-foot span bridge in 2020.

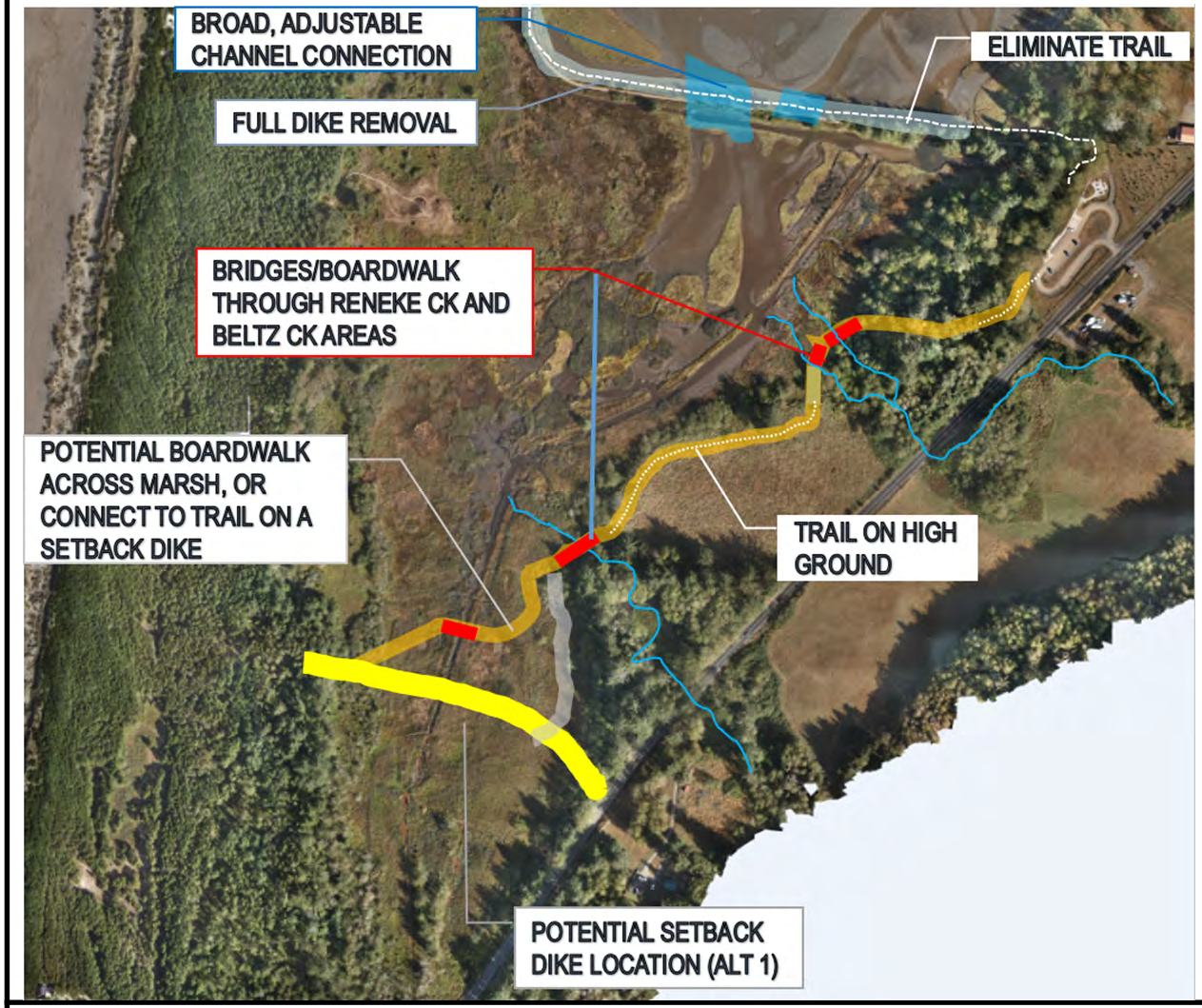
This example serves as a warning to avoid undersizing a bridge over a tidal channel that has the potential to enlarge due to a change in hydrologic conditions/tidal reconnection.

Figure 34
Nisqually NWR Boardwalk Bridge Replaced in 2020 After Channel Enlargement



Note: *This figure shows* a conceptual plan for maintaining recreational access by constructing a boardwalk across the marsh, connecting the Sitka Sedge parking lot/trail head to the rest of the SSSNA trail network. The potential boardwalk aligment shown here would travel through the Reneke Creek confluence wetland area, across Beltz Marsh, and connect to the Elk Knoll viewpoint area. This would allow for full dike removal or a larger, adjustable dike breach without the need to construct a pedestrian bridge over the breach.

Figure 35
Concept Plan for Constructing Boardwalk Across the Marsh to Replace Beltz Dike Trail



Note: *This figure shows* a conceptual plan for maintaining recreational access by constructing a new trail, boardwalks, and bridges southward along the east side of the marsh towards the setback dike locations. This trail would pass through the Reneke Creek confluence wetland area and across Beltz Creek where boardwalk and bridge sections would likely be necessary. The trail could cross the marsh on the setback dike, or on a boardwalk crossing the south end of the marsh where it is narrower.

Figure 36
Concept Plan for Rerouting the Trail Southward Along the East Side of the Marsh

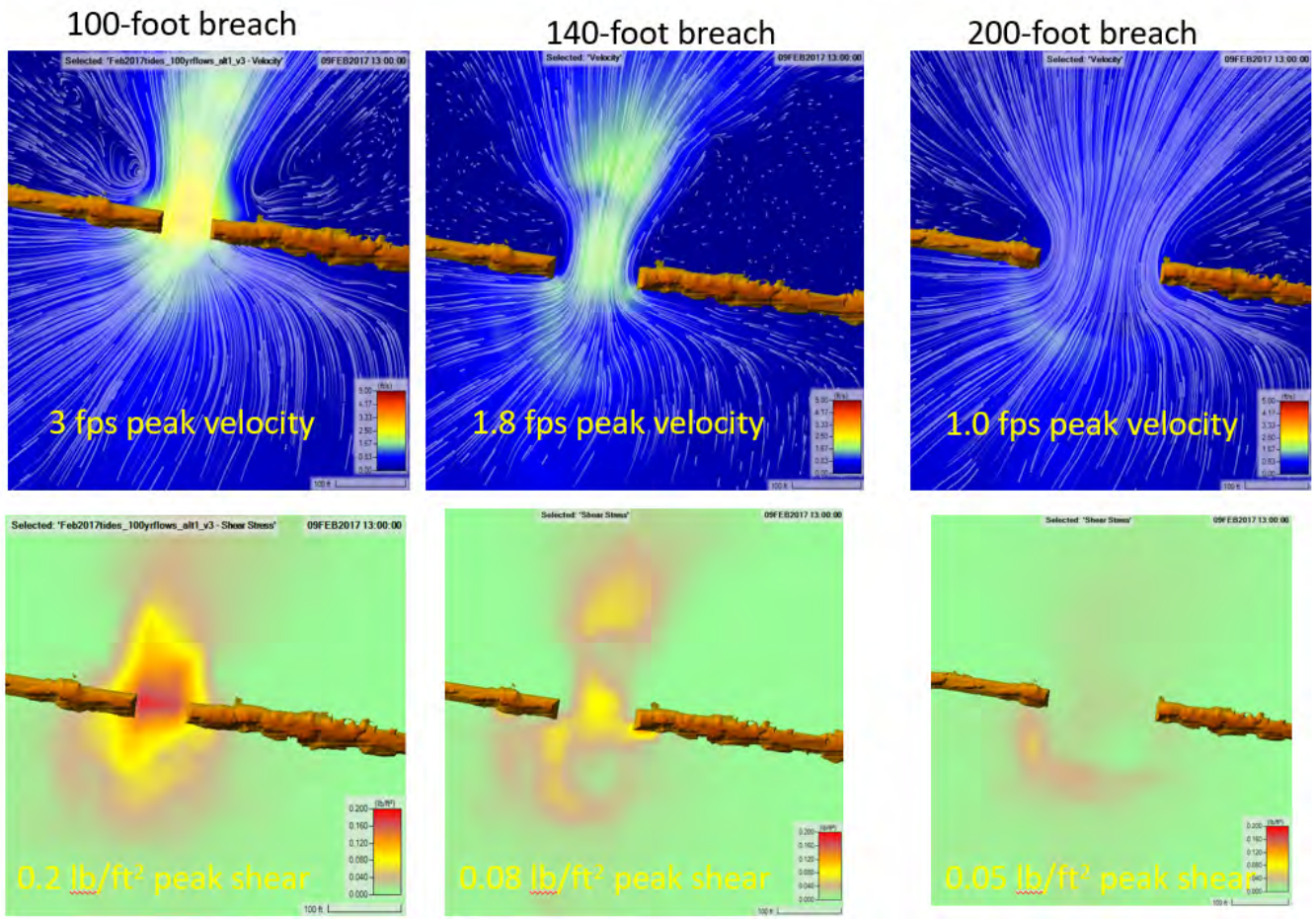


Figure 37

Comparison of Peak Velocity and Shear Stress Through 100-, 140-, and 200-Foot Dike Breaches

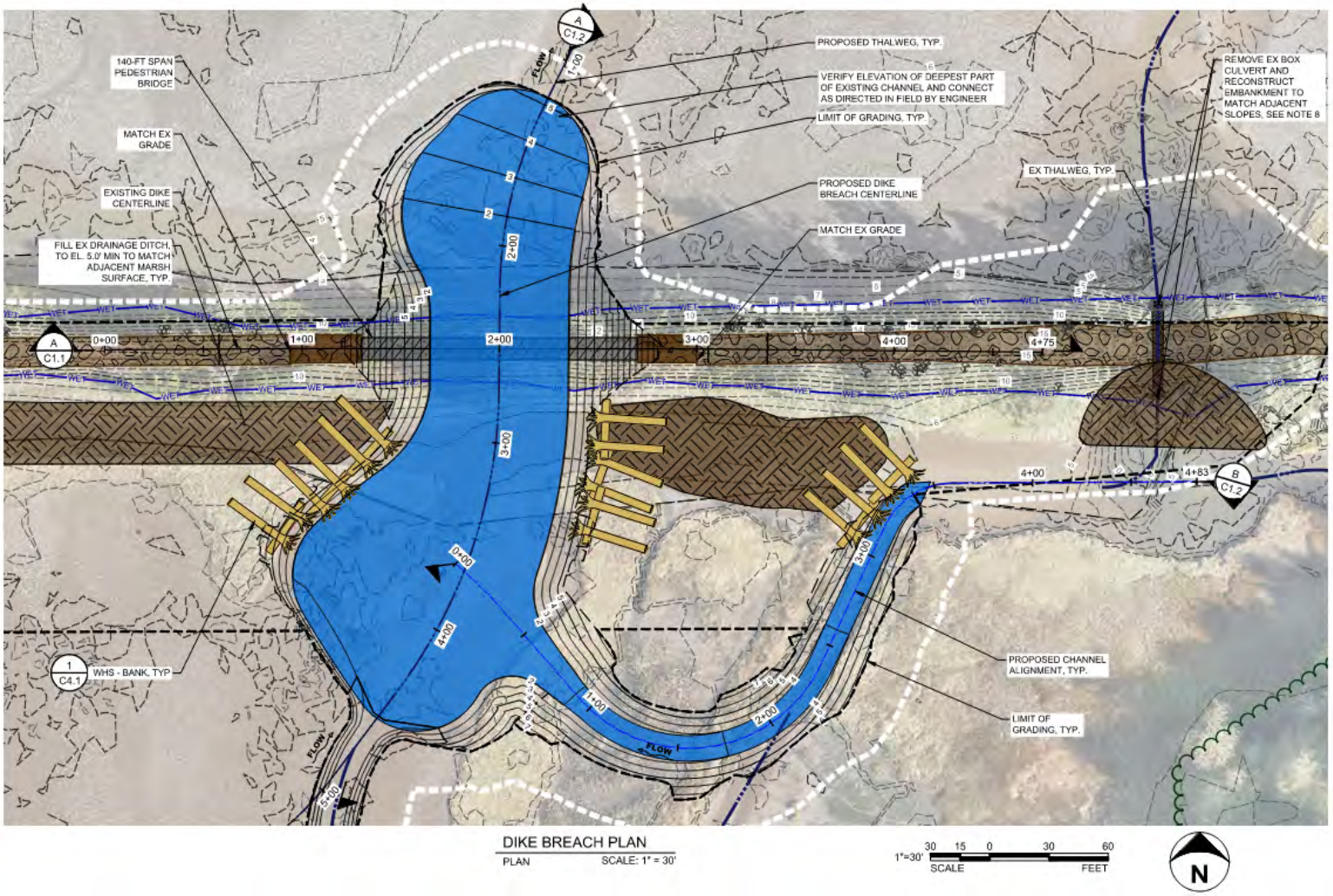


Figure 38

Dike Breach Channel and 140-Foot-Span Pedestrian Bridge - 90% Design Plan View

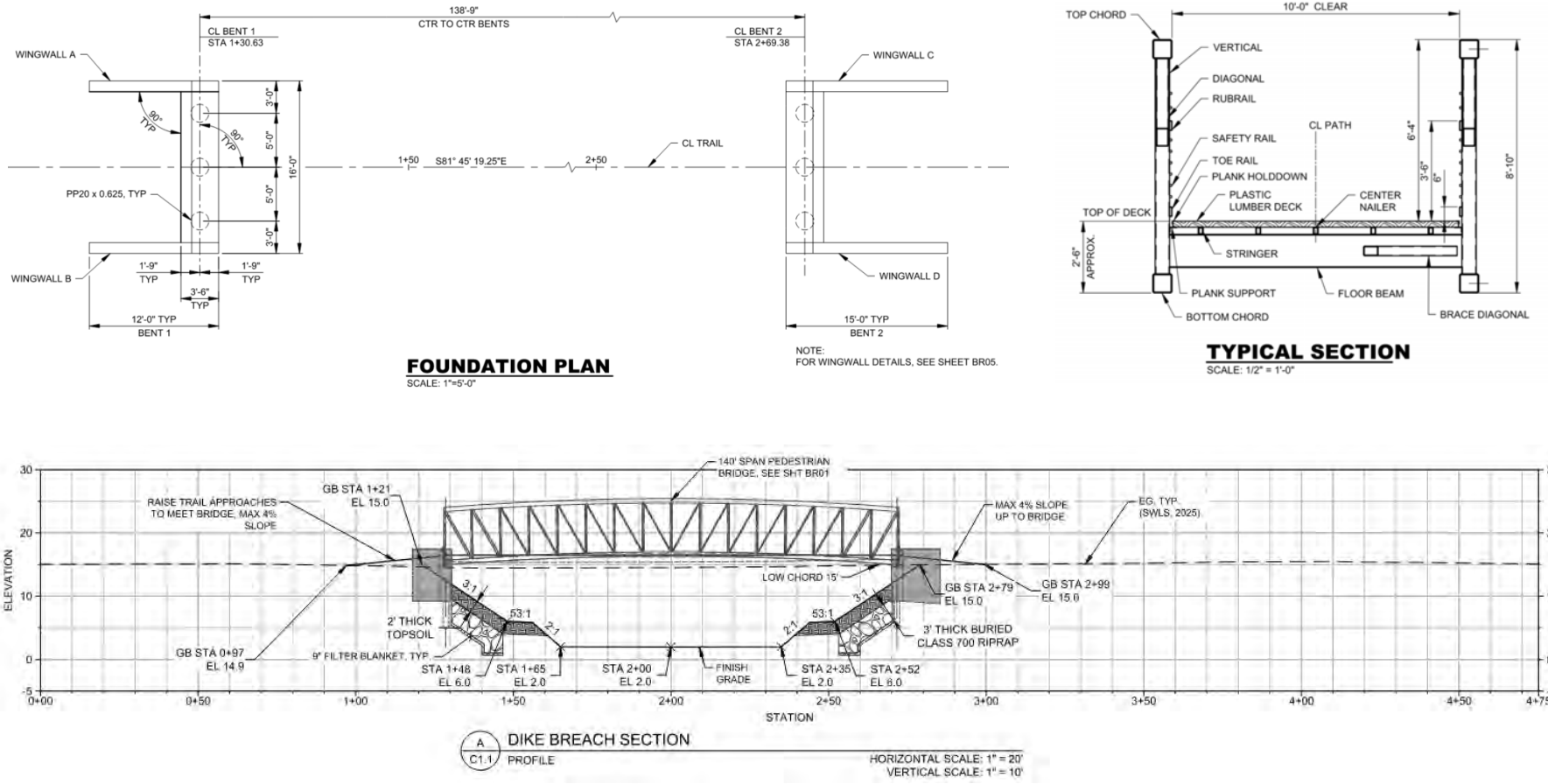
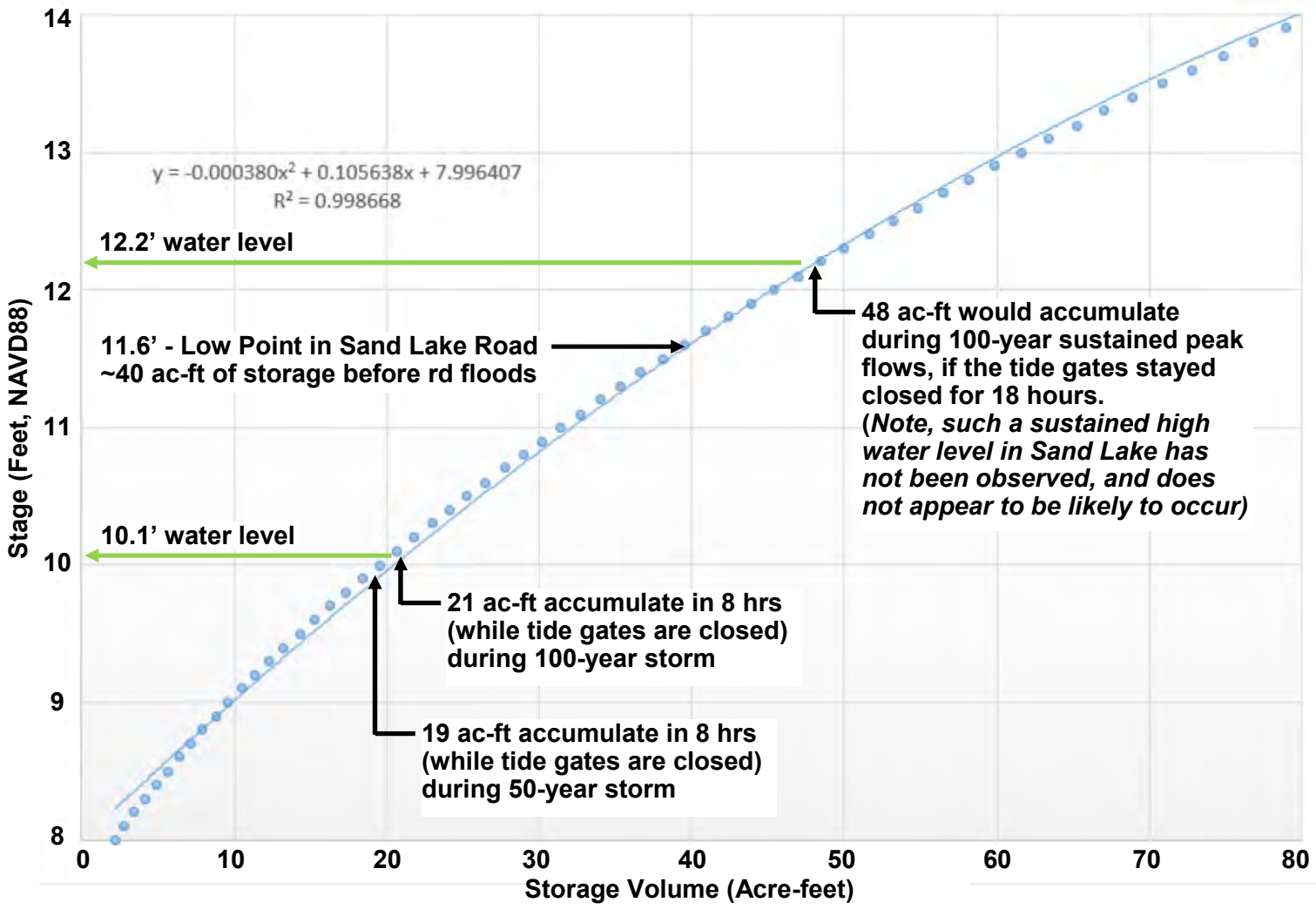


Figure 39

Dike Breach Channel and 140-Foot-Span Pedestrian Bridge - Select 90% Plan Details



Note: *This figure shows the stage-storage volume relationship for a theoretical setback dike constructed near the existing beaver dam, oriented east-to-west, across the south end of Beltz Marsh. The blue dots correspond to storage volume measurements at each 0.1-foot elevation increment. The solid blue line is the best-fit trend line for these data points.*

The setback dike would be intended to allow the Beltz Dike to be fully breached while preventing tidal flooding from occurring at the south end of the marsh and at Tierra del Mar.

Based on preliminary conceptual analysis, it appears that a setback dike in this location would have adequate flood storage capacity to contain the combined 100-year storm surface-water inputs from TDM, the East Marsh, and direct precipitation.

See labels for additional explanation

SOURCE: ESA derived stage-storage relationship based on PhoDAR terrain surface provided by OPRD.

Figure 40

Preliminary Feasibility Analysis of a Setback Dike from 2019 Study

Note: *This figure shows* a conceptual cross section of a setback dike that would likely be appropriate for the Sitka Sedge project, including a 12-foot minimum top width, 3:1 and 5:1 side slopes, resulting in a bottom width/ footprint of 80 to 100 feet.

Setback dike dimensions, build height, and subgrade preparation/stabilization measures will be determined in subsequent design stages informed by a subsurface investigation and geotechnical engineering recommendations.

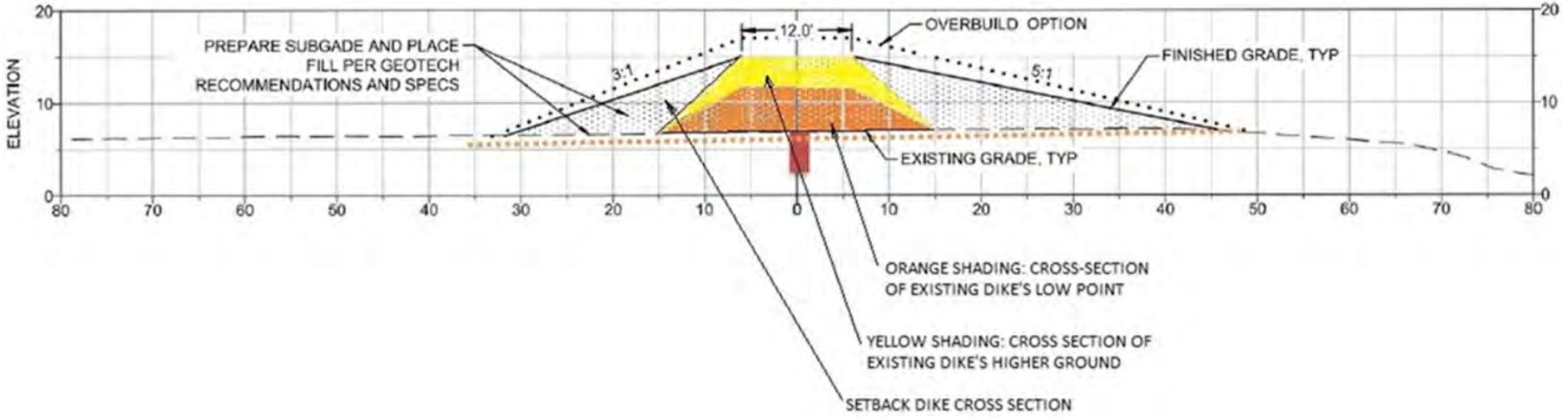


Figure 41
Conceptual Cross Section of a Setback Dike at Sitka Sedge

Note: *This figure shows* a a concept plan for optimizing the setback dike location showing potential setback dike alternative alignments and flow contributions to the area behind a setback dike. (North is down in this image)

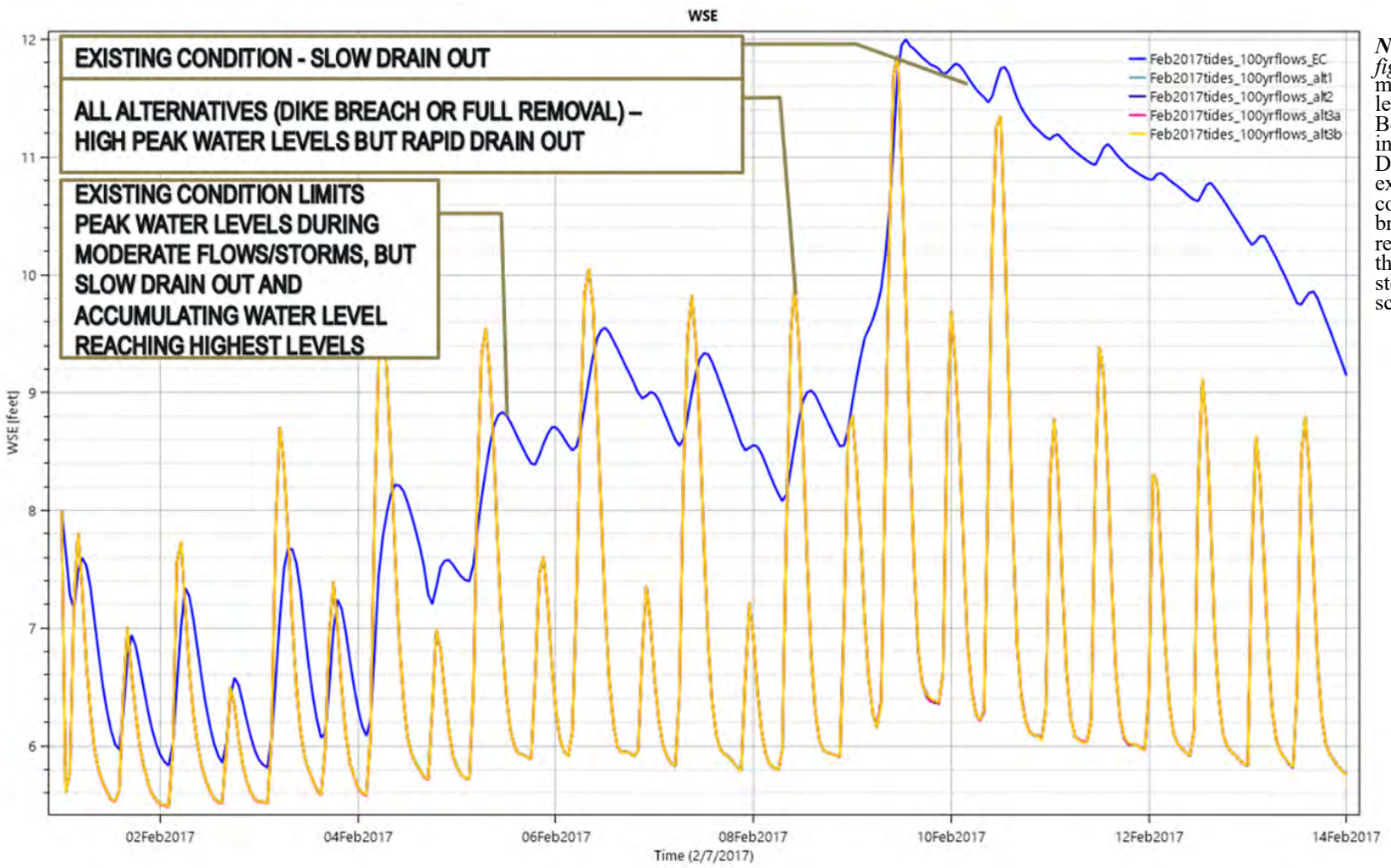


Figure 42
Concept Plan for Optimizing Location of Setback Dike



Note: *This figure* shows four alternative setback dike alignments.

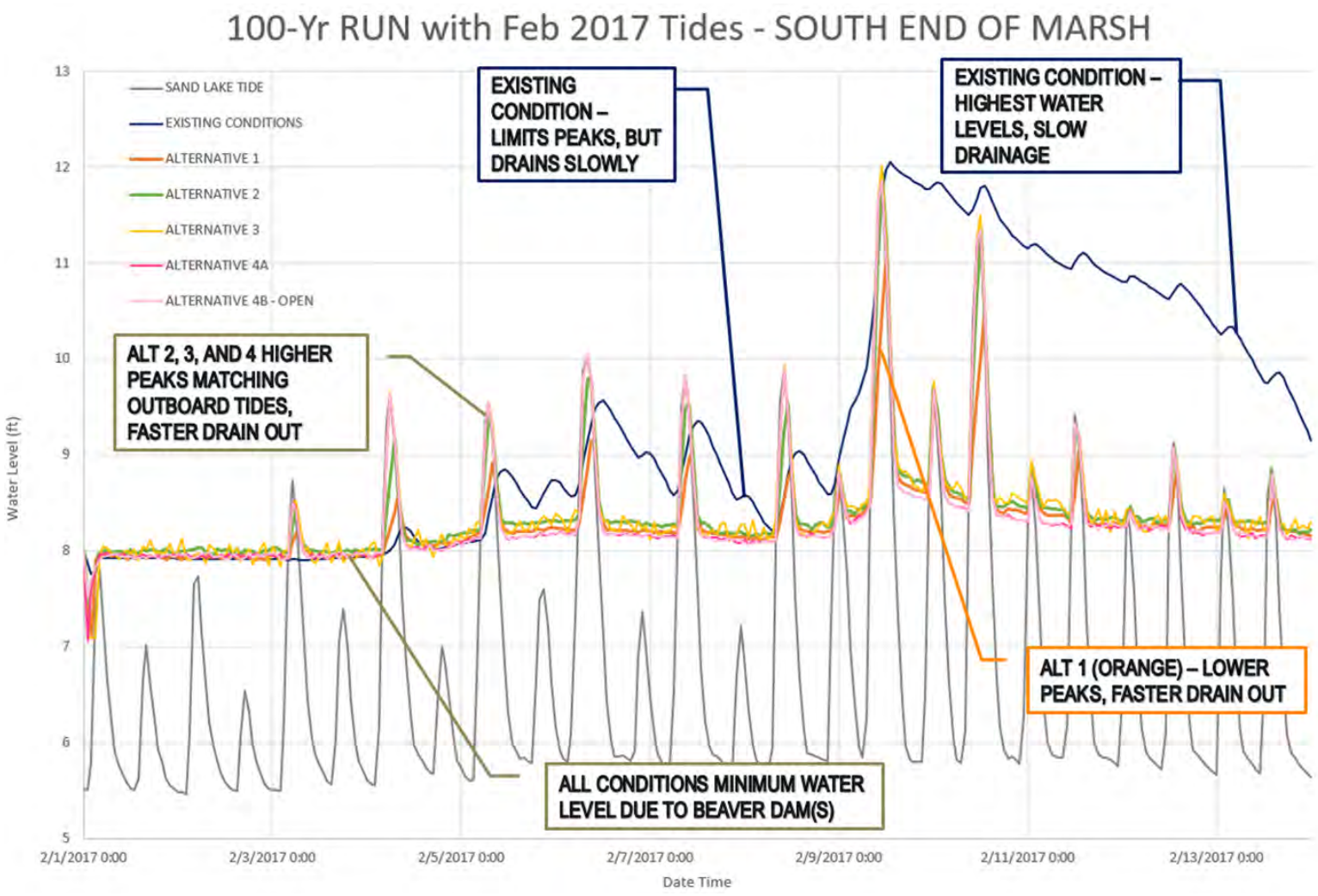
Figure 43
Setback Dike Alternative Approximate Locations



Note: *This figure shows* modeled water levels inside Beltz Marsh (just inside of Beltz Dike) under existing conditions, dike breach, and dike removal during the 100-year storm hydrologic scenario.

Figure 44

Modeled Water Levels Inside Beltz Marsh During 100-Year Storm Scenario under Dike Breach and Dike Removal vs. Existing Conditions



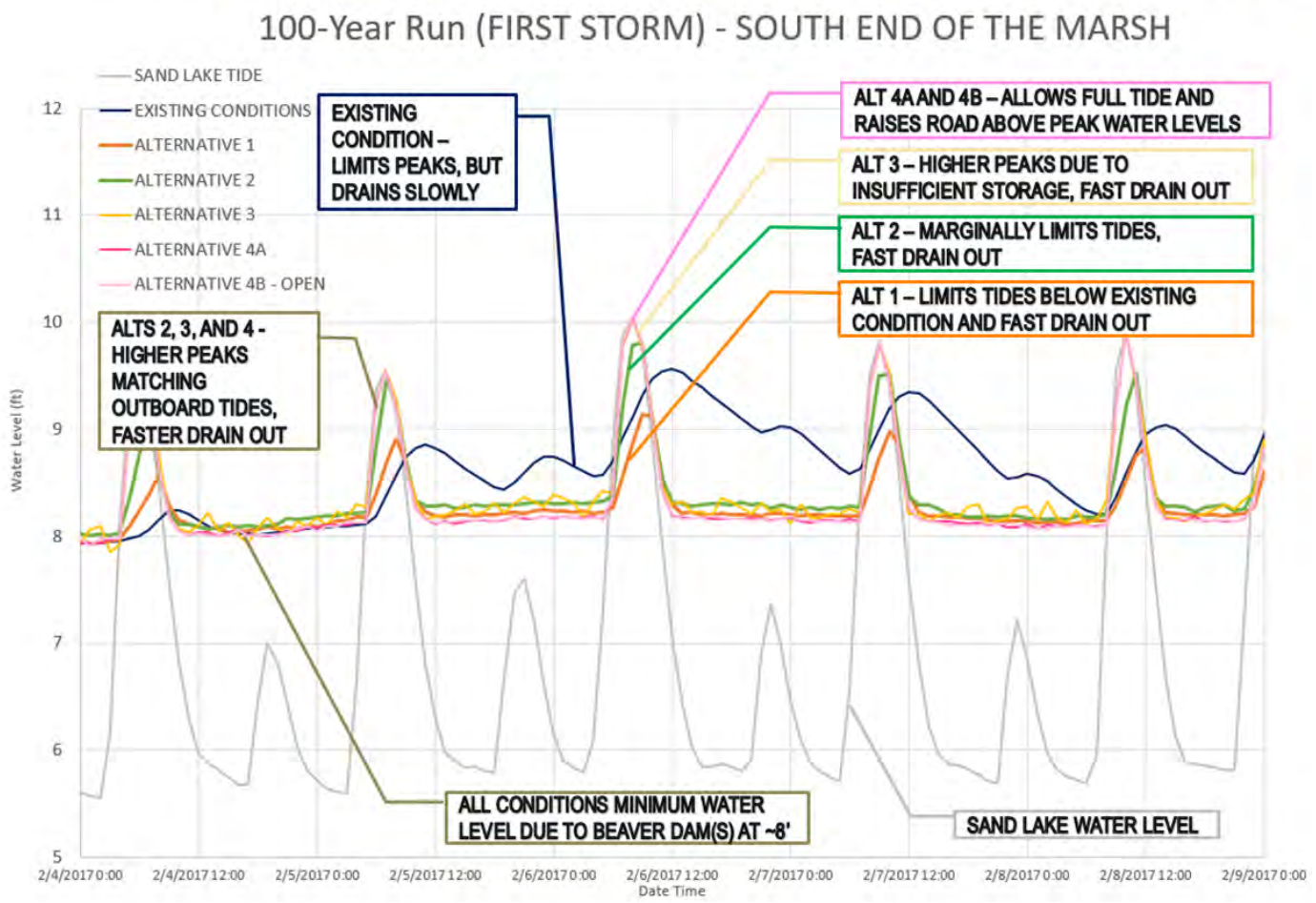
Note: *This figure shows* modeled water levels at the south end of Beltz Marsh/North end of TDM for all setback dike alternatives and existing conditions.

This plot shows the full 14-day duration of the 100-year storm hydrologic scenario which includes a period of typical winter conditions, a first storm (2-year storm with 10' tides) and a second storm (100-year flows and 12' King Tides).

Figure 45

Modeled Water Levels at South End of Beltz Marsh During 100-Year Storm Scenario (Full Duration)

2D MODEL RESULTS – 10' TIDES, 2-YR FLOWS

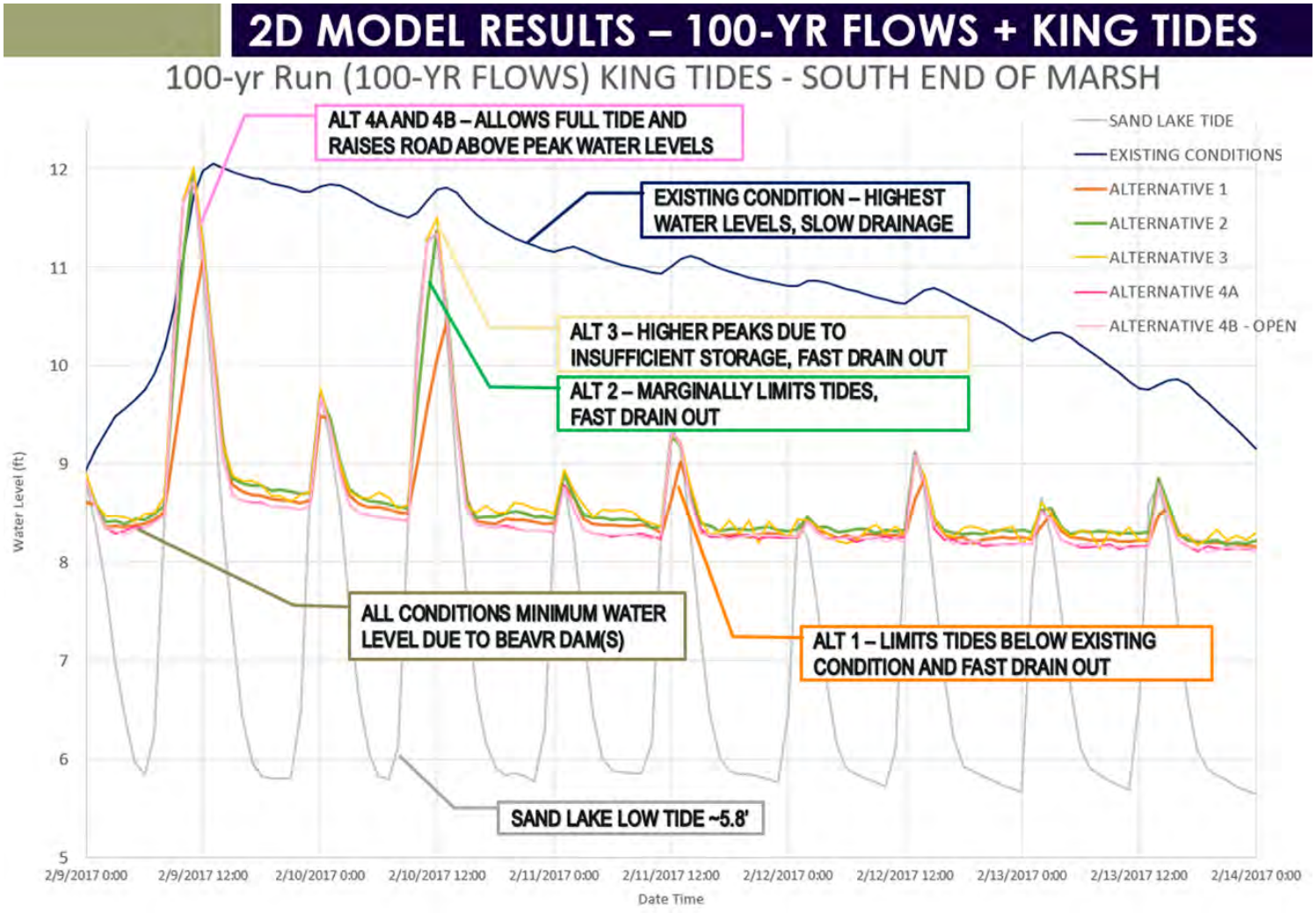


Note: *This figure shows* modeled water levels at the south end of Beltz Marsh/North end of TDM for all setback dike alternatives and existing conditions.

This plot zooms in on the 'first storm' which includes 2-yearstream flows and runoff rates with moderately high tides reaching 10' NAVD88.

Figure 46

Modeled Water Levels at South End of Beltz Marsh - 2-Year Flows and 10' Tides (First Storm)

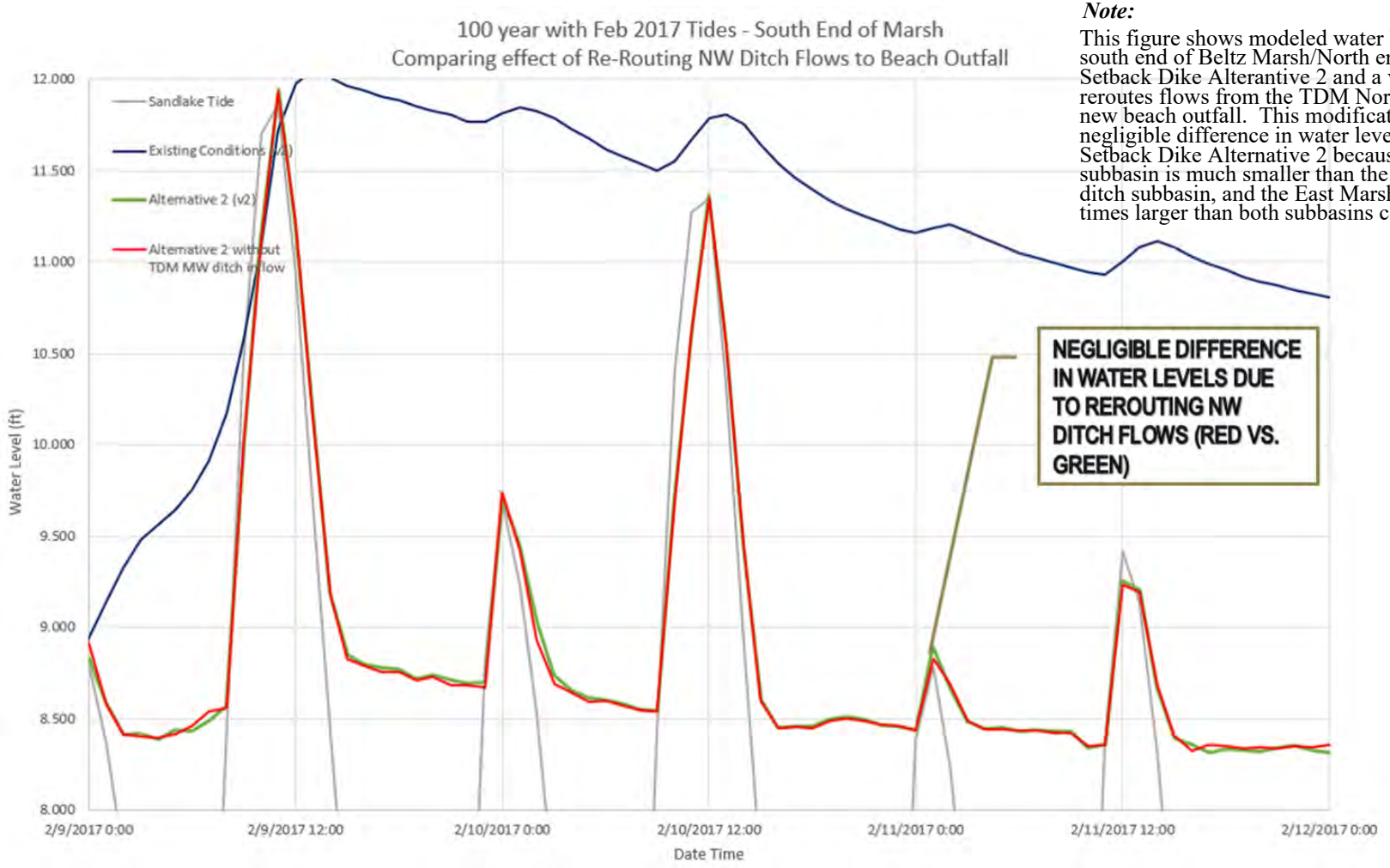


Note: *This figure shows* modeled water levels at the south end of Beltz Marsh/ North end of TDM for all setback dike alternatives and existing conditions.

This plot zooms in on the 'second storm' which includes 100-year stream flows and runoff rates with King Tides reaching 12' NAVD88.

Figure 47

Modeled Water Levels at South End of Beltz Marsh - 100-Year Flows and King Tides

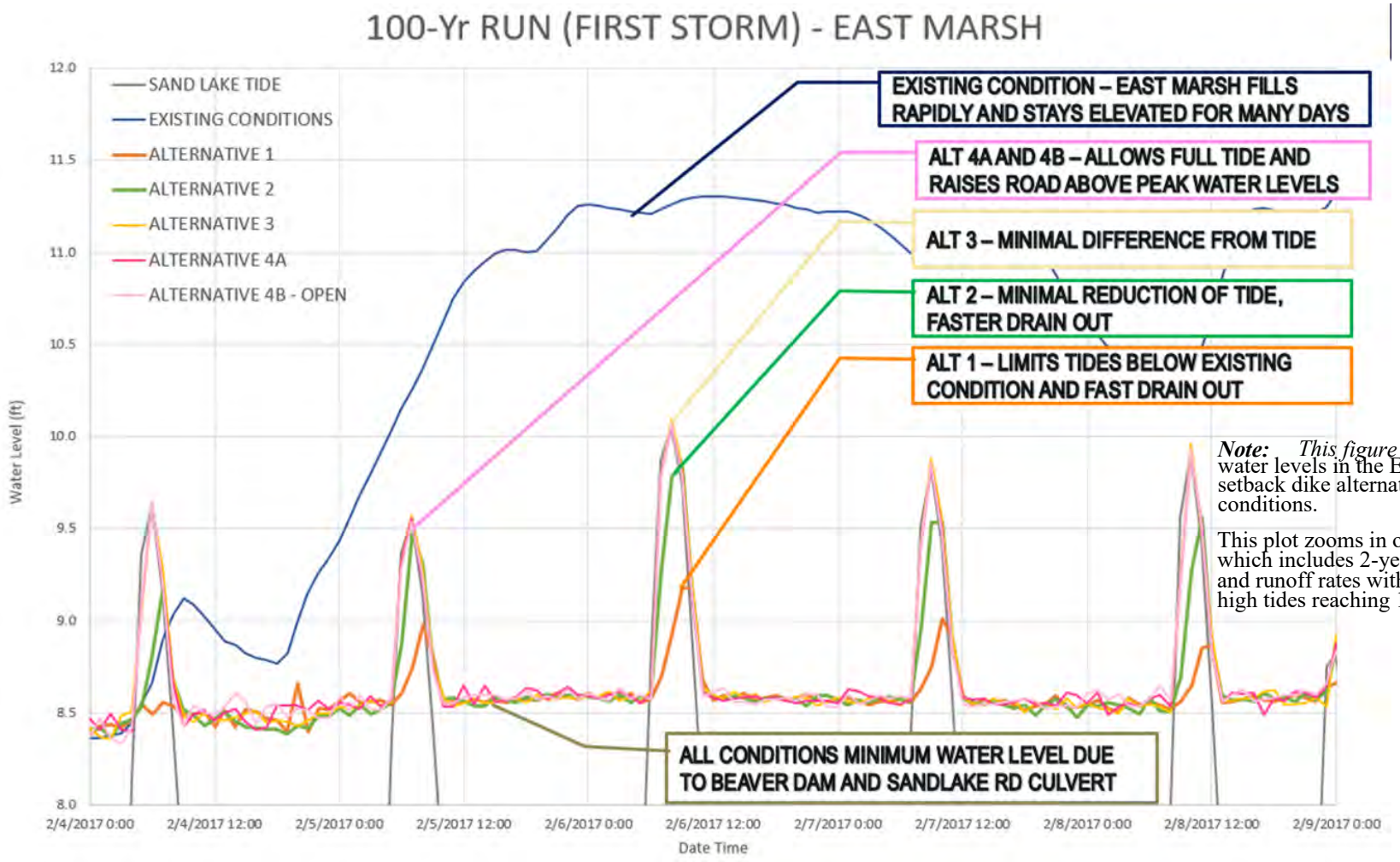


Note:

This figure shows modeled water levels at the south end of Beltz Marsh/North end of TDM for Setback Dike Alterantive 2 and a variation that reroutes flows from the TDM Northwest Ditch to a new beach outfall. This modification results in a negligible difference in water levels behind Setback Dike Alternative 2 because the NW Ditch subbasin is much smaller than the Sandlake Rd ditch subbasin, and the East Marsh watershed is 20 times larger than both subbasins combined.

Figure 48

Model Results Testing Effect of Rerouting Flows from TDM NW Ditch to Beach Outfall

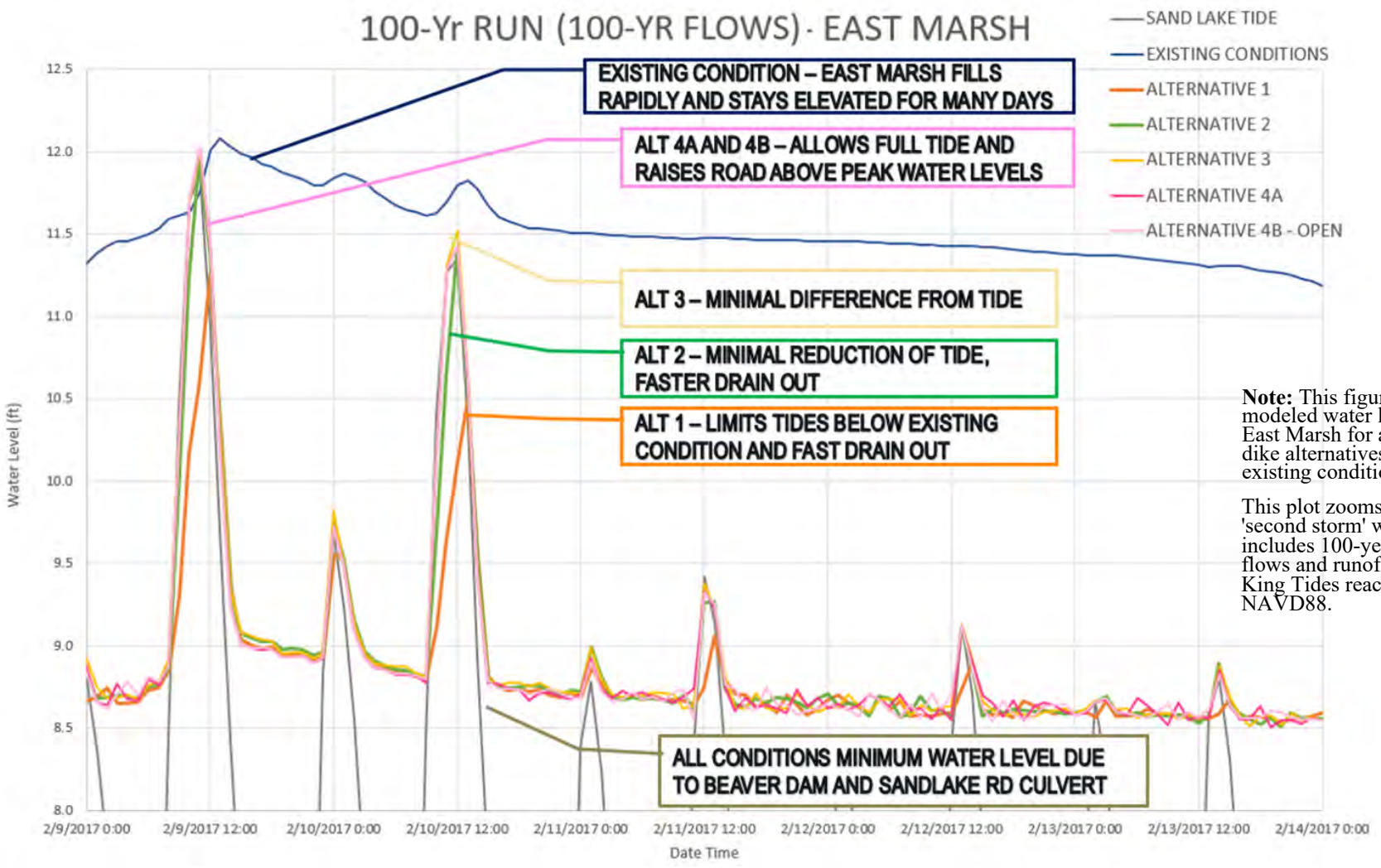


Note: *This figure shows* modeled water levels in the East Marsh for all setback dike alternatives and existing conditions.

This plot zooms in on the 'first storm' which includes 2-yearstream flows and runoff rates with moderately high tides reaching 10' NAVD88.

Figure 49

Modeled Water Levels in East Marsh - 2-Year Flows and 10' Tides (First Storm)



Note: This figure shows modeled water levels in the East Marsh for all setback dike alternatives and existing conditions.

This plot zooms in on the 'second storm' which includes 100-year stream flows and runoff rates with King Tides reaching 12' NAVD88.

Figure 50

Modeled Water Levels in East Marsh - 100-Year Flows and King Tides

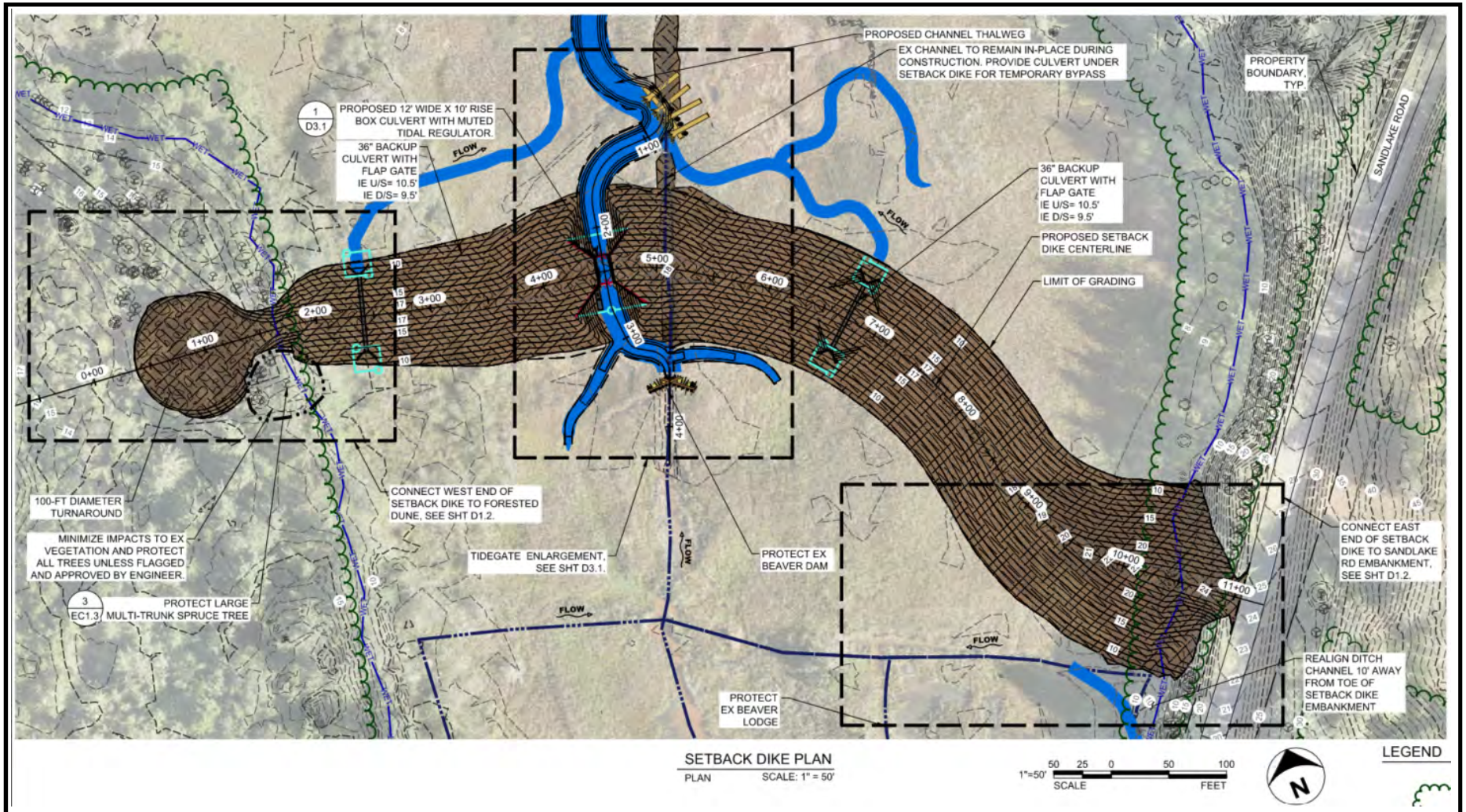


Figure 51

Setback Dike Plan - 90% Design

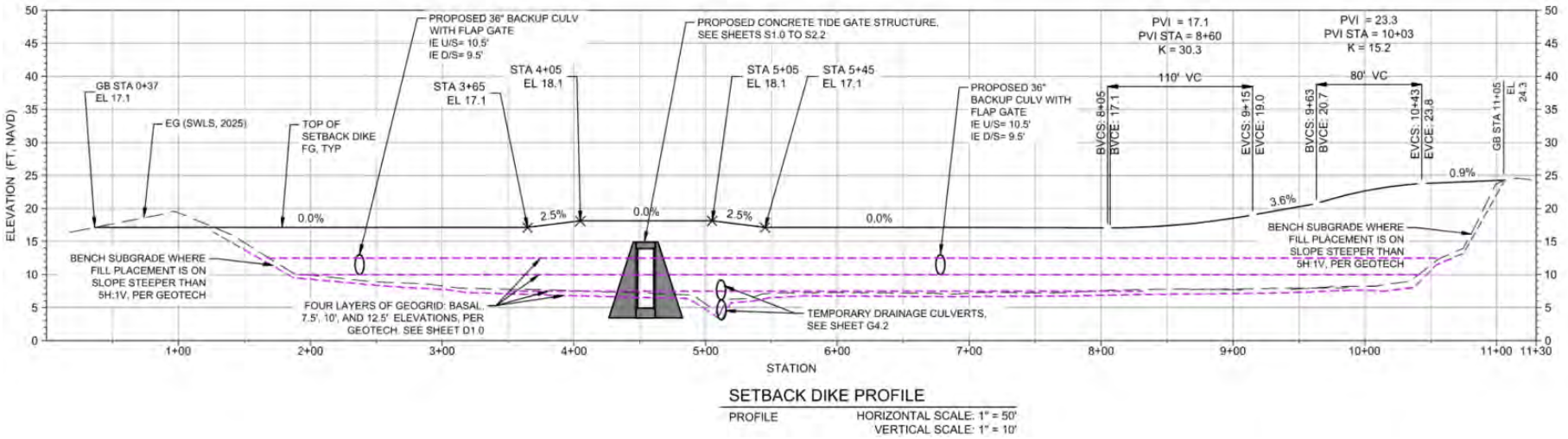


Figure 52

Setback Dike Profile - 90% Design

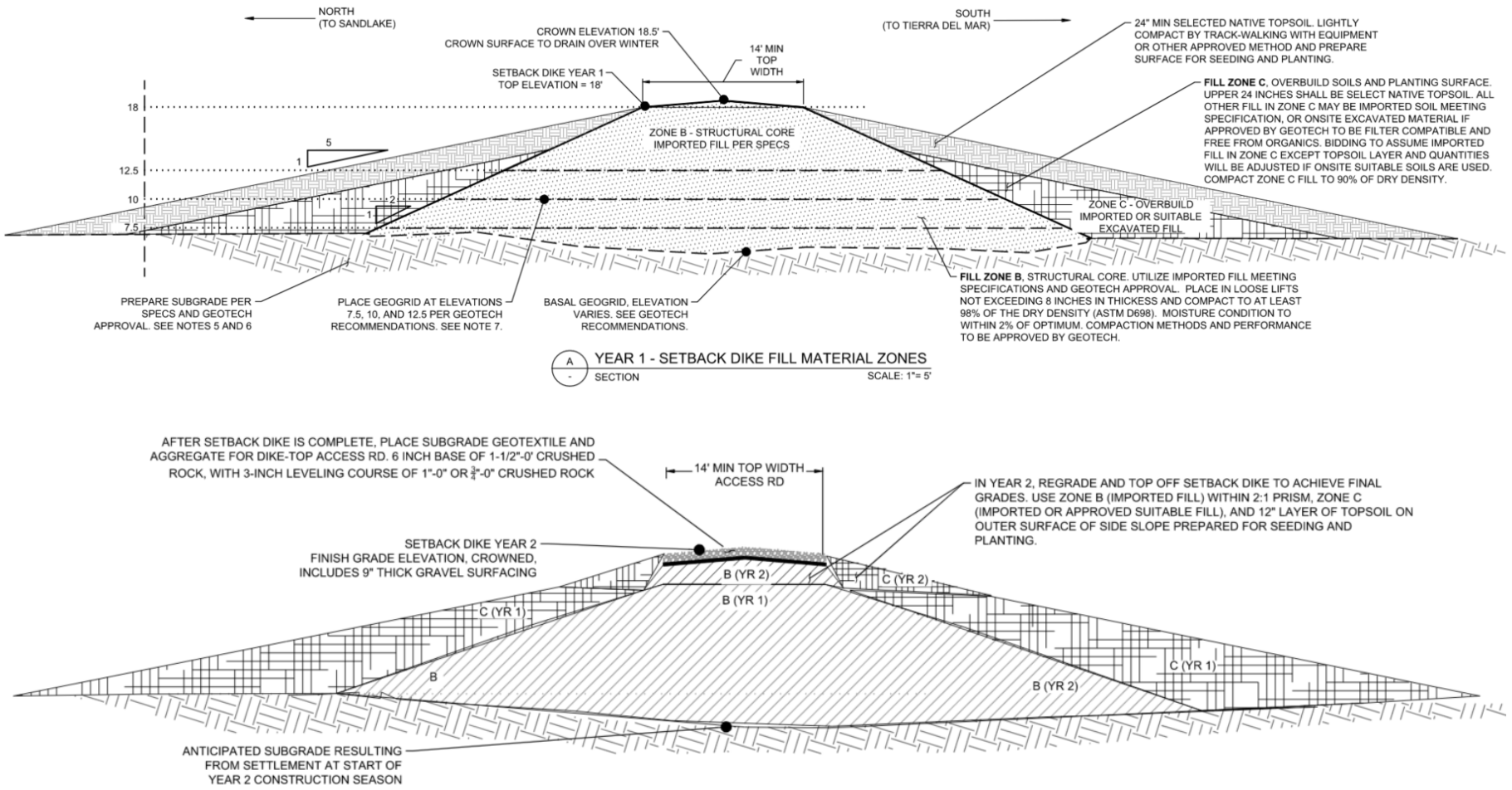
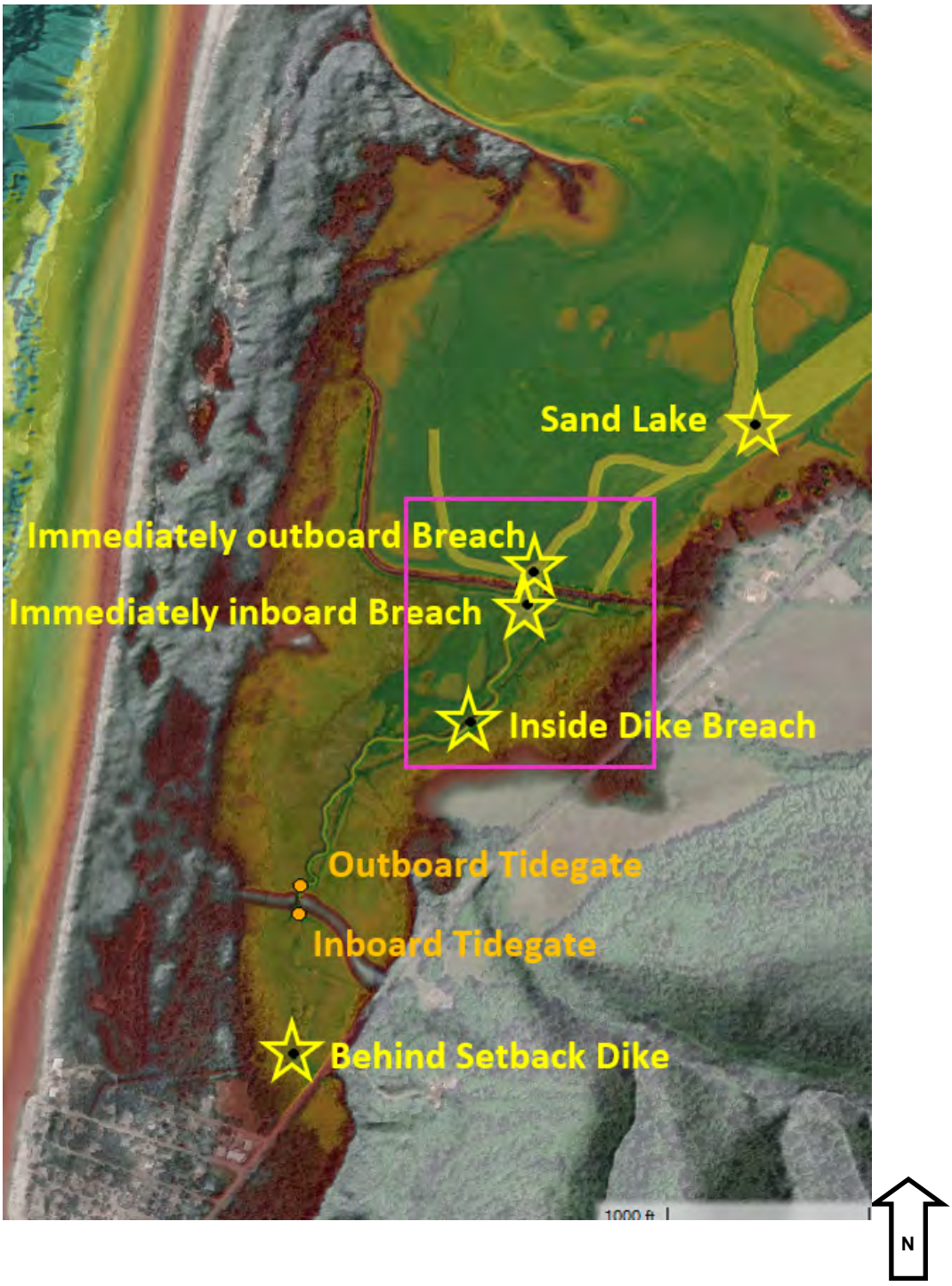


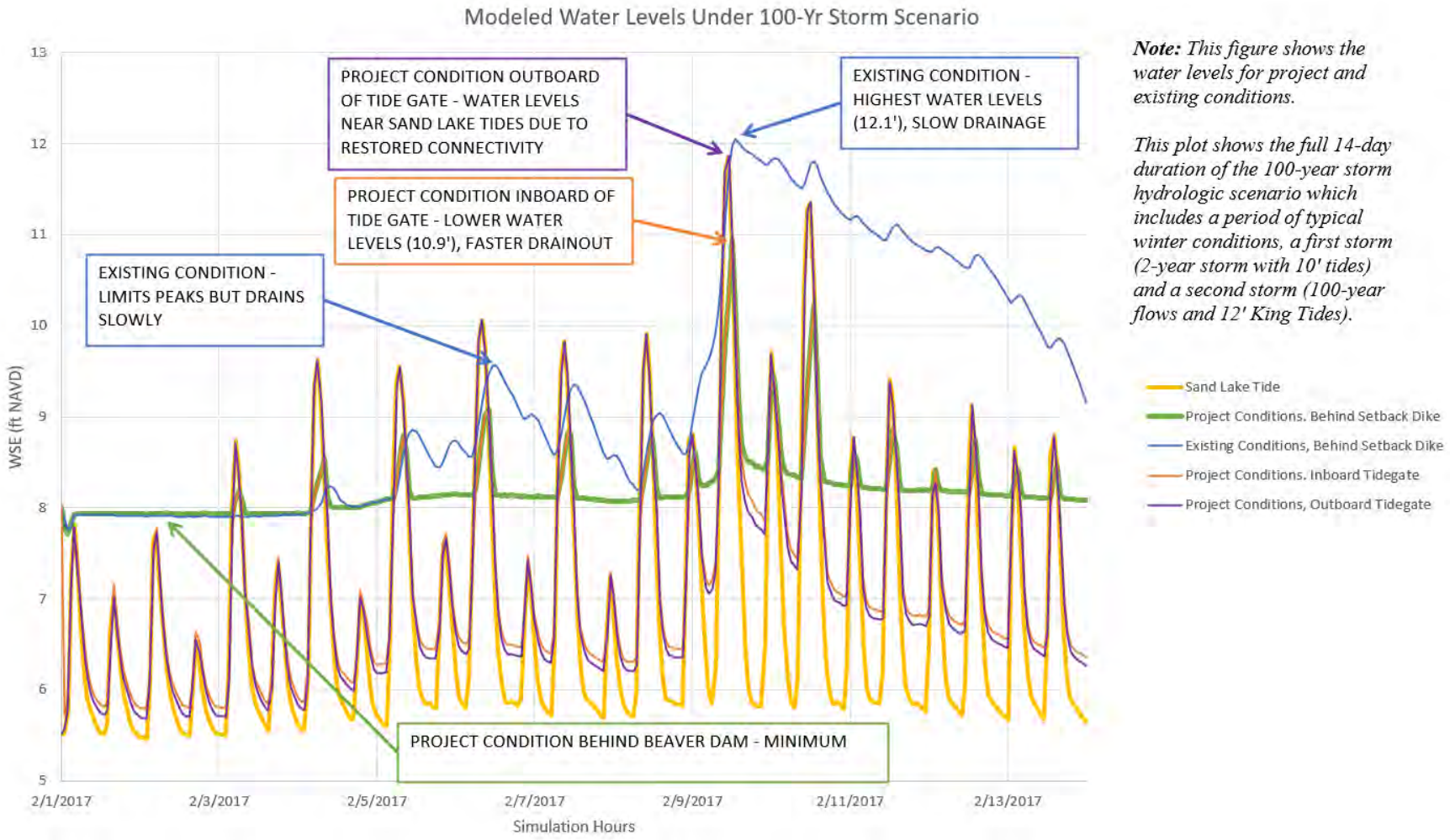
Figure 53

Setback Dike Typical Sections - 90% Design



Note: *This figure* shows the sample location points within the HEC-RAS model for water level and velocity plots.

Figure 54
Sample Point Locations in the 2D Model for Water Level and Velocity Plots



Note: *This figure shows the water levels for project and existing conditions.*

This plot shows the full 14-day duration of the 100-year storm hydrologic scenario which includes a period of typical winter conditions, a first storm (2-year storm with 10' tides) and a second storm (100-year flows and 12' King Tides).

Figure 55

Modeled Water Levels at South End of Beltz Marsh During 100-Year Storm Scenario (Full Duration)

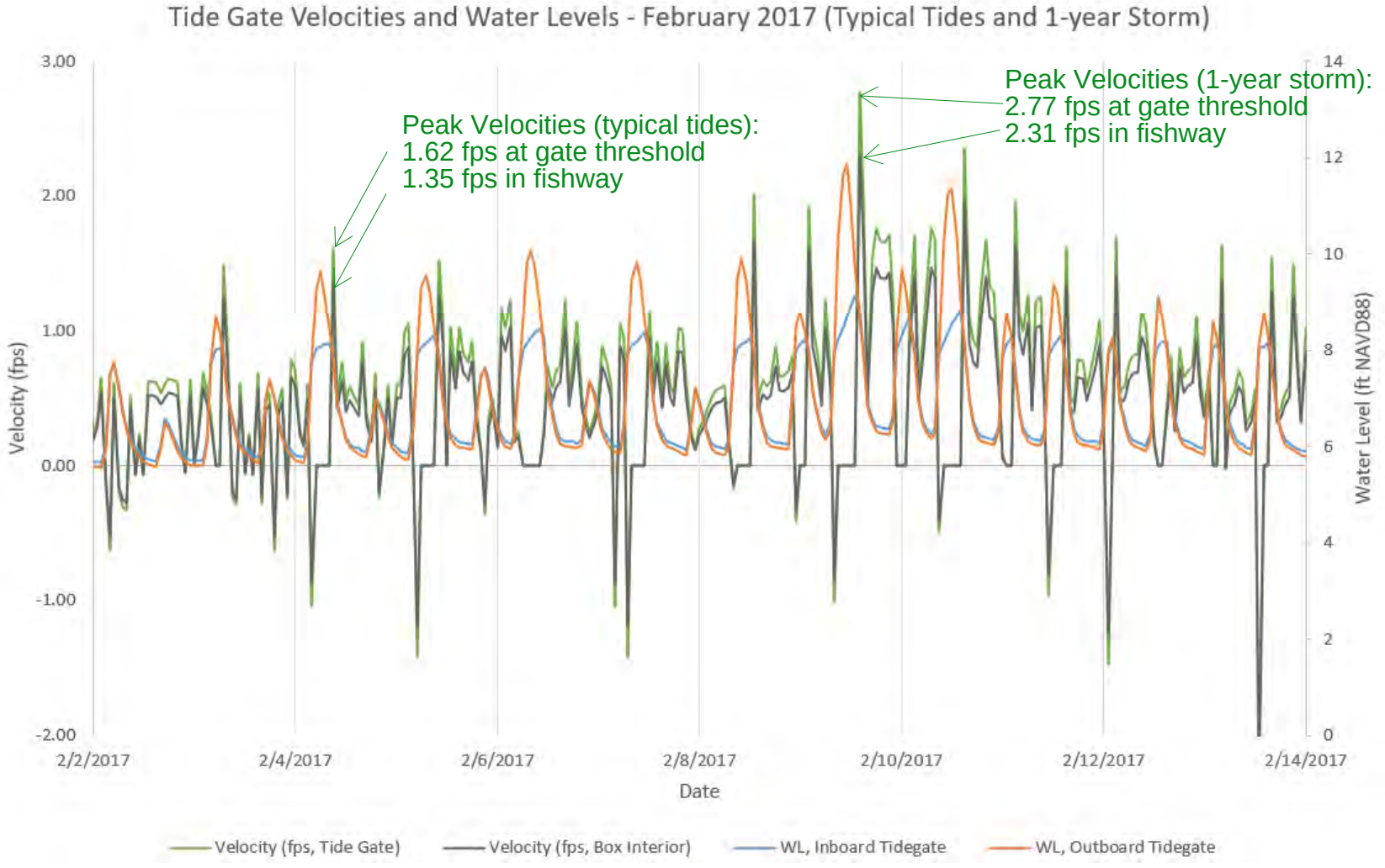


Figure 56

Modeled Tide Gate Velocities and Water Levels - February 2017 Typical Winter Conditions and 1-year Storm

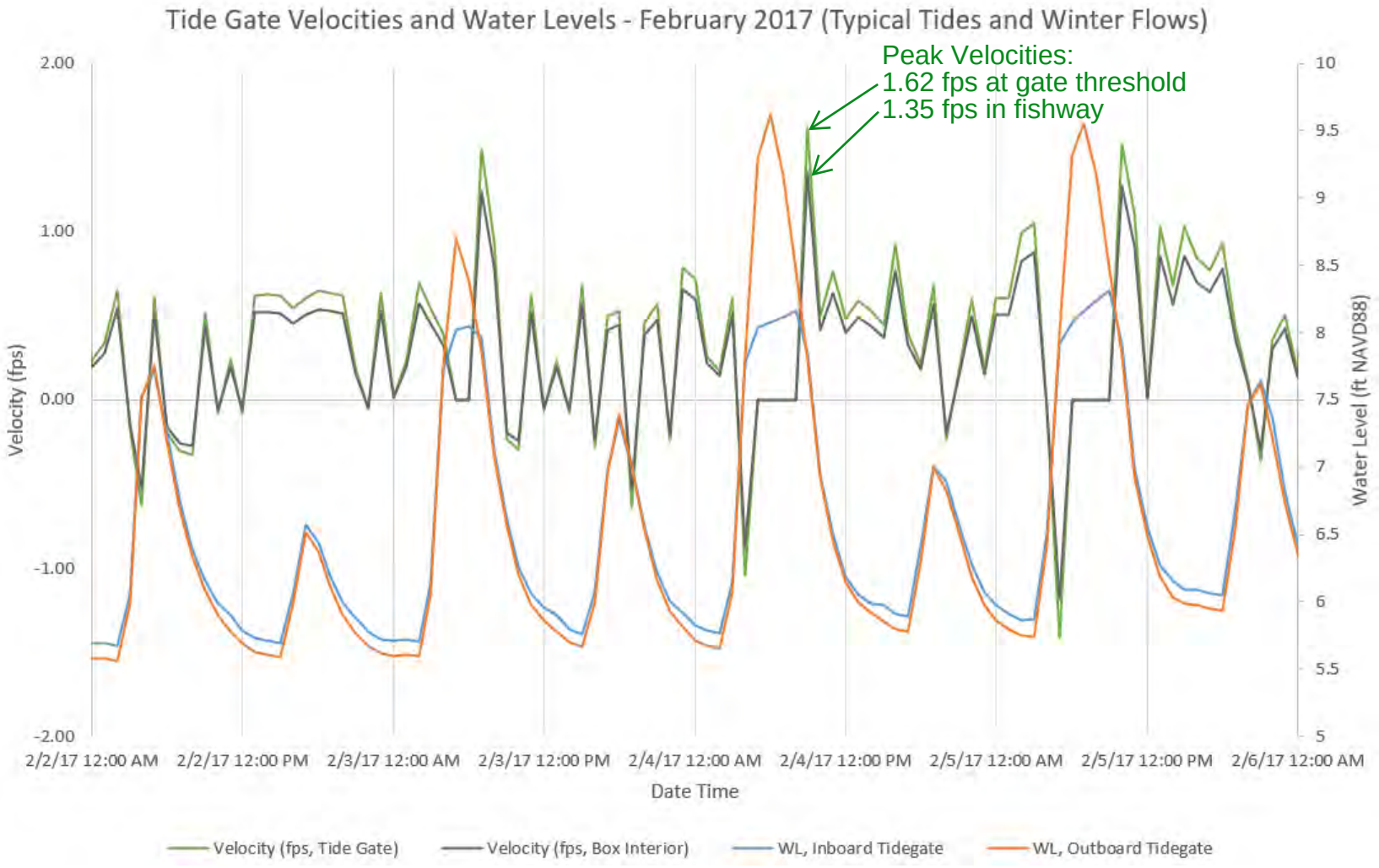


Figure 57
Modeled Tide Gate Velocities and Water Levels - February 2017 Typical Tidal Conditions

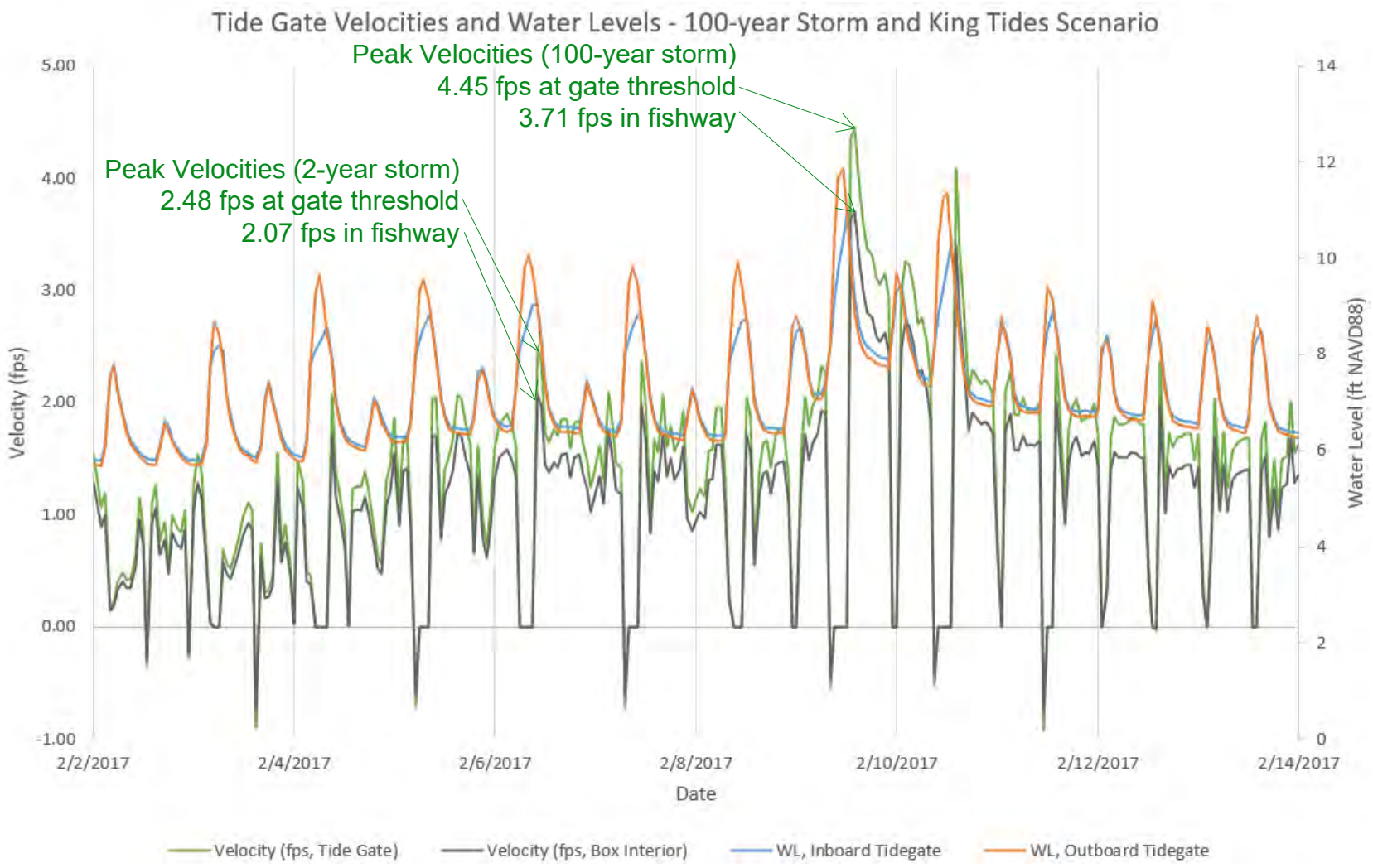


Figure 58

Modeled Tide Gate Velocities and Water Levels - 100-Year Storm Event and King Tides

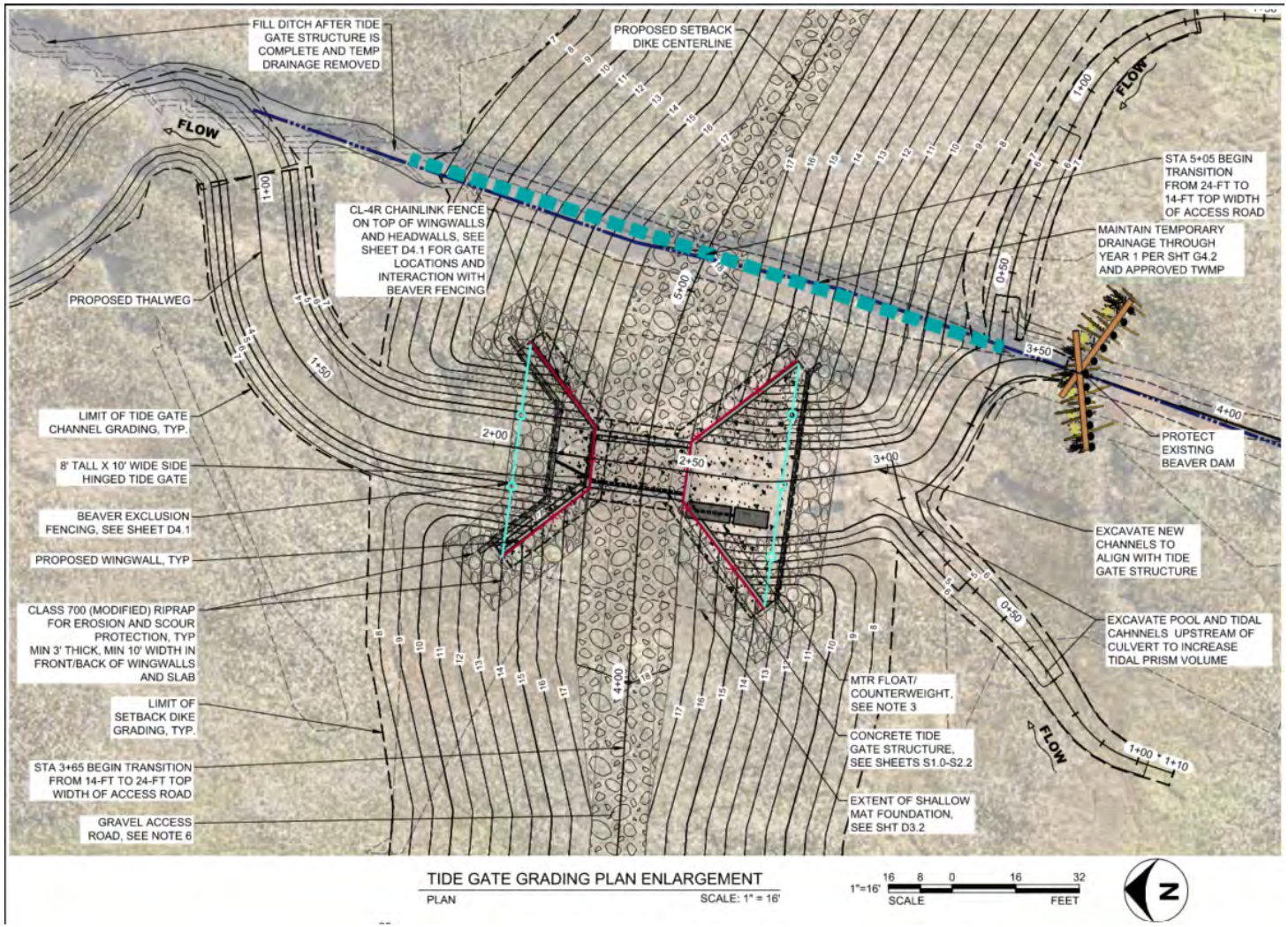
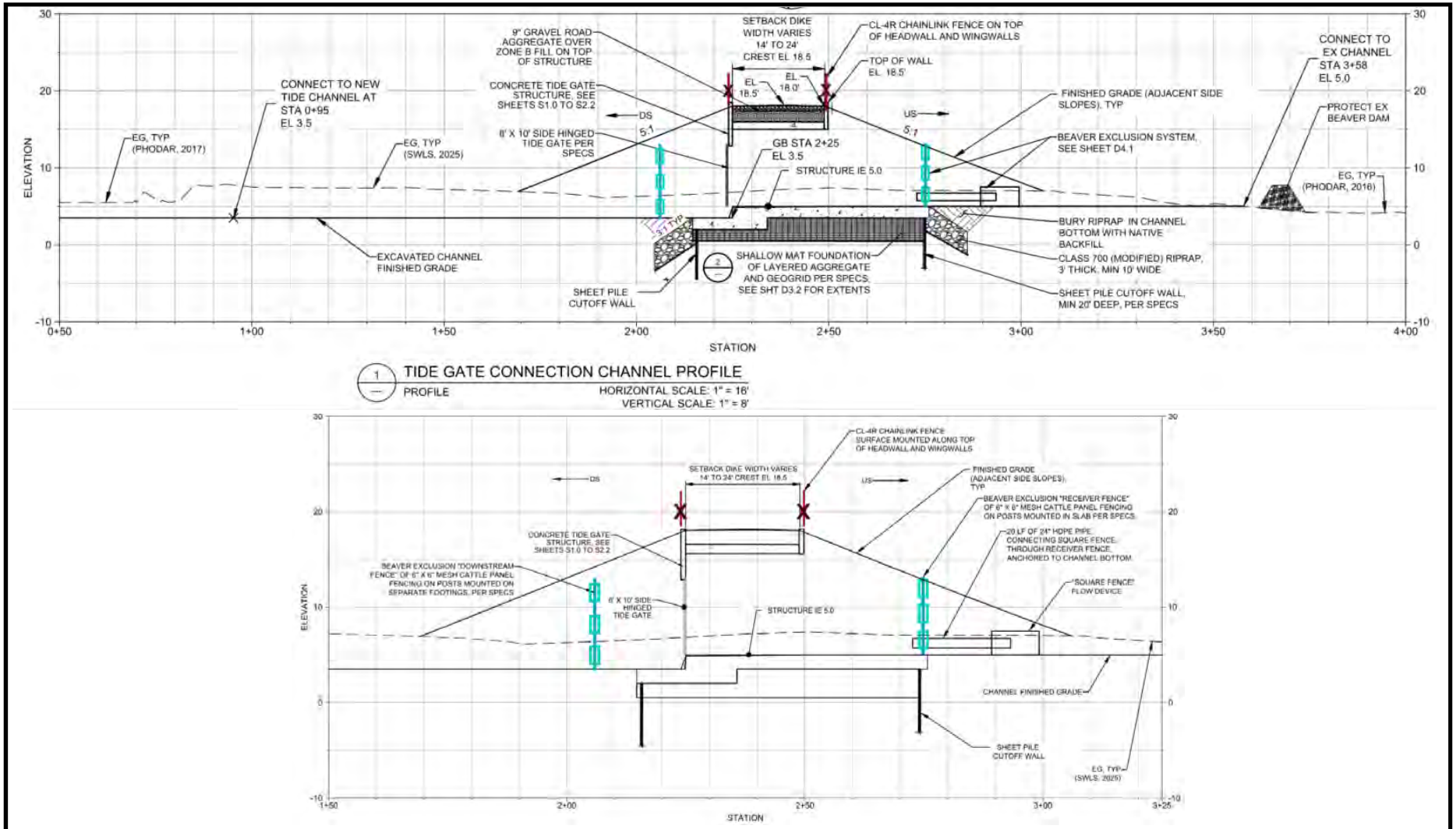


Figure 59
Setback Dike Tide Gate Structure Grading Plan - 90% Design



1 — PROFILE

TIDE GATE CONNECTION CHANNEL PROFILE

HORIZONTAL SCALE: 1" = 16'
VERTICAL SCALE: 1" = 8'

Figure 60

Tide Gate Structure Channel Profile and Beaver Exclusion System Profile - 90% Design

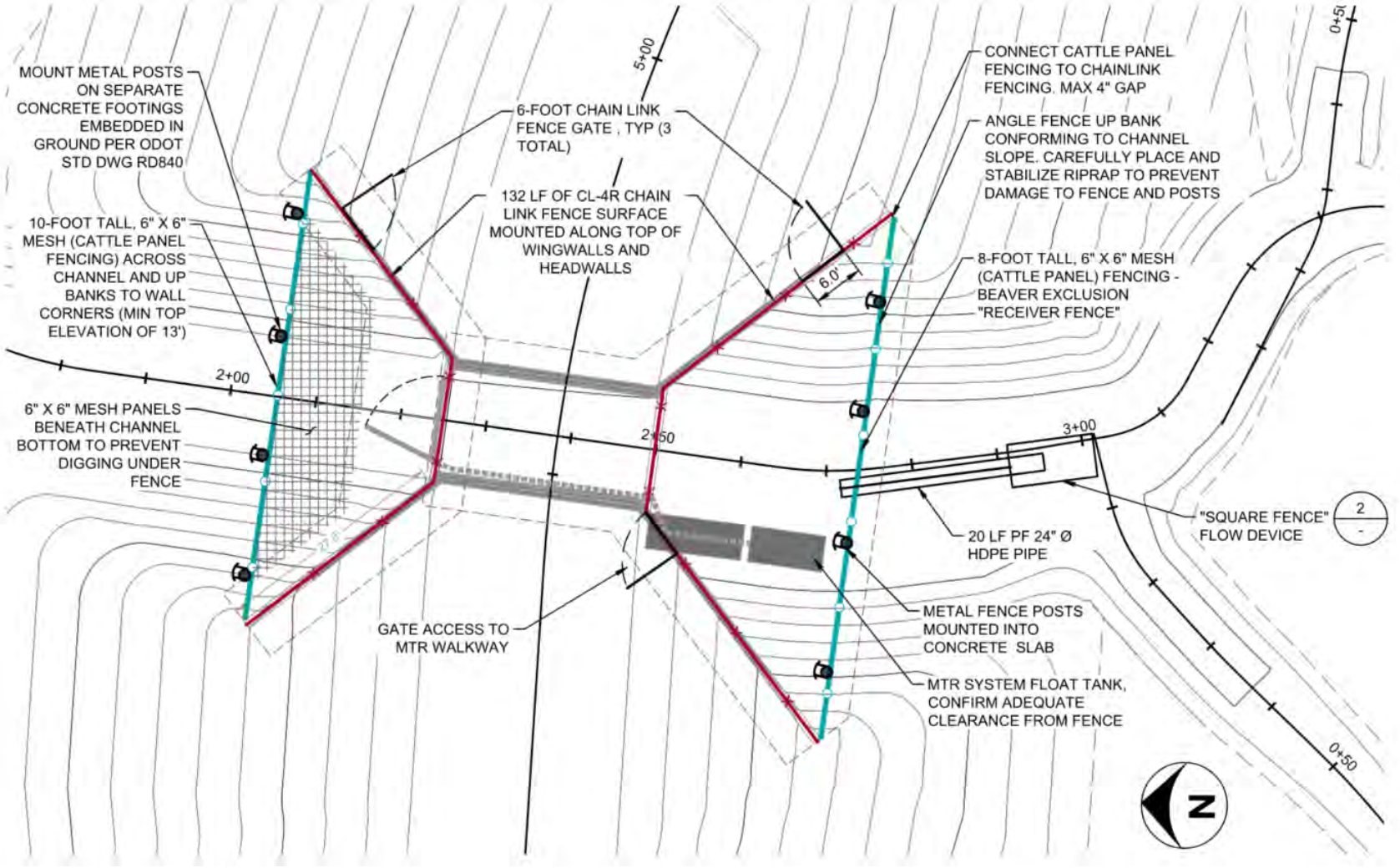


Figure 61

Tide Gate Structure Beaver Exclusion System - Plan View - 90% Design

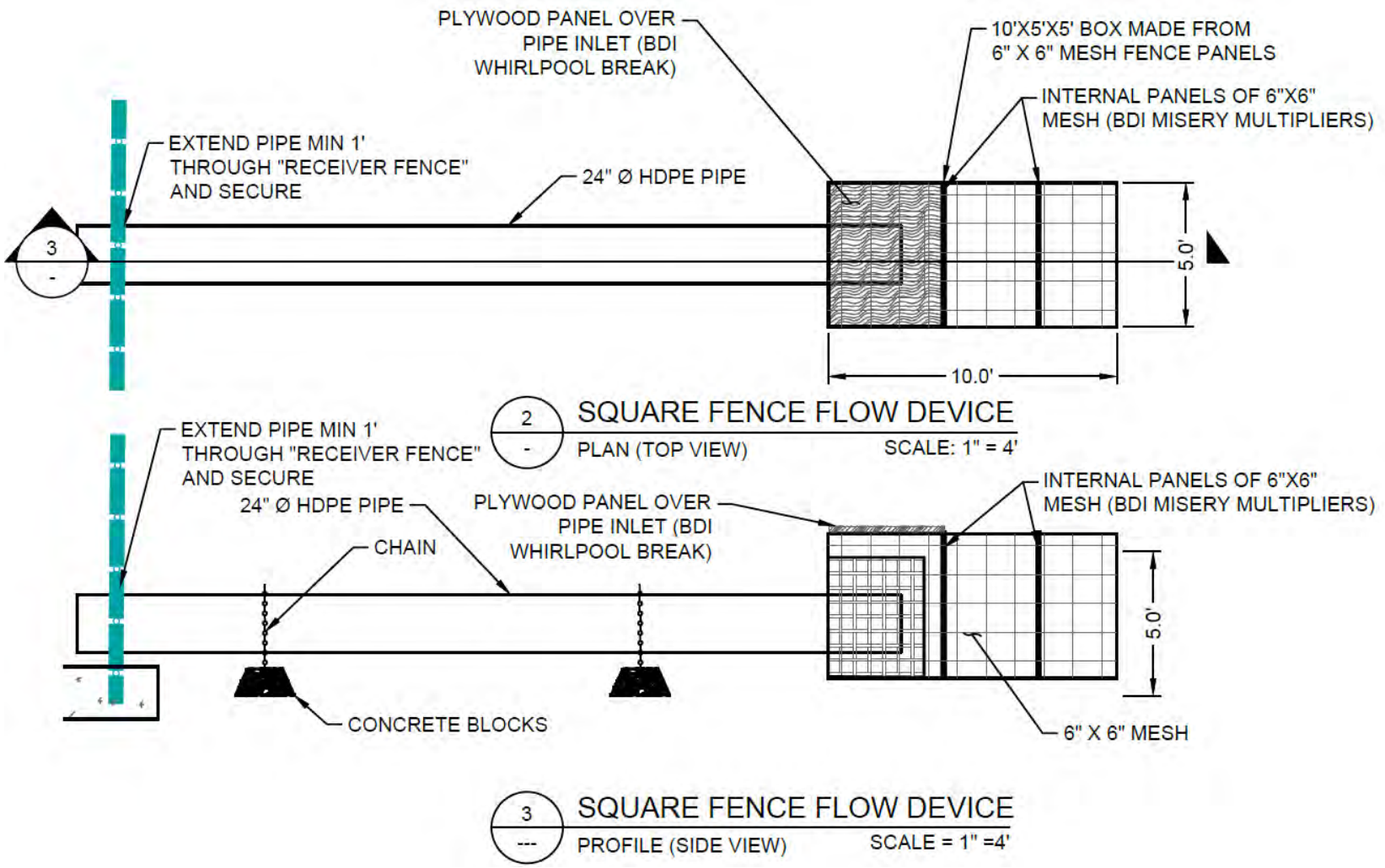


Figure 62

Beaver Exclusion System - Square Fence Flow Device Detail - 90% Design

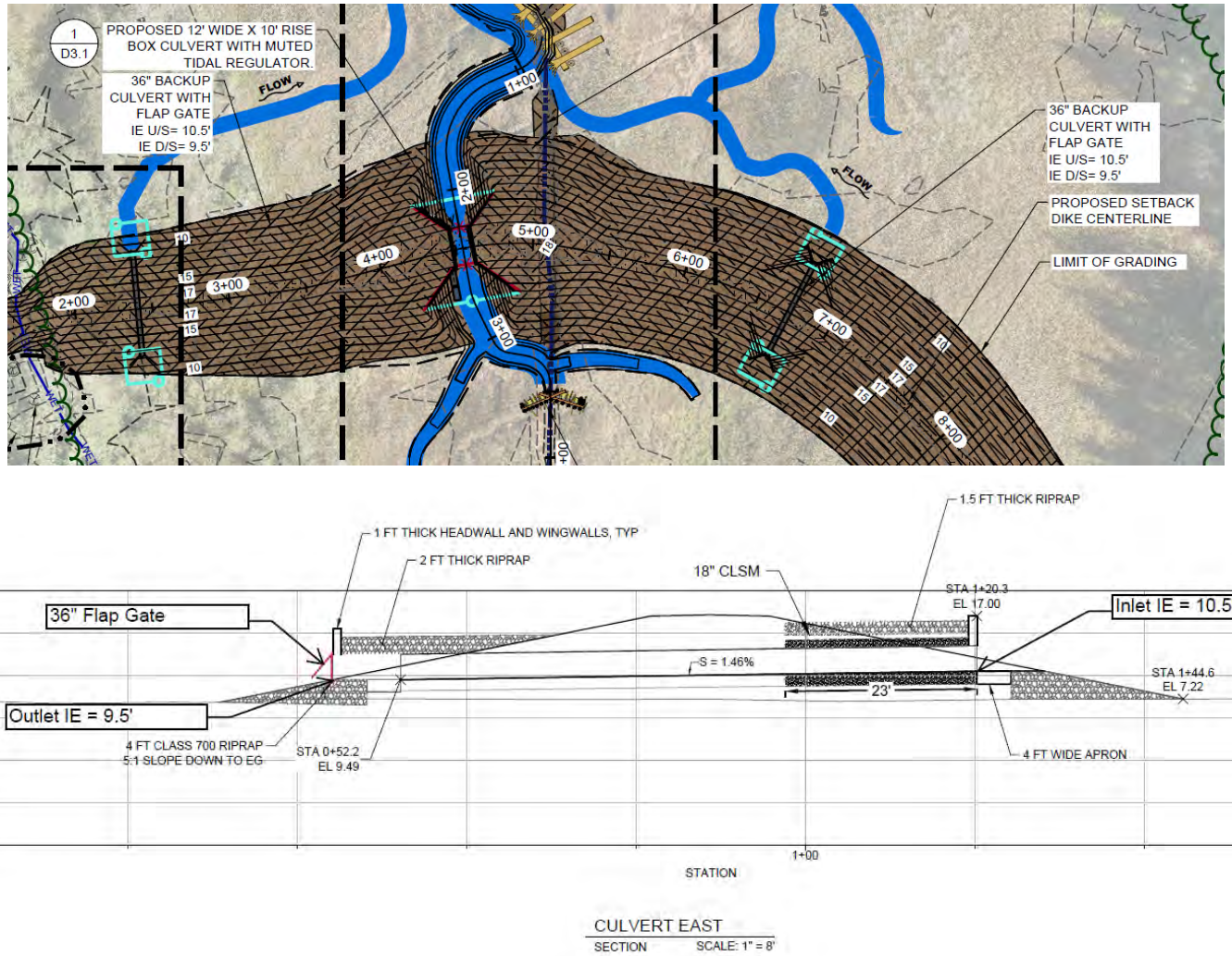


Figure 63
Setback Dike Backup Culvert Pipes - 90% Design

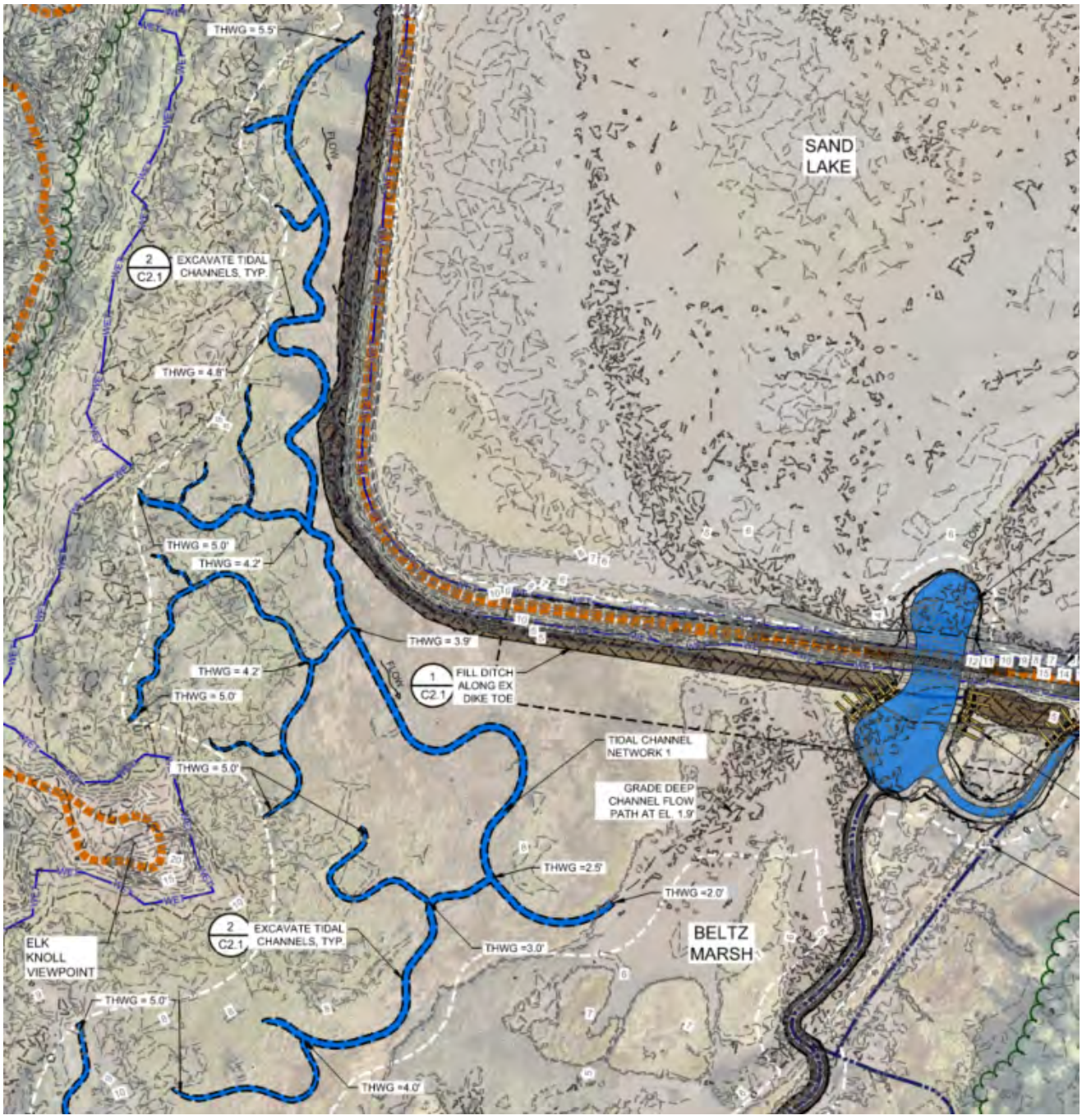


Figure 64
Tidal Channel and Ditch Fill Grading Plan - North

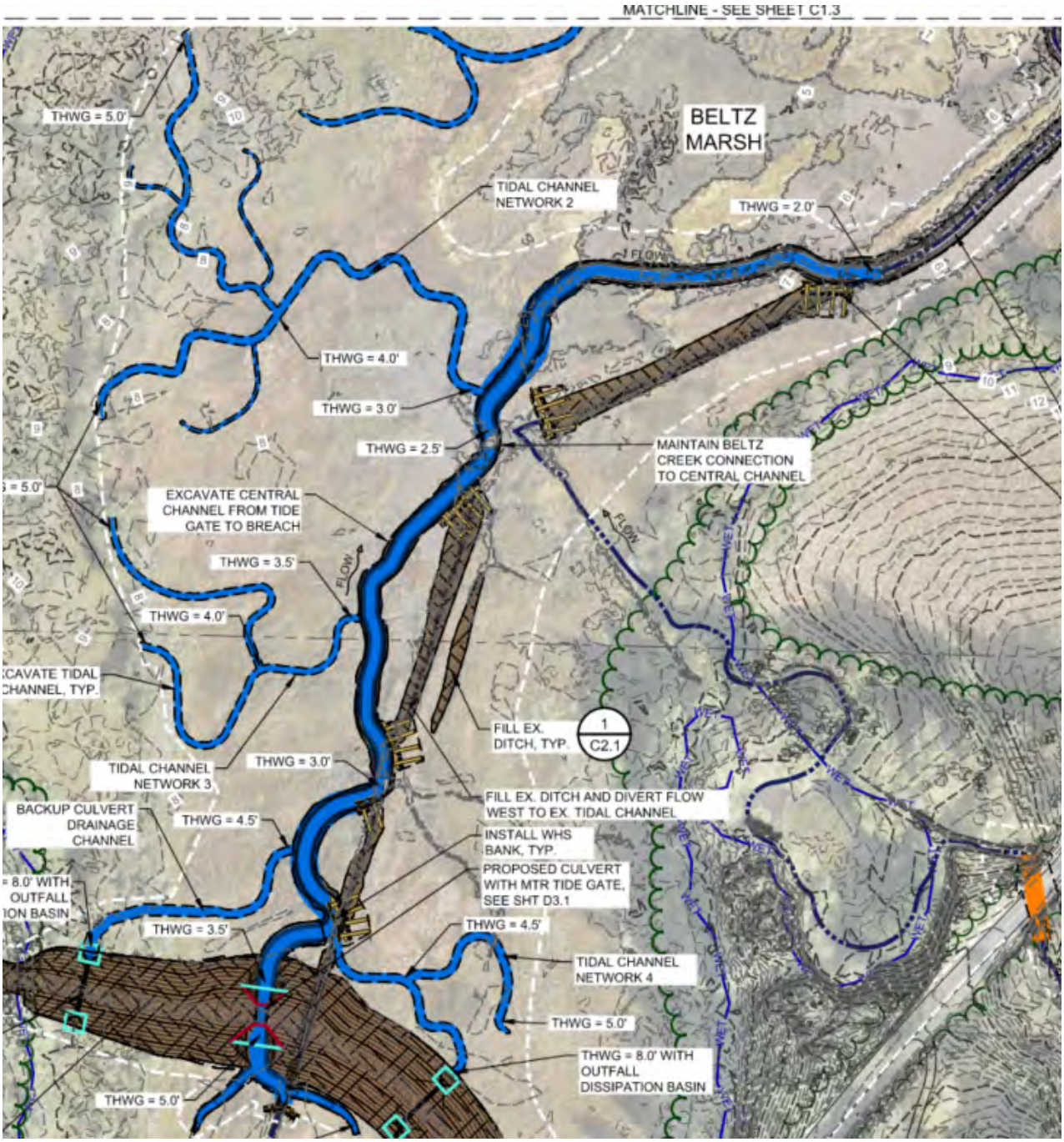


Figure 65
Tidal Channel and Ditch Fill Grading Plan - South

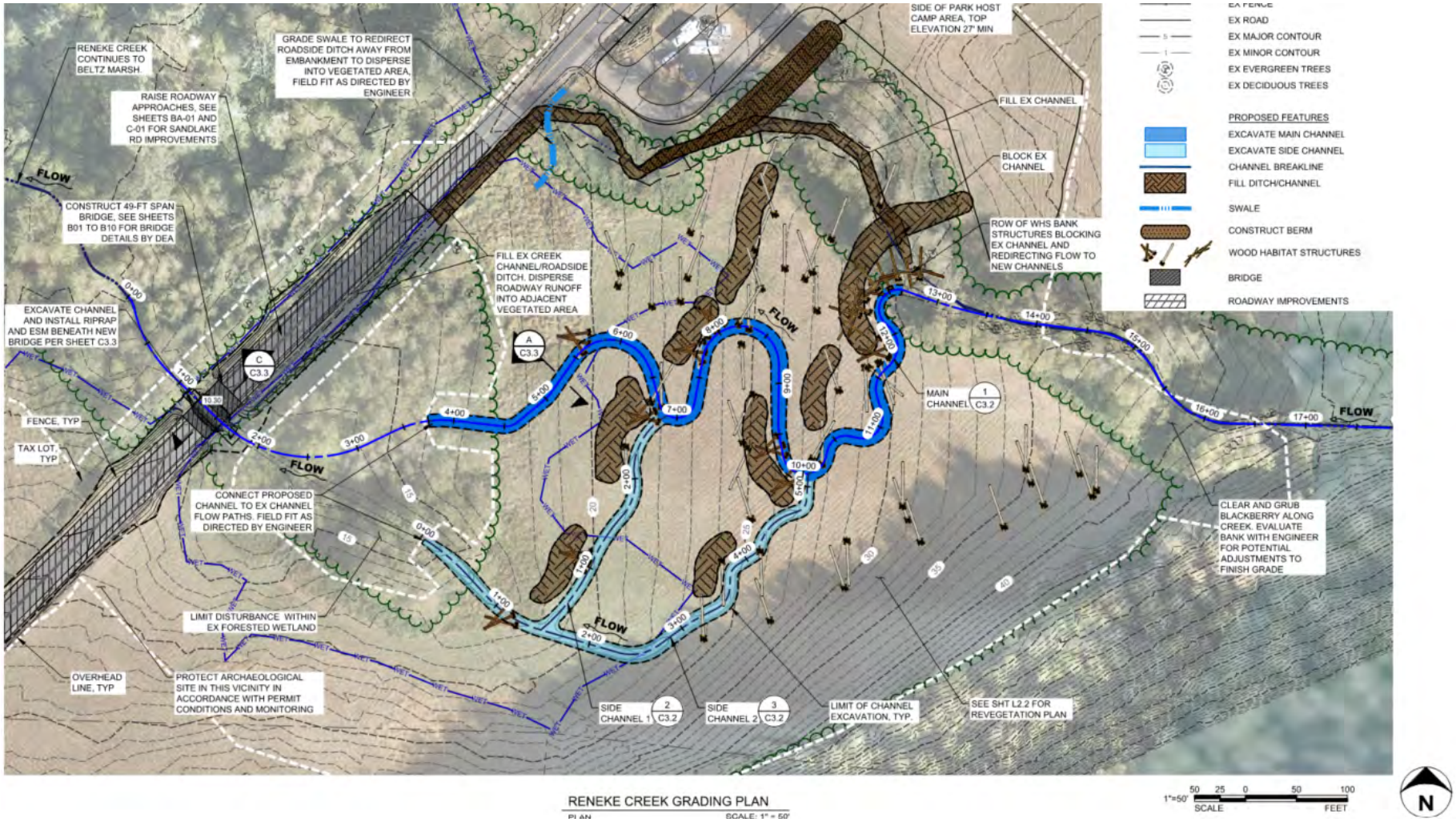


Figure 66
Reneke Creek Channel Realignment Plan

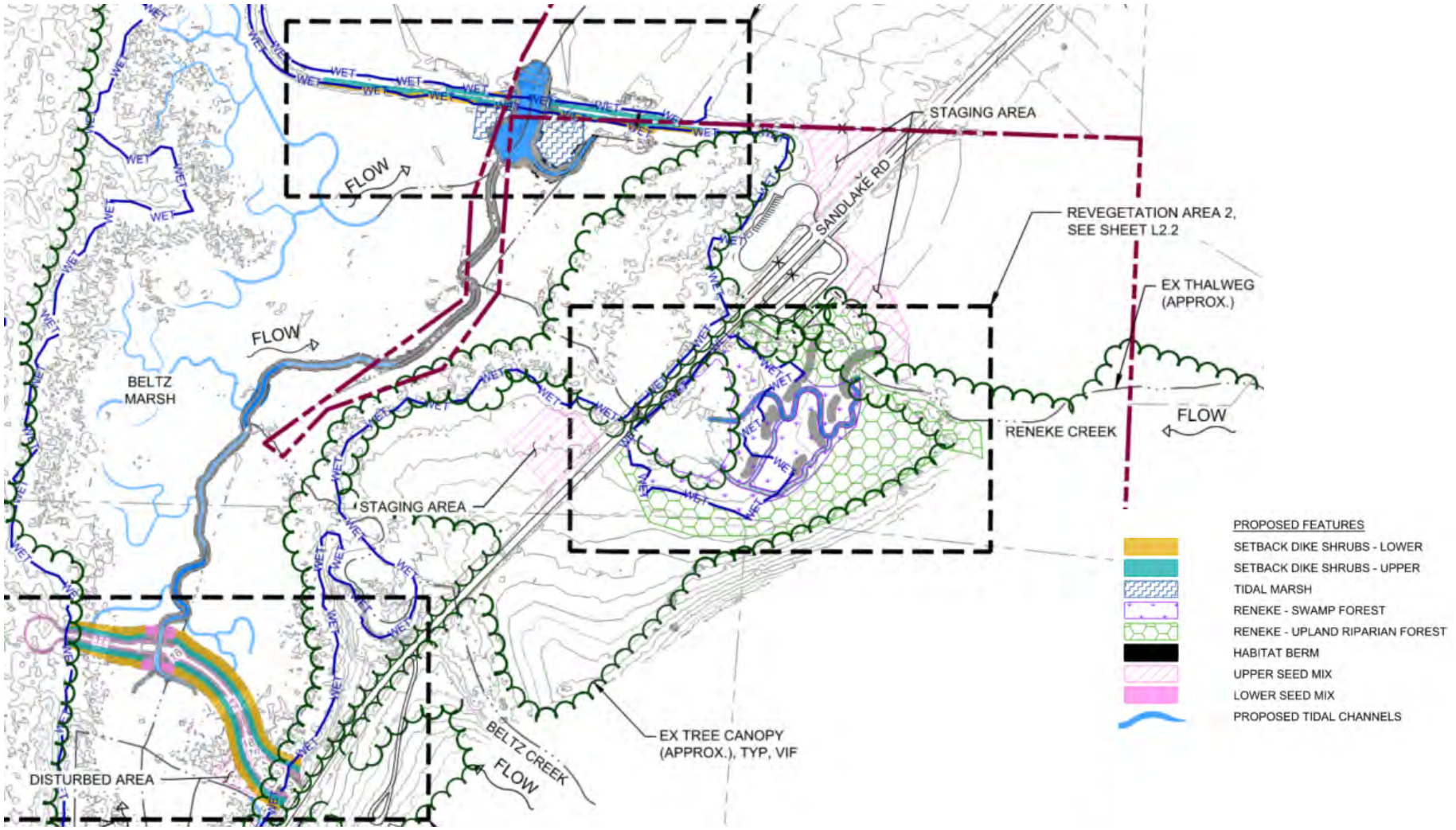


Figure 67
Revegetation Plan Overview

Appendix B.
90% Design Drawings

Appendix C.
90% Engineer's Opinions of Probable Construction Cost

Appendix D.
Sitka Sedge Tidal Wetland Restoration - No Rise Rationale Memo and No Rise Certification

Appendix E.
Sitka Sedge Tidal Wetland Restoration – Fish Passage and Tide Gate Design Memorandum

Appendix F.
Sitka Sedge Tidal Wetland Restoration (Bridges and Culvert) Preliminary Geotechnical Engineering Report

Appendix G.
Sitka Sedge Tidal Wetland Restoration (Dike Setback) Preliminary Geotechnical Engineering Report

Appendix H.
Sitka Sedge Tidal Wetland Restoration Hydraulic Analysis Memorandum

Appendix I.
Reneke Creek Culvert Replacement – Hydraulic and Geomorphic Analysis Memorandum