Final

TULE RED TIDAL RESTORATION

Annual Monitoring Report – Year 1 2020

Prepared for
Westervelt Ecological Services
State and Federal Water Contractors
Agency

February 2021

ESA

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2600 Capitol Avenue
Suite 200
Sacramento, CA 95816
916.564.4500
esassoc.com

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EXECUTIVE SUMMARY

The Tule Red Tidal Restoration Project (Project) was designed to restore tidal wetlands and provide aquatic food web resources for fish, specifically delta smelt, juvenile salmonids, and longfin smelt. Construction of the Project was completed on October 15, 2019 when the exterior natural berm was breached and tidal flows restored to the constructed channels. Year 1 post-construction monitoring was conducted in 2020 (June-December) as required by the Tule Red Adaptive Management and Monitoring Plan (AMMP) and the regulatory permits and approvals issued for the Project.

Monitoring on behalf of the Project sponsors (WES and SFCWA) included a bathymetric survey, tidal hydrology, water quality, vegetation and invasive plants. Food web monitoring was conducted separately by the California Department of Fish and Wildlife Fish Restoration Program monitoring group. Other partners are conducting special studies of food web, fish, and invasive plants (Phragmites).

The Project has made great strides towards its objectives in the first year following construction. The breach and channels are widening and deepening with the tidal forces, which is increasing tidal exchange within the back marsh. As designed, the marsh ponds at the south end have a muted tidal cycle. Primary productivity (chlorophyll-a) in the marsh ponds was greater than levels in the marsh channel, and similar to or greater than levels in Grizzly Bay. Dissolved oxygen levels dropped in August in the back near the CDFW channel, but this was not due to CDFW drain water from the Wildlife Management Area.

Vegetation composition and cover are responding to the recent restoration of tidal influence, creation of aquatic features, and disturbance during construction (habitat berm). Most of the areas within the restoration site are vegetated, with the exception of the upper limits of the habitat berm, above the influence of daily tides. Some of the lower areas (within the intertidal zone) are quickly establishing with native pickleweed. The extent of invasive Phragmites has increased, likely due to changes in hydrology and management practices, as well as recent ground disturbance associated with construction. Some areas that have successfully vegetated with native species (tules, cattails, bulrushes, and pickleweed) will likely be most resilient to Phragmites invasion, while areas in transition (western marsh plain where saltgrass is in decline due to the changed hydrology, unvegetated areas like tidal pannes) are most at risk.

Recommendations for Year 2 monitoring and management according to the AMMP are provided.

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CHAPTER 1

Introduction

1.1 Project Location and Background

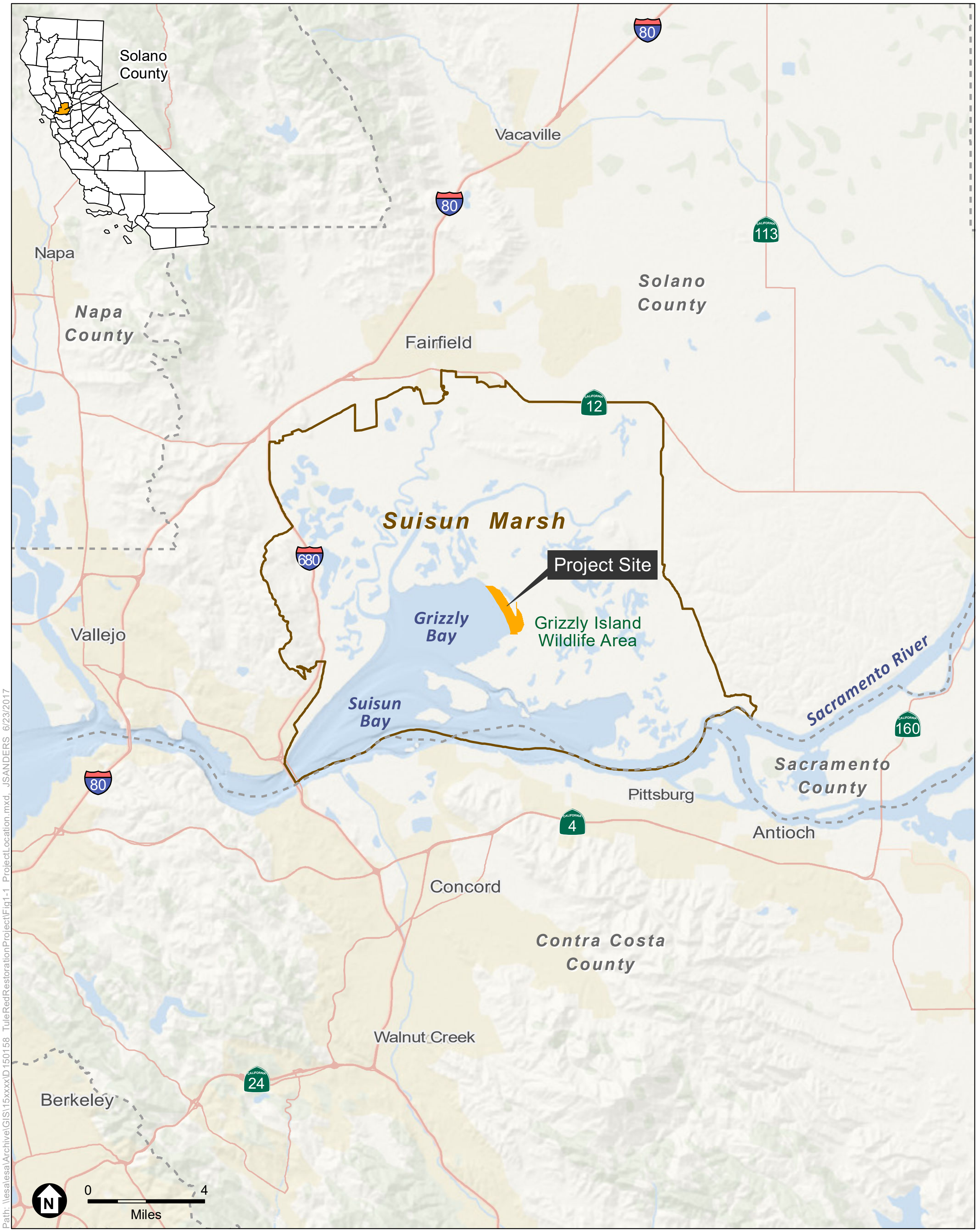
The Tule Red Tidal Restoration Project (Project) is a tidal wetland restoration project located in Suisun Marsh (Solano County, California) that aims to restore and enhance approximately 425 acres of tidal wetlands (**Figure 1-1**). The restored and enhanced tidal wetlands at Tule Red were designed to benefit listed fishes (delta smelt, longfin smelt, and salmonids) in partial fulfillment of the OCAP (Long-Term Operational Criteria and Plan) Biological Opinions (USFWS 2008, NMFS 2009), as overseen by the Fish Restoration Program (FRP).

The Project is a collaboration of the State and Federal Contractors Water Agency (SFCWA), California Department of Fish and Wildlife (CDFW), and Westervelt Ecological Services (WES). As the current landowner, WES will manage the Project for an interim period until DWR or CDFW takes ownership of the property. Upon transfer, either the California Department of Water Resources (DWR) or CDFW will become the land steward and perform long-term monitoring and management tasks.

1.2 Goals and Objectives

The Project goal is to benefit native fish species by establishing tidal connectivity to the Project site. The restoration objectives include:

- **Food Web Contribution**: Enhance regional food web productivity and export to Grizzly Bay in support of delta smelt and longfin smelt recovery.
- **Salmon Rearing Habitat**: Provide rearing habitats for out-migrating juvenile salmonids.
- **Habitat for Other Species**: Provide rearing, breeding, and refugia habitats for a broad range of other aquatic and wetland-dependent species that utilize or depend upon the combination of brackish aquatic-tidal marsh habitat, including Sacramento splittail.
- **Ecosystem Function**s: Provide ecosystem functions associated with the combination of Delta brackish water aquatic, tidal marsh, and upland interfaces that these species require.
- **Habitat Succession**: Provide topographic variability to allow for habitat succession and resilience against future climate change and sea level rise.



SOURCE: Esri, 2012; ESA, 2017

Tule Red Restoration Project

Figure 1-1
Project Location

The habitats to be restored include approximately:

- 18 acres upland habitat (> 7.0' NAVD),
- 377 acres intertidal habitat (MLLW to MHHW [+1.1' NAVD to +7.0']), and
- 30 acres subtidal habitat (tidal channels and ponds lower than MLLW [<+1.1 NAVD]).

1.3 Monitoring and Studies

The purpose of monitoring is to evaluate the effectiveness of restoration and progress towards objectives, comply with Project permits, identify triggers for management, reduce uncertainties, and learn and improve for future restoration and management. A range of monitoring and studies were conducted in 2020 at the Project site by a variety of partners, as shown in **Table 1-1**.

TABLE 1-1
2020 MONITORING AND RESEARCH PARTNERS AT TULE RED

Responsible Party	Leads	Type	Description, metrics
CDFW FRP	Stacy Sherman CDFW, Dan Ellis CDFW	Effectiveness	Foodweb (phytoplankton, zooplankton, benthic invertebrates), water quality
WES, SFCWA, ESA	Rob Capriola WES, Kim Erickson WES, Ramona Swenson ESA	Effectiveness, Compliance	Bathymetry, hydrology, water quality, vegetation, invasive plants
USGS, UCB, ICF	Susan De La Cruz USGS, Isa Woo USGS, Lenny Grimaldo ICF	Special Study	Benthic invertebrates, fish, and terrestrial insects; stable isotope analysis of energy pathways; fish diet.
Suisun RCD, Delta Stewardship Council	Richelle Tanner, Delta Science Fellow, John Takekawa SRCD	Special Study	Phragmites impact on community structure and function during tidal restoration (habitat structure, invertebrates, predator use, birds)
UC Davis, Delta Stewardship Council	Dave Ayers, UCD and Delta Science Fellow	Special Study	Fish habitat use of restored tidal wetlands
CDFW	Aicha Ougzin CDFW	Regional Status and Trends	Suisun Marsh Triennial Vegetation Mapping (in 2021)

1.3.1 Effectiveness Monitoring

Effectiveness monitoring tracks progress towards objectives by measuring indicators of ecological status and function and comparing to expected or hypothesized outcomes. Sampling techniques will include annual terrestrial surveys, continuous hydrologic and water quality monitoring via instrumentation, and seasonal sampling of aquatic food web components and fish presence. Measurements of physical and biological components are used to evaluate the evolution of habitat on the site including tidal channel and marsh morphology, vegetation response (including non-native invasive plants), contributions to the food web, and fish use of habitat.[1]

The Tule Red Adaptive Management and Monitoring Plan (AMMP) (WES and Environmental Science Associates [ESA] 2016) addresses monitoring and maintenance activities during the

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[1] U.S. Fish and Wildlife Service Biological Opinion

Project's interim management period (first five years following completion of construction) and beyond. The AMMP identifies objectives, metrics and monitoring methods, and responsible parties for each of the year (**Table 1-2**). This report summarizes the methods and results for Year 1 (2020) post-breach monitoring under the AMMP. Monitoring of physical and hydrological metrics, water quality, and vegetation was conducted by ESA on behalf of WES and DWR. Monitoring of food web elements is the responsibility of the CDFW FRP monitoring team (Contreras et al. 2019).

1.3.2 Compliance Monitoring

This report also satisfies requirements for post-construction (i.e. after breaching) monitoring in compliance with regulatory permits and approvals issued for the Project:

- San Francisco Bay Regional Water Quality Control Board CIWQS Place ID 818757 and CIWQS Reg. Meas. 403247
- U.S. Fish and Wildlife Service (USFWS) Biological Opinion 08FBCT00-2016-F-0071
- San Francisco Bay Conservation and Development Commission (BCDC) 2016.002.00md

Post-construction monitoring requirements are compiled in **Appendix A**. Permit compliance monitoring that was required during construction (2017-2019) has been reported to the regulatory agencies in previous reports (SFCWA 2020).

1.3.3 Special Studies and Coordination

The Tule Red site provides a rare opportunity to study a newly restored and evolving tidal wetland. The Tule Red team has been coordinating with resource agencies and researchers to manage activities and leverage science opportunities (Table 1-1). A Tule Red coordination meeting was held on May 1, 2020 to share study plans and coordinate sampling equipment and locations. The Tule Red team was also invited by the Delta Science Program to meet with the Suisun Adaptive Management Advisory Team (AMAT) on November 17, 2020. The monitoring and research partners made presentations about initial lessons learned, ongoing monitoring studies and special studies being conducted at the site.

1.4 AMMP Hypotheses

The AMMP hypothesized several expected outcomes for the Project:

- **Hypothesis 1 Physical**: The channel inlet at the breach will self-adjust over time from an initial construction width of about 50 feet and invert of -2 feet NAVD88 to a final equilibrium width of about 160 feet and invert of -5 feet NAVD88 within 7 years after construction. This hypothesis will examine the calculation of equilibrium breach dimensions based on tidal prism within the site, substrate shear strength, and tidal regime (boundary tidal condition). (Note that the initial channel was modified during construction to a width of 100 feet and an invert of -1 foot NAVD88 (SFCWA 2020).)

TABLE 1-2
METRICS, METHODS, AND DURATION OF SAMPLING FOR INTERIM MANAGEMENT PERIOD (TULE RED AMMP 2016)

				Sampling Intervals (Years)								
Monitor Category	**Metric**	**Method**	**Time of Year, Frequency**	**Pre-Breach 1**	**Post-Breach**	**1**	**2**	**3**	**4**	**5**	**Every 5 years**	**Site and Samples**
Physical Processes and Hydrology	Topography and bathymetry (e.g., channel morphology, pond depths)	Ground-based GPS survey, or LiDAR if available, aerial photos	Annual during summer	X	X	X		X		X	X	Project area, up to 9 cross-sections including breach, channels, tidal pannes, marsh ponds, habitat berm
	Tidal Regime	Gauges or water level loggers	All year, automatic measurements (may focus on spring-fall or tidal extremes)		X	X		X		X		3-4 sites (breach, main channel, marsh pond, marsh plain)
	Residence time in ponds and other habitats	Calculated with date from loggers	Annual during summer		X	X		X		X	X	Project area
Water Quality	Water quality (temperature, EC, turbidity, pH, DO)	Continuous data sonde	All year, automatic measurements (may focus on spring-fall period)		X	X		X		X	D	3-4 sites (breach, main channel, pond)
		Discrete seasonal samples	Up to 9 monthly events (Feb-Oct) with food web and fish sampling		X	X	X	X	X	X	D	3-4 sites (breach, main channel, pond)
	Methyl mercury in water	Discrete seasonal grab samples	3 events (spring, summer, fall).	GB	X	X		X		X		3-4 sites (breach, main channel, pond)
		Special Study	*To be determined*	D (GB^2)		D		D				*Special study*, to be determined
	Nutrients (nitrogen and phosphorus species)	Discrete grab samples	Up to 9 monthly events (Feb-Oct) with food web and fish sampling	GB		X	D	X	D	X		Up to 12 sites (3 sites each in Grizzly Bay, main channel, marsh ponds, pannes)
Food Web	Chlorophyll a	Optical sensor (if available); Grab samples	Up to 9 monthly events (Feb-Oct) Typical: 3 events (spring, summer, fall).	GB		X	D	X	D	X		Up to 12 sites (3 sites each in Grizzly Bay, main channel, marsh ponds, pannes)
	Phytoplankton	Plankton tows, lab sorting										
	Zooplankton	Zooplankton tows, lab sorting										
	Benthic macroinvertebrates	Benthic grab samples or sediment cores	2 events (spring and fall)	GB		X	D	X	D	X		Up to 12 sites (3 sites each in Grizzly Bay, main channel, marsh ponds, pannes)
	Epibenthic and epiphytic macroinvertebrates	Sweep net; leaf packs optional										
	Particulate organic matter (POM), dissolved organic matter (DOM)	*Special Study*	To be determined	D	D	D	D	D	D	D		*Special study*, to be determined

TABLE 1-2 (CONTINUED)
METRICS, METHODS, AND DURATION OF SAMPLING FOR INTERIM MANAGEMENT PERIOD (TULE RED AMMP 2016)

Monitor Category	Metric	Method	Time of Year, Frequency	Sampling Intervals (Years)								Site and Samples
Food Web (cont.)	Transport of nutrients and organic matter	Flux-based sampling with USGS if available – *Special Study*	1-3 times per year (spring to fall), depending on partner and funding	D	D	D	D	D	D	D		*Special study*, to be determined
Fish	Larval fish (species, number, size)	Larval fish trawl	Up to 5 monthly events (Feb-June)	GB	X	X	X	X	X	X		Up to 6 sites (3 sites each in main channel and Grizzly Bay nearshore)
	Fish (species, number, size) Chinook salmon presence	Beach seines or lampara seine	Up to 9 monthly events (Feb-Oct)	GB	X	X	X	X	X	X		Up to 12 sites (3 sites each in Grizzly Bay, main channel, marsh ponds, pannes)
		Otter trawl	Up to 9 monthly events (Feb-Oct)	GB	X	X	X	X	X	X		Up to 6 sites (3 sites each in main channel and in Grizzly Bay nearshore credited habitat)
		Fyke net	Up to 9 monthly events (Feb-Oct)		X	X	X	X	X	X		Up to 2 sites (where secondary channels drain to main channel)
Wetlands and Vegetation	General habitat conditions	Photo points (qualitative record)	Annual during growing season (summer)	X		X	X	X	X	X	X	Up to 20 points across site
	Aquatic habitat mapping = delineation	Aerial imagery and ground-truthing surveys	Annual during growing season (summer)		X	X		X		X	D	Map entire site
	Vegetation composition and cover	Percent cover in plots along transects	Annual during growing season (summer)	X		X		X		X	D	4 transects with plots from top of habitat berm through channel to Grizzly Bay edge of vegetation
	Invasive plants	Visual survey (aerial imagery and ground surveys)	Annual during early growing season (spring)	X	X	X	X	X	X	X	X	Survey entire site. Annual checks to continue during qualitative site surveys.

NOTES:
GB = Pre-breach sampling in Grizzly Bay only
Years after breach: X = Sampling proposed in this year, D = Discretionary sampling, contingent on available resources, partners, and project needs.

- **Hypothesis 2 Food Web**: Primary and secondary productivity in the marsh ponds (mean residence time 6 -14 days) will be greater than in the tidal pannes (mean residence time about 3 days), the marsh plain (mean residence time about 3-9 hours), tidal channel, and Grizzly Bay. This hypothesis will examine the value of tidal ponds and tidal pannes and increased residence time in the restoration design in terms of food web production.

- **Hypothesis 3 Fish**: The restored habitats at the Project site (tidal channel, marsh ponds, and pannes) will support a fish community (including juvenile salmonids) similar in composition and relative abundance to that documented in comparable habitats in the Suisun Marsh region. This hypothesis will examine habitat suitability and use by target fish species.

- **Hypothesis 4 Vegetation**: Elevation, hydrology, and existing vegetation within different habitat features will affect colonization of the site by *Phragmites*. This hypothesis will examine which elevations within the created tidal regime are suitable for *Phragmites* colonization, and whether pre-inundation establishment of native vegetation, such as tules, may preempt establishment of undesirable invasive vegetation.

- **Hypothesis 5 Vegetation**: Soil organic matter and planting methods will influence vegetation establishment on the habitat berm. This hypothesis will test the difference between the use of organic matter from stockpiled topsoil and hydroseeding/drill seeding and mulch in establishing desired vegetation on the habitat berm.

1.5 Purpose of Year 1 Annual Report

This Year 1 Annual Report focuses on the physical (bathymetry), hydrological, water quality, and vegetation elements monitored by ESA. The results of CDFW's 2020 food web sampling are still in preparation and will be reported to the IEP in Fall 2021 (Contreras et al. 2019). Most of the special studies are in progress and results will be prepared separately by the principal investigators. Once available, copies will be appended to subsequent Annual Reports.

The Year 1 Annual Report includes the following sections:

1. Introduction – Summary of project goals, objectives, hypotheses, and overview of the types of monitoring and research activities conducted at the site in 2020.

2. Project Description – built features, management actions completed in 2020,

3. Monitoring Activities and Methods – identification of metrics and responsible parties, sampling locations, and methods.

4. Results – detailed results of monitoring conducted by ESA and brief summary of other partners' efforts.

5. Discussion – summary of the Project's performance in 2020, recommendations for site management, assessment of Project hypotheses, and suggested refinements for Year 2 (2021) monitoring workplan.

6. Contributors

7. References

Appendices include:

- Appendix A – Tule Red Regulatory Permit Requirements
- Appendix B – 2020 Photo Documentation Points
- Appendix C – Vegetation Plot Data (2017 and 2020)
- Appendix D – 2020 Vegetation Plot Photos

CHAPTER 2
Project Description

2.1 Project Design

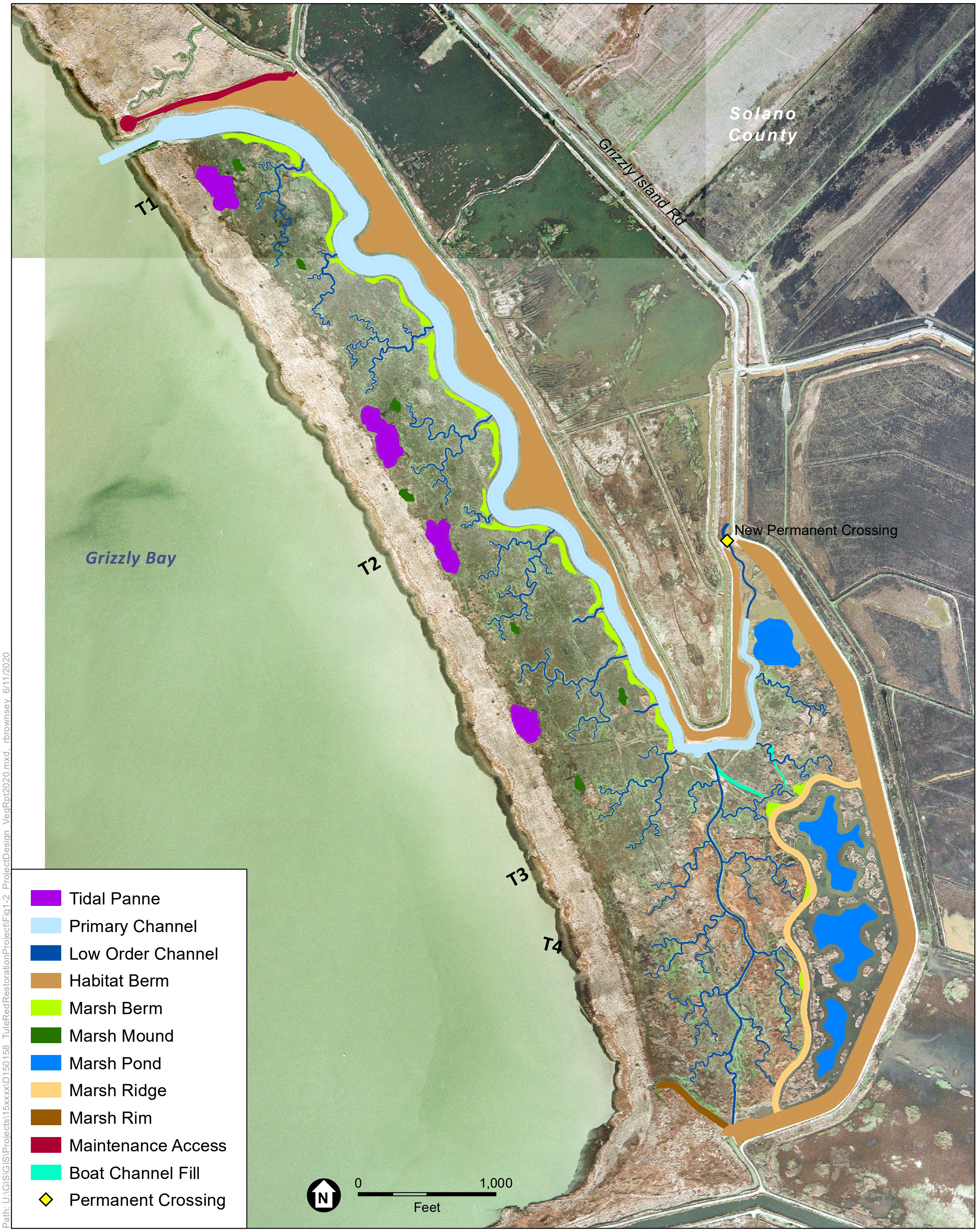
The Project was designed to become a naturally, self-regulating system that would not require active management or intervention. Habitat features are shown in **Figure 2-1** and include:

- a permanent breach of the natural berm to allow for full daily tidal exchange through the interior of the Project site;
- a network of tidal channels that supports a full tidal exchange (i.e., tidal prism) on the Project site;
- a series of tidal pannes/basins intended to retain water for periods up to two weeks to maximize aquatic food production and export; and
- a habitat berm created along the eastern perimeter of the property, which is designed to provide a gradient from marsh to upland habitat and to maintain flood protection for adjacent properties.

2.2 Construction Activities

Construction of the Project was split into two phases. Phase 1 (2017-2018) activities included all the earthwork associated with excavation of the 1st, 2nd, 3rd and 4th order channels and ponds and placement of the excavated material on the habitat berms, marsh berms and marsh ridge. The excavated materials was also used to fill existing boat channels on the site as well as to construct the tidal pannes and ponds and permanent access crossing. Construction work resulted in the restoration of 425 acres of tidal marsh habitats and transitional upland habitat (Figure 2-1). Specifically, 44,925 linear feet of tidal channels (ranging in depth from six inches to four feet from surface elevation), 15 acres of tidal ponds (approximate depth of four feet from surface elevation), and five acres of pannes (approximate depth of 1-1.5 feet from surface elevation) have been created within the site. In addition, a 12,000 foot-long, 50-250 foot-wide, and 7 feet high, undulating transitional habitat berm with a slope ranging from 10:1 to 20:1 along the existing perimeter was constructed.

Phase 2 (2019) activities included completion of construction including removal of the clubhouse, planting of tules, hydroseeding uplands, and all work associated with breach of the natural marsh ridge to establish tidal connectivity to Grizzly Bay. During construction, less than 150 acres of the 425 acre site was cleared of vegetation and contoured to create the physical setting for tidal wetland restoration. Once the physical features of the site were completed, native tules and cattails that had been salvaged were replanted at appropriate tidal elevations, and transitional upland habitat was hydroseeded with a mix of native perennial grasses common in Suisun Marsh.



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SOURCE: NHC, 2017; NHC, 2019

Tule Red Restoration Project

Figure 2-1
Project Design

ESA

Finally, a 100-foot wide section of the outer natural berm was excavated on October 15, 2019 to connect the constructed main channel to Grizzly Bay, thus reintroducing natural tidal hydrology to the constructed site.

No construction activities were conducted in 2020.

2.3 Maintenance Activities 2020

Maintenance activities undertaken during 2020 are shown in **Table 2-1** and included:

- Conducting site visits with agency staff
- Providing access for scientific and educational use
- Maintaining site security
- Removing trash
- Weed control - spot spraying of perennial pepperweed (*Lepidium latifolium*) and mowing the roadsides on the southern habitat berm to retard the growth and seed production of annual mustards, poison hemlock, and thistles that were present.

TABLE 2-1
MAINTENANCE ACTIVITIES COMPLETED DURING THE REPORTING YEAR: 2020

Activity	Method	Date	Location	Size and Habitat Impacted	Responsible Party	BMPs to reduce Impact
Site visits	Park in Parking Lot 1; minimal traffic	Various dates throughout the year	Site	None	Westervelt	None required
Provide access for scientific and educational use	Site visits with DWR, DFW and interested authorized individuals	As needed	Site	NA	Westervelt	NA
Maintain site security	Inspect gates and access points	As needed	Site	NA	Westervelt	NA
Remove trash	Manual	As needed	Site	NA	Westervelt	NA
Weed control	Herbicide, mowing	Spring-summer (growing season)	Habitat berm, roads		Westervelt	

2.4 Grizzly Island WMA operations

The CDFW Grizzly Island Wildlife Management Area (WMA) is immediately adjacent to the Tule Red property. Information about the water operations for the WMA was provided by managers Shawn Overton and Orlando Rocha.

Normally, the ponds are drawn down beginning February 15. Ideally, the WMA managers drain the ponds slowly, targeting complete drainage around April 15. This single pump services a large area and so it takes a long time to complete the pumping. Recently, the pump has not been operational (O. Rocha, pers. comm., January 2021).

Flooding of the ponds typically begins between mid-August (S. Overton) and September 1 (O. Rocha), and ponds are usually full by September 15. The ponds flood by gravity using water from the Roaring River. While the ponds are full, the pump is set to run intermittently to ensure non-stagnant conditions. The pumps operate on an infrequent and irregular schedule to remove and add water. The WMA managers try to minimize the amount of pumping while the ponds are full, usually spilling only one inch of pond water at a time. If water levels exceed a certain level, pumps operate for a few hours to drain some water (Shawn Overton, Grizzly Island WMA, pers. comm.).

There is concern that drainage water may have low levels of dissolved oxygen, which could negatively affect fish in the receiving waters (i.e., Tule Red). Pump 4 drains onto the Tule Red site via a channel just north and upstream of the constructed ponds. Monitoring of the drain water for dissolved oxygen levels is required to avoid impacts to fish.

CHAPTER 3
Monitoring Activities and Methods

3.1 Responsible Parties

The AMMP outlined the monitoring schedule and responsible parties (Table 3-1). Year 1 monitoring year (Year 1) activities are summarized in **Table 3-1**. Monitoring of physical and hydrological processes (bathymetry, water levels), water quality, and vegetation is the responsibility of the landowner. These elements were monitored by ESA on behalf of WES, SFCWA and DWR. CDFW is responsible for FRP monitoring of food web and associated water quality elements. Fish monitoring is not currently permitted for the Project, but information has been collected by regional IEP fish monitoring (Grizzly Bay) and a special study by ICF.

3.2 Sampling Sites

Monitoring was conducted within the restoration footprint of Tule Red and in Grizzly Bay. Aquatic samples were stratified by habitat type as outlined in the AMMP: inside the mouth of the breach, main channel, interior back marsh channel, marsh ponds, and marsh pannes.

3.3 Sampling Methods

All sampling methods were developed in accordance with the recommendations of the Interagency Ecological Program Tidal Wetlands Monitoring Project Workteam (IEP TWM PWT 2017a), and described in the Project AMMP and FRP 2020 Workplan (Contreras et al. 2019). The PWT standard operating procedures provide more specifics on methods and quality control (IEP TWM PWT 2017b).

Field work in early 2020 was delayed due to the emergence of the COVID-19 pandemic.

3.3.1 Physical Processes and Hydrology

3.3.1.1 Topography and Bathymetry

Topographic and bathymetric surveys were performed to document site morphology and evolution. Surveys were conducted in cross-section format, with nine (9) cross-sections distributed across the site to capture the breach, tidal channel, tidal pannes, marsh ponds, habitat berm, and marsh plain (**Figure 3-1**). One section is located at the breach at the edge of the vegetation/mudflat intersection, and the remaining eight sections run east to west across the interior of the site. Transect data is used to evaluate whether marsh plain and mudflats are receiving sedimentation at the expected rates, the ponds are maintaining functionality, and whether or not the breach and channel dimensions are evolving to match a shifting tidal prism.

TABLE 3-1
MONITORING ACTIVITIES CONDUCTED DURING 2020

Monitoring Element	Metrics	Method	Dates	Location	Responsible Party	Notes
Physical Processes and Hydrology	Topography and bathymetry	Survey with RTK-GPS and survey-grade echosounder	6/4, 9/1	Breach transect, eight (8) interior site transects	ESA	
		Aerial photos	8/6	Tule Red (entire site)	ESA/ TetraTech	
	Tidal regime	Water level gauges	Continuous 6/9 – 12/4	Breach, Pond C, back marsh	ESA	
		Water level gauge	Continuous	Outside breach, main channel	USGS	Special study, not part of FRP-required monitoring
		Temperature loggers	Continuous 6/9 – 12/4	Tidal pannes (4)	ESA	
Water Quality	Water quality (temperature, EC, turbidity, pH, DO)	Water quality sonde	Continuous 6/9 – 12/4	Breach, Pond C	ESA	Temperature, conductivity (salinity), dissolved oxygen, turbidity, chlorophyll-a
		Water quality sonde	Continuous	Grizzly Bay CDEC station GZL	IEP/DWR	Temperature, conductivity (salinity), dissolved oxygen, turbidity, chlorophyll-a, pH
		Dissolved oxygen probe	Continuous 6/9 – 12/4	CDFW Channel	ESA	Temperature, dissolved oxygen
		Water quality sonde	Continuous	Outside breach, main channel	USGS	Special study, not part of FRP-required monitoring Temperature, salinity
		Discrete measurements by handheld sonde	8/12, 10/9	Grizzly Bay	CDFW	Concurrent with food web sampling
	Nutrients (NH_4-PO_4)	Grab samples, standard methods	8/12, 10/9	Grizzly Bay Main channel	CDFW	Concurrent with food web sampling
	Methyl mercury (MeHg)	Grab samples, unfiltered water	6/9, 9/1, 10/29	Breach	ESA	Collected on ebb tide
Food Web	Chlorophyll-a	Water quality sonde	Continuous 6/9 – 12/4	Breach, Pond C	ESA	
		Grab samples	6/9, 6/30, 7/22, 9/1, 10/29	Breach, Pond C	ESA	To calibrate sonde measurements
		Water quality sonde	Continuous	Grizzly Bay CDEC station GZL	IEP	
		Discrete measurements by handheld sonde	8/12, 10/9	Grizzly Bay Tule Red main channel, pond	CDFW	Concurrent with zooplankton sampling

TABLE 3-1 (CONTINUED)
MONITORING ACTIVITIES CONDUCTED DURING 2020

Monitoring Element	Metrics	Method	Dates	Location	Responsible Party	Notes
Food Web (cont.)	Phytoplankton	Grab samples, lab sorting	8/12, 10/9	Grizzly Bay Tule Red main channel, pond	CDFW	Concurrent with zooplankton sampling
	Mesozooplankton	Zooplankton tows, lab sorting	8/12, 10/9	Grizzly Bay Tule Red main channel, pond	CDFW	
	Macrozooplankton	Mysid net, lab sorting	8/12, 10/9	Grizzly Bay Tule Red main channel, pond	CDFW	
	Benthic macroinvertebrates	Benthic grab samples or sediment cores, lab sorting	8/12, 10/9	Grizzly Bay Tule Red main channel, pond	CDFW	
	Surface invertebrates	Neuston tow	8/12, 10/9	Grizzly Bay Tule Red main channel, pond	CDFW	
	Epibenthic/epiphytic macroinvertebrates	Sweep nets	8/12, 10/9	Grizzly Bay Tule Red main channel, pond	CDFW	
	Benthic macroinvertebrates	Benthic sediment cores	May	Tule Red main channel, pond	USGS	Special study
	Terrestrial insects	Fall through traps	May	Tule Red main channel, pond	USGS, ICF, UCB	Special study
Fish	Fish community	Larval trawl	May	Tule Red main channel, outside breach mouth	ICF	Special Study Fish sampling by CDFW or landowner not currently permitted within Tule Red.
Wetlands and Vegetation	General habitat conditions	Photo points (qualitative record)	5/8	19 permanent locations on top of habitat berm	ESA	Same locations for 2017, 2019
	Vegetation composition and cover	CDFW VegCAMP protocol	5/8	4 transects with 41 fixed plots	ESA	Same plots from 2017
	Vegetation mapping	Aerial imagery and ground surveys	8/5	Entire site	ESA, Tetra Tech	
	Invasive plants	Visual survey (aerial imagery and ground surveys)	5/8, 8/5	Entire site, focus on habitat berm and roads	ESA	

Path: U:\GIS\GIS\Projects\15xxxx\D201500158.01_TuleRedMonitoring_Year1\03_MXDs_Projects\FigX_SurveyPlan.mxd, bdeshetler 1/7/2021

SOURCE: Aerial (Tetra Tech 2020), NAIP

Tule Red Monitoring . D201500158.05

Figure 3-1
Survey Plan

ESA

All surveys were completed using Real-Time Kinematic GPS (RTK-GPS) rover units, sometimes in conjunction with a survey-grade echosounder. Topographic data collection was completed in June 2020 and bathymetric data collection was completed in June and September 2020[2]. Cross-section endpoint monuments were installed during the survey effort in order to facilitate accurate reoccupation in subsequent monitoring years. The eastern endpoints of all eight interior transects are monumented with rebar and PVC, and both the north and south endpoints of the breach cross-section are monumented with PVC.

All survey position coordinates were established in the North American Datum 1983 (NAD83) 2011 (Epoch 2010.00), projected in California State Plane Zone 2, in US Survey Feet. All elevations were established in North American Vertical Datum 1988, provided in US Survey Feet (Geoid 12B). Basis of coordinates and RTK-GPS position corrections were provided by the Leica SmartNet North America GNSS base station network (SmartNet). Pre-existing control points set by RFE Engineering in 2015 were located and surveyed for quality control purposes, with the original intent of adjusting ESA survey data to the project datums as necessary. However, irreconcilable elevation discrepancies were found between the coordinates surveyed by ESA and those provided by RFE Engineering. Furthermore, analysis of the ESA measured tide elevations relative to those reported by the National Oceanic and Atmospheric Administration (NOAA) Port Chicago tide station (9415144) show close agreement. ESA is working with the engineer of record to resolve these discrepancies, but it is not yet resolved. For the purposes of this monitoring report all reported elevations are provided relative to SmartNet GPS observations. The RFE Engineering control points surveyed by ESA, along with their SmartNet-derived elevations, are provided in **Table 3-2**. It is recommended that the discrepancy between elevation sources be resolved prior to future monitoring work.

TABLE 3-2
SURVEY CONTROL

Point ID	Easting	Northing	Elevation (ft NAVD)
CP 101	6566932.34	1808770.11	8.83
CP 105	6568404.09	1804607.78	3.92
CP 115	6563766.45	1811027.07	7.94
CP 124	6564771.46	1802168.20	8.18

3.3.1.2 Water Level Monitoring

Water level monitoring was performed to document the hydrological processes on the site. Two separate methods of water level data collection were employed: water level data were collected at three locations across the site using non-vented pressure transducers, and water inundation data were collected in the four constructed tidal pannes using paired temperature sensors (**Figure 3-2**).

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[2] Due to weather and timing complications during site visits, the tidal pond portion of cross-section 8 was surveyed on September 1, 2020. All other survey points were collected in June 2020.

Path: U:\GIS\GIS\Projects\15xxxx\D201500158.01_TuleRedMonitoring_Year1\03_MXDs_Projects\FigX_InstrumentLocations.mxd, bdeshetler 1/22/2021

SOURCE: Aerial (Tetra Tech 2020), NAIP, Esri

Tule Red Monitoring . D201500158.05

Figure 3-2
Water Quality and Water Level Instrument Locations

Three non-vented pressure transducers were deployed to capture water level fluctuations and monitor the development of tidal exchange through the site. One gauge was installed just inside the levee breach, in order to capture the tidal signal at the entrance to the site. A second gauge was installed in a third-order channel at the far south of the site interior, near the removed clubhouse. This back marsh gauge is located to capture the tidal signal reaching the areas of the tidal system that are furthest from the tidal source, in order to check for and document any potential tidal muting through the site. A third gauge was installed in tidal Pond C, the central of the three marsh ponds, to capture water level fluctuations and tidal connection of the pond complex.

Water level data were collected using three non-vented pressure transducers and one barometric pressure transducer placed inside 2-inch perforated ABS stilling wells. The pressure transducers were programmed to record at 10-minute sample intervals and data was collected from June 9, 2020 to December 4, 2020.

Download and maintenance of the gauges was done on a six-week cycle. Quality control of the electronic measurements were made at the time of downloading and included a visual observation of the tide gauge to check for equipment degradation, an open air calibration reading, compensation for barometric pressure, and a water surface elevation survey to check for instrument drift. Depth measurements recorded with the pressure transducers were converted to feet (ft) NAVD88 by surveying water surface elevations directly and taking hard measurements to the water surface from a surveyed point on the stilling wells at the time of measurement.

Paired temperature sensors were used to monitor inundation in the four constructed tidal pannes to determine if the pannes were holding water after spring tide filling cycles (Figure 3-3). Temperature variations in the pannes as compared to open air were used as a proxy for measuring panne inundation. T-posts were driven into the mud in the lowest elevation portion of each tidal panne and a temperature sensor was installed just above the mud surface. Air temperature data was also collected using a paired sensor located above nearby marshplain elevation where it would be consistently exposed to open air. The specific heat of water is higher than that of air, meaning that it takes more energy to increase the temperature of water compared to air. As a result, diurnal temperature fluctuations in water will be smaller than in open air. If the tidal panne is dry, the temperature variation will appear the same as in open air. The temperature sensors were programmed to record at 1-hour sample intervals and data was collected from June 9, 2020 to December 4, 2020. Data for the tidal panne 4 temperature logger is not available from September 2, 2020 to November 15, 2020 due to equipment malfunction.

3.3.2 Water Quality

Water quality data was collected continuously at the project site using two multiparameter water quality sondes and a dissolved oxygen/temperature probe. Additionally, discrete grab samples were collected to test for methyl mercury content. Equipment was installed in June 9, 2020 and has remained in place through December 2020. The last data download for this report was December 4, 2020.

3.3.2.1 Continuous sondes

Continuous water quality sondes were installed and maintained at two locations in order to monitor temperature, conductivity, dissolved oxygen, turbidity, and chlorophyll-a (Figure 3-2). One sonde was installed just inside the breach adjacent to the breach water level gauge. A second sonde was installed in Pond C, the central of the three ponds within the marsh pond complex, adjacent to the Pond C water level gauge. The sondes were programmed to collect measurements at 1-hour sampling intervals and were serviced according to manufacturer recommendations and the USGS "Wagner Method" (USGS, 2006). In-Situ Aqua TROLL 600 multiparameter sondes were used with Tube 300R telemetry systems which push the measured water quality data to an online server via cellular every 3 hours. The telemetry systems minimize potential for data loss, allow for remote access to near-real-time data throughout the monitoring period, and reduces the frequency of service visits needed. Data was collected from June 9, 2020 to December 4, 2020. Data for the breach water quality sonde is not available from June 30, 2020 to July 22, 2020 due to an equipment malfunction which required the sonde to be sent into the manufacturer for service.

To provide a basis of calibration for chlorophyll-a data from the breach and Pond C water quality sondes, grab samples were collected on service visits (Table 3-1). At each location, duplicate samples were taken at the same depth and directly adjacent to the sonde. Samples were collected and transported according to lab testing standards, and analyzed for chlorophyll-a and pheophytin by the DWR Bryte Analytical Lab in West Sacramento, CA. The duplicate samples were averaged together, giving a total of five (5) samples for each sonde which were used to relate the water quality sondes' fluorescence readings (relative fluorescence units [RFU]) to chlorophyll-a concentration (µg/L) using a regression equation. Unfortunately, four of the five samples collected at the breach location were taken at the extreme low-range of readings (<0.03 RFU), which created an uncertain regression curve for that location due to insufficient calibration points in the mid- and high-range. Because of this, chlorophyll-a analysis for this report has been done focusing on units of RFU, and calibration curves to chlorophyll-a concentration will not be completed until additional samples are collected and a reliable curve can be completed in future monitoring efforts.

3.3.2.2 Dissolved Oxygen at CDFW Channel

A continuous dissolved oxygen/temperature probe was installed at the location where the CDFW channel flows into the back corner of the site in order to document any potential dissolved oxygen deficiencies that may occur due to proximity to the CDFW Grizzly Island WMA drainage (Figure 3-2). The probe was placed downstream (south) of the water control structure that separates the tidal reach of Tule Red site from a small dead-end channel that receives WMA drain water. An Onset HOBO U26 Dissolved Oxygen Data Logger was installed in a 2-inch perforated ABS stilling well. The well was relocated on September 1, 2020 to a deeper position in the channel where the sensor would be continuously submerged. Prior to that date, the sensor went dry during extreme lower-low spring tides. The sensor was programmed to collect measurements at 1-hour sampling intervals, and was serviced according to manufacturer recommendations and the USGS "Wagner Method."

3.3.2.3 Methyl Mercury

To monitor the methyl mercury (MeHg) concentration of water exiting the site during ebb tides, three grab samples were collected at the site breach on three separate dates, for a total of nine samples. All samples were collected during an ebb tide, with the three samples per day spread out across the ebb cycle. In order to prevent any contamination of the sample, the "Clean Hands/Dirty Hands" technique was used from EPA Method 1669 (DWR 2019). Samples were collected and transported according to lab testing standards, and processed by Caltest Analytical Laboratory in Napa, CA. All samples were tested for bulk MeHg (unfiltered) and preparation and analysis was done according to EPA 1630 methods. The laboratory reporting limit is 0.05 ng/L and method detection limit (MDL) is 0.020 ng/L.

3.3.3 Food Web

Food web monitoring is the responsibility of the CDFW FRP monitoring group. The general methods are summarized here, based on the CDFW FRP 2020 Study Plan (Contreras et al. 2019). Sampling sites were located in Grizzly Bay and within Tule Red (channel and ponds). The original schedule was to sample in spring, summer and fall. In 2020, however, COVID-19 restrictions curtailed spring sampling. Sampling was conducted on August 12 and October 9, 2020. Information on sample processing, data analysis, and results will be prepared separately by CDFW, and appended to the next year's report when available.

Phytoplankton samples were collected from Tule Red and Grizzly Bay. At each zooplankton trawling station, field crews measured chlorophyll-a florescence using a YSI 6600 sonde. All grab samples are analyzed for nutrients (organic nitrogen and carbon, inorganic nitrogen and phosphorus), chlorophyll-a and pheophytin by the DWR Bryte Laboratory. Community composition analysis is being conducted by EcoAnalysts (Moscow, ID).

Field crews sampled meso- and macrozooplankton by trawling in Grizzly Bay and within Tule Red. Samples are being identified by the CDFW Stockton laboratory or EcoAnalysts, Inc., Moscow, ID.

Benthic invertebrates were collected from Grizzly Bay using ponar grabs and from Tule Red using hand-deployed cores. Epifaunal invertebrates were collected with sweep nets from emergent vegetation and submerged vegetation within the site. Terrestrial fallout invertebrates were sampled using a neuston net in Grizzly Bay and Tule Red. Invertebrate samples are being identified for major invertebrate taxa by the CDFW Stockton laboratory.

3.3.4 Fish Sampling

Fish sampling as described in the AMMP is not covered under the Project BO, nor is it covered for the CDFW FRP Monitoring Team. Information on fish use near the Project site (Grizzly Bay) comes from IEP long-term surveys and the USGS/ICF/UCB special study. ICF conducted fish sampling using a larval townet outside the breach and in the Tule Red main channel in May 2020.

3.3.5 Wetlands and Vegetation

ESA conducted Year 1 vegetation monitoring and documented general site conditions. Vegetation monitoring occurred in two periods: May 8, 2020 for the habitat berm upland and transitional wetland habitats, and July 22 and August 5, 2020 for tidal marsh. Monitoring was timed to capture the maximum growth period of the respective tidal elevations.

3.3.5.1 General Habitat Conditions- Photo Points

Nineteen permanent locations for photo points were established 2017 to document the pre-construction conditions on the site (**Figure 3-3**. Photos were taken in 2017 (May 4), 2019 (May and December), and 2020 (May 8) from each of the photo points to document conditions before, during and after construction (ESA 2018, SFCWA 2020). **Appendix B** compares the 2017 pre-construction photos to the 2020 post-breach photos.

3.3.5.2 Vegetation Composition and Cover

ESA revisited the same plots monitored in 2017 during pre-construction vegetation monitoring (ESA 2018). Vegetation composition and cover were recorded at permanent plots located along four permanent transects oriented perpendicular to the habitat berm. A stratified random approach was used to define plot locations in 2017 based on the habitat patches in the Project design drawings (SFCWA, Westervelt, and NHC, 2016). Vegetation monitoring transect and plot locations are shown on **Figures 3-3** and **3-4**.

The plots were located in the field using GPS data, and vegetation data were collected according to the same methods. At each plot, the following were recorded:

- **Logistics** – date, time, observers, photos, and location information
- **General notes** – narrative discussion of notable topography, hydrology, soils conditions, and wildlife observations
- **Surface cover** – percent of the surface occupied by water, fines (sand, soil, mud), litter, living stems, rock/gravel, or other type as noted.
- **Vegetation description** –
  - Height and phenology of dominant layer
  - List of plant taxa with cover estimate (and notes, if needed) for each
  - Total cover of vascular plants
  - Cover estimate for non-vascular plants and algae, if present

Vegetation composition and cover was assessed using two square-meter plots located along transects. ESA used the CNPS Relevé protocol to record percent cover by plant taxon, as well as the plot total vegetation cover. This data provides a quantitative record of vegetation composition and cover which was used to classify the vegetation type at the alliance-level based on membership rules defined in the Manual of California Vegetation (Sawyer et al., 2009). This also corresponds with the vegetation types used in the CDFG's triennial Vegetation Map Update for Suisun Marsh. The maximum canopy height of each taxon within the plot was also recorded. Using the results of the vegetation monitoring and associated classification of vegetation types, ESA created an updated aquatic habitat map for comparison with the pre-construction aquatic habitat map, and with reference site information presented in the *Tule Red Tidal Restoration Project Pre-Construction Aquatic Habitat and Vegetation Monitoring Report* (ESA, 2018).

3.3.5.3 Vegetation Mapping and Aquatic Habitat

Aerial imagery was collected at the site by Keystone Aerial Surveys at 11:15 on the morning of August 6, 2020. The imagery was captured on a low tide in 26 images and in two flight lines. All imagery was controlled by airborne global positioning system (GPS) and intertial measurement unit (IMU); no ground control was used. Imagery was collected as both a RGB color mosaic and a color infrared (CIR) mosaic image.

An object based image analysis (OBIA) was then performed on the CIR imagery using a combination of ESRI's ArcMap and the statistical analysis program R. Multiband CIR imagery, opposed to RGB, is the industry preferred imagery format for remotely mapping vegetation.

An OBIA workflow is comprised of two broad steps: segmentation and classification. First, segmentation is used to subdivide the imagery so that pixels with the same spectral signature are grouped together into objects. This computationally-intensive process uses an algorithm to assign each pixel a numerical value based on the spectral signature of that pixel and the signature differential between pixels and their neighbors. This signature is based on the value of the infrared band contained within the imagery. A distance function is then used to spatially aggregate like-values (based on a set tolerance) into larger groupings (objects). In theory, these objects represent different land-cover (water, mudflat, vegetation, etc.), which will then be classified in the following step.

Prior to classification, a series of summary statistics are extracted from the underlying data for each object using the zonal statistic tools native to ArcMap. These statistics become the input data for the classification step. Most statistics used in this classification were derived from a Normalized Difference Vegetation Index (NDVI). NDVI is a commonly used metric in vegetation mapping, particularly to distinguish vegetation from other landcover types. It is calculated, for each pixel, based on the ratio between reflectance (infrared band) and absorption (red band). Once the underlying data has been extracted for each object a supervised classification was performed in R using a random forest classification algorithm. A supervised classification algorithm assigns each feature (object) a probability of belonging to a given landcover class (vegetation). In this case, vegetation alliances were classified within the broader vegetation class. Prior to running the classifier, a training dataset was generated from vegetation alliance field observations. This field data was used to manually assign a subset of objects their corresponding vegetation alliance.

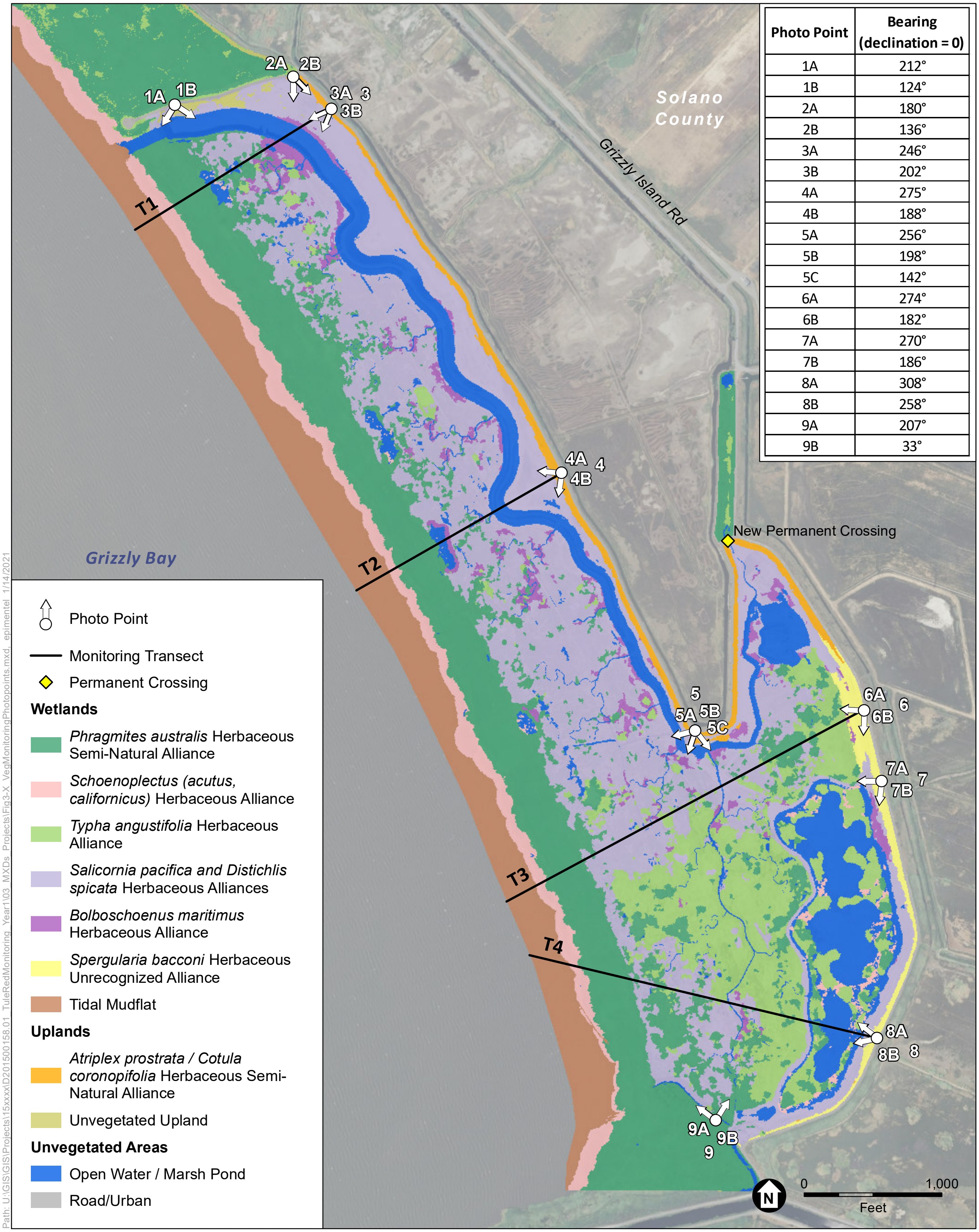

Photo Point	Bearing (declination = 0)
1A	212°
1B	124°
2A	180°
2B	136°
3A	246°
3B	202°
4A	275°
4B	188°
5A	256°
5B	198°
5C	142°
6A	274°
6B	182°
7A	270°
7B	186°
8A	308°
8B	258°
9A	207°
9B	33°

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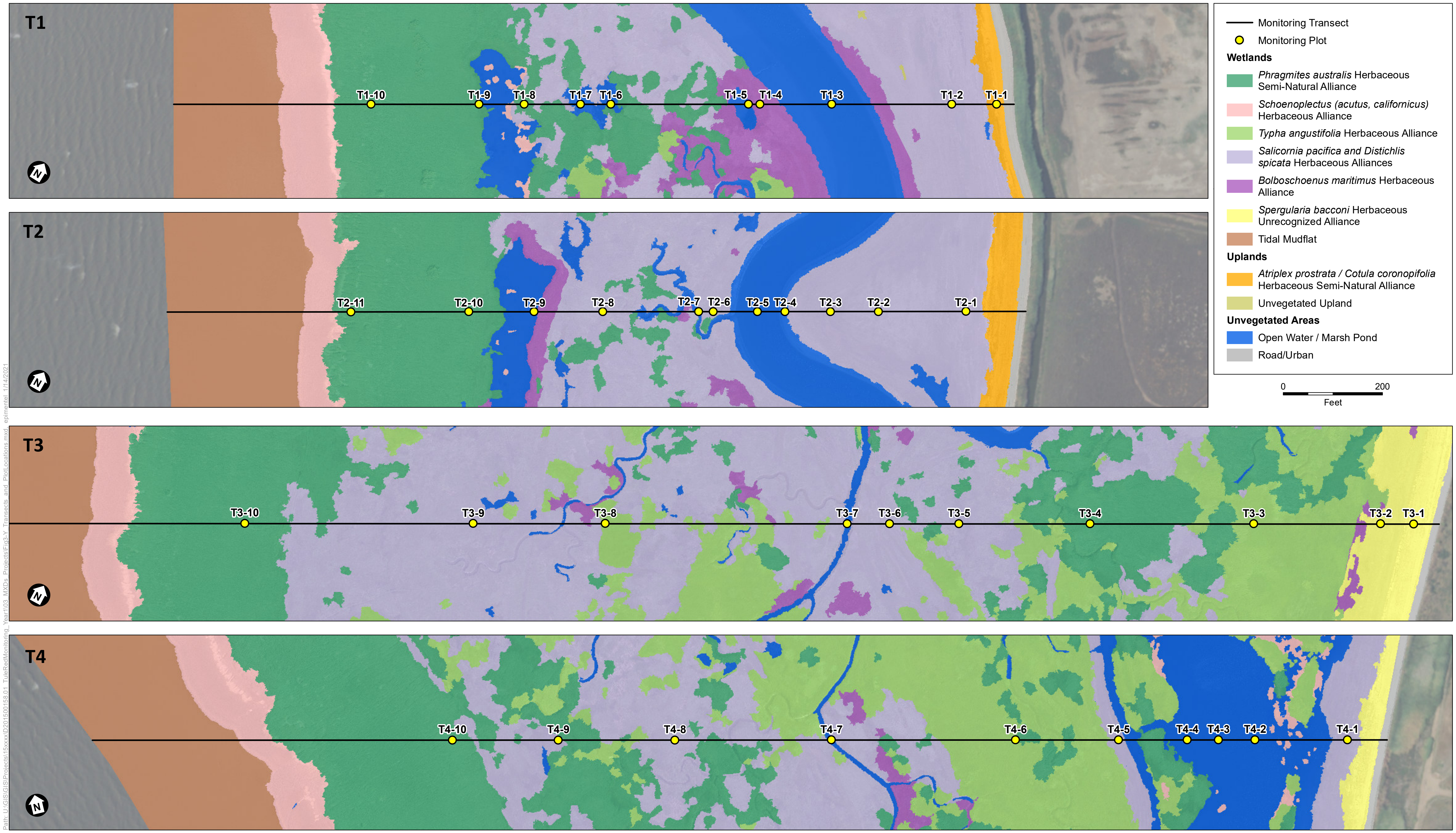
SOURCE: USDA, 2018; TetraTech, 2020(August); ESA, 2021

Tule Red Year 1 Monitoring

Figure 3-3
Location of Photo Points and Vegetation Transects

ESA



SOURCE: USDA, 2018; TetraTech, 2020 (August); ESA, 2021

Tule Red Year 1 Monitoring

Figure 3-4
Location of Vegetation Transects and Monitoring Plots, with 2020 Vegetation

ESA

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A random forest classifier works by generating a series of decision trees, based on the zonal input variables, for each object. Each tree assigns an object to a known vegetation alliance based on its relationship to the attributes of the aforementioned training dataset. What distinguishes a random forest algorithm from a simple decision tree, is that under the random forest approach thousands of trees are generated for each object, using a randomly sampled subset of the training data for each tree. From these thousands of decision trees each object is assigned the most commonly generated classification type, or vegetation alliance. Lastly, some manual edits were made using field data after vegetation alliance classification.

Each vegetation alliance was classified as wetlands or upland based on vegetation composition and dominance. Unvegetated areas were classified as either aquatic habitats such as channels and ponds, or as upland, which includes the habitat berm levee crown. This categorization, based on vegetation and topography provides an overall calculation of the total area of aquatic resources, for comparison with baseline conditions.

3.3.5.4 Invasive Plants

Invasive plant monitoring occurred alongside field surveys for vegetation composition and cover in May 8, July 22, and August 5, 2020. Where invasive plants were observed on the habitat berm their location was reported to WES so that they could be removed or treated. The exception to this is Phragmites (*Phragmites australis*). Phragmites was prevalent at Tule Red prior to construction, and was still prevalent in 2020. The location and extent of Phragmites at Tule Red in 2020 was captured through the vegetation mapping and classification steps described above.

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CHAPTER 4
Results

4.1 Physical Processes and Hydrology

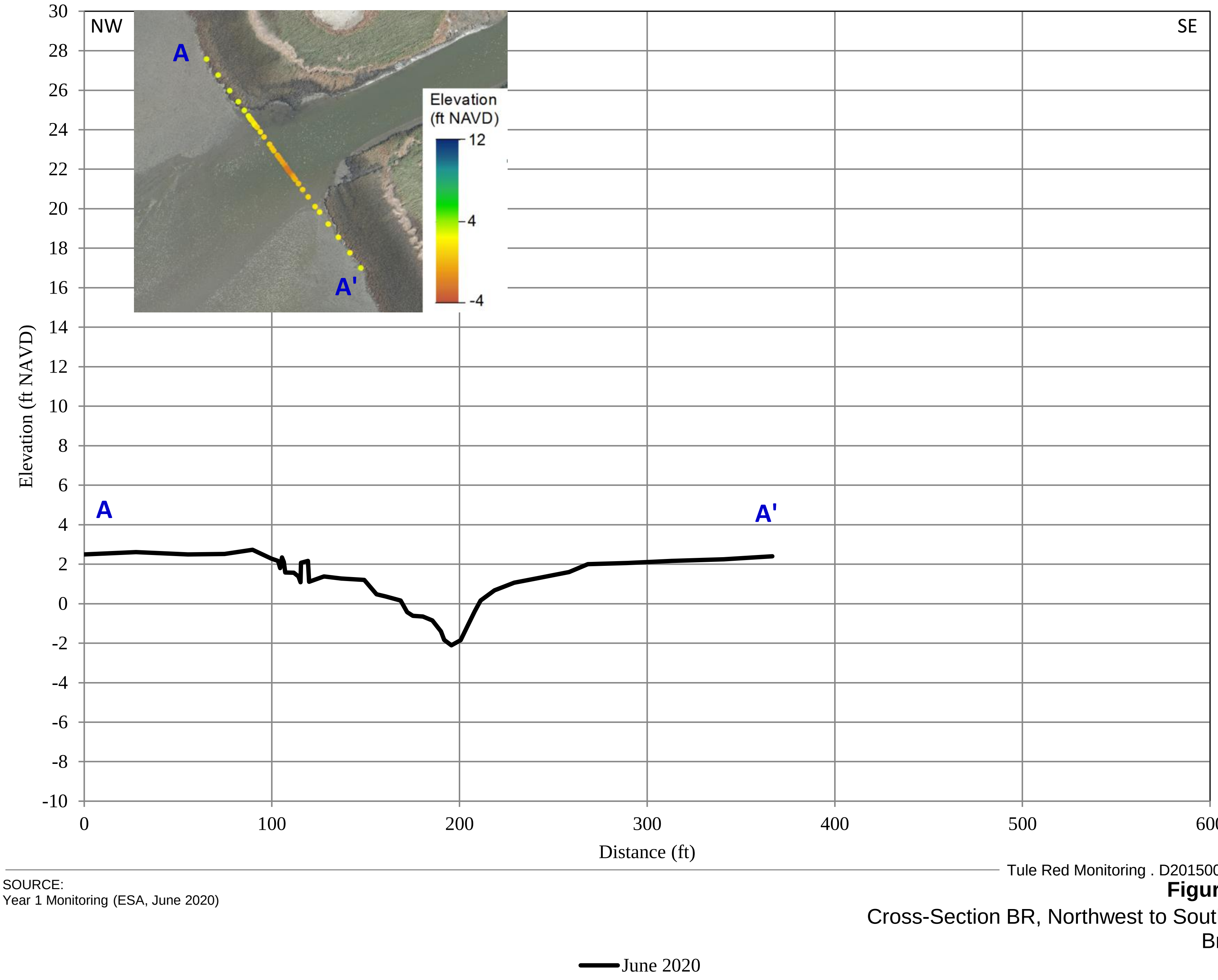
4.1.1 Topography and Bathymetry

Topographic cross-section data collected during Year 1 survey efforts are shown in **Figures 4-1 through 4-9**. Elevation comparisons were made to nearby As-Built survey points, if possible, in order to get a general sense for site progress since construction completion. However, due to the differences in survey methods between the two datasets and the discrepancies found in the control point survey described in Section 3.1.1, these comparisons are merely general observations. More thorough analyses of geomorphic evolution along each profile can be made in future monitoring years when the AMMP survey methods are repeated (scheduled for Year 3, 2022).

Across the site, survey data on the marshplain, in and around the tidal pannes, and along the habitat berm and levee shows little change between as-built conditions and Year 1 surveys. Geomorphic changes primarily occurred within tidal channels, especially near the breach.

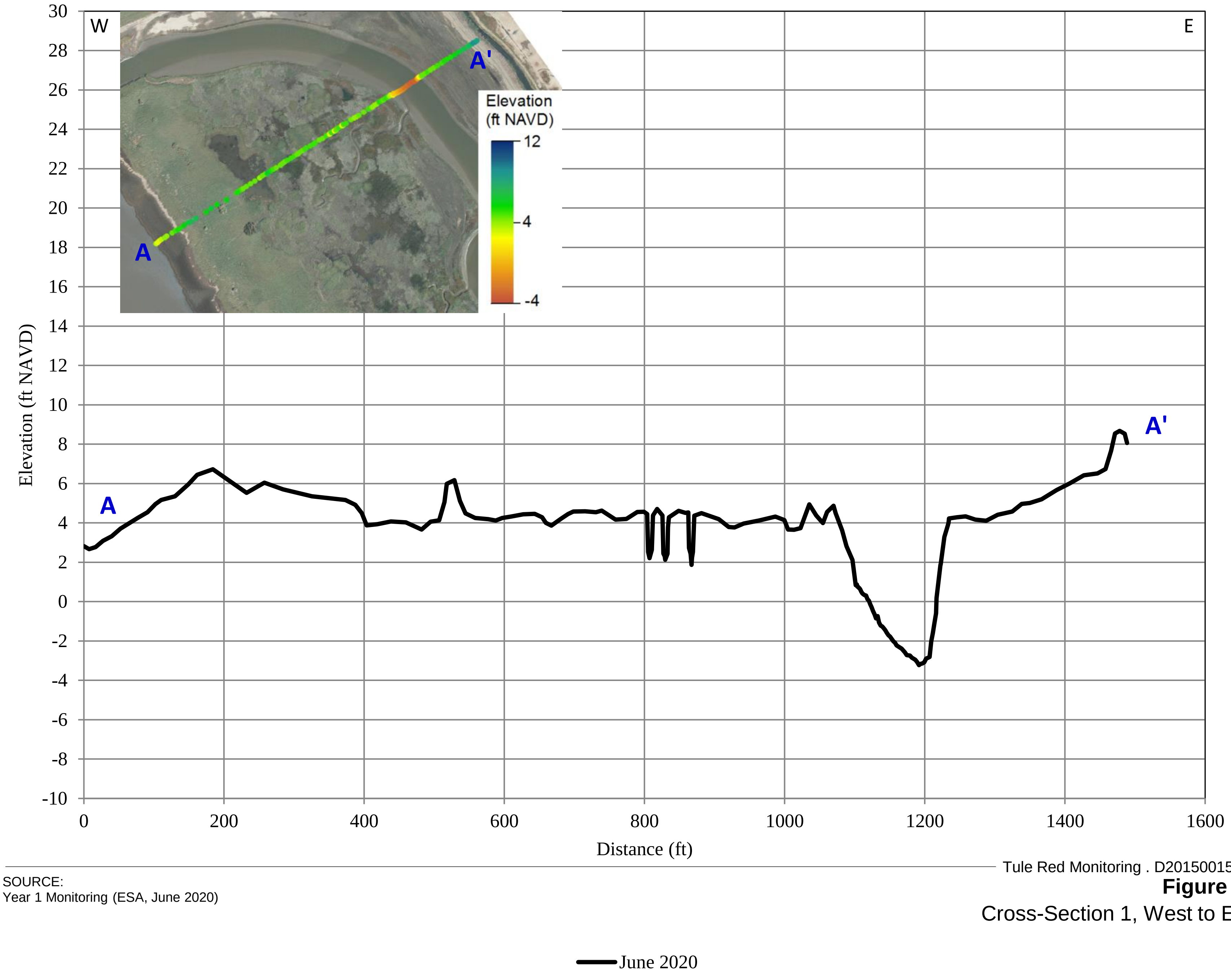
Cross-section BR (Figure 4-1), located just bayward of the site breach, shows that the breach channel sits at approximately -2.1 ft NAVD. The breach was approximately 179 feet wide, with a maximum channel depth approximately 4.5 feet deep. Nearby As-Built survey points indicate that nearly 2 feet of channel deepening has occurred at this location since breach. Visual observations of persistent channel bank slumping and widening in the breach corridor throughout Year 1 monitoring efforts indicate that the breach is re-sizing to match the tidal prism of the site interior.

Cross-section 1 (Figure 4-2) is located near a large bend in the primary fourth-order channel, which compared to design shape appears to be aggrading along its inside (west) bend. It also passes through the northernmost constructed tidal panne, which has a depth of approximately 1 foot as compared to nearby marshplain elevations to the west and has a panne bottom at approximately 4 ft NAVD. Cross-sections 3, 4, and 5 pass through the other three constructed tidal pannes, which vary in depth along the profiles from 1.0-1.5 feet and all have a bottom that sits at approximately 4 ft NAVD (Figures 4-4 through 4-6). Cross-sections 2 through 5 show mounds in the profile along the bottom of the primary fourth-order channel (Figures 4-3 through 4-6), which could be slump blocks indicating erosive widening activity in nearby lower order channels. Cross-section 6 (Figure 4-7) shows that the third-order channel which drains the back marsh (the deepest channel in the profile) has deepened to -2.4 ft NAVD from an as-built bed elevation of approximately 0 ft NAVD. This channel was visually observed to be slumping substantially during survey efforts (**Figure 4-10**), indicating active channel expansion. Cross-sections 7 and 8 cross through the constructed marsh ridge surrounding tidal ponds B, C, and D.



SOURCE:
Year 1 Monitoring (ESA, June 2020)

Figure 4-1
Cross-Section BR, Northwest to Southeast Breach



SOURCE:
Year 1 Monitoring (ESA, June 2020)

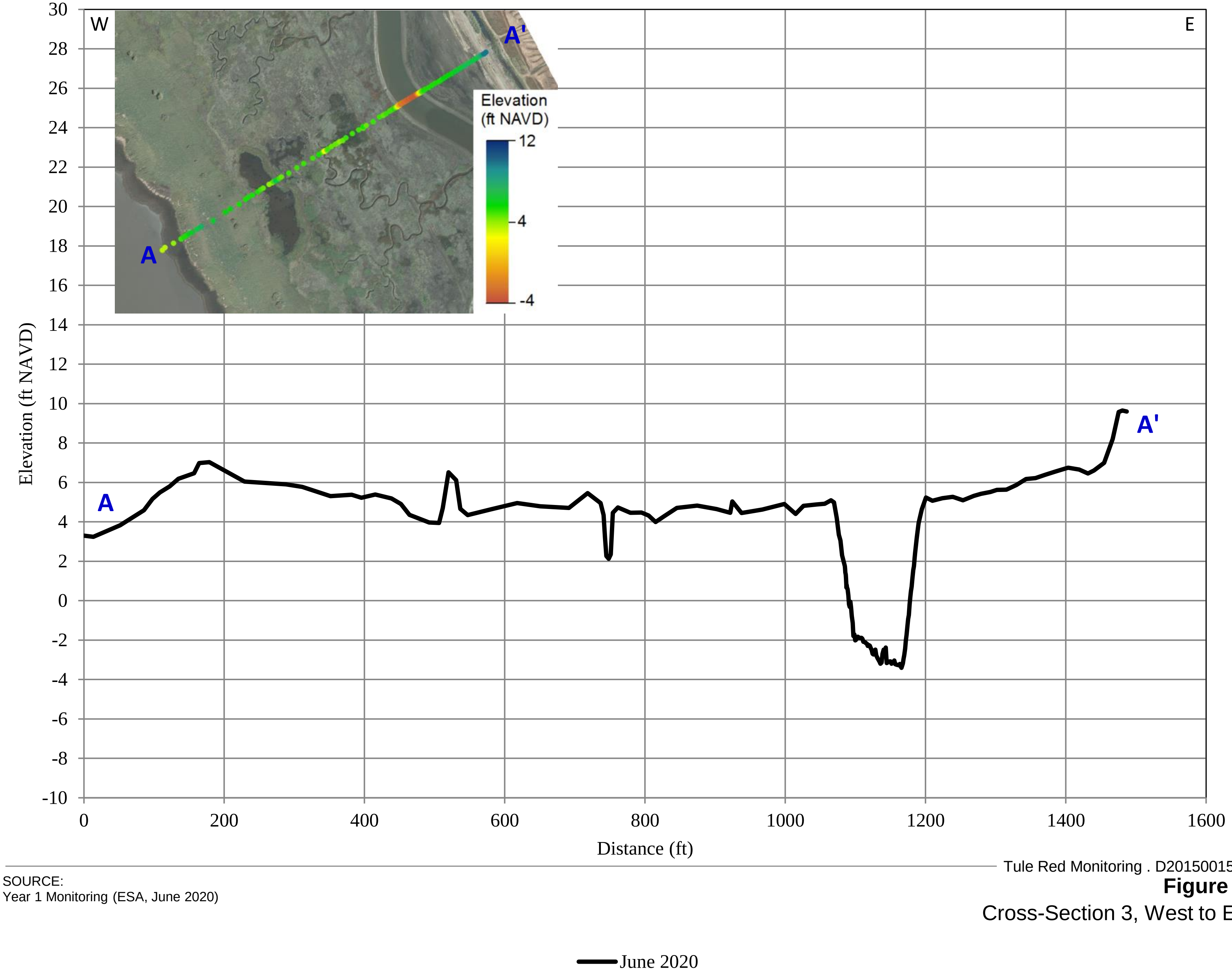
Tule Red Monitoring . D201500158.05

Figure 4-2

Cross-Section 1, West to East

SOURCE:
Year 1 Monitoring (ESA, June 2020)

Figure 4-3
Cross-Section 2, West to East

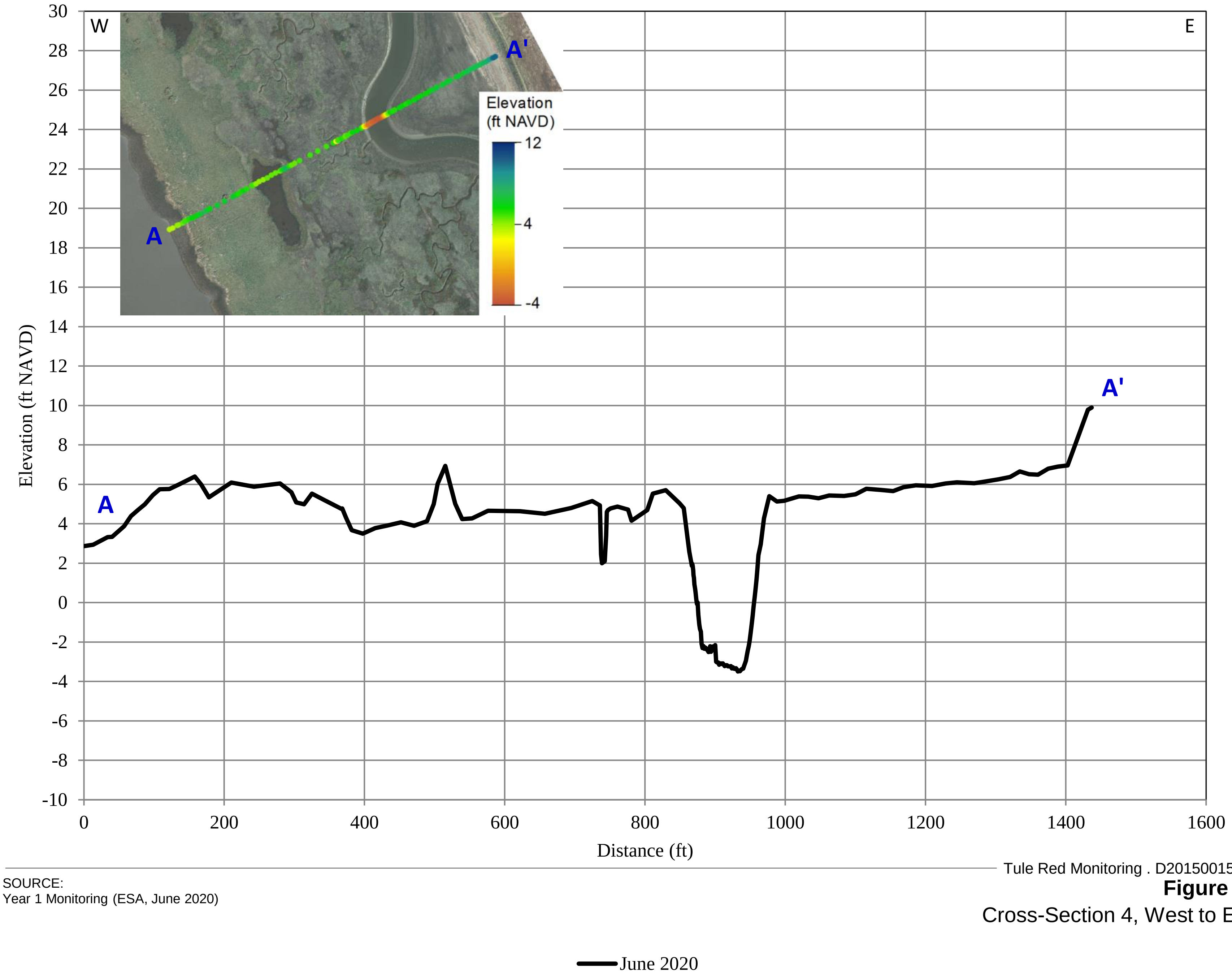


SOURCE:
Year 1 Monitoring (ESA, June 2020)

Tule Red Monitoring . D201500158.05

Figure 4-4

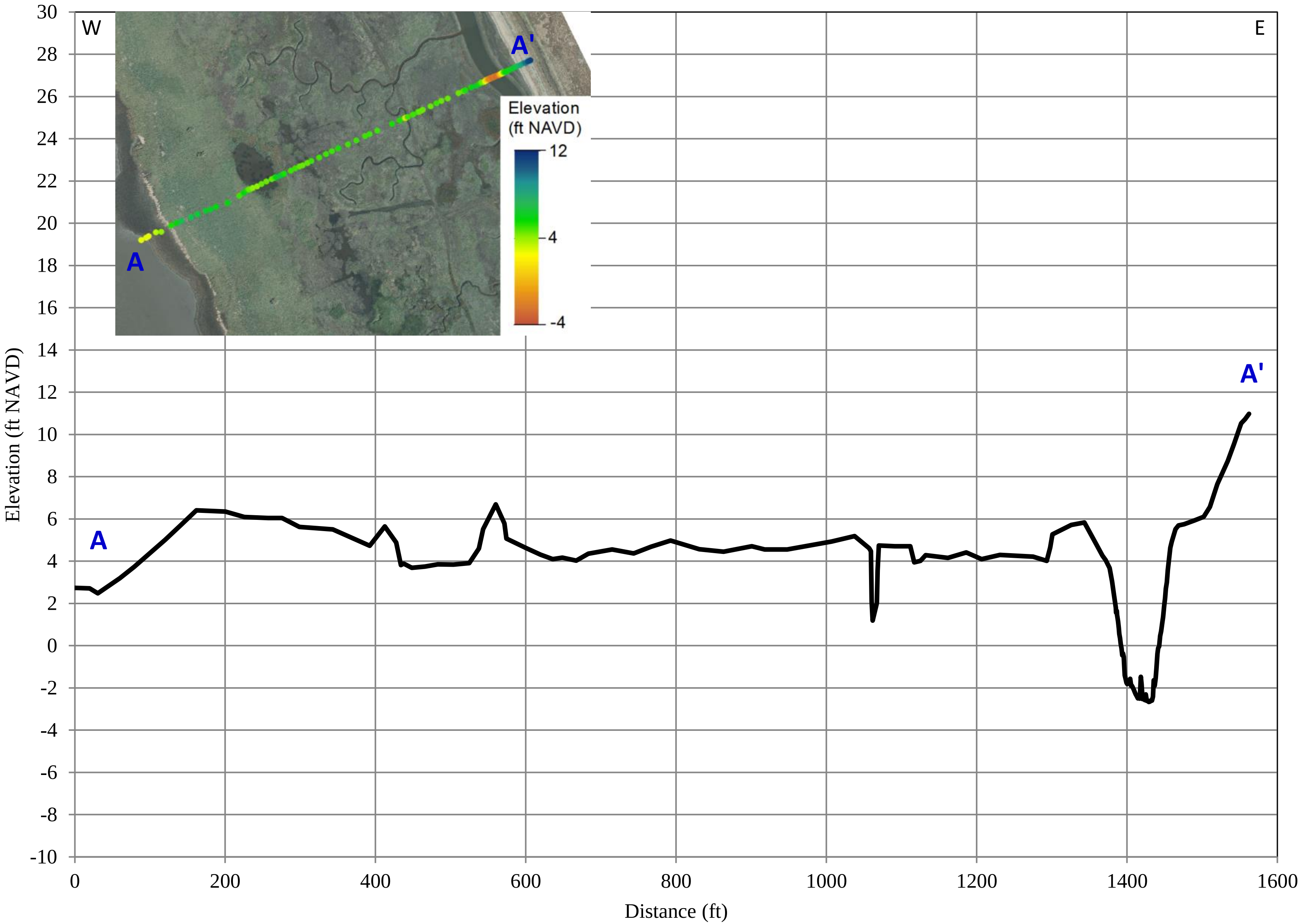
Cross-Section 3, West to East



SOURCE:
Year 1 Monitoring (ESA, June 2020)

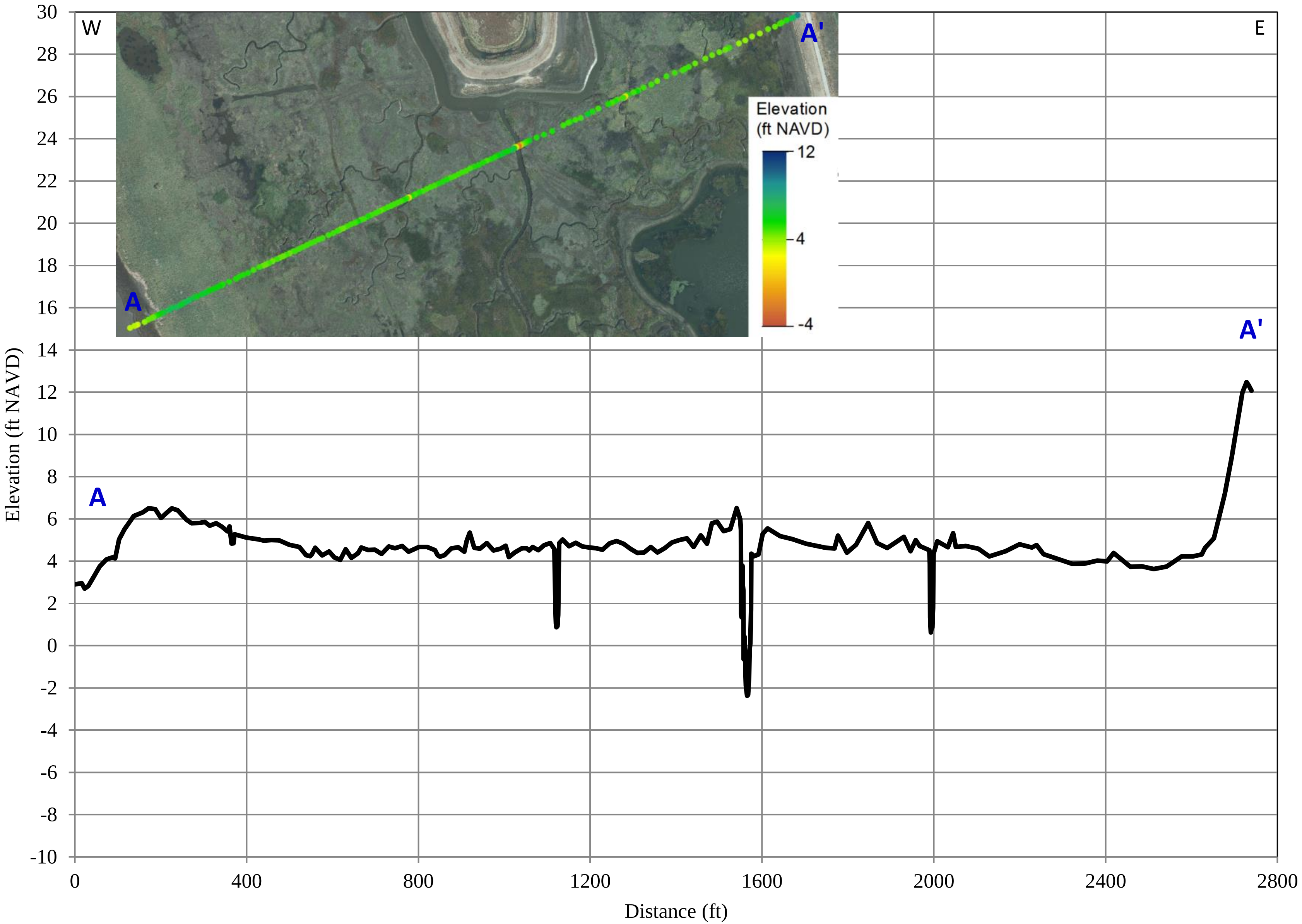
Figure 4-5

Cross-Section 4, West to East



SOURCE:
Year 1 Monitoring (ESA, June 2020)

Figure 4-6
Cross-Section 5, West to East



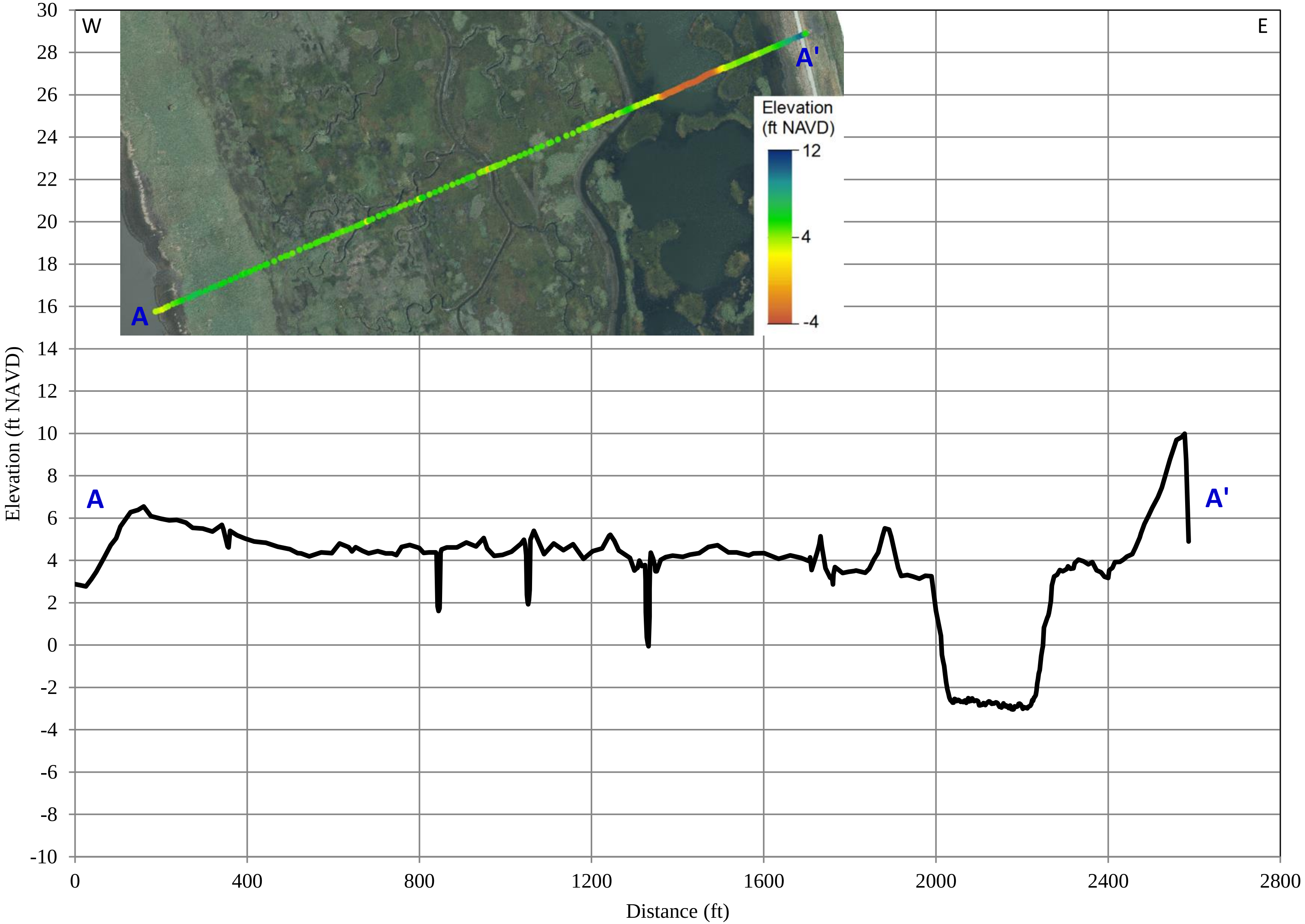
SOURCE:
Year 1 Monitoring (ESA, June 2020)

Tule Red Monitoring . D201500158.05

Figure 4-7

Cross-Section 6, West to East

June 2020

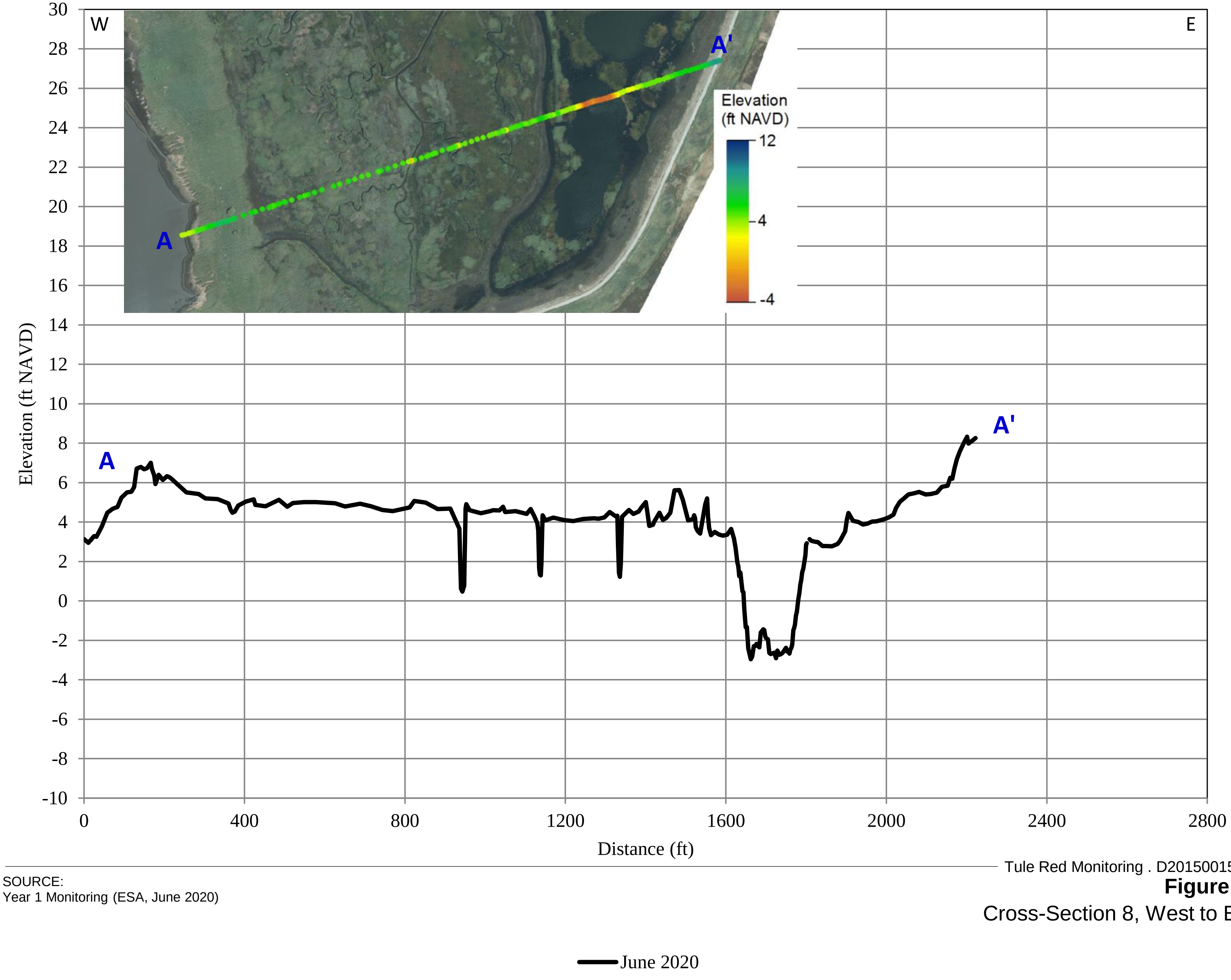


SOURCE:
Year 1 Monitoring (ESA, June 2020)

Tule Red Monitoring . D201500158.05

Figure 4-8

Cross-Section 7, West to East



SOURCE:
Year 1 Monitoring (ESA, June 2020)

Tule Red Monitoring . D201500158.05

Figure 4-9

Cross-Section 8, West to East

Tule Red Tidal Restoration Annual Monitoring Report

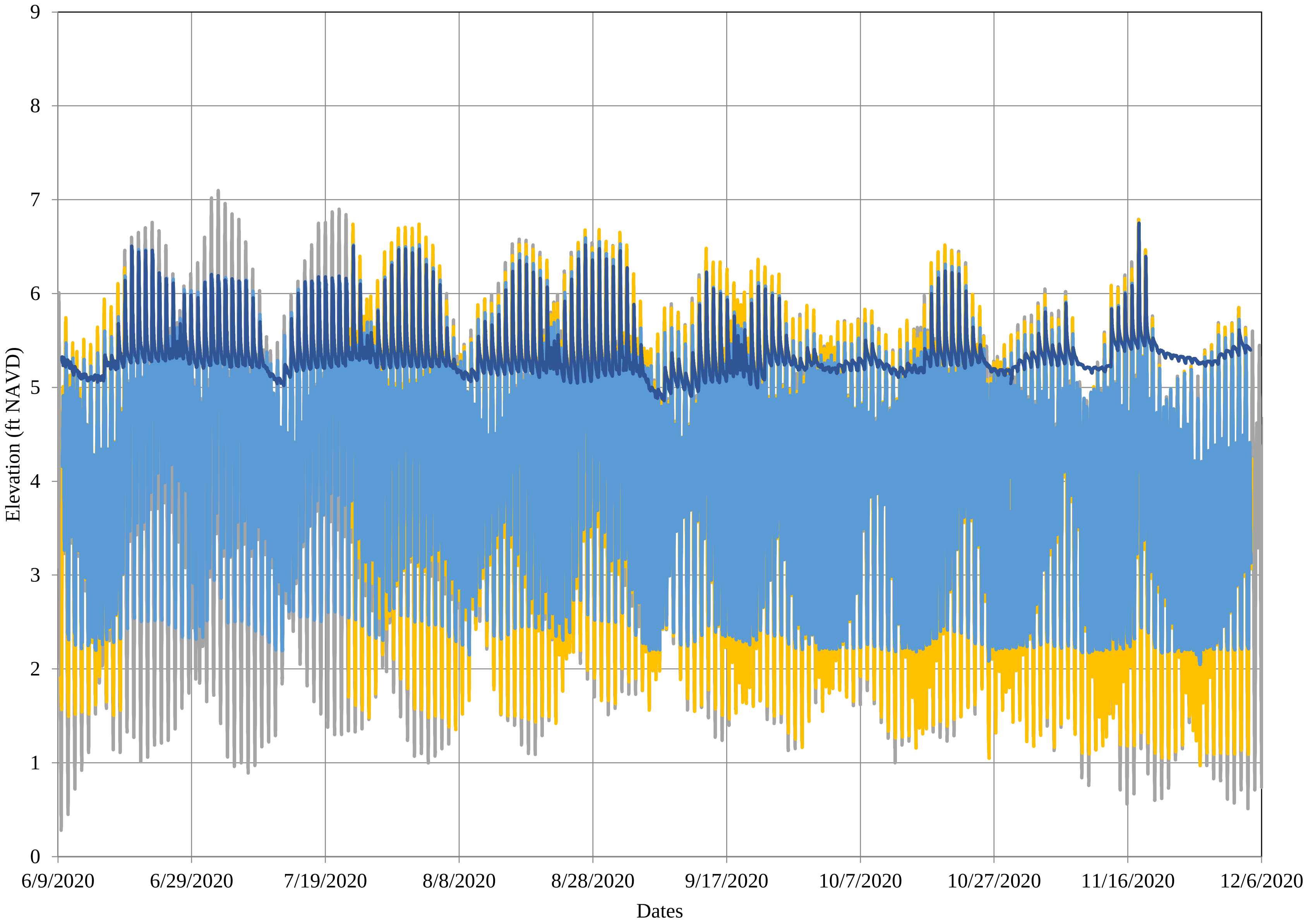
Figure 4-10
Slumping erosion in 3rd order channel near Cross-section 6

The surveyed elevation of the marsh ridge along these profiles was approximately 5.5 and 5.6 ft NAVD, respectively (Figures 4-8 and 4-9). Each of the eight marsh transects passes over the natural marsh berm along their western extent, and the berm crest elevations range from approximately 7.2 ft NAVD down to 6.4 ft NAVD.

4.1.2 Water Levels

Tidal water level data from June 9, 2020 to December 4, 2020 are shown in **Figures 4-11 to 4-13**. Water levels at the breach location, back marsh, and Pond C are shown alongside verified water levels at the NOAA Port Chicago tide gauge (9415144).

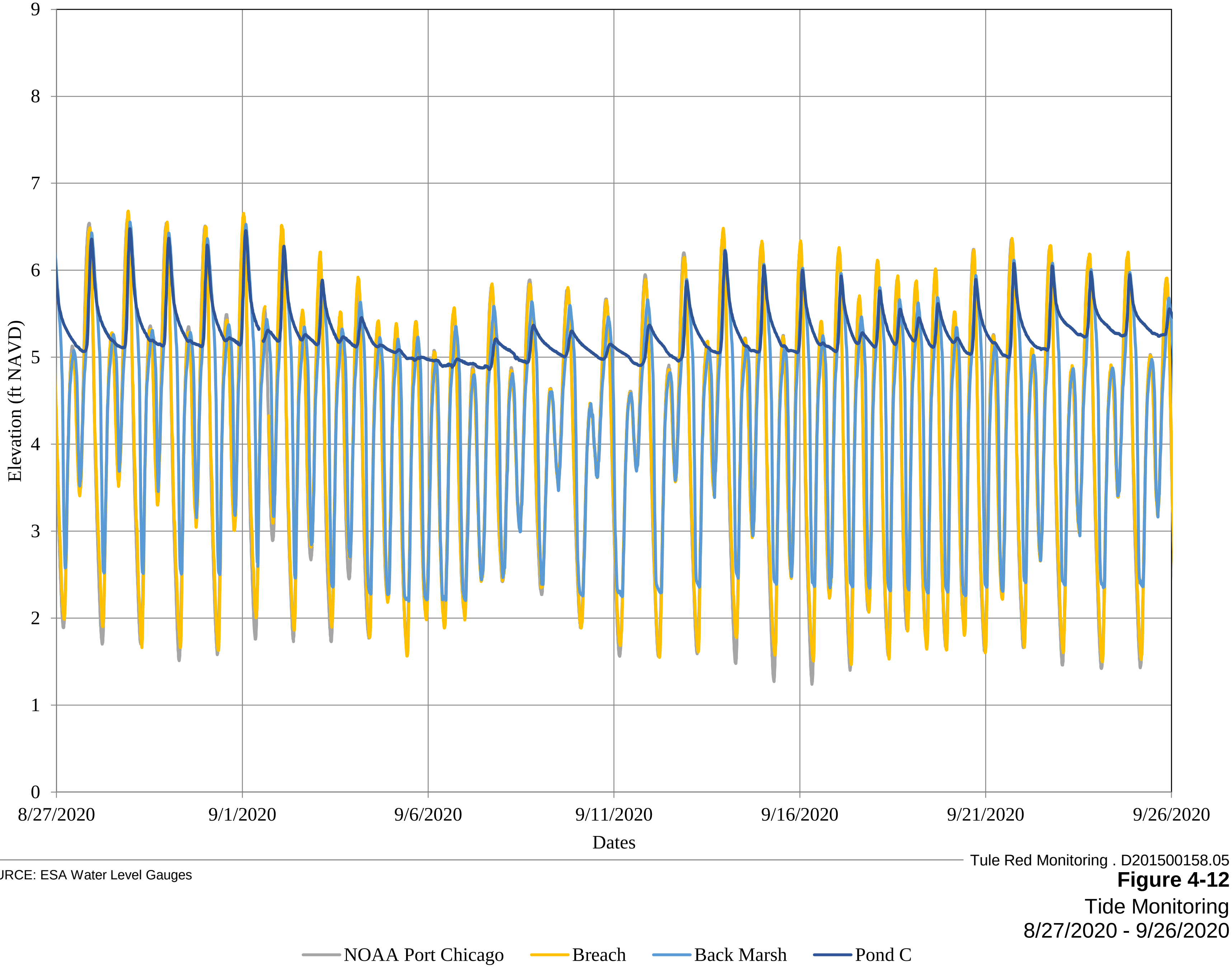
Water level data at the breach shows an expanding tide range as the year of monitoring progressed, indicating improved conveyance throughout the year as the outboard channel and breach enlarge (Figure 4-11). Peak tides at the breach closely match those observed at Port Chicago throughout the year, with episodic differences likely resulting from regional weather patterns such as wind setup. Lower-low tides at the breach were constricted through the year as compared to Port Chicago, as ebb tide drainage was limited by still-developing channels that are undersized with relation to the tidal prism of the site. That said, the ebb tide drainage improved steadily as the year progressed, with lower-low tides limited to a minimum of approximately 1.5 feet NAVD in June 2020 and 1.0 feet NAVD in December 2020. This equates to a 0.5-foot increase in tide range during the 6 months of monitoring.



SOURCE: ESA Water Level Gauges

Tule Red Monitoring . D201500158.05

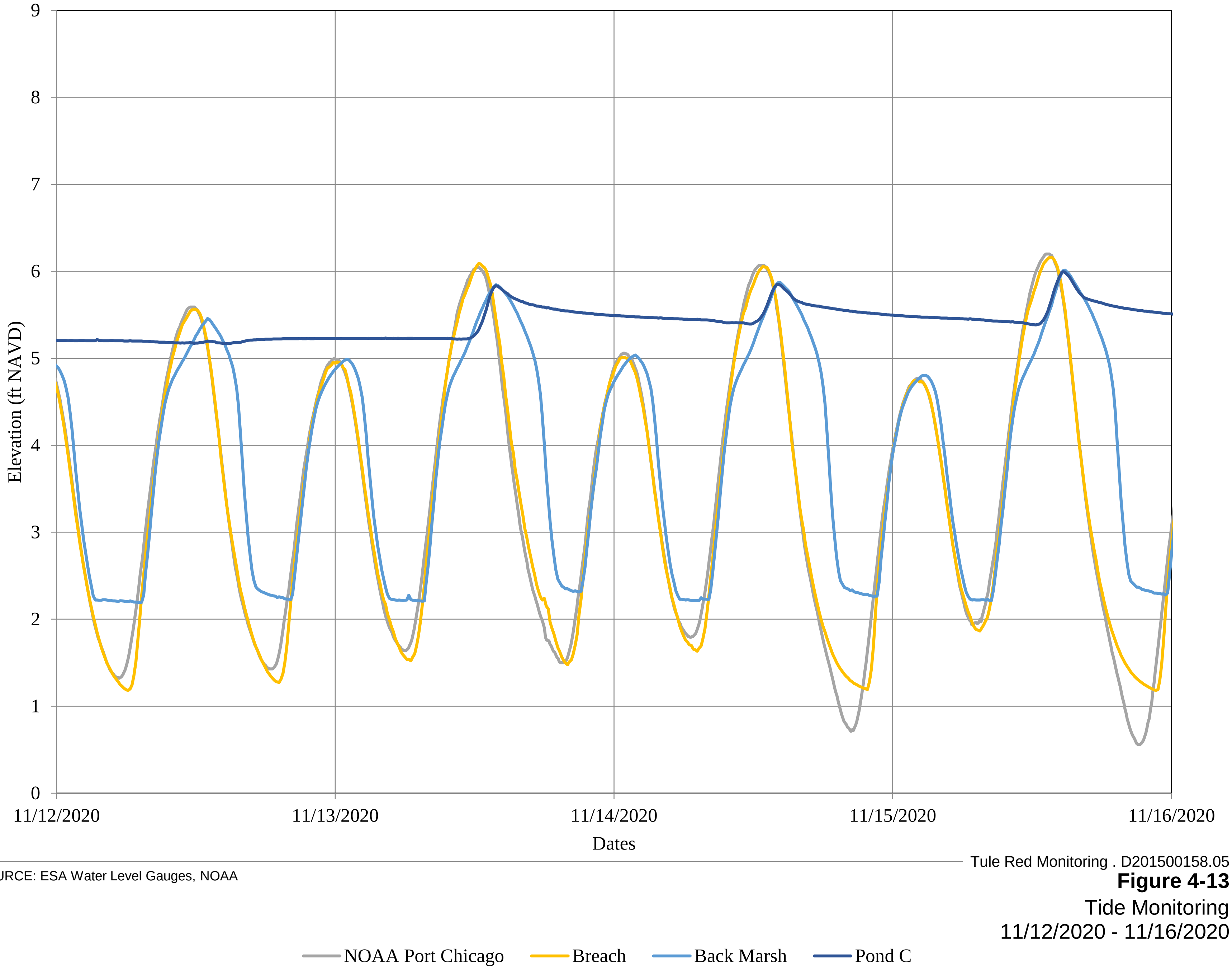
Figure 4-11
Tide Monitoring
6/9/2020 - 12/6/2020



SOURCE: ESA Water Level Gauges

Figure 4-12

Tide Monitoring
8/27/2020 - 9/26/2020



SOURCE: ESA Water Level Gauges, NOAA

Tule Red Monitoring . D201500158.05

Figure 4-13

Tide Monitoring

11/12/2020 - 11/16/2020

In the back marsh, water levels during peak tides are slightly lower and delayed compared to those at the breach (Figures 4-12 and 4-13). This indicates that tidal muting is occurring at the back of the site due to the undersized and still-developing tidal channel network. The delay between peak tides at the breach and back marsh showed no discernible change over the monitoring period. Drainage is also limited at the back marsh, especially from higher-high spring tides, as water slowly drains from the marshplain and marsh ponds through the developing tidal network. This is consistent with the active widening occurring in the third-order channel connecting the back marsh to the main tidal channel, as observed during the survey effort (Figure 4-10). As channels continue to widen and deepen, tidal exchange will improve and muting effects will diminish.

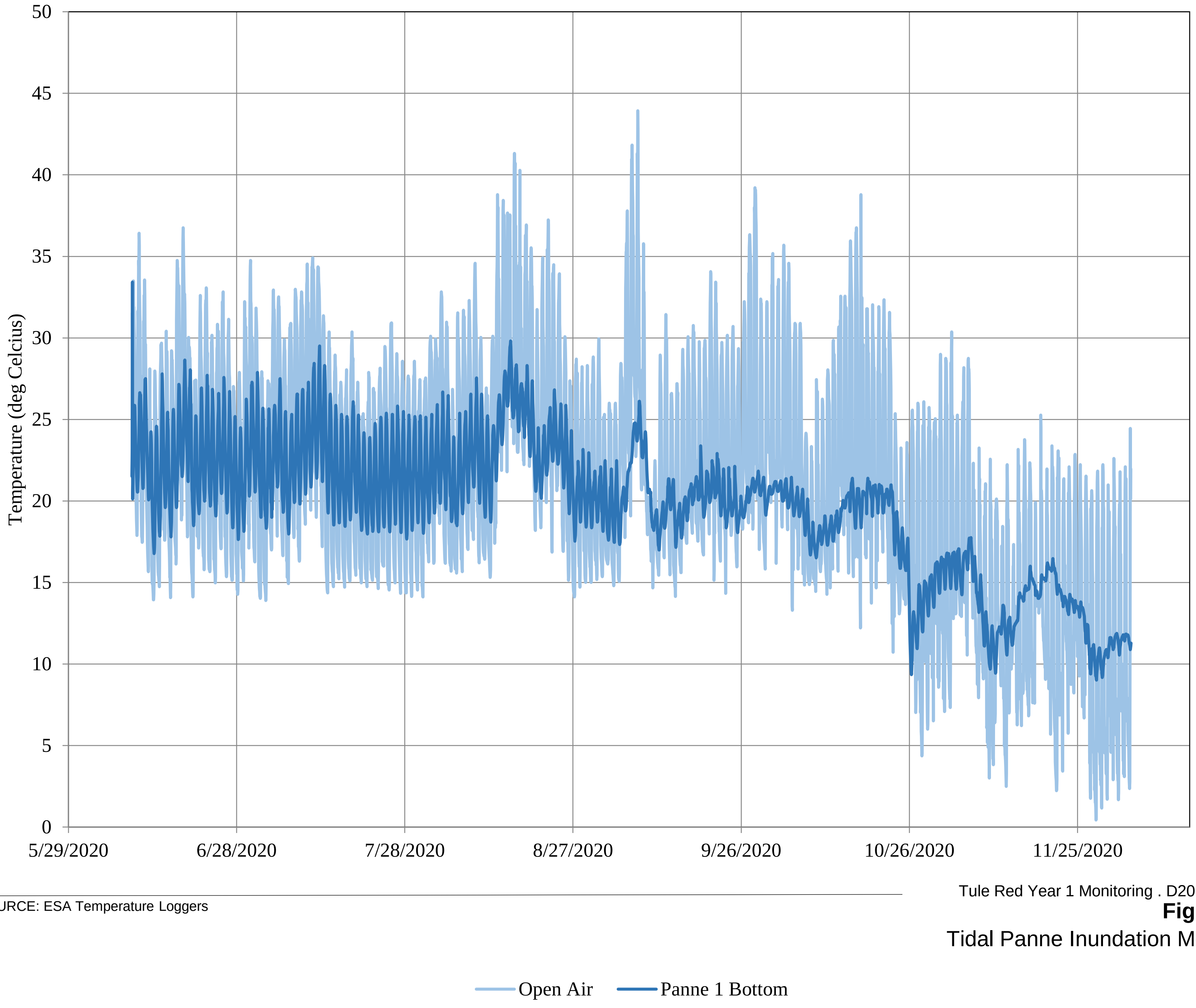
In the back marsh, a tidal flood stage attenuation threshold was observed at approximately 4.6 ft NAVD (Figure 4-13). Based on nearby survey data from cross-sections 6, 7, and 8 (Figures 4-7 through 4-9), this elevation corresponds to the height of surrounding marshplain. On flood tides, the rate of rising water levels slows when the tide reaches marshplain elevation (4.6 ft NAVD), where the cross-sectional area being filled increases substantially. The reverse happens on ebb tides: around marshplain elevation, the rate of drainage rapidly increases when the area being drained is limited to channels.

Water level data in Pond C shows the pond filling during spring tide cycles and draining during ebb tide cycles (Figure 4-12). The marsh pond only fills when water levels at the nearby back marsh gauge exceed approximately 5.3 ft NAVD, which corresponds closely to the elevation of low points (swales) in the marsh ridge (**Figure 4-14**). No marsh ridge swales were surveyed during Year 1 monitoring, but their design elevation is 5.5 ft NAVD. Water level data from Year 1 monitoring shows no discernible change in the elevation where the marsh pond begins filling, indicating that any potential erosion of the swales is not significantly affecting pond hydrology at this time. On ebb tides, Pond C drains at the same rate as the back marsh until approximately 5.6ft NAVD, when water levels reach the marsh ridge elevation surveyed in cross-sections 7 and 8 (Figures 4-8 and 4-9). Below this level, the pond drains more slowly as it funnels through the marsh ridge swales. During neap tide periods when water levels are not high enough to spill over the pond sill, Pond C slowly loses water to seepage and evaporation (Figure 4-12).

Tidal panne temperature data from June 9, 2020 to December 4, 2020 are shown in **Figures 4-15 to 4-18**. Temperature readings from the bottom of each panne are plotted with open air readings corresponding to nearby marshplain elevation. The daily temperature fluctuations in all four pannes were much smaller than open air fluctuations, indicating that all of the tidal pannes stayed inundated throughout the monitoring period.

Tule Red Tidal Restoration Annual Monitoring Report

Figure 4-14
Ebb tide drainage being “funneled” through a marsh ridge swale, a low point in the berm surrounding Ponds B, C and D

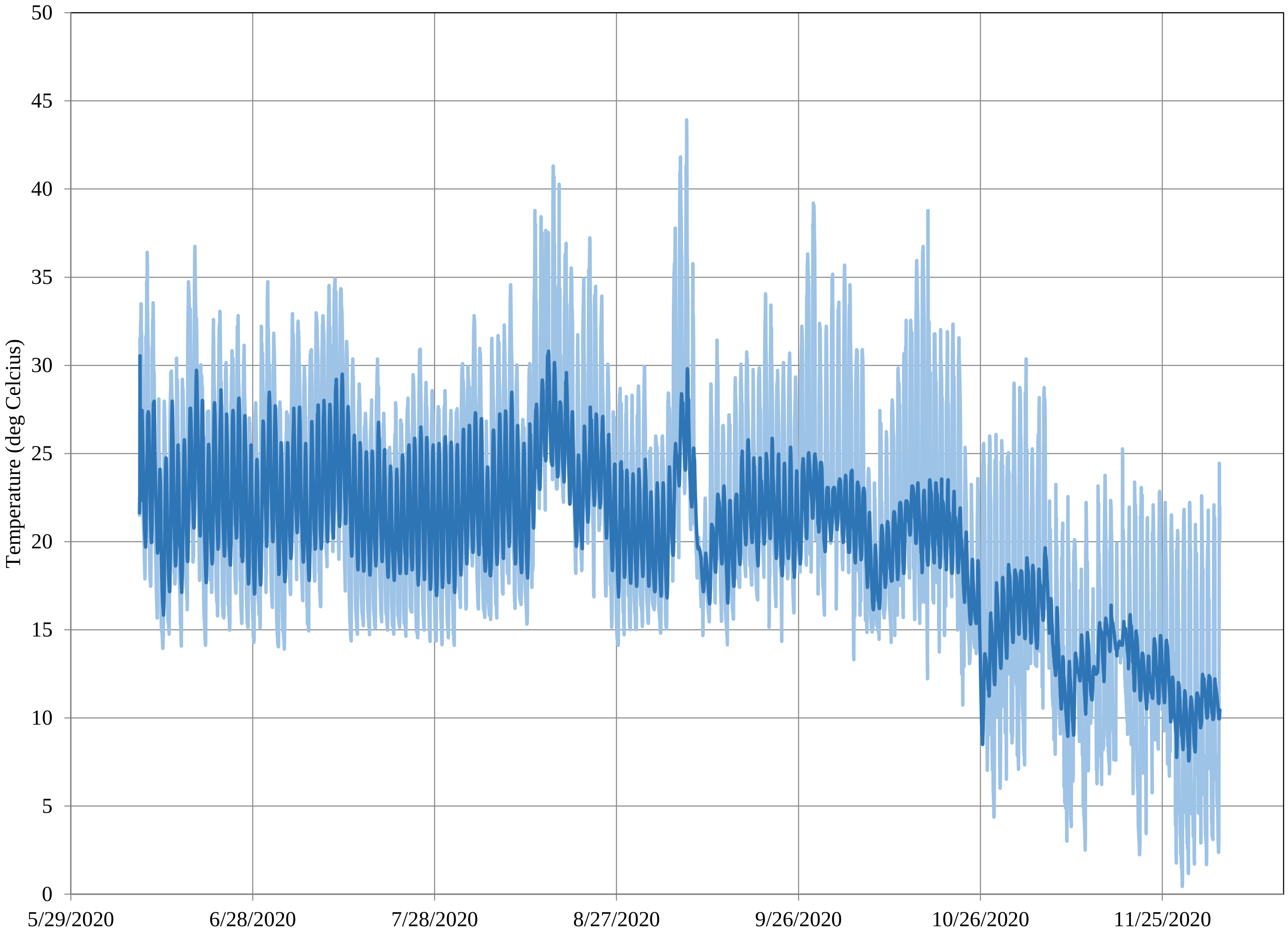


SOURCE: ESA Temperature Loggers

Tule Red Year 1 Monitoring . D201500158.05

Figure 4-15

Tidal Panne Inundation Monitoring
Panne 1

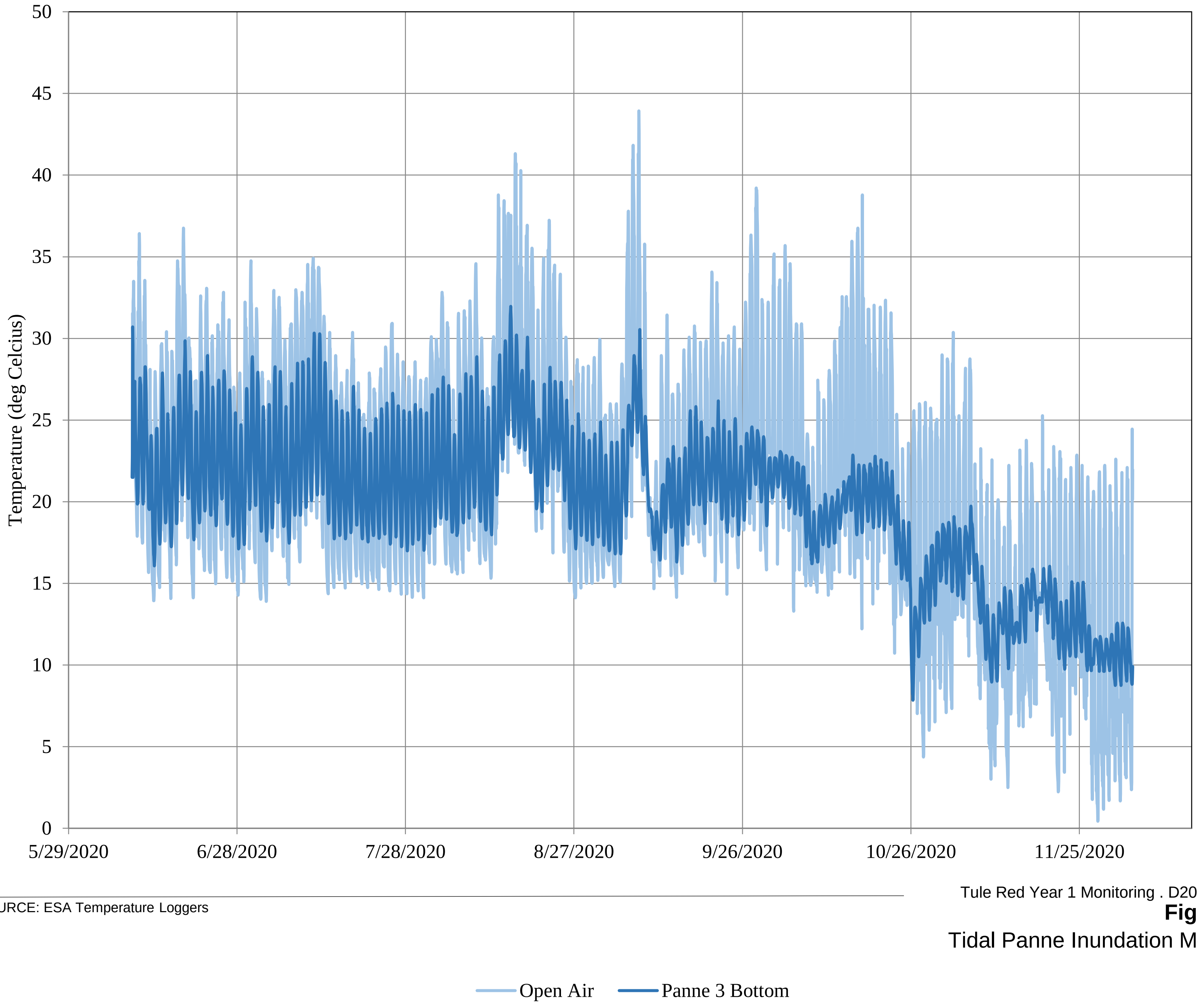


SOURCE: ESA Temperature Loggers

Tule Red Year 1 Monitoring . D201500158.05

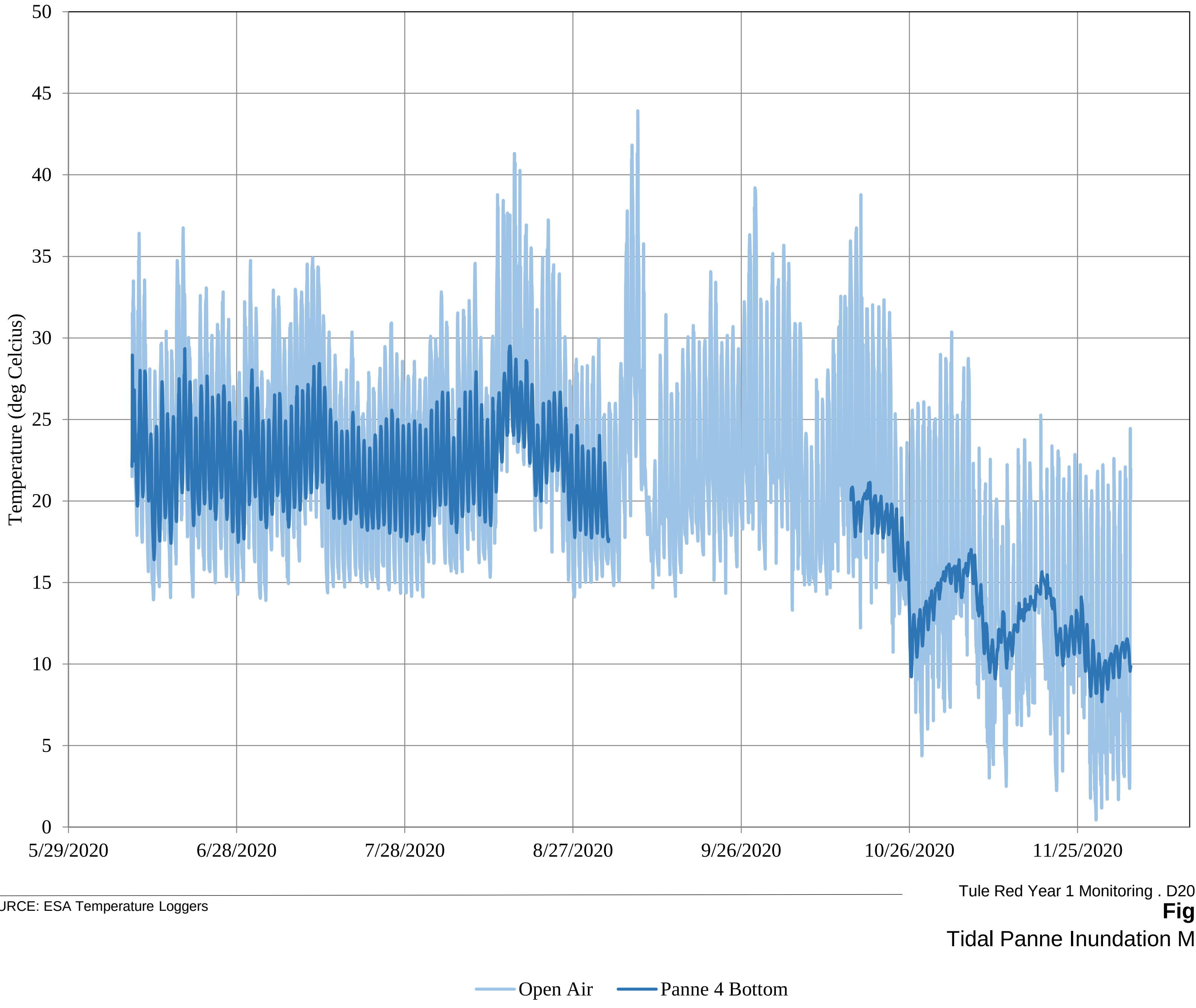
Figure 4-16

Tidal Panne Inundation Monitoring
Panne 2



SOURCE: ESA Temperature Loggers

Figure 4-17
Tidal Panne Inundation Monitoring
Panne 3



SOURCE: ESA Temperature Loggers

Tule Red Year 1 Monitoring . D201500158.05

Figure 4-18

Tidal Panne Inundation Monitoring
Panne 4

4.2 Water Quality

Water-quality data collected during Year 1 monitoring are shown in **Figures 4-19 to 4-27**. Observed parameters presented in this section are continuous time series of water temperature, salinity, chlorophyll-a fluorescence, dissolved oxygen concentration and percent of saturation concentration, and turbidity. For each of these time series, 24-hour moving averages were calculated to remove the short-term fluctuations caused by diurnal processes. Also presented are discrete water samples analyzed for methyl mercury concentration by volume.

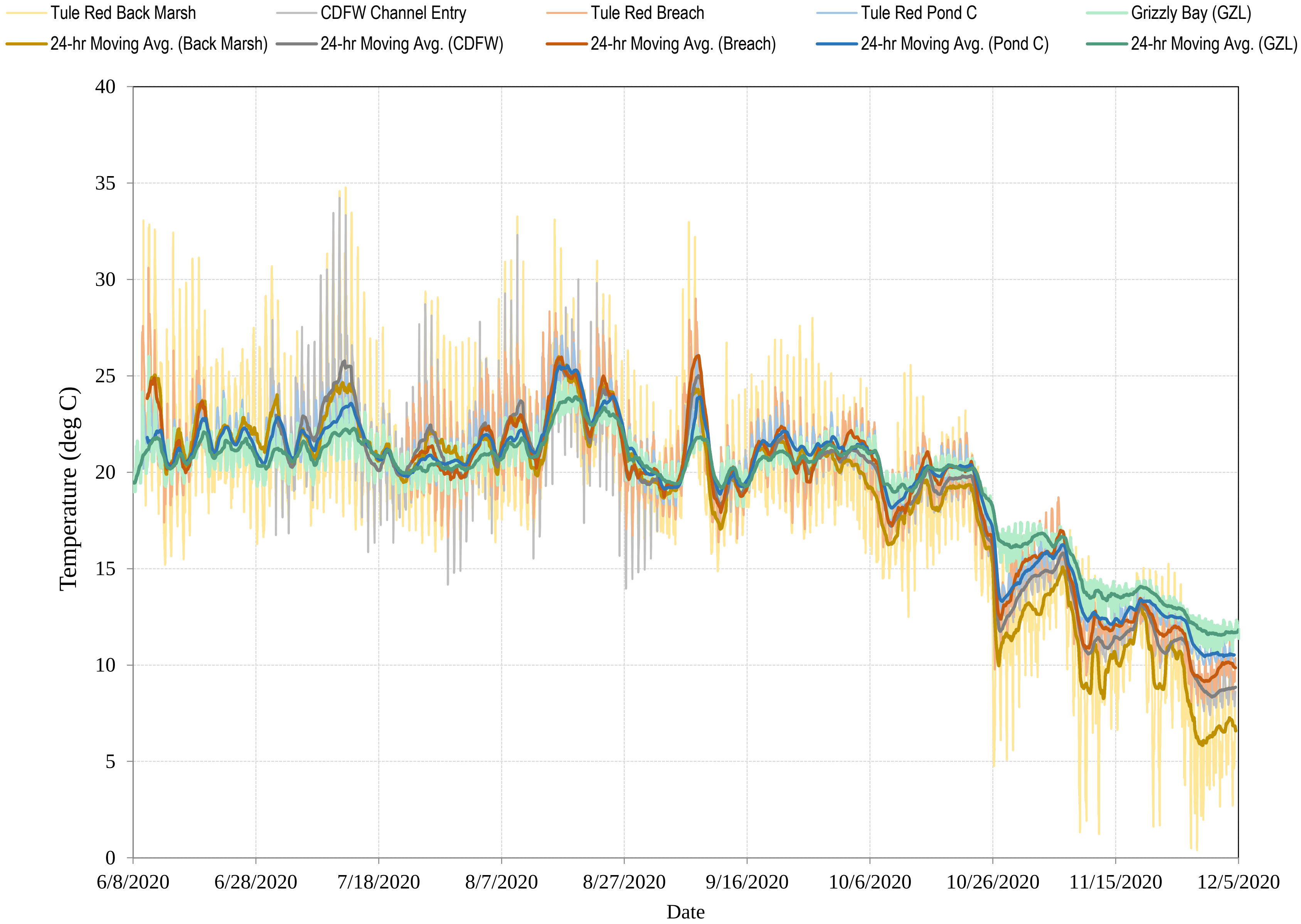
4.2.1 Water Temperature

Water temperature data are shown in Figure 4-19 from four instrument locations: breach, back marsh, Pond C, and CDFW channel entrance. Throughout the observation period, water temperatures at back marsh exhibited the greatest diurnal variability, while those at Pond C exhibited the least diurnal variability. Temperatures at the breach and CDFW channel entrance exhibited greater diurnal variability during the summer months. Temperature at the breach location varied at the tidal time scale (two local maxima and minima per day), although the diurnal signal was dominant. Peak temperatures at the back marsh (34.5 degrees C) and CDFW channel entrance (34.2 degrees C) were observed during early- to-mid July. It is likely peak water temperature at the breach also occurred during this period. However, this cannot be confirmed due to missing data. In contrast, the peak temperature in Pond C (27.1 degrees C) occurred in mid-August. At the subtidal time scale (that is, the 24-hour moving trendlines), water temperatures at all locations were generally similar in value to each other throughout the summer months. Water temperatures at Pond C were generally lower than those at the other locations until mid-August, when the pond experienced a warming event. Average water temperatures were between 20 and 25 degrees C until late October, when water temperatures dropped about 8 degrees C over several days. During November and December of 2020, the average temperature exhibited greater variability among the locations, with average temperatures highest at Pond C and lowest at the back marsh location.

4.2.2 Salinity

Salinity data are shown in Figure 4-20 for the breach and Pond C locations only. Salinity during June was similar (6-9 psu) across the breach location, Pond C, and Grizzly Bay. Greater variability in salinity at shorter time scales was evident at the breach location due to tidal influence, while little variability was observed at Pond C due to muted tidal conditions. At the seasonal time scale, average salinity at both locations increased over the observation period in response to seasonal reductions in watershed runoff and, particularly in the case of Pond C, increases in evaporation (~11.5-12.5 psu).

Salinity in Grizzly Bay fluctuated more than salinity in the Project site due to stronger tidal effects. Average salinity was consistently greater in Grizzly Bay than the breach location or ponds from mid-July onward, with a steep increase from October to December (16 psu).

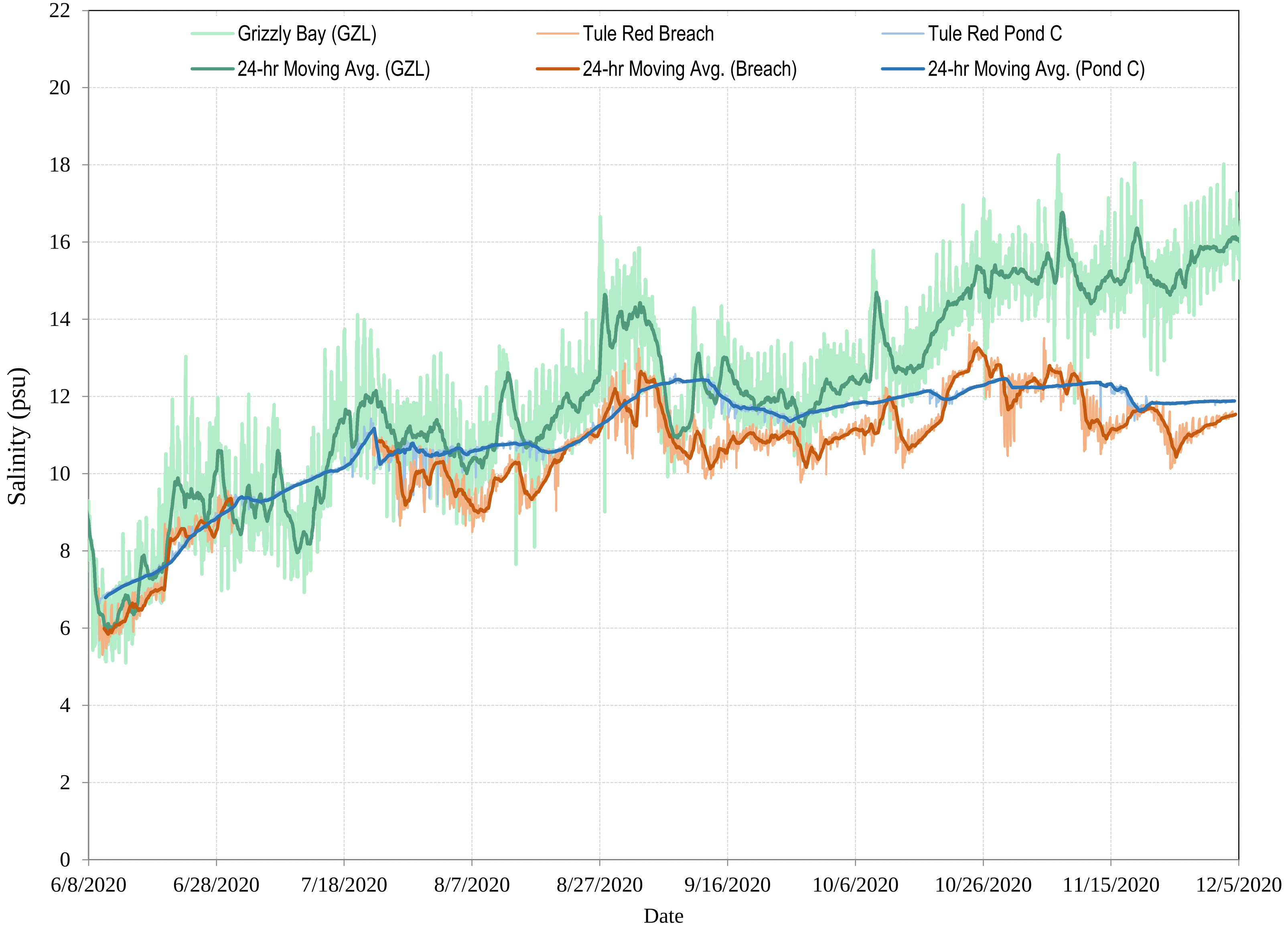


SOURCE: ESA Water Quality Gauges, ESA Water Level Gauges, CDEC

Tule Red Year 1 Monitoring. D201500158.05

Figure 4-19

Temperature



SOURCE: ESA Water Quality Gauges, CDEC

Tule Red Year 1 Monitoring. D201500158.05

Figure 4-20

Salinity

4.2.3 Chlorophyll-a

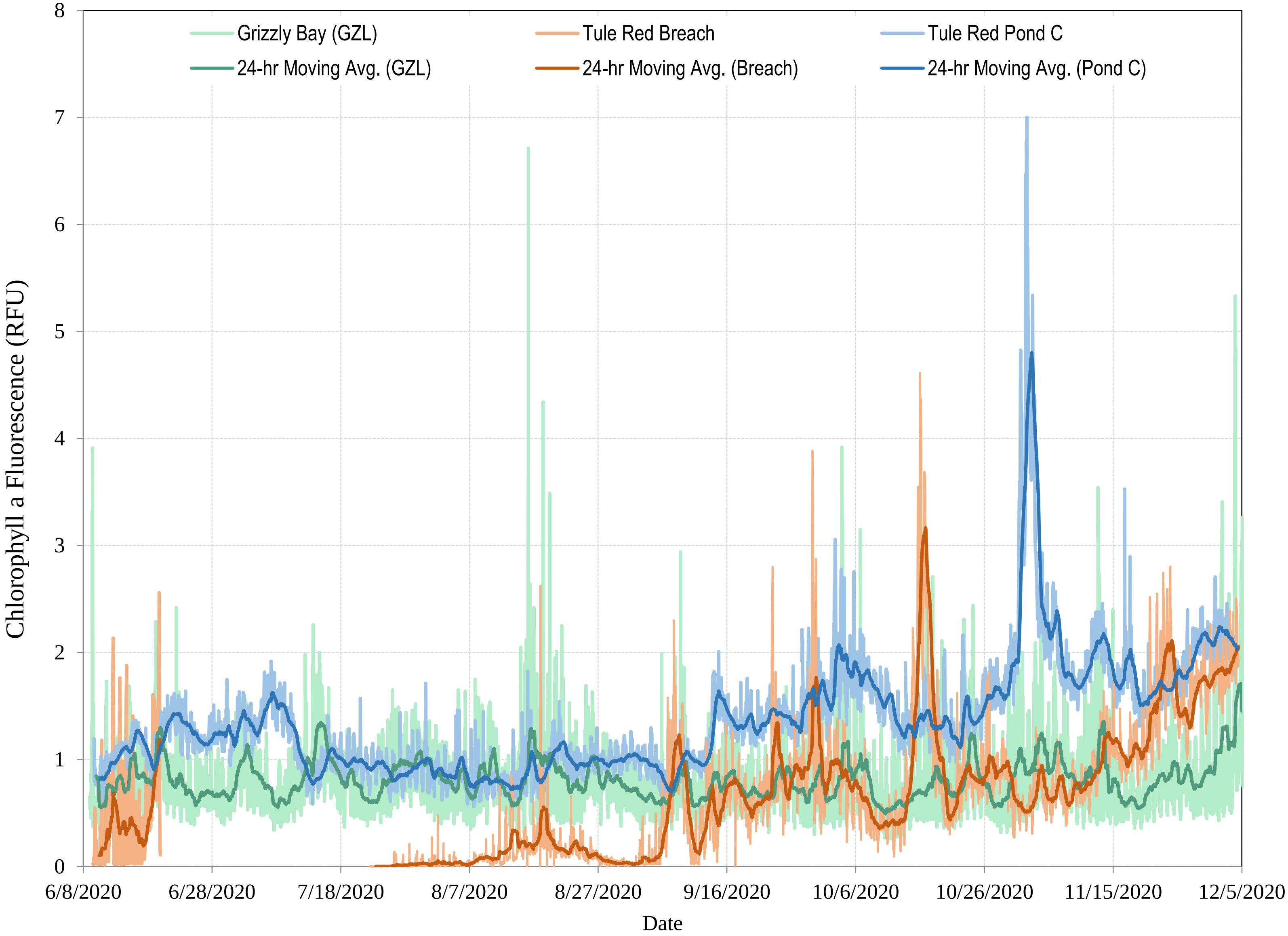
Chlorophyll-a fluorescence data are shown in Figure 4-21 for the breach and Pond C locations from this study along with data from a Grizzly Bay water-quality sonde from CDEC (station ID: GZL). Due to limited calibration samples, data from these locations are presented in relative fluorescence units (RFU). At shorter time scales (tidal to diurnal), chlorophyll-a exhibited greatest variability at the Grizzly Bay sonde. The signals at the Grizzly Bay and breach locations have similarity in the beginning of the record, with approximately concurrent peaks during the period August 16-18 and again during September 5-11, which may indicate phytoplankton blooms in Grizzly Bay that were advected to the breach and into in the project area. On average, chlorophyll-a concentrations were highest in Pond C and suggest primary production occurred locally, at the pond scale. Peak chlorophyll-a concentrations in Pond C (7 RFU) occurred in early November 2020 (Figure 4-21), during a local maximum in water temperature (as seen in the 24-hr moving average water temperature, Figure 4-19). The breach and Pond C locations showed an increasing trend in chlorophyll-a fluorescence over the period from early September 2020 through December 2020. From mid-November 2020 through December 2020, chlorophyll-a fluorescence at the breach exceeded that in Grizzly Bay, which could indicate primary production within the project area that was exported to Grizzly Bay.

4.2.4 Dissolved Oxygen

Dissolved oxygen (DO) time series for the Year 1 study period are presented as concentration (in mg/L) in Figure 4-22 and as percentage of saturation concentration (referred to as %sat) in Figure 4-23 for the breach, Pond C, and CDFW channel entrance locations. During the observation period, DO concentration and %sat were highly variable at shorter time scales for all locations. The time scale of variability was tidal at the breach and CDFW channel locations, and diurnal at the Pond C location. Short-term variability was greatest at the CDFW channel location and smallest at the Pond C location. Average DO conditions over the Year 1 study period (as measured by a 24-hour moving average) were similar at Pond C (8.1 mg/L, 94.0 %sat) and the breach (8.1 mg/L, 92.4 %sat) and higher than at the CDFW channel entry (7.1 mg/L, 75.9 %sat).

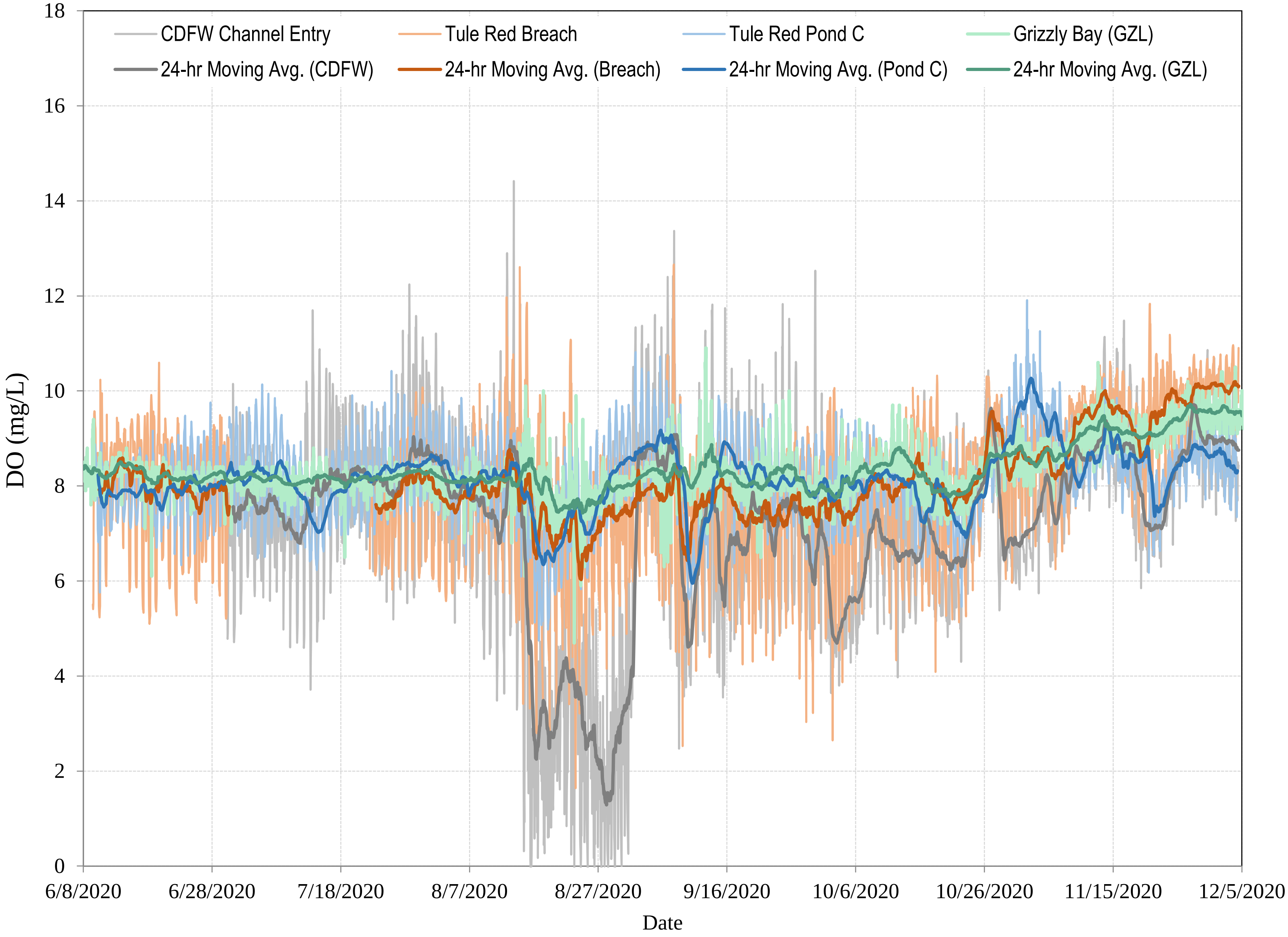
DO concentration at the breach location is tidally affected, with DO concentrations generally lower during low tides and higher during high tides (Figure 4-24). DO and water depth are generally in phase, meaning that lowest-DO is observed at low tide and highest DO is observed at high tide. These data suggest higher-DO waters from outside the project area (in Grizzly Bay) entering on flood tides and lower-DO waters from within the project area leaving on ebb tides. It is also possible that there is greater effective respiration at low tides because there is less water and the local pelagic and benthic biota are being squeezed into a smaller volume of water.

At the tidal time scale, DO concentrations at the CDFW channel entry location have a greater range than at the breach location, with greater maxima and lower minima (Figure 4-22). Compared to water depth at the breach location (Figure 4-24), DO data at the CDFW channel entry show a phase lag of 3-6 hours, meaning that there is a delay between lowest and highest water depths at the breach and local maxima and minima in DO at the channel location.



SOURCE: ESA Water Quality Gauges, CDEC

Figure 4-21
Chlorophyll a

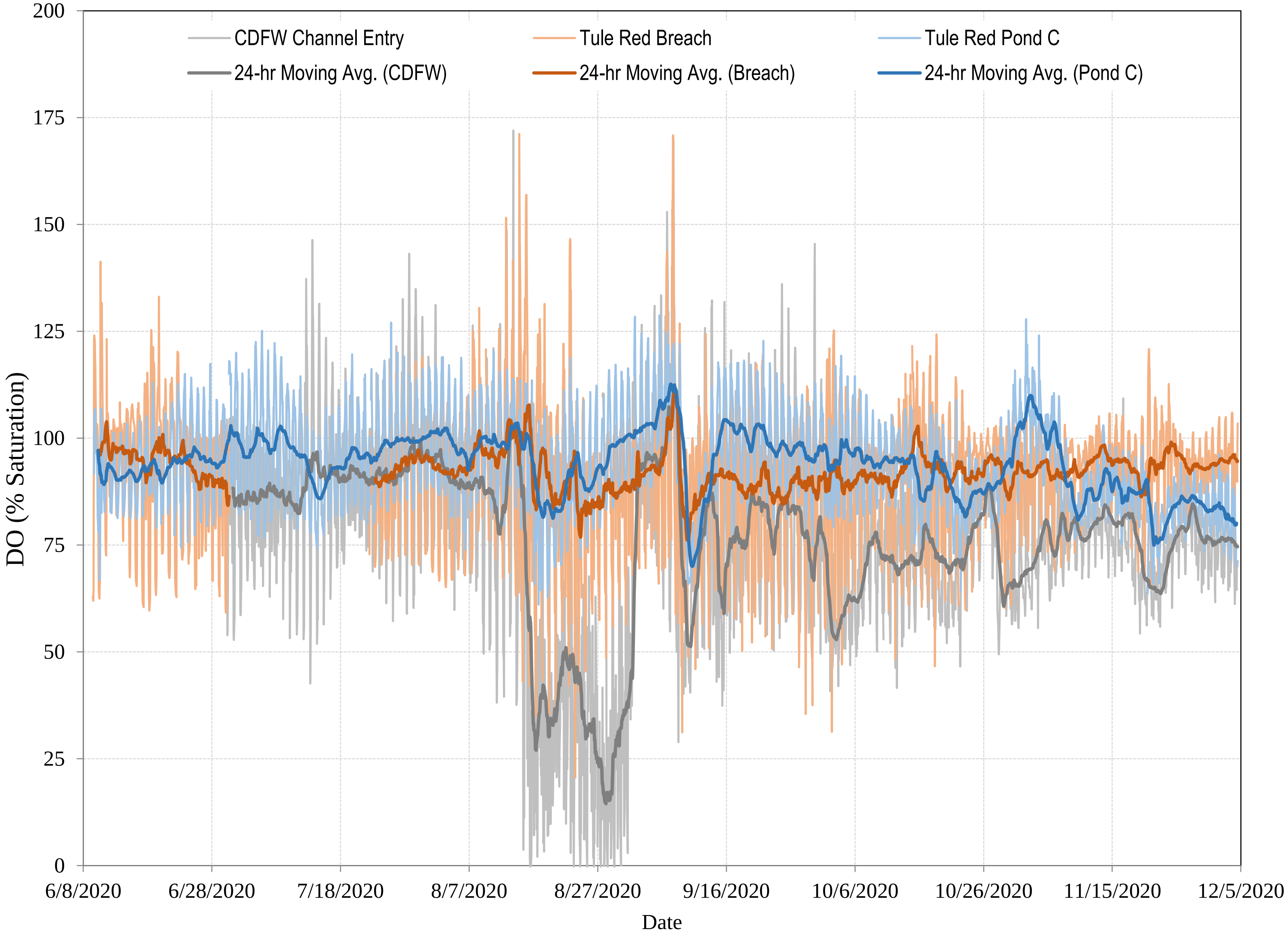


SOURCE: ESA Water Quality Gauges, CDEC

Tule Red Year 1 Monitoring. D201500158.05

Figure 4-22

Dissolved Oxygen

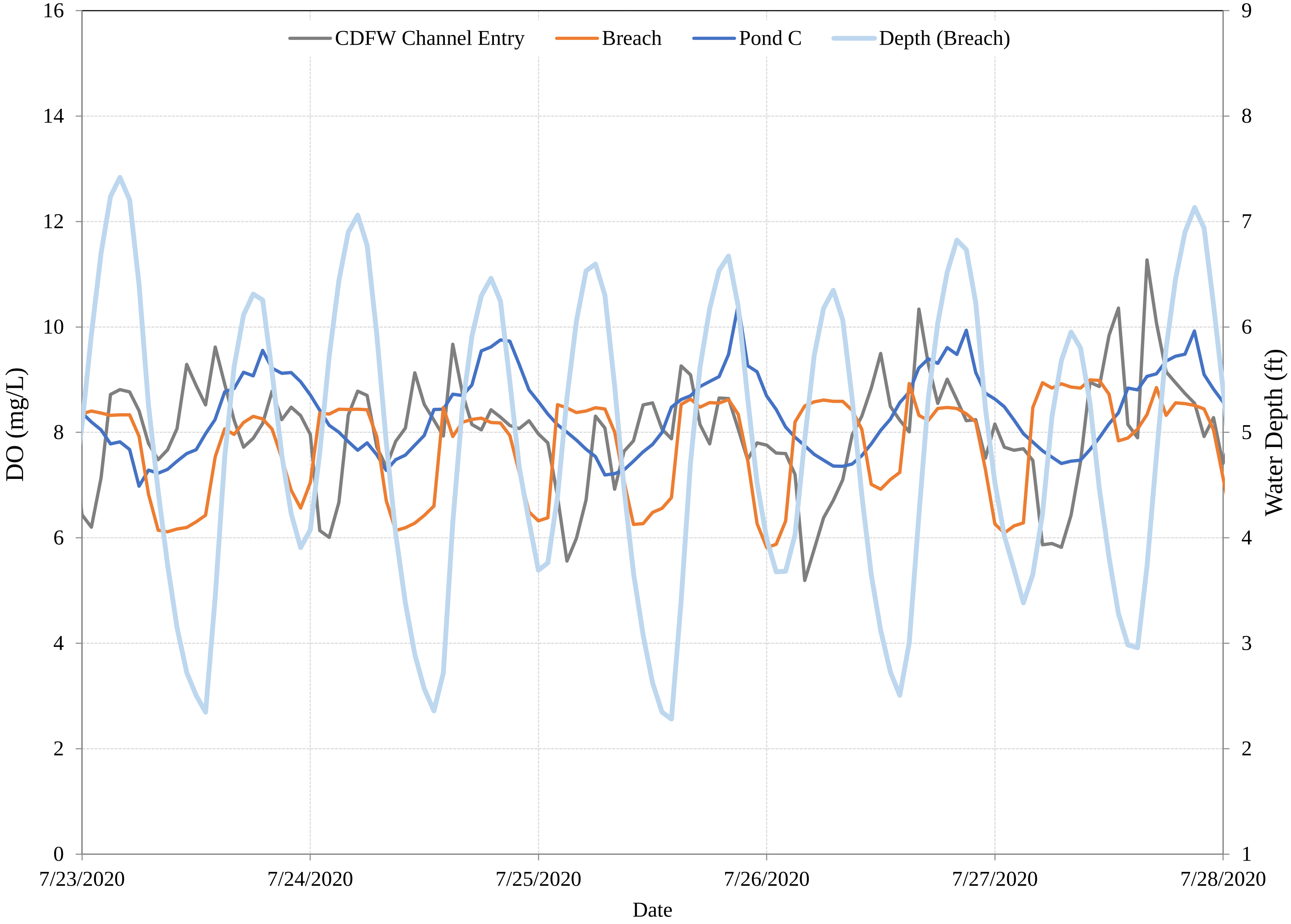


SOURCE: ESA Water Quality Gauges

Tule Red Year 1 Monitoring. D201500158.05

Figure 4-23

Dissolved Oxygen



SOURCE: ESA Water Quality Gauges

Figure 4-24

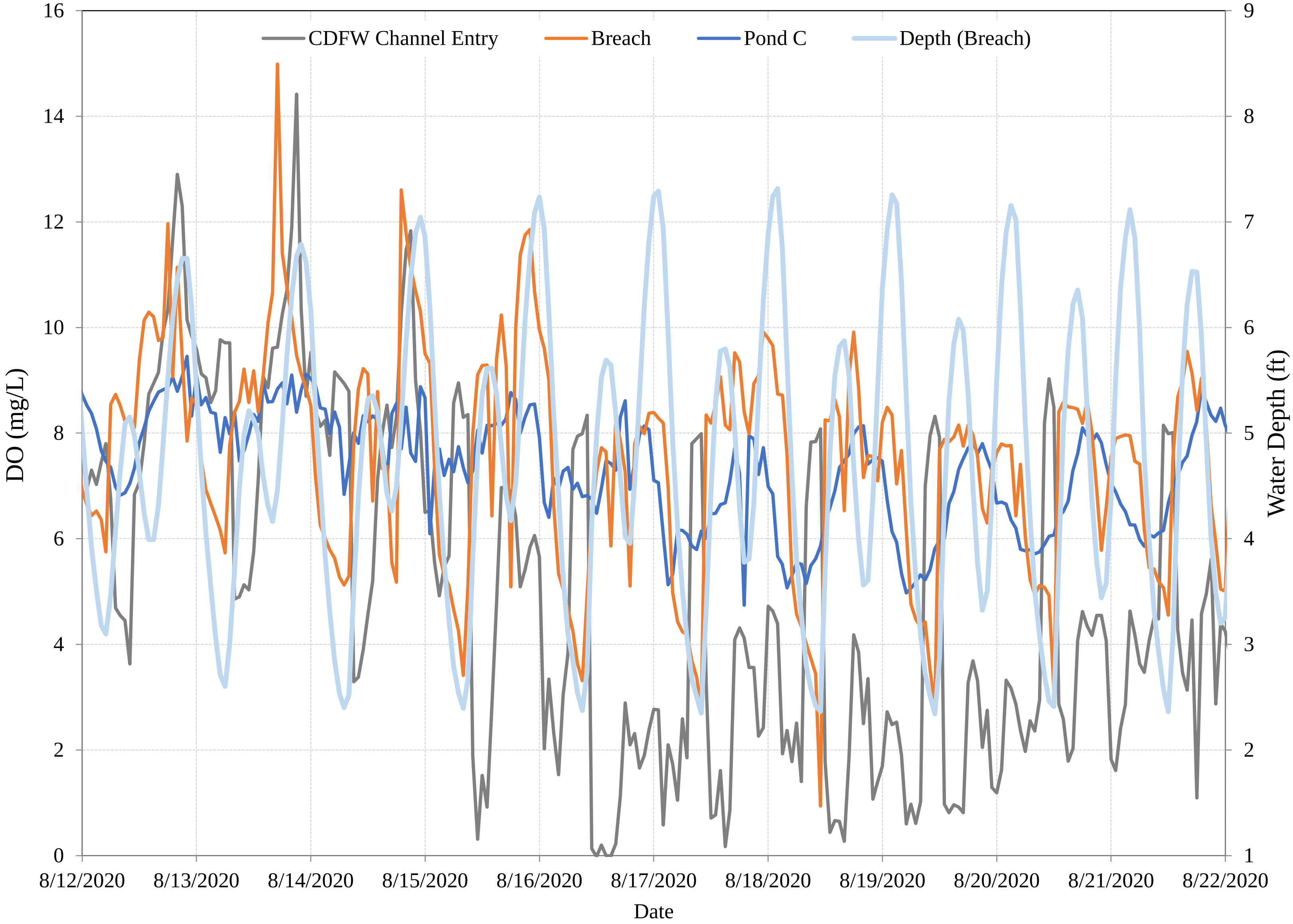
Dissolved Oxygen with Water Depth

July 2020

DO concentration at Pond C location in large part exhibited a diurnal signal (Figure 4-24), with highest values in the late hours before sunset and lowest values in the early morning hours before sunrise. This pattern is consistent with diurnal patterns of algal photosynthesis and respiration.

During the period August 15-20, a low-DO event (concentrations below 5 mg/L and %sat below 50%) was observed at the CDFW channel entry location (Figures 4-22 and 4-23). Note that according to CDFW WMA managers, the pump that drains to the channel into Tule Red was not pumping in summer (September is the period for pond flood-up, not drainage). Before this period, average DO was similar at all locations (around 8.5 mg/L, Figure 4-22). Average DO concentration at the CDFW channel entry decreased from 8.5 mg/L on August 14 to about 2.3 mg/L on August 16, while at the other locations it decreased from about 8.5 mg/L to about 6 mg/L over the same period (Figure 4-22). This low-DO event appears to be a local phenomenon in the vicinity of the CDFW channel entry; detailed comparison of DO concentrations at all three locations with water depth at the breach location (Figure 4-25) demonstrates a change in the DO signal beginning on August 15 from local minima occurring after lower-low water to local maxima concurrent with lower-low water. This change could indicate the advection of higher-DO water from the constructed tidal pond complex (including Pond C) past the sensor on the stronger daily ebb tide, or increased mixing of the water column associated with higher water velocity. DO concentrations at the breach location retain a signal similar to the period before the low-DO event (Figure 4-25), although daily maximum and minimum values are decreased. The decrease in the daily minimum DO concentration at the breach during lower-low tide suggests the advection of low-DO water out of the project area on ebb tides and is consistent with the low-DO conditions being a local phenomenon. DO concentration in Pond C retains a diurnal signal (Figure 4-25), with minor decreases in daily maximum and minimum values. Water temperatures increased about 4 degrees C at the beginning of this period from August 13 to August 16 (Figure 4-26). The initial period of low-DO concentrations at CDFW channel entry (11:00 PST on 8/15/20, Figure 4-25) is nearly concurrent with a large peak in water temperature at the back marsh location (15:20 PST on August 15, Figure 4-26). These warming conditions may be a contributing factor to the onset of the low-DO event.

DO concentrations varied spatially. At the CDFW channel entry location, DO frequently dropped below 5 mg/L throughout the Year 1 study period (Figure 4-22). During the low-DO event at the CDFW channel entry (August 15-30), DO concentrations at CDFW channel entry averaged between 2 and 4 mg/L; instantaneous DO concentrations were nearly always below 5 mg/L, except on lower-low tides (as measured by water depth at the breach location). During this same period, DO concentrations at Pond C drop below 5 mg/L only on one day, in the early evening of August 17. At the breach location, DO concentrations dropped below 5 mg/L only periodically, on lower-low tides, during the period August 14 to October 22; during the remainder of the tidal cycle, DO concentrations are above 7 mg/L.

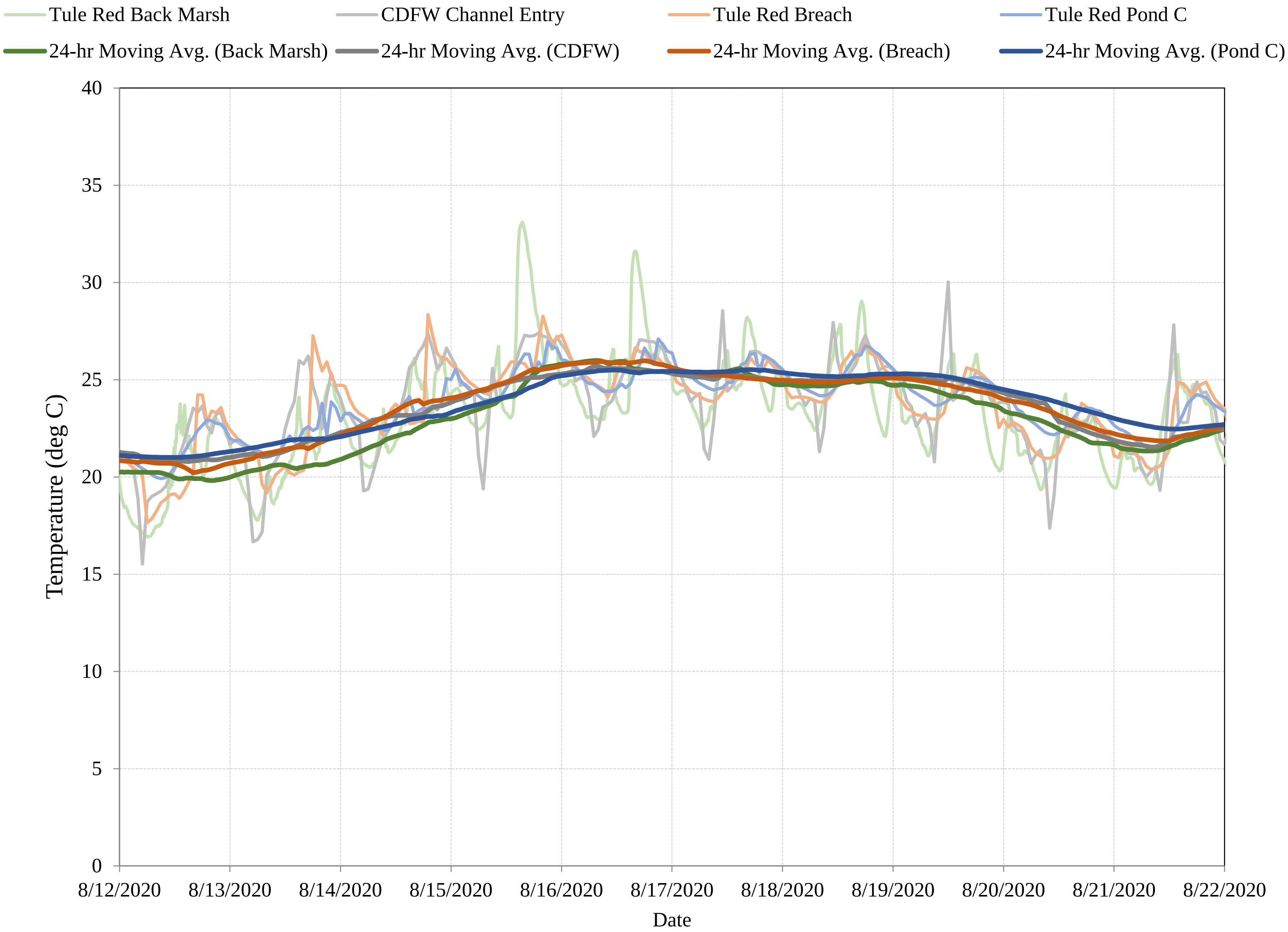


SOURCE: ESA Water Quality Gauges

Tule Red Year 1 Monitoring. D201500158.05

Figure 4-25

Dissolved Oxygen with Water Depth
August 2020



SOURCE: ESA Water Quality Gauges, ESA Water Level Gauges

Tule Red Year 1 Monitoring. D201500158.05

Figure 4-26
Temperature
August 2020

4.2.5 Turbidity

Turbidity data are shown in Figure 4-27 from the breach and Pond C locations only. Throughout the observation period, turbidity was much greater (one to two orders of magnitude higher) and more variable at the breach location compared to the Pond C location. Turbidity variations in response to semi-diurnal tidal currents and spring-neap tidal cycle variations in tidal energy were evident at the breach location but not at Pond C. Highest peak and average turbidity values were nearly concurrent for the two locations—peak turbidity at the breach location (1360 NTU on 6/30/20) was near the same time as that at Pond C (47 NTU on 7/3/20). Greatest average turbidity at Pond C occurred during the period June 10 to July 22; although data at the breach location are unavailable for a portion of this period, available data suggest average turbidity was highest at the breach for this same period.

4.2.6 Methyl Mercury

Results from methyl mercury concentrations, in mass per unit volume, analyzed from discrete grab samples at the breach location, are shown in **Table 4-1**. During each of the three sampling dates, three water samples were collected approximately one hour apart on falling tides during ebb-directed flow (Table 4-1). Methyl mercury concentrations varied within and across sample dates. Methyl mercury concentrations were highest and most variable during the June 2020 sampling (range: 0.12 – 0.27 ng/L) and lowest and least variable during the September 2020 sampling (range: 0.04 – 0.06 ng/L).

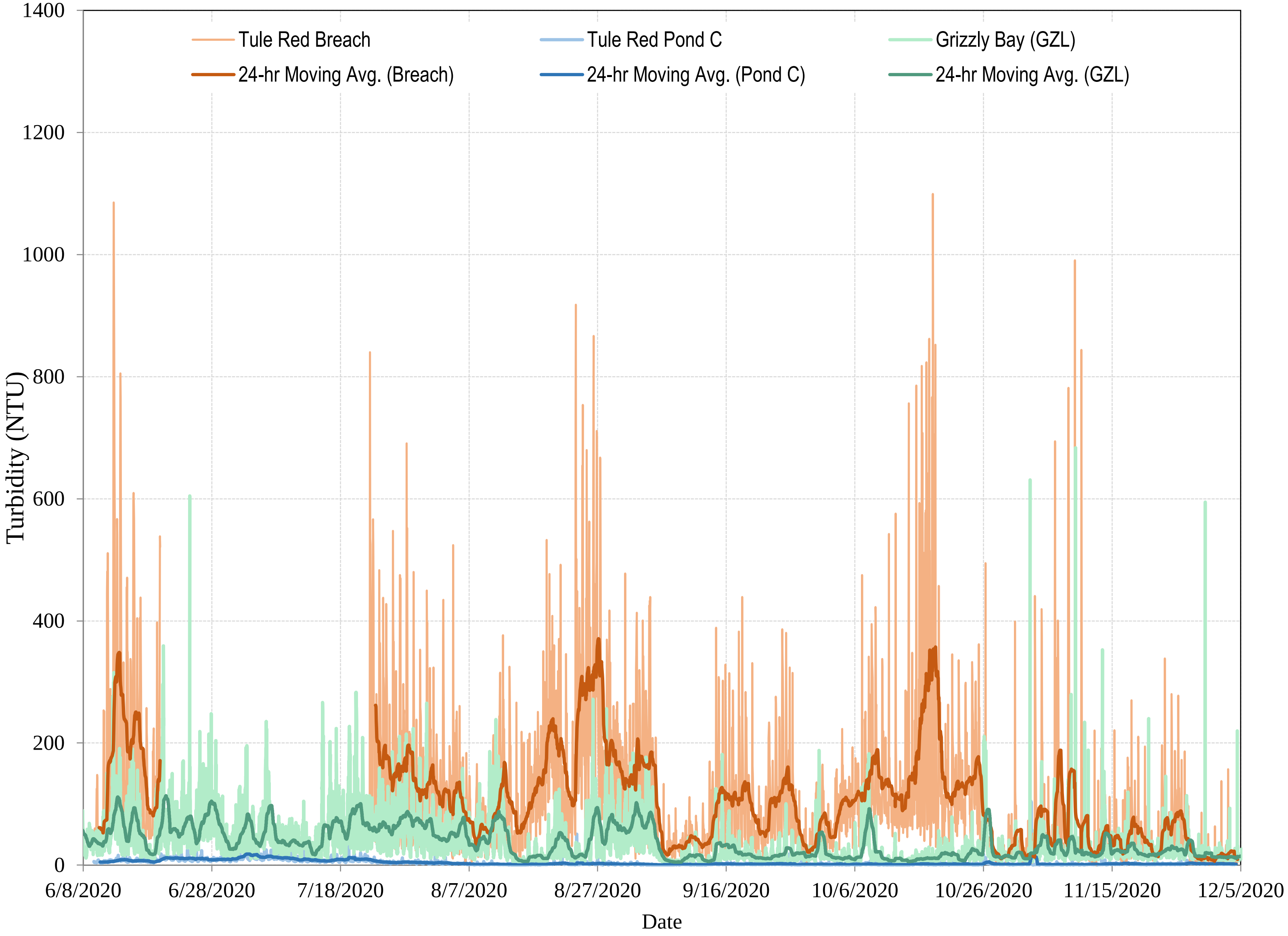
TABLE 4-1
METHYL MERCURY SAMPLES

Date	Time	Tide at Breach (ft NAVD)	MeHg (ng/L)	Mean MeHg (ng/L)
6/9/2020	8:50	4.50	0.12	0.21
	9:50	3.50	0.24	
	10:50	2.22	0.27	
9/1/2020	16:35	5.35	0.06	0.05
	17:20	4.90	0.04	
	18:20	4.33	0.05	
10/29/2020	15:30	4.88	0.06	0.40
	16:10	4.29	0.09	
	17:27	3.50	0.24	

Notes: Water samples collected on ebb tide. MeHg samples tested by Caltest Analytical Laboratories in Napa, CA. R.L. 0.05, MDL 0.020.

4.3 Food Web

Food web samples collected by CDFW are still being processed and analyzed.



SOURCE: ESA Water Quality Gauges, CDEC

Tule Red Year 1 Monitoring. D201500158.05

Figure 4-27
Turbidity

4.4 Fish

Fish sampling in 2020 was limited to that conducted as part of regional surveys and special studies, since the Project proponents do have the necessary take permits and the CDFW FRP monitoring team did not include Tule Red in their fish surveys for 2020 (Contreras et al., 2019).

Following the Tule Red coordination call on May 1, 2020, ICF, as part of their fish studies in Suisun Marsh with DWR, conducted brief trawling on May 7, 2020 in the main channel and successfully documented larval longfin smelt (L. Grimaldo, ICF, pers. comm.) (**Figure 4-28**). ICF also seined the marsh ponds March 3 and June 8 as part of a food web study by UC Berkeley. Fish species included threespine stickleback (most common), prickly sculpin, staghorn sculpin, and an unidentified goby (*Tridentiger* species) (I. Woo, USGS, pers. comm.). IEP's regional fish surveys in Grizzly Bay documented longfin smelt but no delta smelt or Chinook salmon in 2020 (**Table 4-2**).

Source: L. Grimaldo (ICF) Tule Red Tidal Restoration Annual Monitoring Report

Figure 4-28
Larval longfin smelt sampled in Tule Red Main Channel

TABLE 4-2
CATCH OF FISH SAMPLED BY VARIOUS IEP PROGRAMS IN GRIZZLY BAY IN 2020

Survey	Station	Chinook Salmon	Delta Smelt	Longfin Smelt
Smelt Larval Survey	602	0	0	108
20mm Survey	602	0	0	9
Spring Kodiak Trawl	602	0	0	2
Summer Townet	602	0	0	0
Fall mid-water trawl	601, 602, 603, 604	0	0	0
Bay Study	431	Not available		
FRP surveys	602FRP	Not available		

4.5 Wetlands and Vegetation

4.5.1 Photo Points

Photo points taken in 2017 document the pre-construction conditions on the site. The 2020 photo points document conditions on the site in the year following final construction, including the breach. A comparison of photos from each photo point in 2017 to 2020 is provided in **Appendix B**. These photos are oriented from the habitat berm facing out across the marsh. In 2020 much of the area in the foreground of the photos from points 1, 2, 3, and 4 is still unvegetated, or has low-growing pickleweed (*Salicornia pacifica*) and bulrush (*Bolboschoenus maritimus*). In photos from points 5, 6, 7, and 8, the vegetation existing prior to construction is still evident in the distance, while the foreground has sparse or low-growing vegetation.

4.5.2 Vegetation Composition and Cover

The vegetation composition and cover data recorded in 2020 reflects vegetation that is currently responding to the recent restoration of tidal influence, creation of aquatic features, and in some areas, especially on the habitat berm, responses to disturbance during construction. These data are a snapshot in time, and vegetation will continue to change over the next few years. Total vegetation cover by taxon for each plot for 2017 pre-construction and 2020 post-breach is provided in **Appendix C.** A summary of the 2020 vegetation composition and cover is provided below in **Table 4-3**.

TABLE 4-3
VEGETATION COVER BY VEGETATION TYPE, BASED ON VEGETATION PLOT DATA

Vegetation type (MCV Alliance)[1]	Number of plots	Plot ID	Total vegetation cover (%) Range	Total cover of non-native plants (%) Range
Atriplex prostrata - Cotula coronopifolia Herbaceous Semi-Natural Alliance	2	T1-1, T1-2	35 - 50	34 – 50
Bolboschoenus maritimus Herbaceous Alliance	2	T1-3a[2], T1-4	23 - 35	3.5 – 8.5
Distichlis spicata Herbaceous Alliance	4	T1-9, T2-6, T3-9, T4-8	35 - 80	0 - 15
Phragmites australis - Arundo donax Herbaceous Semi-Natural Alliance	6	T1-10, T2-10, T2-11, T3-4, T3-10, T4-10	60 - 98	58.5 - 98
Salicornia pacifica Herbaceous Alliance	13	T1-6, T1-7, T1-8, T2-1, T2-2, T2-3, T2-8, T2-9, T3-5, T3-6, T4-1, T4-5, T4-9	2 - 42	0 - 8
Spergularia bocconi Unrecognized Herbaceous Alliance[3]	2	T3-1, T3-2	8 - 25	8 – 25
Typha (angustifolia, domingensis, latifolia) Herbaceous Alliance	3	T3-3, T3-8, T4-6	35 - 65	36.5 - 45
Open Water	10	T1-3, T1-5, T2-4, T2-5, T2-7, T3-7, T4-2, T4-3, T4-4, T4-7	0	0

NOTES:

[1] Nomenclature in this table reflects the vegetation types defined in Sawyer et al., 2009

[2] This is a new monitoring plot

[3] These vegetation alliances are not recognized in Sawyer et al., 2009, but are defined based on dominant vegetation.

SOURCE: ESA, 2020

Most of the areas within the restoration site are vegetated, with the exception of the upper limits of the habitat berm, above the influence of daily tides. None of the hydroseed application in this area resulted in successful establishment of the seeded species. Within the habitat berm and also within the limits of the High Tide Line (HTL), pickleweed (*Salicornia pacifica*) has established well and is discussed in the next paragraph. As the elevation increases along the habitat berm and moves outside of tidal influence, the species composition changes from densely vegetated pickleweed to sparsely vegetated areas supporting non-native transitional species including fat hen (*Atriplex prostrata*), rabbitsfoot grass (*Polypogon monspeliensis*), brass buttons (*Cotula coronopifolia*) and Boccone's sand spurry (*Spergularia bocconi*), as well as some native pickleweed and salt grass (*Distichlis spicata*) (see photos for plots T1-1, T2-1, and T3-1 in **Appendix D**). The lack of establishment from the hydroseed application likely opened up opportunities for the natural recruitment of such vegetation. Much of this vegetation also occurs in patchy, linear distributions along the habitat berm and alternates between different species, with no clear influence of elevation on vegetation occurrences (Photopoints 3A, 3B, 4A, 4B, and 6B). Such patchy, linear distributions of non-native vegetation communities may have been influenced by the equipment used to track walk the habitat berm and associated ground disturbance, and may also have to do with how the material was placed. Since these areas do not support contiguous vegetative cover, containing large amounts of bare soil, they are vulnerable to additional recruitment of non-native plant species.

Some of the lower portions of the habitat berm, specifically those areas within the intertidal zone, are quickly establishing with the native pickleweed (see photo for plot T2-2, Appendix C), while some other areas are dominated by non-native species. The age structure of such individuals is young, indicating recent germination; these occurrences are also within areas that were disturbed during project implementation. It is unclear as to the vector of establishment. Past management efforts included the mowing and discing of pickleweed to create a mosaic of unvegetated and vegetated areas suitable for waterfowl, as well as providing opportunities for preferred waterfowl food such as the non-natives fat hen and brass buttons (ESA, 2017). Such mowing and discing of pickleweed likely moved plant materials, including seeds, underneath an appropriate germination or sprouting depth. It is possible that such materials were moved into an appropriate germination or sprouting depth during the earth moving activities associated with constructing the habitat berm. Alternatively, the high rate of pickleweed establishment within the intertidal zone of the habitat berm could also be due to seed dispersal influenced by daily tides (i.e., hydrochory). Regardless of the vector of establishment, such areas now dominated by pickleweed are healthy and expected to persist.

When comparing with baseline data collected in 2017 in relation to the marsh plain located between the natural berm and the main channel, there are some substantial differences in vegetation composition within sampled areas that were not disturbed during project implementation, likely a result of the recent changes in hydrology. Some such areas that previously supported intertidal plant species are now permanently inundated at shallow depths, and, as a result, these areas are transitioning to different vegetation types. For example, areas previously dominated by pickleweed or salt grass that are now inundated throughout the day – not just during high tide – show signs of vegetative stress and also contain native wetland graminoids that were not previously documented in such locations, including alkali bulrush (*Bolboschoenus* *maritimus*; sample plot T3-5). Furthermore, some areas that previously supported sparse covers of wetland graminoids have more than doubled in their cover and height (sample plots T3-3, T3-8, and T4-6), likely due to their now permanent inundation.

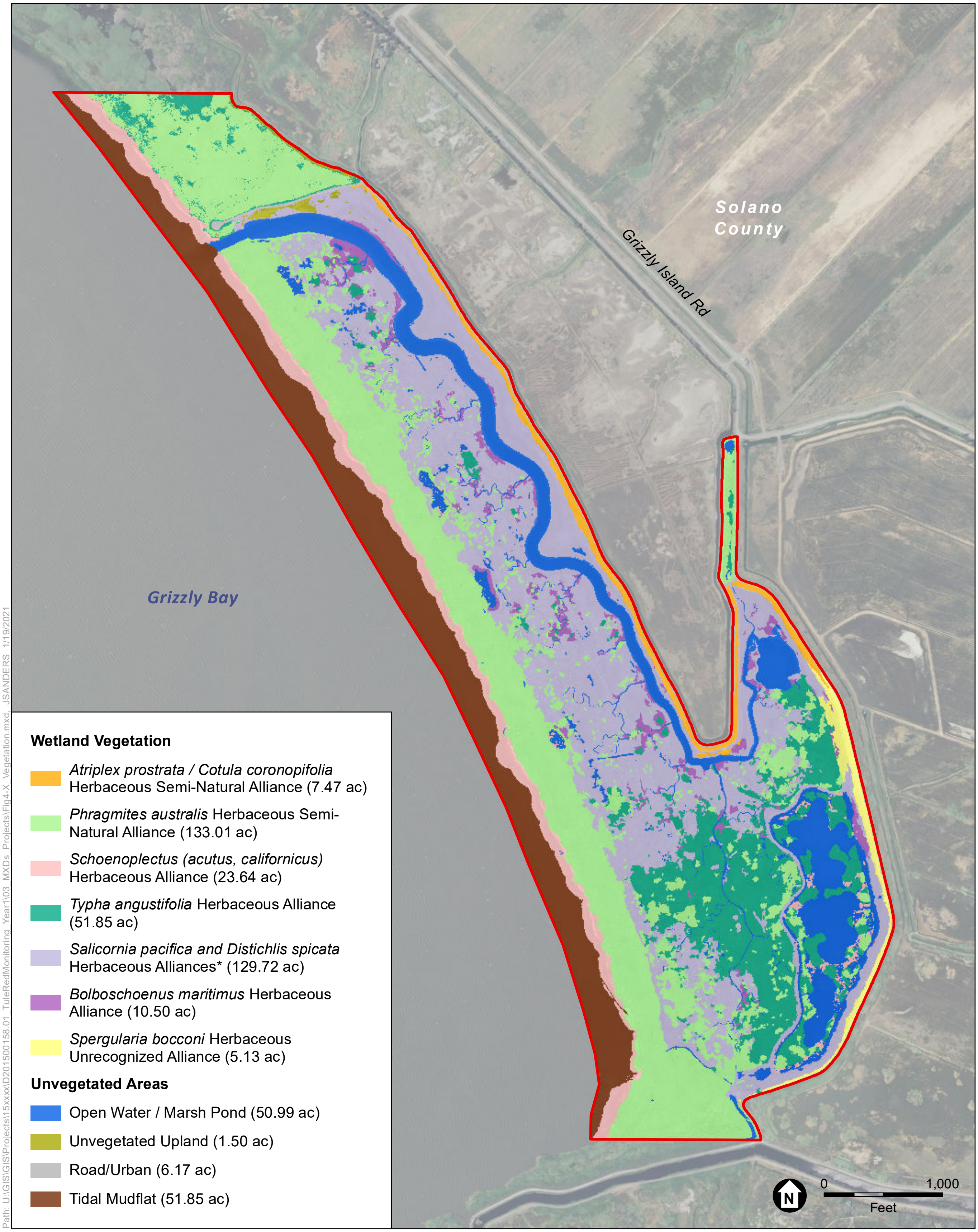
In addition to successional changes in plant species composition and cover, several sampling plots (n=10) that previously contained vegetation now occur within unvegetated tidal channels or marsh ponds that were created or expanded during project construction (Table 4-3).

Overall, this site is still responding to the recent restoration of tidal influence and is expected to continue to change over the next several years and settle into more stable vegetation communities over the longer term. Existing vegetation has responded to the changes in hydrology; lower marsh species are establishing in newly created subtidal zones, and middle marsh species are establishing in newly created intertidal zones, and it appears that existing populations have aided in this succession.

4.5.3 Vegetation Mapping

Vegetation mapping in 2020 (**Figure 4-29**) shows that there has been an increase in the number of wetland vegetation types since 2014 (ESA 2015). In particular, there were 10.50 acres mapped as the *Bolboschoenus maritimus* Herbaceous Alliance in 2020 and 5.13 acres mapped as *Spergularia bocconi* which is not a recognized alliance (**Table 4-4**). It is important to note that since much of the vegetation within the site is newly establishing, that associated low vegetation cover values do not result in pronounced spectral signatures. As a result, it was difficult to distinguish *Salicornia pacifica* Herbaceous Alliance and *Distichlis spicata* Herbaceous Alliance using aerial imagery. So these two vegetation types were combined into one vegetation type for mapping purposes, which is consistent with the 2017 mapping effort. (In the vegetation plot results presented above (Section 4.5.2), however, *Distichlis spicata* and *Salicornia pacifica* Herbaceous Alliance are listed separately because it was feasible to classify the plots separately.)

Prior to restoration, this area was inundated for a portion of the year, and then drained for the rest of the year as part of duck club management practices. Now this area is subject to the daily tides and it is clear that this area is responding through signs of vegetation community changes. As mentioned above, new to this mapping is the occurrence of the *Bolboshoenus maritimus* Herbaceous Alliance throughout the site, which was only observed in low abundance in 2017, not enough to meet the membership rules of this vegetation community. This reflects the increase in water availability throughout the site and the expansion of lower marsh vegetation.



SOURCE: USDA, 2018; TetraTech, 2020(August); ESA, 2021

* The *Salicornia pacifica* Herbaceous Alliance and *Distichlis spicata* Herbaceous Alliance were not distinguishable using remote sensing, even with plot data. They are therefore combined into one vegetation type.

Figure 4-29
Vegetation Types

TABLE 4-4
COMPARISON OF VEGETATION MAPPING BETWEEN 2017 AND 2020

Vegetation Community	2017 Mapping Area (acres)	2020 Area Mapping (acres)
Upland Vegetation Communities		
Baccharis pilularis – Annual Grass	0.36	0.00
Lepidium latifolium – Conium maculatum	3.42	0.00
Road / Urban	6.28	6.17
Unvegetated Upland	0.00	1.50
Total Upland Vegetation Communities	***10.06***	***7.67***
Wetland Vegetation Communities		
Atriplex prostrata - Cotula coronopifolia	0.00	7.47
Phragmites australis	78.61	133.01
Schoenoplectus (*acutus, californicus*)	14.61	23.64
Salicornia pacifica – Distichlis spicata	155.21	129.72
Typha angustifolia	124.86	51.85
Bolboschoenus maritimus	0.00	10.50
Spergularia bocconi	0.00	5.13
Tidal Mudflat	64.78	51.85
Open Water / Marsh Pond	23.38	50.99
Total Wetland Vegetation Communities	***461.45***	***464.16***

SOURCE: ESA, 2015, ESA, 2017; ESA 2020

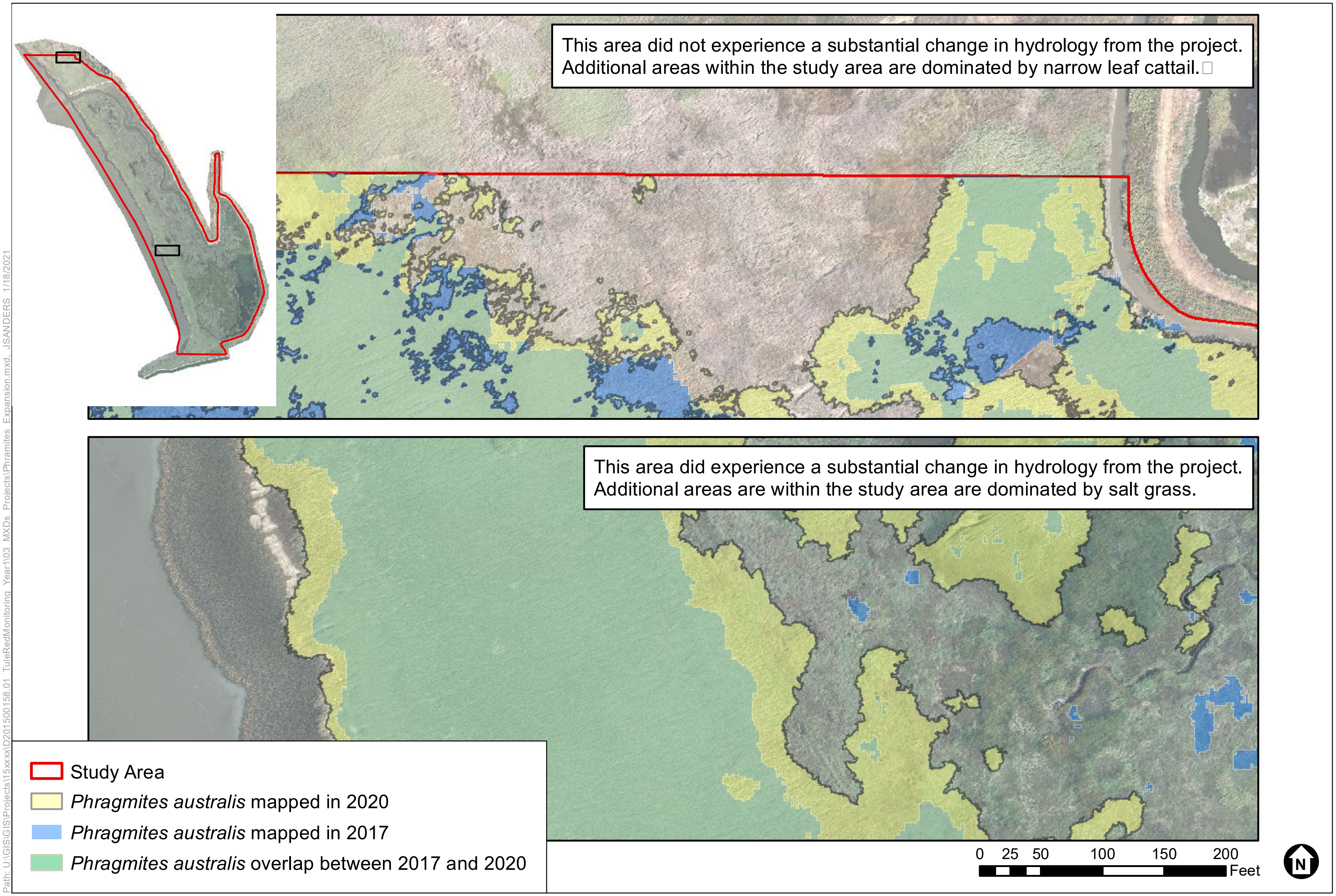
4.5.4 Invasive Plants

Invasive plants were mapped in the field during the vegetation monitoring events and their locations and densities were shared with Westervelt. Subsequent monitoring events following recommended treatments, primarily along the road bordering the habitat berm, showed that such efforts were successful. Additionally, aerial imagery was used to remotely map Phragmites throughout the site, and the 2020 extent is shown in **Figure 4-30**. In 2017 the previously mapped extent of Phragmites within the site was 120.53 acres, while in 2020 it was calculated to occur over 133.01 acres, a 10.35 percent increase over a three-year period, which included construction. It is important to note that the 2017 baseline mapping effort for Phragmites utilized imagery from 2014 due to its high resolution and distinct spectral signatures. Due to the consistent vegetation management practices at the site, including mowing and spraying of Phragmites annually, the baseline mapping utilizing the 2014 imagery is considered representative of 2017 conditions.

The distribution and extent of the invasive Phragmites appears to be affected by a combination of changes in hydrology and management practices, as well as recent ground disturbance associated with construction. It is important to note that there is a portion of the area to the north of the newly constructed main channel that has not experienced changes in hydrology associated with this project (see top frame in **Figure 4-31**). In reviewing the Phragmites mapping performed in 2017 and 2020, it appears that expansions of existing Phragmites patches are still occurring in the

SOURCE: USDA, 2018; TetraTech, 2020(August); ESA, 2021

Figure 4-30
Year 1 (2020) Location and Extent of *Phragmites australis*


This area did not experience a substantial change in hydrology from the project. Additional areas within the study area are dominated by narrow leaf cattail.

This area did experience a substantial change in hydrology from the project. Additional areas are within the study area are dominated by salt grass.

SOURCE: USDA, 2018; TetraTech, 2020 (August); ESA, 2021

Tule Red Year 1 Monitoring

Figure 4-31
Comparison of the extent of common reed in 2017 and 2020

absence of changes in hydrology (Figure 4-31). However, the expansion appears to be slower in this northern area than in other areas, likely due to the presence of well-established adjacent narrow leaf cattail (*Typha angustifolia*). In other areas that contain shorter herbaceous vegetation such as salt grass, pickleweed, or fat hen, this expansion rate appears to increase (sample point T2-8). Additionally, unvegetated areas including portions of the habitat berm and constructed tidal pannes are particularly susceptible to rapid expansions of Phragmites. Finally, the prior land management practice of regular mowing of vegetation no longer is practiced, which has likely allowed Phragmites to expand in many areas. This is consistent with the hypothesis that biotic and abiotic factors within different habitat features affect colonization of the site by Phragmites.

CHAPTER 5
Discussion

The Tule Red Project proponents and CDFW FRP monitoring team conducted Year 1 post-breach monitoring in 2020 according to the AMMP and as specified under the Project's FRP crediting agreement and regulatory permits. This report summarizes the results from bathymetric, hydrologic, water quality and vegetation monitoring conducted from June 8 to December 5, 2020 by ESA. Results from the CDFW FRP monitoring team's foodweb and fish monitoring are in processing and analysis; a final report is expected to be submitted to IEP in fall 2021 (Contreras et al. 2019).

5.1 Effectiveness Monitoring

The Project has made great strides towards its objectives in the first year following construction. The breach successfully restored a tidal hydrologic regime to this former duck club, with full tidal exchange through the primary and secondary channels, and a muted tidal regime in the marsh ponds. The newly restored tidal regime converted the previous non-tidal habitats (318.95 acres managed marsh, 11.32 acres managed channels, 10.13 acres managed ponds (ESA 2015 and 2017)) to tidal wetlands as measured by vegetation mapping (361.32 acres vegetated wetlands, 50.99 acres open water and marsh ponds, Table 4.4).

The vegetation within the site is responding to the recent restoration of tidal influence, and these changes are expected to continue over the upcoming years. Such changes in the existing vegetation prior to the breach are noticeable within only one year of the event; such an acute change in hydrology has already resulted in a variety of existing vegetation to expand and colonize into new areas. This site it is also expected to respond to future climate change and sea level rise through the utilization of the existing, diverse vegetation.

The Year 1 results can be used to assess how well the Project is functioning in comparison to hypothesized outcomes.

5.1.1 Hypothesis 1 - Physical

The channel inlet at the breach will self-adjust over time from an initial construction width of about 50 feet and invert of -2 feet NAVD88 to a final equilibrium width of about 160 feet and invert of -5 feet NAVD88 within 7 years after construction. (note: initial construction modified to 100 feet wide and -1 foot NAVD88.)

During the June 2020 bathymetry survey the breach channel measured approximately 179 feet wide. With a channel invert sitting at approximately -2.1 ft NAVD, the maximum channel depth was approximately 4.5 feet. The bathymetry survey and other visual observations through the year documented that the breach channel and all channels within the site are widening and deepening in response to the breach and restored tidal flows. The breach is re-sizing to match the tidal prism of the site interior. As channels continue to expand, tidal connection throughout site will improve.

5.1.2 Hypothesis 2 - Food Web

Primary and secondary productivity in the marsh ponds (mean residence time 6 -14 days) will be greater than in the tidal pannes (mean residence time about 3 days), the marsh plain (mean residence time about 3-9 hours), tidal channel, and Grizzly Bay.

The marsh ponds did perform with a muted tidal regime, connecting mainly on spring tides (infer a residence time around 2 weeks). The main channel had full tidal exchange, and hence shorter residence time. The tidal pannes remain inundated through the year and did not dry out, and likely functioned more as shallow ponds. The sensors used in the pannes were not designed to measure water levels. However, one can infer a muted tidal regime due to the pannes' location on the marsh plain above the channels.

Year 1 food web monitoring by ESA focused on primary productivity (measured continuously as chlorophyll-a RFU) in the tidal channel and marsh ponds and compared to levels measured in Grizzly Bay by IEP. During the period of record (June 8-December 5, 2020), primary productivity on average was highest in Pond C compared to the main channel near the breach and Grizzly Bay. By the end of the year, RFU was greater in both Pond C and the breach than in Grizzly Bay, indicating an opportunity for primary production in these ponds to be exported and provide a regional boost in food supply and increase export of productivity to adjacent open water habitat used by delta smelt and longfin smelt. Food delivery potential will be aided by improved tidal connection over time. Currently, tidal exchange in the back marsh is considerably muted, limiting flushing capabilities.

5.1.3 Hypothesis 3 - Fish

The restored habitats at the Project site (tidal channel, marsh ponds, and pannes) will support a fish community (including juvenile salmonids) similar in composition and relative abundance to that documented in comparable habitats in the Suisun Marsh region.

Opportunistic sampling by ICF successfully documented larval longfin smelt in the main channel in May. Seining in the marsh ponds by ICF for isotope study samples found small native fish species common to the Suisun Marsh region. No other fish sampling was conducted at Tule Red in 2020.

5.1.4 Hypothesis 4 - Phragmites

Elevation, hydrology, and existing vegetation within different habitat features will affect colonization of the site by Phragmites. This hypothesis will test which elevations within the created tidal regime are suitable for Phragmites colonization, and whether pre-inundation establishment of native vegetation, such as tules, may preempt establishment of undesirable invasive vegetation.

Phragmites is expanding throughout the site, largely due to the changes in management of the site. Prior land management, which focused on creating and maintaining habitat for waterfowl, included regular mowing of Phragmites as well as periodic herbicide foliar application. Now that mowing and spraying no longer take place Phragmites is expanding into new areas. Phragmites is expanding primarily by vegetative clonal expansion (via rhizomes) from existing patches. This allows for the invasion of areas that typically do not support seed germination, including continuously flooded areas (Baldwin et al, 2010). Additionally, there are areas where Phragmites appears to be invading via seed or rhizome fragments, indicated by the absence of adjacent Phragmites, which is restricted to high marsh areas. Overall, Phragmites appears to be expanding at the full range of tidal elevations at Tule Red, and stands that existed prior to the restoration of tidal hydrology that are now located at low marsh elevations do not appear to be stressed.

It also appears that Phragmites expansion rates are affected by existing vegetation types, with existing native vegetation that is taller in stature, which also tends to support an accumulated thatch layer, being able to withstand invasions better than shorter vegetation with overall less ground cover. Such areas with taller vegetation tend to include wetland graminoids (e.g., cattails, bulrushes and tules) that are restricted to low and mid marsh areas. These differing rates of expansion of Phragmites within different vegetation types could be due to the increased competition provided by certain native vegetation types. Additionally, differing establishment rates may also reflect the differing expansion mechanisms (i.e., clonal growth vs seed or rhizome fragment dispersal) as a result of differing elevations and hydrologic regimes.

5.1.5 Hypothesis 5 – Vegetation Establishment

Soil organic matter and planting methods will influence vegetation establishment on the habitat berm. This hypothesis will test the difference between the use of organic matter from stockpiled topsoil and hydroseeding/drill seeding and mulch in establishing desired vegetation on the habitat berm.

Observations and data support that there was varying vegetation establishment across the site. More information on the revegetation methods implemented and continued monitoring are needed to assess the effectiveness of soil preparation and placement, as well as varying seeding methods on vegetation establishment.

5.2 Compliance Monitoring

As specified under the FRP crediting agreement and regulatory permits, the Project proponents and CDFW FRP monitoring team conducted Year 1 post-breach monitoring in 2020 according to the AMMP. Three metrics were specifically mentioned in the BCDC permit: dissolved oxygen in CDFW drain water, methyl mercury, and cover of invasive vegetation.

5.2.1 Dissolved Oxygen

As stated in the BCDC permit: “In order to prevent low dissolved oxygen water from being released to the site, the permittees shall maintain the water control structure and drain pipe aerator associated with the CDFW drain water in perpetuity. Monitoring of the drain water for dissolved oxygen levels shall be performed before releasing any water onto the site until the aerator structure is installed, operating as designed and increasing the level of dissolved oxygen in the drainage water. The permittees shall also provide to the Commission the monitoring results for the dissolved oxygen quarterly sampling as described in the project's AMMP.”

The DO probe was placed at the channel leading from the CDFW drain, on the south side of the water control structure that separates the tidal reach of Tule Red site and a short dead-end channel that receives discharge from the WMA. Monitoring revealed that DO levels in August dropped most sharply at the CDFW channel (mean < 4 mg/L August 15-30), as well as dips at the pond, breach and Grizzly Bay (Figure 4-22). This was a period when CDFW pumps were not operating. The peak discharge from the WMA typically occurs February-March during pond drawdown. This suggests that the low DO patterns were not related to CDFW drain water, but rather driven by summer conditions of temperature, algal blooms, and tides.

Dissolved oxygen monitoring in 2022 will focus on the drawdown period. The location of the DO probe will be adjusted to measure conditions above the water control structure.

5.2.2 Methyl Mercury

Methyl mercury levels (unfiltered water samples) measured on the outgoing (ebb) tide ranged 0.04-0.27 ng/L, with the highest and most variable concentrations in June (Table 4-1). These levels are consistent with the range reported from other restoring tidal wetlands studied by DWR, including Blacklock and lower Yolo Bypass (Lee and Manning 2019). Those wetlands do not appear to be net exporters of methyl mercury (Lee and Manning 2019).

5.2.3 Invasive Vegetation

As stated in the BCDC permit: “Invasive Plant Control. The permittees shall develop and implement an invasive plant control plan for the identification, eradication and monitoring of undesirable plant species over the 10 year monitoring period that shall be subject to approval by or on behalf of the Commission. The monitoring shall include providing the results of the eradication efforts necessary to keep levels of invasive plants, such as non-native reed (*Phragmites australis*), perennial pepperweed (*Lepidium latifolium*), or other invasives, at 5% or less increase over baseline (aerial coverage) of the project site.”

An Invasive Control Plan was developed for the Project site (ESA 2020). Monitoring noted some localities of weeds in the restoration area, which were subsequently treated. Cover of Lepidium declined from baseline levels, but cover Phragmites increased 10.35%. Achieving the target of less than 5% increase is difficult and likely infeasible for a large site where Phragmites was already well-established.

The Phragmites expansion within the site is expected to continue in the absence of active management. Some areas that have successfully vegetated with native species (tules, cattails, bulrushes, and pickleweed) will likely be most resilient to Phragmites invasion, while areas in transition (western part of the marsh plain where saltgrass is in decline due to the changed hydrology, shallow tidal pannes that are currently unvegetated) are most at risk. Focused efforts on controlling Phragmites are recommended over the upcoming years to adequately manage this invasive plant species. When possible in areas where Phragmites is just beginning to expand clonally, hand pulling or other mechanical methods should occur .

Certain herbicides can be used to treat Phragmites patches, where mechanical methods are infeasible or ineffective, for experimental plots or as part of a large-scale treatment proposal. Depending upon the location, size, and other characteristics of the planned treatment, additional permits or authorizations may be necessary. Such management efforts can act as a disturbance, resulting in potentially suitable sites for reinvasion events, and so sometimes revegetation is recommended post-weed treatment. However, there is research suggesting that above-ground dominance of Phragmites does not affect the seed bank underneath as much as site topography and physical structure of wetlands (Hazelton et al, 2017). Tule Red appears to have some combination of a persistent seed bank of native and non-native plants and areas that experience high levels of seed deposition, indicated by the establishment of several native vegetation types into new areas within only one year of the breach event. Additionally, it has been documented that some common aquatic herbicides applied to vegetative plant material, such as glyphosate, do not deleteriously affect existing seed banks (Hazelton et al, 2017). Areas that are effectively disturbed during future Phragmites weed control efforts should also then support the natural recruitment of native vegetation.

Phragmites remains a recognized and pervasive problem throughout Suisun Marsh and much of North America, and continual research is needed to better understand and address it. Past studies can inform management decisions in some cases (Hazelton, et al 2014), and this effort continues with DWR studying control methods at nearby restoring sites, Blacklock and Bradmoor Islands (Darin 2021). New, site-specific treatment lessons learned could be tested in select areas. Additionally, a special study is planned at Tule Red by the Suisun RCD and Delta Science Program Fellow, Richelle Tanner, to investigate the effects of Phragmites on community ecology in the wetlands. Future monitoring and management should use an adaptive approach as understanding evolves for feasible management.

5.3 Site Management

No management problems were identified during the 2019 monitoring year.

Weed management efforts (spot spraying and mowing) were conducted in response to the weed monitoring performed during the vegetation monitoring events. These efforts were focused on accessible areas along roadsides. Observations during late summer vegetation monitoring events indicated these treatments were successful. However, the areas treated were limited to roadsides.

5.4 Recommendations for Year 2 (2021) Monitoring and Studies

The Year 2 monitoring program will continue measuring certain metrics from Year 1, according to the AMMP schedule (Table 1-2). The Year 2 report will analyse data collected during December 6, 2020 to December 5, 2021. Metrics for 2021 include the following:

- Dissolved Oxygen at CDFW channel
- General habitat conditions – Photopoints
- Invasive plants – visual survey

We also suggest the following refinements or additions to the AMMP monitoring, based on the findings in this first year of post-breach monitoring:

- Elevations - We recommend resolving the elevation discrepancy found between site control points. It is unlikely that subsidence or ground swell between the survey dates is the cause of the discrepancy, and because so much of site function is reliant on tide elevations, understanding site elevation relative to tidal elevations is critical to evaluating site function. Setting a baseline now, for future monitoring efforts and relatability to future projects, will be beneficial to the project and greater region as a whole.

- Dissolved Oxygen at CDFW channel - We observed low dissolved oxygen (DO) in August in drain channel. While these low DO levels were not due to WMA drainage, the cause is uncertain. There is some evidence of back marsh low DO independent of pumping mechanisms, so it is recommended to move the DO sensor from channel entry point up into the actual channel in order to capture discharging water. We also recommend monitoring during the pond drawdown period in March to April to better understand any effects of that discharge on DO levels.

- Vegetation Plots – The next full vegetation survey is scheduled for Year 3 (2022). Given the poor vegetation cover on the upper habitat berm, however, we recommend a targeted survey in Year 2 (2021) to increase our understanding of the succession of this feature, and to study effects of soil placement and seeding methods that were implemented during restoration activities. Monitoring will focus on the existing four monitoring points on the berm, plus four additional points. Additionally, several of the baseline vegetation monitoring points (2017) are now within tidal channels, so the overall sample size of points that capture vegetation has decreased (2020). Moving forward, we recommend replacing these lost points when the vegetation survey is repeated in Year 3.

- Chlorophyll-a - In years with continuous monitoring of chlorophyll-a, we recommend additional focused Chl-a sampling during blooms, informed by telemetered data from sondes, in order to build a useable regression curve to report chl-a concentration instead of just RFU.

CHAPTER 6

Contributors

State and Federal Contractors Water Agency – Project Sponsor

Bruce Di Gennaro

Westervelt Ecological Services – Project and Site Manager

Rob Capriola
Kim Erickson
Matt Coyle

Environmental Science Associates – Year 1 monitoring, data analysis, report preparation

Ramona Swenson, Ph.D.
Rachel Brownsey
Damien Kunz
Joseph Sanders
Becca Shetler
Maureen Downing-Kunz

California Department of Fish and Wildlife – Fish Restoration Program Monitoring Team

Stacy Sherman

California Department of Fish and Wildlife – Grizzly Island Wildlife Management Area

Shawn Overton
Orlando Rocha

US Geological Survey – Food web special study

Susan De La Cruz, Ph.D.
Isa Woo, Ph. D.

ICF International – Fish special study

Lenny Grimaldo, Ph.D.
Jake Sousa

Northwest Hydraulic Consultants – Site Topography and Elevation

Brian Wardman

Tetra Tech – Aerial imagery

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