Martin Slough Enhancement Project
2022 Monitoring Report

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INTRODUCTION

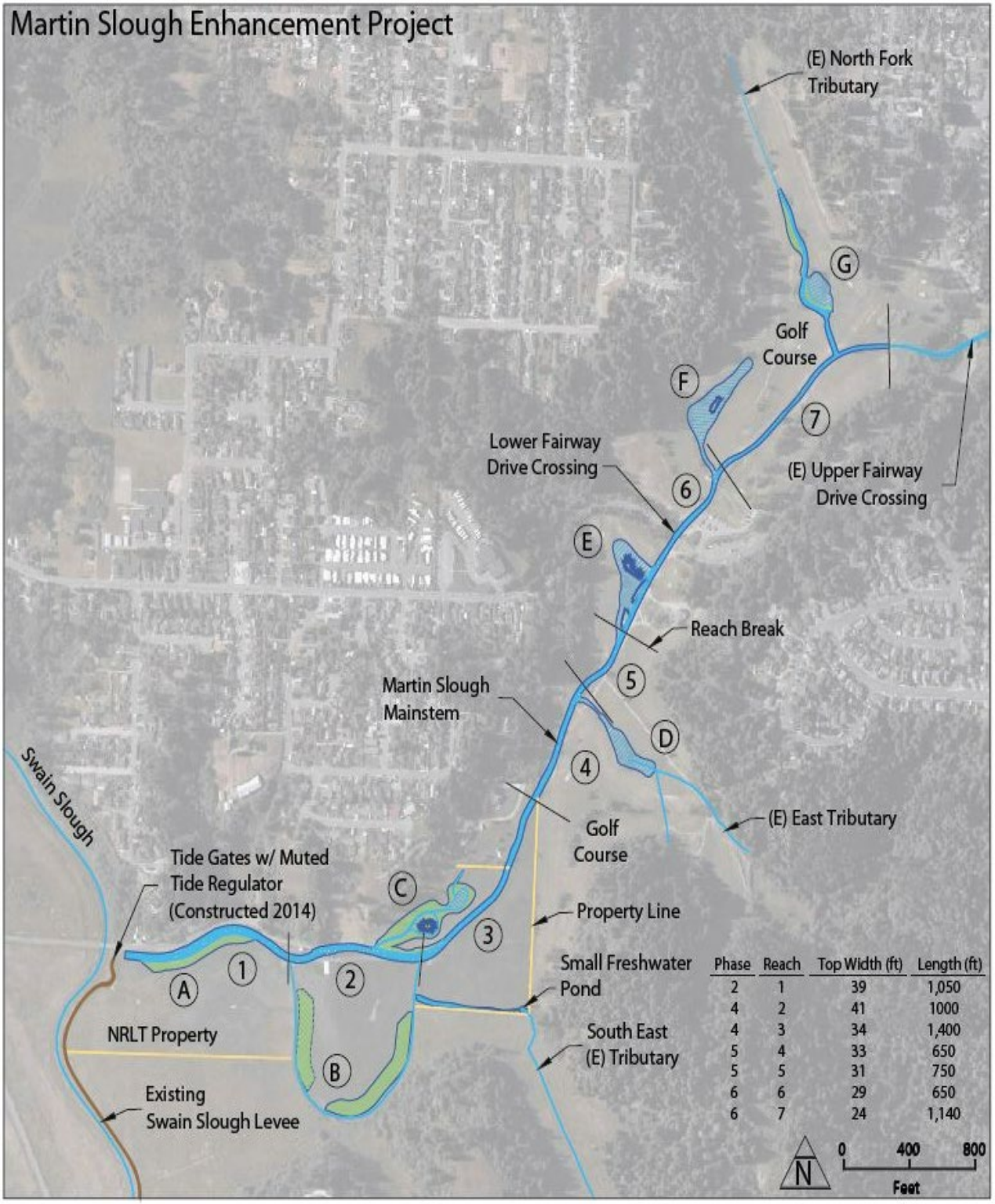
This report summarizes Year 2022 monitoring of the Martin Slough Enhancement Project (project). This report was prepared by the Natural Resources Services Division of Redwood Community Action Agency (RCAA) with information and support provided by partners and subcontractors and in accordance with the Martin Slough Monitoring Plan (Plan; RCAA 2021 revision).

Background

Martin Slough is a tributary of Elk River, a watershed that is part of the larger Humboldt Bay ecosystem. Martin Slough was identified by the California Department of Fish and Wildlife (CDFW) as playing a key role in the life cycle of coho salmon (*Oncorhynchus kisutch*) by providing ideal rearing habitat for juvenile coho. Juvenile coho occur in Martin Slough in relative abundance (see Fisheries Monitoring section below). The federally endangered tidewater goby (*Eucyclogobius newberryi*) also occurs in Martin Slough; the slough is within the HUM-3 Humboldt Bay tidewater goby critical habitat unit (Federal Register 2013). Nearly the entire project area is designated critical habitat for coho, Chinook salmon (*O. tshawytscha*) and steelhead trout (*O. mykiss*).

In 2006, the North Coast Regional Water Quality Control Board (NCRWQCB) and the U.S. Environmental Protection Agency (USEPA) listed the Elk River Watershed under Section 303(d) of the Clean Water Act as sediment-impaired, citing impaired water quality, impaired spawning habitat, and increased depth of flooding due to sediment. The project site is diked, former tideland degraded by previous management practices. Straight-line channels were excavated, riparian vegetation was removed, dikes were built, and tide gates were installed at the confluence of Martin Slough and Swain Slough. Tidal exclusion resulted in loss of sediment transport and natural fluvial geomorphic processes that maintained the tidal wetlands and channel capacity. In response to these stressors, the Martin Slough Enhancement Project was developed with the goal of enhancing fish habitat for endangered coho salmon and reducing the extent and duration of flooding in agricultural and urban recreational lands.

The project area encompasses 2 contiguous properties: 40 acres of pasture owned by the Northcoast Regional Land Trust (NRLT) and 120 acres owned by the City of Eureka (COE) and operated as the Eureka Municipal Golf Course (EMGC or golf course; Figure 1). The project was initiated in 2001 when RCAA and partners began preparing a feasibility study, completed in 2006. Between 2007 and 2014, RCAA contracted with Michael Love & Associates (MLA) and GHD, Inc., to develop designs for a new tide gate at the confluence of Martin Slough and Swain Slough, along with enhancements to the slough channel, new tidal marshes, and off-channel brackish and freshwater ponds. The tide gate replacement was completed in 2014, and enhancement work on the NRLT property was completed in 2019. Enhancement on the Golf Course began in 2019 and was completed in 2021.



Phase	Reach	Top Width (ft)	Length (ft)
2	1	39	1,050
4	2	41	1000
4	3	34	1,400
5	4	33	650
5	5	31	750
6	6	29	650
6	7	24	1,140

Figure 1. Martin Slough Enhancement Project area showing Northcoast Regional Land Trust and Eureka Municipal Golf Course properties plus design channel reaches and off-channel ponds.

Project Purpose

The purpose of the Martin Slough Enhancement Project was to improve aquatic and riparian habitat and reduce flooding of pasture and golf course greens and fairways throughout the project area. Specific goals of the project included the following:

1. Improve fish passage from Swain Slough into Martin Slough,
2. Reduce flood impacts to current land use,
3. Improve sediment transport,
4. Increase the amount of riparian corridor and riparian canopy,
5. Improve water quality (increase circulation, decrease nutrient inputs, decrease sedimentation),
6. Increase the extent of the estuarine ecotone in Martin Slough, providing a gradual transition from brackish water to freshwater habitats,
7. Enhance and create low-velocity off-channel/backwater habitats.

Project Phasing

The Martin Slough Enhancement Project was implemented in 5 phases. Table 1 summarizes each phase. These phases do not necessarily correspond to phasing as described in earlier compliance documents and reports, however, the project was implemented as described in Table 1.

Phase	Action	Year Completed
1	Replaced three dilapidated tides gates on Martin Slough at the confluence with Swain Slough with two 6'x 6' side hinged gates, one 6'x 6' top hinged gate, and one 2'x 2' auxiliary gate, fitted with muted tidal regulators that allow a muted tide into Martin Slough	2014
2	Enlarged Martin Slough channel throughout NRLT property; built Marsh Plains A and B and off-channel Pond C; realigned the Southeast Tributary and constructed a freshwater pond; replaced two culvert crossings; installed a bridge to access agricultural land and a barn.	2018
3	Enlarged Martin Slough channel on the lower EMGC up to the East Tributary; enhanced Pond D; removed undersize culvert; installed new golf cart access bridge.	2019
4	Enlarged Martin Slough channel up to the North Fork tributary confluence; enhanced off-channel Pond E and constructed Pond F; replaced golf cart bridges.	2020
5	Enlarged remainder of the upper Martin Slough channel and the North Fork; constructed North Fork Pond G; installed temporary salinity barrier.	2021

MONITORING OVERVIEW

Purpose

The objectives of Martin Slough project monitoring are threefold:

1) Ensure implementation of the project according to established plans, including construction and schedules,
2) Document the effectiveness of the project in terms of its stated goals of improving wetland and riparian habitats and reducing flooding,
3) Adaptatively manage if project goals, objectives or success criteria are not being met.

The essential purpose of Martin Slough project monitoring is to indicate whether the enhancement component/current course of action is functioning as intended and to adaptively manage when and where necessary. Monitoring results should provide support for either continuation of current practices or making management adjustments. Thorough project evaluation will help provide information about sound design or design flaws, and effective or ineffective management techniques to apply or avoid by land managers, restoration designers and practitioners when planning or implementing similar estuarine restoration projects in and around Humboldt Bay.

Parameters

The Monitoring Plan (RCAA 2021) described 5 general post-construction parameters: topography, hydrology, water quality, fisheries and vegetation. These parameters are directly linked to individual long-term objectives established for the project and provide a multi-parameter basis for evaluating the final success of the project. These 5 parameters were selected to ensure that overlapping structural and functional components assessing both physical and biological characteristics of the site will be measured to evaluate project success.

This report covers post-construction monitoring for project Phases 2 through 5 and addresses all 5 parameters. Post-construction monitoring was conducted according to RCAA's 2021 Monitoring Plan and all project permits.

Performance and Success Criteria

Performance criteria are annual quantitative and qualitative benchmarks against which project progress is measured. Final success criteria will be used to determine if the project has substantially met its individual and overall objectives within the 5-year monitoring period. Attainment of final success criteria will indicate that the project is trending toward meeting long-term habitat goals with minimal chance of failure. While monitoring will continue for a 5-year period post-construction, if final success criteria are reached for a particular parameter in less than 5 years, monitoring of that parameter may be discontinued or reduced in scope and frequency.

There are separate annual performance and final success criteria for each parameter and parameter-specific monitoring methods and schedules. Specific performance and final success criteria are summarized for each parameter in Table 2.

Table 2. Topographic, hydrologic, water quality, fisheries and vegetation monitoring parameters, schedule, performance, and success criteria. (See text for MHHW and MLLW definitions.)

Parameter	Type of Monitoring	Frequency	Schedule	Performance Criteria	Success Criteria	Remedial Actions
Topography	Repeat surveys: - longitudinal channel profiles of mainstem Martin Slough - cross section of slough channels, marsh plains, and ponds	Surveys in: Year 1 Year 3 Year 5 post-construction	Once annually	- No high points restricting drainage of ebb tides in mainstem thalweg profile. - Less than 10% net change in cross sectional area below design MHHW of 5.5 feet (NAVD 88) at each cross section.	- No high points restricting drainage of ebb tides in mainstem thalweg profile. - Less than 20% net change in cross sectional areas below design MHHW of 5.5 feet (NAVD 88) at each cross section within project after 5 years.	- Identify cause(s) of high points restricting drainage. Remedial actions may include channel excavation or changes to tidal prism. - Analyze root cause(s) of excess aggradation or scour and address root cause(s).
Hydrology	Data logger used to continuously record water levels in Swain Slough and Martin Slough	Download data approximately every six weeks	Continuous through period where muted tide regulator (MTR) is being adjusted or, if funding is available, through the end of Year 5 after last construction phase completed	**Muted high tides sufficient during growing season to inundate constructed marsh plains**		Adjust 6'x 6' MTR gate and auxiliary MTR gate to increase time gate is open
				Tide gate is open ≥35% of the time (not including auxiliary door) Assume muted tide is only through auxiliary MTR gate.	Tide gate is open ≥50% of the time (not including auxiliary door).	
				Summer MLLW in Martin Slough >2.0 ft (NAVD 88)		Identify potential high points or channel aggradation. Actions may include channel excavation or changes to tidal prism.

Parameter	Type of Monitoring	Frequency	Schedule	Performance Criteria	Success Criteria	Remedial Actions
Water Quality	Surface and bottom salinity and temperature meters placed at the three Martin Slough water level monitoring stations. Spot measure dissolved oxygen, salinity and temperature during downloads. Additional spot measure w/fisheries monitoring.	Continuous, download every 6-8 weeks	Year round through Year 5 following final phase of implementation, as funding allows	- Average daily water temperature ≤18ºC during expected salmonid period of use - Maximum daily water temperature ≤21ºC during expected salmonid period of use - Pond G and Southeast Tributary Pond DO ≥4 ppm and salinity ≤4 ppt during expected salmonid period of use		- Adaptive management: meet and - - discuss water quality data with fisheries biologists and agency staff. Possible actions could include: - Increase circulation through MTR gate adjustments - Increase riparian vegetation for shading to cool water and reduce aquatic vegetation growth - Modify inlet/outlet of ponds to increase circulation.
Fisheries	**Salmonids**: Seining at selected locations consisting of varying habitat types (pond and channel) and longitudinal locations within the project area	One or more days per month during expected salmonid period of use, as funding allows	Post-construction for 3 years, or up to 8 years as funding allows	Annual average net increase of 50% over pre-project coho salmon numbers (combined total for juvenile young-of-the-year and one-year fish) recorded by CDFW	Annual average net increase of 50% over pre-project coho salmon numbers (combined total for juvenile young-of-the-year and one-year fish) recorded by CDFW	Performance and success may be subject to uncontrollable variables (i.e., ocean conditions, run size) affecting abundance. Follow water quality remedial actions.
	Tidewater goby: Seining	In conjunction with salmonid sampling	Post-construction for 5 years, as funding allows	Presence in new terminal ponds at upper end of new slough channels	Presence in new terminal ponds at upper end of new slough channels	Performance and success may be subject to uncontrollable variables. Follow water quality remedial actions.
Vegetation	Plant cover surveys and species composition	Years 2 and 5 each phase post-construction. Contingency Years 3 and 4	Spring/summer	Performance criteria shown in Tables 6 and 7 below	Success criteria shown in Tables 6 and 7 below	Replant, re-seed until criteria met; mechanically or manually remove invasive plants within revegetated areas of the project.

TOPOGRAPHY AND STRUCTURES

Overview

The objective of topographic monitoring is to evaluate post-construction topographic conditions. Monitoring objectives are to:

1) Assess channel bank stability and identify scour and/or aggradation within project reaches,
2) Assess aggradation in the constructed ponds,
3) Evaluate rates of scour or sediment aggradation on tidal marshes.

Topographic monitoring involves field survey and reoccupation of known benchmarks and includes a thalweg profile along the mainstem of Martin Slough and multiple channel cross sections along the main channel, tributary channels and across each of the ponds and marsh plains.

Topographic, hydrologic and water quality results are organized by water years that begin October 1 and end September 30. The topographic component of Martin Slough project monitoring is conducted every other year up to year 5 within each project phase. Topographic monitoring was completed for water year 2019 for the portions of the project constructed on NRLT (Phase 2) property. In 2021 topographic monitoring for Phase 2 Year 3 and Phases 3 and 4 Year 1 was conducted. Phase 5 Year 1 monitoring was delayed one year to consolidate all the topographic monitoring for all the phases to occur in odd years. This report provides monitoring results and findings for water year 2022, thus, does not include quantitative topographic monitoring.

Methods

Large wood features previously placed throughout the project were visually inspected at the conclusion of water year 2022. These included large wood cover structures on the North Fork tributary and log weirs installed in the mainstem at the upstream end of the project as part of Phase 5 construction. Topography was visually assessed on December 7, 2022 from the channel bank as part of the visual inspection of log weirs and large wood structures. The inspection focused on determining if any of the wood had moved, if any steel anchors were loose or corroded, and if any undesirable scour induced by the structure had occurred (MLA 2022).

Results and Discussion

Mainstem Channel Condition

Bank at Weirs, Upstream End of Project

Channel alignment at the upstream end of the project caused scour along the right bank of the upstream-most log weir, previously noted in the 2021 monitoring report. This condition appears to be improving as the upstream channel adjusts to the downstream weir elevations. Vegetation growing on the eroded bank is helping stabilize it and no active erosion was observed. This location should continue to be visually monitored. The downstream weirs have been partially buried by sediment, likely caused by backwater from the high-flow constriction created by the steel plates and brackets associated with the downstream salinity barrier.

Bank at Confluence with Pond F
During Phase 5 construction, there was bank sloughing into the channel on the left bank upstream of the confluence with Pond F. RCAA planted vegetation along the bank for stabilization and sedges have become well-established and a few willow stakes have established. The bank does not appear to have eroded further and the toe of the bank has not spread further into the channel.

Bank at NRLT Bridge
Immediately upstream of the new bridge and sheet pile retaining wall at the NRLT barn, a section of the right bank appears to be slumping into the channel at low tide. There are numerous seeps emerging from the adjacent hillside and high groundwater along the base of the adjoining hillslope appears to be driving the instability. Observations during low tide on December 7, 2022, confirmed that the extent of the slump appears to be relatively unchanged when compared to previous year's observations.

Large Wood Structures

The large wood structures were visually inspected from the bank on December 7, 2022. All structures (log cover structures, rood wad deflectors and habitat structures, log constrictors, log weirs) appeared stable and showed no signs of shifting since construction. No adverse scour along the banks was found in proximity to the structures. The complex wood structures located in the ponds' open water were partially or completely submerged during the low tide.

During the 2021 construction season RCAA staff filled and compacted voids that formed around the pile logs at the Pond D weirs. These areas appeared stable, and no additional erosion or scour was noted. Cattails have colonized the shallow section between Pond D and the most upstream weir where concrete mats are placed over the existing gas line crossing.

(See Appendix A, *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022.)

HYDROLOGY

Overview

The objectives of hydrologic monitoring are to measure water level fluctuations in amplitude and longitudinal extent relative to tidal influence within the project area. The objectives of hydrologic monitoring are to:

1) Evaluate the extent to which the project muted tides match the design muted tidal ranges
2) Assess flow conveyance (in both directions) through project reaches
3) Assess whether the higher muted tides (spring tides) during the dry season are remaining within acceptable ranges and not inundating adjacent NRLT pasture and/or greens and fairways of EMGC.

Results from hydrologic monitoring may be used to guide Muted Tide Regulator (MTR) adjustments and identify whether flow constrictions are affecting project performance.

Methods

The following sections were excerpted/adapted from the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022 (Appendix A).

Water Level Monitoring

Four submersible water level loggers were installed: three on the mainstem of Martin Slough and one in the North Fork tributary. The loggers measure hydrostatic pressure above the sensor and are corrected using recorded atmospheric pressure to calculate the stage, or water level, in 15-minute intervals. A reference benchmark was established at each site and surveyed to determine water surface elevations in North American Vertical Datum (NAVD88). Data loggers were downloaded approximately every two months. At least one water level observation was made during each download period to calibrate the recorded data to the reference benchmark, placing all water level data into the NAVD88 vertical datum.

Stage data were recorded after Phase 1 completion starting in March 2017, expanded after Phase 2 completion and expanded further following Phases 3, 4, and 5 completions.

Property Line
Middle Reach of Martin Slough on NRLT property, near the property line with EMGC. A water level gage was installed on March 14, 2017, and was in operation through July 11, 2018, when it was removed for construction of Phase 2. This gage was discontinued and replaced by the Hole 18 (MS-18) gage after construction in 2018.

Swain Slough
A logger was installed in Swain Slough near the tide gate on February 11, 2018, and remains operational.

MS-Pond C
Lower Martin Slough on NRLT property. A logger was installed upstream of the confluence with Pond C on December 17, 2018, and remains operational.

MS-18 (Hole 18)
Middle reach of Martin Slough on EMGC. A logger was installed between Holes 17 and 18 downstream of Pond E on November 19, 2018, and removed on October 22, 2019, for Phase 3 construction. Following Phase 3 construction the logger was reinstalled on November 5, 2019; it was attached to the newly constructed vehicle bridge and remains operational.

MS-NF
Upper reach of Martin Slough downstream of the North Fork Tributary confluence on EMGC. A logger was installed on November 5, 2019, and removed on September 9, 2020 for Phase 4 construction. It was reinstalled in December 2020; however, the station was moved to a bridge on the North Fork Tributary just downstream of the existing irrigation pond and the future site of Pond G. The gage was removed from May 2021 to November 2021 for maintenance and construction of Phase 5. The gage remains in the North Fork tributary and is operational. See Table 1 in Appendix A for gaging station type and installation information.

Tidal Datums

Humboldt Bay experiences semidiurnal tides: two high tides and two low tides per day. The tidal datums of Mean Higher High Water (MHHW), Mean Lower High Water (MLHW), Mean Higher Low Water (MHLW), Mean Lower Low Water (MLLW), and sometimes Mean Tide Level (MTL) are used for designing and evaluating performance of tidal restoration projects. A key metric in sizing and maintaining tidal channel geometry is the average tidal prism, defined as the volume of water that drains between MHHW and MLLW.

The Humboldt Bay North Spit (NOAA Station No. 9418767) tidal datums converted to NAVD88 were used as a reference for unmuted tidal conditions. Tidal datums for each monitoring station were calculated on a per-month basis and seasonally using recorded water levels. A spreadsheet algorithm was used to identify the daily MHHW, MLHW, MLLW and MHLW and calculate the monthly averages.

Tidal Prism

The tidal prism is a key parameter in the design and self-sustainability of the project. Though Martin Slough receives freshwater inflows, the hydraulic geometry of the tidal channel of Martin Slough will be governed by the daily tidal flux created by the muted tide rather than less frequent high flow events from upstream. The daily tidal prism is a governing factor in the dimensions of the channel; a significant reduction in the tidal prism could cause sedimentation and a decrease in the channel cross-sectional area. MHHW or MLLW changes during the dry season, suggesting a change in tidal prism, could require changes in tide gate settings to restore the intended tidal prism and maintain geomorphic stability of the tidal channels. Tidal prism is calculated based on surveyed cross sections, thus, results are presented only for the years when a topographic survey is completed.

Results and Discussion

The following results and discussion were excerpted/adapted from the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022 (Appendix A).

Muted Tide Regulator (MTR) Settings and Target Water Levels

During water year 2022 the muted tide in Martin Slough was controlled using the 6’x 6’ side hinge gate and associated MTR in combination with the 2’x2’ auxiliary door (slide gate) connected to its MTR. The 6-foot by 6-foot MTR gate was set to close when water levels in Martin Slough reached approximately 3.25 feet (NAVD88). The auxiliary gate closed when Martin Slough water levels approached 5.2 feet elevation. This elevation varied by several tenths of a foot from one tide cycle to the next.

Water Level

Water level data, combined with salinity and water temperature data, were plotted for each month of the 2022 water year (Appendix A, *MLA 2022, Appendix A*).

Swain Slough
Water levels fluctuated like those recorded at the NOAA North Spit tidal station (No. 9418767), except that the water level never dropped below 1.0 foot. Two conditions effected this: 1) the Swain Slough gage is in an outlet scour pool below a drainage flap gate, and the pool becomes disconnected from Swain Slough at the lowest tides; and 2) a tidal sill located on Elk River downstream of the confluence with Swain Slough results in the lowest tide levels being between elevation 0.5 to 1 foot (NAVD88).

Martin Slough near Pond C
Water levels at the Pond C gage showed water level fluctuating as expected, with the distinct signature of a muted tide that typically peaks just above elevation 5 feet (NAVD88) and does not drop below an elevation of 1 foot. Higher high tides appear to peak at about 5.5 feet, with an occasional peak just above 6 feet and the highest peak of 6.44 feet on December 23, of 2021. Peaks above 5.5 feet typically occurred over one or two days associated with elevated stream flows due to rainfall events.

Martin Slough near Hole 18
This monitoring station, MS-18, is located on the golf course vehicle bridge of the Martin Slough mainstem approximately 500 feet downstream of Fairway Drive, immediately downstream of the confluence with Pond E and a short distance upstream of the confluence with Pond D. Tidal influence extends past the Hole 18 gage; water level typically peaks at 5.0 feet with occasional peaks near 5.5 feet. Water level approaching 6 feet is usually associated with an exceptionally high tide or rainfall event. During water year 2022 the highest water level recorded at MS-18 was 6.29 feet on April 19, 2022, followed by 6.26 feet on December 23, 2021. During the dry weather monitoring period (June through September) the MS-18 is tidally influenced with a muted tide pattern fluctuating between 1 foot and 5.44 feet, closely corresponding to the water levels recorded at the Pond C gage.

North Fork Martin Slough
The North Fork Tributary gage was installed and operational on November 12, 2021 following Phase 5 construction. The baseflow water level during the period recorded was consistently between 2 and 5 feet elevation. The highest water level peak of 6.3 feet, was recorded on December 23, 2021. During the irrigation months (April to August) water level was controlled by the temporary salinity barrier (see Water Quality section below. From mid-April through early June high tide peaks were above elevation 4 feet, and the weirs were submerged during the peak high tide. From Early June through mid-August the barrier was raised to elevation 5.0 feet and flow was backed up behind it. Once the barrier was removed in mid-August water levels fluctuated daily with the tide between 2 feet and just above 5 feet.

Field Observations of Water Level Conditions
The brackish marsh around Pond C was observed during a low tide during the visual inspection on Dec 7, 2022 (see Appendix A, MLA 2022 Figure 9). The floodplain was wet from the previous high tide and brackish vegetation was established throughout the area indicating that brackish water is reaching the upper marsh plains as intended by design. Wood structures on the marsh plains were partially submerged during high tide, creating cover habitat.

Tidal Datums

Stage data was analyzed and tidal datums were calculated relative to the NAVD88 vertical datum. Monthly values are provided in Appendix A (MLA 2022, Appendix C), and averages for the dry season of July through September are provided in Table 3 below. This represents the period of minimal freshwater influence on the tidal channel. The yearly tidal datums calculated at the North Spit from 1983 to 2001, July through September datums for water year 2022, and the design muted tidal datums also are included. Tidal datums for the North Fork Tributary gage were not determined due to data collection interrupted by construction activities and by installation of the salinity barrier.

Table 3. Tidal datums for dry period of July through September 2022 and (2021) at each gage station.

	Water Level (NAVD88)			
Location	**MLLW**	**MTL**	**MHHW**	**Ave. Diurnal Range**
North Spit epoch 1983-2001)	-0.34 ft	3.36 ft	6.51 ft	6.85 ft
North Spit (July -Sept. WY 2022)	0.27 ft	3.95 ft	7.13 ft	6.86 ft
Swain Slough	1.48 ft (1.55 ft)	3.95 ft (3.98 ft)	6.69 ft (6.79 ft)	5.21 ft (5.24 ft)
Martin Slough				
MS Design	1.50 ft	Not Provided	5.50 ft	4.00 ft
MS at Pond C	1.46 ft (1.39 ft)	3.43 ft (3.45 ft)	5.11 ft (5.19 ft)	3.65 ft (3.80 ft)
MS at Hole 18	1.32 ft (1.22 ft)	3.26 ft (3.26 ft)	4.92 ft (5.01 ft)	3.61 ft (3.79 ft)

(From MLA 2022, p. 17)

Except for MLLW, which is influenced by a tidal sill in the Elk River Slough that limits draining of the tide, the Swain Slough data collected during this monitoring period are similar to North Spit, although higher. This is likely due to periods of elevated flows in Elk River that raise water levels in Swain Slough. When compared to the previous water year (2021) the MLLW, MTL and MHHW decreased by 0.07 feet, 0.03 ft and 0.10 feet, respectively. At the Pond C gage, when compared to the water year 2021 datums, the MTL and MHHW decreased by 0.02 and 0.08 ft, respectively while the MLLW increased by 0.07 feet. At the Hole 18 gage, the tidal datums for MLLW increased by 0.10 feet, MTL stayed the same, and the MHHW decreased by 0.09 compared to the previous year.

The tidal datums can be used to determine the inundation frequency of areas that have been revegetated with brackish-tolerant plant species. With completion of Phase 5 in 2021, the tide gate settings were no longer operated based on interim conditions. However, the tidal range increase to 5.5 feet to meet MHHW design criteria was not implemented due to concerns with

tidal flooding of low-lying golf course greens and increased salinity in the upstream ponds and channel reaches, intended to provide seasonal freshwater habitat.

(See Appendix A, *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022.)

WATER QUALITY

Overview

The objectives of water quality monitoring are to:

1) Assess the parameters of salinity, dissolved oxygen (DO) and temperature in terms of suitability for target species and habitat,
2) Ensure that salinity does not extend upstream to the golf course irrigation pump intake when in use.

Performance Criteria

The project monitoring plan (RCAA 2021) defines performance criteria for salinity, water temperature, and dissolved oxygen. The performance criterion for DO concentrations is ≥4 mg/l when salmonid presence is expected. This metric is mainly applied to surface DO concentrations, as bottom concentrations can be substantially lower when fish are present. For Pond G and the North Fork tributary this applies year-round, as Pond G and the North Fork were intended to provide over-summering habitat for rearing juvenile salmonids. Ponds C, D, E and F and the mainstem channel are expected to provide seasonal over-wintering salmonid habitat and the water quality criteria apply from late fall into mid to late spring.

Water temperature performance criteria were based on daily values. Water temperature should maintain a daily average of <18°C and daily maximum of <21°C during periods when salmonids are expected to be present.

The salinity threshold is 4 ppt and generally applied to surface salinity concentrations due to higher DO and lower concentrations near the surface where fish are expected to mainly occur.

The project, once completed, was intended to create a longitudinal gradient of salinity, with the highest salinity near the tide gate transitioning to freshwater conditions at the upstream end and each pond having different concentrations of brackish water. Additionally, stratification is expected to provide a vertical gradient from more saline waters at the bottom to less brackish water near the surface. During rainfall-runoff events the entire project channel length and all the ponds are anticipated to be predominately freshwater. With completion of the project's upstream reach in 2021, the water year 2022 salinity data show brackish conditions have moved upstream as expected.

Temporary Salinity Barrier

The EMGC currently diverts surface water from Martin Slough for irrigation of turf using their riparian water right. The irrigation diversion is in the North Fork channel of Martin Slough, approximately 265 feet upstream from the confluence with the mainstem. The water pumped from the channel originates from both the North Fork and mainstem of Martin Slough due to the low gradient of the slough and resulting backwatering of the pond from the mainstem. In mid-April, a temporary salinity barrier was installed in the mainstem just downstream of the confluence with the North Fork to isolate the municipal golf course irrigation intake from the tidal prism (Figure 2). At that time salinity in water pumped for irrigation was too high for watering greens and fairways. The salinity barrier was intended to allow for a year-round muted tidal regime downstream of the North Fork confluence with the Martin Slough mainstem following construction completion in 2021 (MLA 2022). The salinity barrier's intended operation period was the irrigation season with removal by the end of 2026, unless golf course irrigation system upgrades were completed beforehand.

Figure 2. Temporary salinity barrier installed to isolate the EMGC irrigation intake from the tidal prism. Located on the Martin Slough mainstem just downstream of the confluence with the North Fork.

Methods

The following methods section was excerpted/adapted from the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022 (Appendix A).

Temperature and salinity data loggers were installed at the same locations as the water level loggers, except at Swain Slough. Salinity data loggers also recorded water temperature and were installed in each perforated standpipe, one at the bottom coupled to the water level logger and one attached to a float that traveled the height of the standpipe and measured conditions approximately 10 inches below the surface. At the MS-NF site only surface salinity was recorded. Salinity and temperature were recorded continuously on the same 15-minute interval as the stage data loggers. Salinity data loggers were not installed at the Swain Slough station, but Swain Slough water temperatures were recorded by the water level logger placed at the bottom of the water column. Spot measurements of salinity, temperature and dissolved oxygen were also taken using a YSI handheld meter and recorded on data sheets as the data loggers were downloaded, typically at a low tide. Additional water quality measurements were taken during fisheries monitoring and covered in the Annual Fishery Monitoring Report (Appendix B).

Surface and bottom salinity concentrations and water temperatures recorded at each gaging station in water year 2022 were plotted with water level (Appendix A, *MLA 2022*, *Appendix A)*. The plots included daily rainfall totals measured at the National Weather Service (NWS) office on Woodley Island, Humboldt Bay, for reference. A table of water quality spot measurements recorded during each data download is presented in Appendix A, *MLA 2022*, *Appendix B*. Spot measurements include water temperature, salinity, and DO concentrations. Plots of daily average and daily maximum water temperatures are shown in Figure 3.

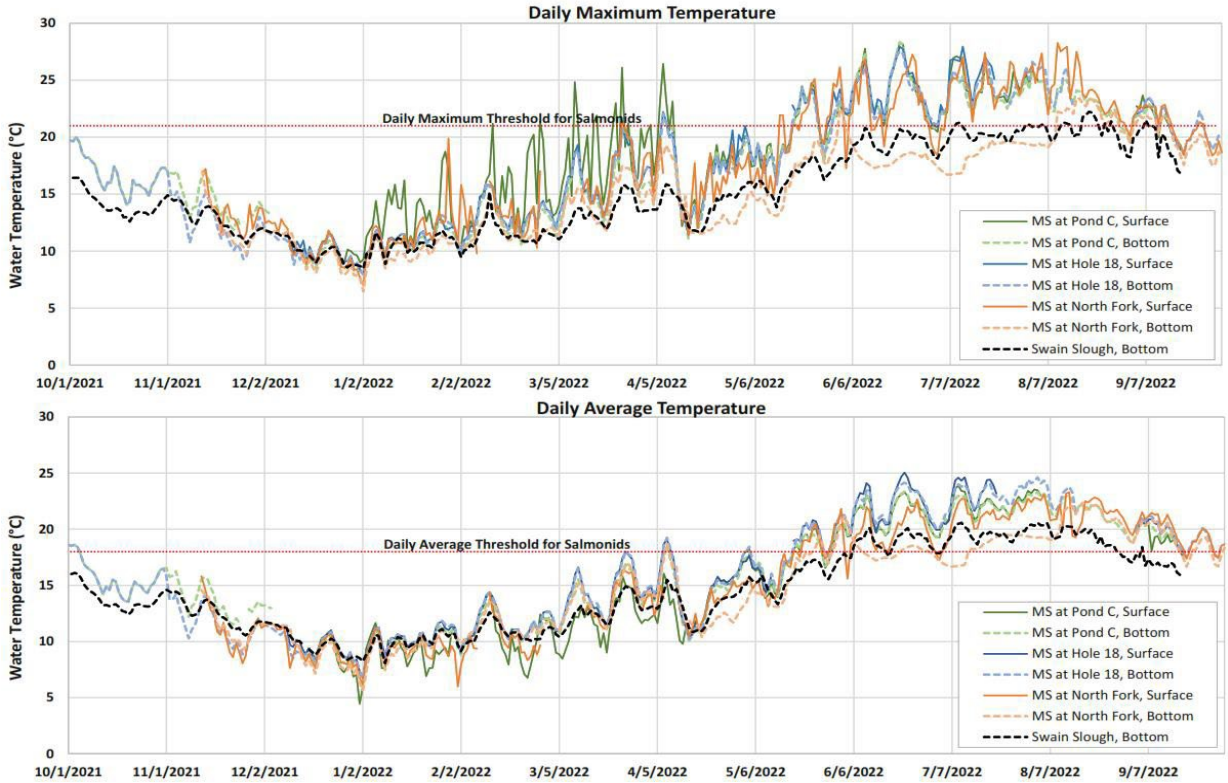


Figure 3. Daily maximum and daily average water temperatures for water year 2022 recorded at the Swain Slough, Martin Slough at Pond C, Martin Slough at Hole 18 and the North Fork Tributary gaging stations.

Results and Discussion

The following results and discussion were excerpted/adapted from the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022 (Appendix A).

Salinity and Water Temperature

Water temperatures within the project area are dependent on air temperature, temperature of freshwater inflow from upstream, and temperature of inflow from Swain Slough. During winter months temperatures are expected to be similar to freshwater streams around Humboldt Bay. During the dry season, areas with brackish water should experience higher water temperatures due to influence from Humboldt Bay and Swain Slough. These can readily exceed 20°C due to shallow inundation of mudflats during rising tides in the daytime. Water temperature data from water year 2019 through 2022 show these trends.

A Note Regarding Data Loggers

At the end of water year 2021 and beginning of water year 2022, many data loggers that had been in use for the duration of the project began to fail. Loggers were returned to the manufacturer and data were recovered when possible. Data not recovered created a gap in the data plots. Periodically the surface salinity data loggers, attached to a float, would become tangled in the standpipe and remain stuck when water receded. Downloading the data and reinstalling a logger resets the logger's position and it can be difficult to parse the data to determine when the logger became stuck. Data for those time periods were removed from the data set whenever possible.

Swain Slough

Water temperatures in Swain Slough during the fall of 2021 and early winter of 2022 were similar to those measured in the freshwater reach of Martin Slough near MS-18 and upstream at the North Fork Tributary gage, with small diurnal temperature fluctuations (Figure 3**)**. However, by mid-April 2022, water temperatures became elevated and both diurnal and tidal influenced temperature fluctuations became more apparent.

Salinity was not recorded in Swain Slough.

Martin Slough near Pond C

In Martin Slough at Pond C, the salinity was highly correlated with precipitation, and stratification was present during periods not dominated by freshwater inflows. During periods between rainfall events the bottom salinity would fluctuate dramatically with incoming and outgoing tides, while the surface salinity generally fluctuated less and was less brackish. During periods with precipitation, salinity concentrations were close to zero for days at a time. Several days following the cessation of rainfall, the bottom salinity increased relatively rapidly, while the

surface salinity slowly increased with each tide cycle. This pattern was most pronounced in January 2022.

Water temperatures in Martin Slough near Pond C remained low throughout the fall and early winter months. Surface and bottom temperatures were nearly identical much of the time, with periods where the surface water temperature was colder and fluctuated much more with tidal cycles than along the bottom. This seemed to be associated with stratification during flood tide and mixing during ebb tide. By May 2022, temperatures at this location began to rise, as did salinity, due to lack of rainfall. During the summer months water temperatures were between 18° and 22°C and were consistently warmer than Swain Slough.

Martin Slough near Hole 18
Salinity measurements in Martin Slough near Hole 18 showed that during winter and early spring both surface and bottom salinity fluctuated between 0 and 22 ppt almost daily with the tidal cycle. However, starting in April, salinity decreased dramatically with the onset of rainfall. Water temperatures in Martin Slough near Hole 18 fluctuated with tides and showed diurnal fluctuation with changes in precipitation and ambient air temperature. These fluctuations grew more exaggerated in the warmer months starting in April and continued through September.

North Fork Martin Slough
Salinity measurements were recorded at the surface at the North Fork Tributary gage, located just upstream of the confluence with the mainstem. Data showed that saline water is reaching the upper reach of the Martin Slough project area. When the temporary salinity barrier was installed surface salinity dropped to less than 0.5 ppt. With its removal in August the salinity fluctuated with the tide between 0 and 18 ppt.

Temperature values showed normal diurnal fluctuations, with warming during the summer months. Water temperature performance criteria are applied year-round due to the goal of providing year-round conditions suitable for rearing salmonids in this section of the project. The salinity barrier installation influenced water temperatures by increasing surface temperature and decreasing bottom temperatures, presumably due to lack of mixing that occurred after the barrier was installed.

Comparison to Performance Criteria

Salinity
Spot measurements of salinity were almost always above the 4 ppt threshold unless there was rainfall, with the exception of the North Fork tributary that recorded low values of 0.1 and 0.4 ppt during the salinity barrier installation period. The continuous data (Appendix A, *MLA 2022*, *Appendix B*) showed that during the winter months surface salinity at all three gage stations fluctuated with the tide cycle, often dropping below the 4 ppt threshold during low tide and for extended periods during precipitation events. During the warmer and drier summer months Pond C and Hole 18 surface salinity levels showed less fluctuation. Salinity generally remained above 16 ppt and 12 ppt in Pond C and Hole 18 beginning in May and June, respectively.

In the spring, prior to installation of the salinity barrier, North Fork Tributary gage salinity levels periodically exceeded 4 ppt. Despite the barrier, salinity remained too high for irrigation with the pump and in August the salinity barrier was removed by EMGC staff in an attempt to flush the upstream ponds and capture freshwater. Following its removal salinity climbed to between 12 and 18 ppt. Concentrations far exceeded those suitable for rearing salmonids due to the substantial amount of tidal inflow to the North Fork combined with a lack of freshwater inflow to keep the reach fresh.

The 2022 water year experienced 25.48 inches of rainfall based on the NWS Woodley Island gage in Eureka, CA. The Eureka 20-year average rainfall for 1991 to 2020 was 41.40 inches. The 2022 water year was 62% of normal; this drier than normal year is one likely cause of high salinity levels due to lack of freshwater flowing through the project area or entering from Elk River via Swain Slough.

Water Temperature

Temperature values recorded during the water year are shown in Figure 3. During the months of October through April maximum daily and average daily water temperatures were below the thresholds of 21°C and 18°C, respectively, for juvenile salmonids. During the summer months the daily average temperature increased to between 18°C and 25°C. From June to August, Swain Slough temperatures were also above the daily average threshold of 18°C. The North Fork gage recorded the lowest values of the four gage stations during the summer months, however, the North Fork data set was incomplete due to construction in fall of 2021. The data suggest the inflow of tidal water from Swain Slough governs the water temperatures in Martin Slough due to the large degree of tidal cycling. The drier than normal water year and resulting low base flow is one likely cause of the higher temperatures in the 2022 water year.

Dissolved Oxygen Spot Measurements

Spot measurements of DO by RCAA staff during each data logger download are provided in Appendix A (*MLA 2022*, *Appendix C)*. The measured DO levels at the four sites were generally above the minimum performance criteria of 4 mg/l on the surface, and were often substantially higher. The DO levels were considered acceptable for rearing salmonids and other aquatic organisms.

(See the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022, Appendix A.)

TOPOGRAPHY, HYDROLOGY AND WATER QUALITY RECOMMENDATIONS

The following recommendations were excerpted from the *Martin Slough Enhancement Project, 2022 Physical Monitoring Report* (Michael Love and Associates 2022).

The Martin Slough Enhancement Project was implemented in phases with the final construction phase completed in 2021. While the restoration project was completed, the EMGC is still working on establishing an alternative irrigation supply. In the interim the golf course used the temporary salinity barrier, attempting to maintain freshwater at its screened pump intake on the

North Fork. The salinity barrier affected the upstream hydrologic and water quality conditions. However, it did not appear to influence downstream water quality.

Channel Conditions

The high point identified along the thalweg profile near the NRLT bridge is still present. It originated from a slumping bank associated with high groundwater and saturated soils close to the base of the adjoining hillslope. Material may continue to slump at this location, but currently is not significantly constricting the channel or influencing the tidal amplitude. The project manager and project engineer should continue to inspect this site to detect if any additional slumping occurs, and/or if the channel is scouring this material.

The second area of sedimentation noted in the 2019 survey at the property line near the previous grade control should also continue to be monitored to see if this material scours-out or causes a reduction in tidal exchange or outflow of freshwater. This will be evaluated as part of the topographic monitoring in 2023.

The previously noted eroding bank at the upstream end of the project may continue to adjust and should be monitored to ensure the upstream-most log weir adjacent to this location remains stable. Minor bank armoring might be needed to protect the upstream weir and piles. Future channel surveys should include the channel immediately upstream of the project on the mainstem to assess changes to bed elevation and width.

Water Levels

The 2022 water level data show that the tidal amplitude and MHHW in Martin Slough are both less than the design values (Table 3 above). Further increasing the muted high tide by adjusting the tide gate settings to better achieve the design condition was discussed but considered undesirable, as it would further increase salinity concentrations in the upper portions of the project, the area intended to provide low salinity aquatic habitat during the dry season. Additionally, there are low areas on the golf course adjacent to the channel that could become inundated during spring tides if the gate is adjusted to increase tidal amplitude. Even with the current lower than design setting, the tidal amplitude and MHHW water levels are inundating the constructed surfaces (i.e., marsh plains) and vegetation is becoming established as intended.

Water Quality Conditions

The water quality monitoring shows that water temperatures and salinity concentrations in the North Fork are exceeding the performance thresholds during summer and early fall. When the salinity barrier was in place, the salinity concentrations were within criteria, but the water temperature remained above the performance thresholds (Figure 3 above). The higher salinity concentrations are likely due to lower summer stream flows and more tidal-freshwater mixing than assumed during the design. Drought conditions resulting in below average stream flows during 2022 likely further influenced water quality. Adaptive management options to reduce salinity and water temperatures in the upper reaches of the project should be explored but appear to be limited at this time.

Monitoring Protocols
The water quality and stage monitoring equipment has been in operation since 2017. Some equipment likely requires servicing or replacement, especially given the project's corrosive brackish water environment. Battery levels should continue to be monitored and replaced when the voltage is consistently falling below 3.4 to 3.3 volts.

Monitoring stations should be examined to ensure that the t-posts are sufficiently embedded and the straps holding each pipe are sound. Stainless steel cables inside the standpipes have corroded and were replaced with nylon cord and should be examined during each download.

Access to the Pond C gage is along a log that extends from the toe of the bank into the channel (Appendix A; *MLA 2022*, *Appendix C Figure 7*). An additional length of metal safety grating should be installed along the log to provide sure footing when accessing the standpipe. A rope staked into the bank would also be helpful for traversing the steep bank.

Increasingly, the floats in the standpipes that keep the upper salinity data logger at the water surface have become stuck after high tides, leaving them dry until the next high tide event. This unfortunately leaves portions of the upper salinity dataset unusable. The floats should be replaced with a smaller spherical float that allows for unfettered movement as the tide rises and falls. The standpipes are 4-inch diameter, and a 3-inch diameter or smaller ball float should improve the performance. Additional weight applied to the existing data loggers may also help.

FISHERIES

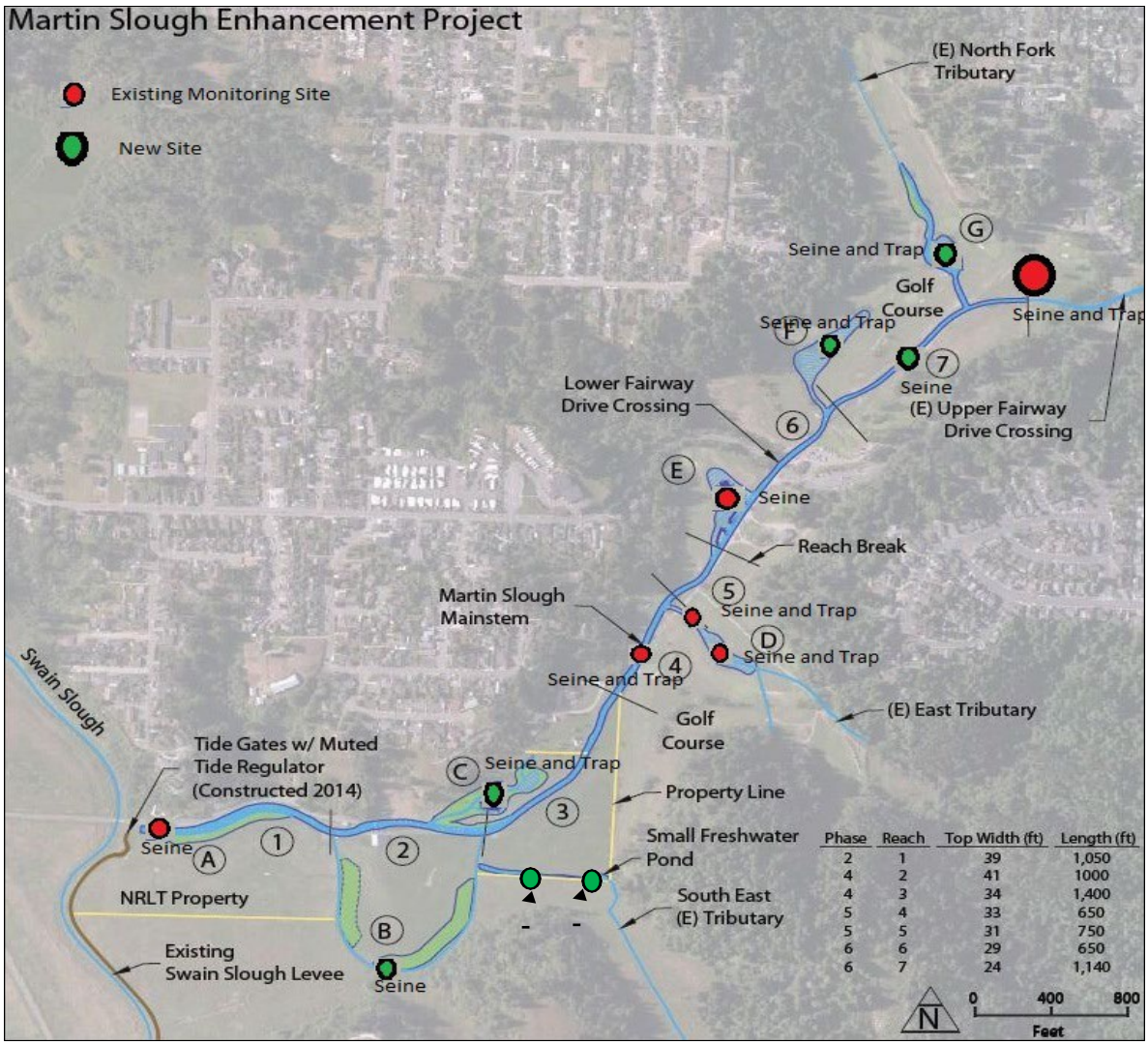
Overview

The objectives of fisheries monitoring include documenting fish presence, species diversity and associated water quality within a variety of sampling locations in all habitat types within the Martin Slough project area. Beginning in 2019, Ross Taylor and Associates (RTA) and graduate students from Cal Poly Humboldt conducted work including Passive Integrative Transponder (PIT) tagging juvenile coho salmon (*Oncorhynchus kisutch*), generating growth rates from recaptures of previously tagged fish, determining coho residency times and timing of smolt out-migrations and assessing off-channel habitat use by juvenile coho.

Methods and Materials

The following section was excerpted/adapted from the *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023), attached as Appendix B.

Fisheries monitoring occurred 2 days per month, starting in November 2021 and ending in June 2022, thus, all references to '2022' fish monitoring include November and December of 2021. Sampling sites were distributed throughout the project area (Figure 4). On the NRLT property, established monitoring sites were located at Pond C, Southeast Tributary and the Oxbow Channel. On EMGC property monitoring sites were located at Ponds D, E, F and G, and the mainstem below and above Fairway Drive. The number of sites monitored per month ranged from 5 to 11.



Phase	Reach	Top Width (ft)	Length (ft)
2	1	39	1,050
4	2	41	1000
4	3	34	1,400
5	4	33	650
5	5	31	750
6	6	29	650
6	7	24	1,140

Figure 4. Martin Slough Enhancement Project reaches, ponds and fisheries monitoring locations.

A variety of seine net sizes (lengths of 10, 20, 22, 30, 80 and 100 feet) was used, depending on the site, tide levels and water depths. The 10-foot through 30-foot nets were 4 feet tall and the 80-foot and 100-foot nets were 6 feet tall. When sampling most locations a net with ¼-inch mesh was used, however, for areas known to support tidewater goby, nets used were 1/8-inch mesh.

The method of fish capture processing depended on the species caught and location. For example, threespine stickleback (*Gasterosteus aculeatus*) and Pacific staghorn sculpin (*Leptocottus armatus*) were counted out of the seine net and immediately released. When large numbers of stickleback were encountered, they were batch-counted in visual estimates of 25 fish per aquarium net-scoop. Tidewater goby (*Eucyclogobius newberryi*) and smelt species were not held in buckets due to Endangered Species Act status (goby) or fragility (smelt). All coho and other salmonids were temporarily held in dark-colored 5-gallon pails with lids and battery-powered aerators. Processing salmonids involved anesthetizing, measuring, weighing, scanning and/or tagging.

Captured salmonids were anesthetized using Alka-Seltzer Gold. The lowest concentration of the medication (1 fully dissolved aspirin-free tablet) that permitted safe handling was used. Fork length (FL) to the nearest mm and weight to the nearest 0.01 g were recorded for each fish captured. Each fish was scanned for a PIT tag. Anesthetized fish >75 mm FL were surgically implanted with 12-mm or smaller PIT tags; fish 65-75 mm FL were implanted with 9-mm PIT tags or smaller; and fish <60-mm FL were not tagged.

A PIT tag antenna array was previously established in the main channel of lower Martin Slough to record outmigration.

Processed juvenile coho were allowed to recover in an aerated bucket and monitored until all fish appeared upright and swimming. Fish were released back into their capture locations and were carefully observed during their post-surgery release. When large numbers of fish were processed, both the anesthetizing bath and recovery container water were changed to avoid subjecting fish to increased water temperatures.

At each sampling location, water quality measurements were taken with handheld YSI water quality meters that included dissolved oxygen, temperature, and salinity taken at near-surface to a maximum depth in 1-foot intervals. Survey start and end times were also recorded.

Data Storage/Processing

Data from the handheld PIT tag reader and notebook were downloaded in the RTA office and entered into Excel. Spreadsheets were created for juvenile coho salmon catch, growth rate calculations of recaptured coho, tidewater goby catch, general fish catch, and water quality measurements. Growth rates were computed for recaptures of previously tagged fish by subtracting the fish's most recent length and weight from its previously recorded length and weight, then dividing the difference by the number of days between capture events (days at large). When individual fish were recaptured multiple times, the month-to-month growth rates depicted how growth changed over the course of the fall/winter/spring season.

Another objective of fish monitoring was documenting the out-migration timing of coho salmon smolts in Martin Slough. A PIT tag antenna array and data logger system were installed in the lower reach of Martin Slough near the barn on the property owned and managed by the NRLT (Figure 5). This system consisted of a Biomark® IS1001 Multiplexing Transceiver system and two 10'x 3' pass-through antennas. The antennas were arranged side-by-side to cover the channel cross-section. This side-by-side arrangement provided better coverage of tagged fish migrating downstream, at the expense of having the antennas set above and below each other to detect direction of movement (direction is documented by a fish passing by one antenna and then the next antenna). All juvenile coho were tagged upstream of the array, therefore, all tag detections consisted of out-migrating coho smolts. Unknown tags or fish tagged in other Humboldt Bay drainages were assumed to be moving in an upstream direction through the array, having entered Martin Slough through the tide gate located approximately 1,200 feet downstream. The side-by-side orientation of the antennas provided better coverage during the wide variations in channel depth and width because of tide changes (Figures 5 and 6). Biomark® auto-tuned the antennas, which is important in a tidally influenced area with changes in water depths and salinity levels.

Figure 5. PIT tag antenna array system in lower Martin Slough at low tide on April 25, 2022.

Figure 6. PIT tag antenna array system in lower Martin Slough at high tide on April 27, 2022.

Due to technical problems associated with electrical interference and delays in obtaining equipment to address the problem a fully functioning system with two antennas was operational by late April 2022, probably a month after the commencement of the coho smolt out-migrations. PIT tag detection data from the IS1001 unit were downloaded in approximately one-month intervals and the site was visited 2 or 3 times monthly to clear debris off the antennas and make sure the IS1001 unit was running properly.

Results and Discussion

The results section was excerpted/adapted from the *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023, Appendix B.

Sampling Dates and Locations

Fourteen sites within Martin Slough were sampled during the 2021-2022 season (Figure 4). Sampling typically occurred 1 day per month in the upper reaches of Martin Slough, followed by a day lower in the watershed. Between 3 and 8 sites were sampled per day depending on tides, ease of access, and/or numbers of juvenile coho captured.

Species Numbers and Capture Sites

Fourteen fish, 2 crustacean, 2 amphibian and 1 reptile species were captured during the 2022 season (see Appendix B for specific capture information). Juvenile coho and tidewater goby captured numbered 1,691 and 1, 355, respectively. The 14 fish species captured varied in distribution. Threespine stickleback was the most abundant species encountered and present at all 14 sampling locations. Tidewater goby was abundant; its distribution increased over the four years of project construction as the upstream extent of brackish water increased. Tidewater goby were captured in 12 of the 14 sampling locations; they were absent from the 2 sites upstream of brackish water intrusion. The upstream distribution of Pacific staghorn sculpin increased similarly to tidewater goby; as the brackish water extended farther upstream, so did the presence of staghorn sculpin. Eighty-five percent of fish species were captured in Pond F. In contrast, just 2 species (14%) were captured in the East Tributary Pond D.

Coho Salmon Catch and Growth Rates

Out of 1,691 juvenile coho salmon caught in 2022, 1,519 (90%) were fry caught in May and June and suspected progeny of adults successfully spawning in Martin Slough. There were 173 captures of age-0 and age-1+ fish that most likely migrated into Martin Slough from the Elk River during the late-fall/early-winter juvenile redistribution period. Most of the newly emerged fry were caught in the main channel, above or near the confluence with the North Fork of Martin Slough. In May 2022, a sub-sample of these fish were measured and weighed and were between 46 and 54 mm in FL and 0.6 to 1.6 g (too small to tag; Figure 7).

Figure 7. Coho salmon smolt and 6 fry caught at the Upper Fairway Drive site on May 19, 2022.

RTA implanted 133 PIT tags in coho and recaptured 36 (169 coho captured). Two smolts that failed to out migrate in 2021 were captured in Pond D in November and December of 2021. Most (89%; 117 tagged and 34 recaptured) of the juvenile coho were in pools at Upper Fairway Drive sampling locations. The remaining tags were implanted in juvenile coho captured at Pond G (18 fish), North Fork Channel below Pond G (8), main channel near the North Fork confluence (8), Pond E (7), Pond F (6), and the main channel near the East Fork confluence (3). The two recaptures outside the Upper Fairway Drive sites occurred in Pond G and the North Fork channel immediately below Pond G.

Daily growth rates were computed for all previously PIT tagged fish, recaptured in February, March, April and May. In February, computing daily growth rates of recaptured fish was straightforward because recaptures were only from the previous month. In March through May, fish were recaptured with varying numbers of days at large and some fish were recaptured multiple times. (For tables with all of the daily growth computations from PIT tag recaptures see Appendix B, *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023.)

Growth rates tended to increase as the rearing season progressed and water temperatures generally increased (Table 44. The individual fish with the highest growth rate was tagged and recaptured in a brackish water location of the North Fork, just below Pond G, and provided our only documentation of growth rates in brackish water. At this location, the salinity measurements on February 24 equaled 2.2 ppt at the near-surface and 8.8 ppt at a depth of 1.0 feet. On the day of its

recapture on March 28, the salinity measurements were 0.5 ppt at the near-surface, 0.7 ppt at a depth of 1 foot, and 1.8 ppt at a bottom depth of 1.5 feet.

Table 3. Average month-to-month growth rates for juvenile coho salmon in Martin Slough, January through May of 2022. Water temperature measured in the lower pool at Upper Fairway Drive when coho salmon were sampled.

Growth Period	Number of Recaps	Average Growth - length	Average Growth - weight	Water Temp at Upper FW Drive
January to February	6 fish	0.16 mm/day	0.08 g/day	Jan = 9.0ºC
February to March	11 fish	0.32 mm/day	0.11 g/day	Feb = 5.9ºC
March to April	8 fish	0.55 mm/day	0.14 g/day	March = 8.8ºC
March to May	3 fish	0.51 mm/day	0.15 g/day	April = 10.3ºC
April to May	2 fish	0.35 mm/day	0.14 g/day	May = 13.0ºC

Recaptures of previously tagged juvenile coho indicated minimal movement of fish between capture events. All but one fish recaptured were in the location of initial capture. Length of residency in the Upper Fairway Drive pools varied from 113 to 59 days. A fish with 3 recaptures, tagged on January 25, experienced increased growth rates each time it was recaptured: 0.20 mm/day between January and February, 0.40 mm/day between February and March, and 0.56 mm/day between March and April.

Coho Salmon Out-Migration and Antenna Array Detections

The PIT tag antenna array system located in lower Martin Slough was operating with one functional antenna on April 8 and was fully operational (two antennas) on April 25. Between April 8 and June 21, 50 individual tags were detected by the array; 49 tags were in juvenile coho salmon including 1 coho from Freshwater Creek. Of the 133 fish tagged in Martin Slough, 37% were detected by the array. In April, 13 tagged fish were detected; in May, 29 fish were detected; and in June, 8 fish were detected. The final download of the array's data logger occurred on July 27, after the final tag was detected on June 21. As stated previously, a portion of the out-migration season was missed due to equipment malfunction prior to April 8 and partial function prior to late April. Research spanning nearly a 70-year period confirmed that April and May are the peak months in California for coho salmon smolt out-migration (Shapovalov and Taft 1954; Drucker 1972; Ettlinger et al. 2021).

Most of the Martin Slough array detections (33 of 49) occurred during periods of darkness. Of the 16 detections that occurred during daylight hours, 7 were between 6:00 AM and 7:00 AM and 3 were after 4:00 PM. Twenty of the 49 detections (41%) occurred between 10:00 PM and 4:00 AM. RTA's results regarding diel timing of out-migration movement were consistent with other studies that documented most movement occurring at night. Meehan and Siniff (1962) found that on the Taku River the peak migration of coho smolts occurred between 11:00 PM and 3:00 AM. Mace (1983) reported that coho smolts were rarely observed out-migrating during daylight hours, and they appeared in the transition zone between freshwater and the estuary only in the afternoon and evening hours.

Water Quality Measurements

The overall trend observed in 2022 monitoring was the persistently high salinity readings in all of the off-channel ponds, including Pond G, the uppermost pond on the EMGC. During the 4 years of project construction, salinity in the Martin Slough ponds increased each year as more of the channel was excavated, the muted tide gate became fully operational in the fall of 2020, and the upstream extent of high tides increased (Table 5). Ponds D, E, F, and G were all constructed with high tailwater controls which prevented the ponds from fully draining, including more dense brackish water from draining out of the ponds. It also appeared that rain events created a low-salinity lens on the near-surface to one-to-two feet of depth. Deeper than 2 feet, the waters remained highly brackish, too salty to support over-winter rearing of juvenile Coho Salmon.

Table 5. Salinity readings in parts per thousand (ppt) in 4 off-channel ponds. The 2021 data were collected by Cahill/CPH and the 2020 and 2022 data were collected by RTA. The first value is near-surface and second value is salinity at the pond's maximum depth.

Sampling Date	Pond D	Pond E	Pond F	Pond G
4/23/20	0.2 – 0.2	0.2 – 0.2	Not sampled	Not constructed
5/26/20	0.2 – 0.2	0.2 – 0.2	Not sampled	Not constructed
1/31/21	0.3 - 5.1	0.1 – 0.4	0.1 – 0.2	Not constructed
2/24/21	0.1 – 0.7	0.2 – 0.2	0.2 – 0.8	Not constructed
3/17/21	0.1 – 0.1	0.2 – 0.7	Not sampled	Not constructed
4/14/21	0.2 – 0.4	1.4 – 1.8	2.5 – 4.6	Not constructed
5/17/21	0.3 – 0.3	5.5 – 6.2	7.4 – 8.1	Not constructed
1/25-26/22	0.3 – 18.3	11.1 – 15.7	7.1 – 15.3	1.0 – 19.1
2/24/22	Not sampled	Not sampled	7.1 – 20.2	Not sampled
3/28/22	0.3 – 11.8	21.7 – 22.8	3.4 – 20.3	5.3 – 16.2
4/25-26/22	Not sampled	1.9 – 3.6	0.6 – 15.2	0.8 – 14.8
5/19-20/22	10.3 – 11.1	10.3 – 11.1	7.6 – 11.2	2.0 – 15.2

Dissolved oxygen, water temperature and salinity measurements are provided in Appendix B, *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023.

Recommendations

The following section was excerpted/adapted from the *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022,* Ross Taylor and Associates 2023, Appendix B.

During the 2022 8-month sampling period 14 sites within the project area were sampled and each site was sampled multiple times. During the second sampling season in the fall/winter/spring of 2022-2023 RTA intends to sample at similar frequency and effort. In an attempt to tag as many fish as possible, sampling intensity may increase in freshwater and low-salinity areas where more

juvenile coho are likely to be present. Less frequent sampling is planned in areas with high densities of tidewater gobies, specifically to reduce potential impacts to this endangered species. These areas include Pond C and the Pond C terminal channel.

One juvenile coho detected in Martin Slough originated in Freshwater Creek. This fish was captured and tagged at the Freshwater Creek downstream outmigrant trap on June 5 and 12 days later it was detected in Martin Slough. The distance between these 2 locations is approximately 11 miles; the fish's path through Humboldt Bay was unknown but assumed to be a pathway hugging the eastern shore of the bay, which may not be the preferred pathway of out-migrating smolts (Pinnix et al. 2013). Movements of juvenile coho between various tributaries within Humboldt Bay were previously documented, however, this is a relatively rare occurrence (Halloran 2020). Acoustic tagging and tracking of coho smolts in Humboldt Bay determined that smolts spent between 15-22 days in the bay prior to out migrating to the ocean (Pinnix et al. 2013). This study found that coho smolts used deep channels with narrow intertidal margins, as opposed to shallow channels, intertidal mudflats or eelgrass meadows (Pinnix et al. 2013). This study determined that out migrating coho smolts spent from less than 1 to up to 4 days in the lower estuary of Freshwater Creek; this could explain the multiple detections over several days with some tagged fish in lower Martin Slough. A second pair of antennas would allow for better determining movement patterns of coho smolts in lower Martin Slough, however, budget currently is lacking for additional equipment purchases.

The presence of newly emerged coho salmon fry in Martin Slough in May and June of 2022 was a surprise. CDFW biologists who conducted numerous years of sampling in Martin Slough prior to the channel enhancement project stated that large numbers of newly emerged fry were never documented (M. Wallace, pers. comm.). RTA assumed that these fish were the result of successful spawning of adult coho salmon in upper Martin Slough during the winter of 2021-2022. As far as is known, this is the first-time adult salmon have recently spawned in Martin Slough.

The persistently high salinity levels in the off-channel ponds during the fall/winter/spring of 2021-2022 coincided with very few juvenile coho sampled in off-channel habitats. Between December 2021 and April 2022, 140 juvenile coho were caught and 29 (21%) of these were in off-channel ponds. The numbers of fish captured by pond were: Pond D,2; Pond E, 7; Pond F, 1; and Pond G, 19. In 2021 the salinity levels were relatively low in Ponds D, E, and F when sampling occurred in off-channel habitats. At this time, the muted tide gate was fully operational, yet these ponds remained only slightly brackish. Catches in 2021 included relatively high numbers of juvenile coho. For example, on March 17 the coho catch was 36 in Pond D, 26 in Pond E and 41 in Pond F; all when maximum salinity readings were less than 1.0 ppt. The channel excavation work was completed during the summer of 2021, and it appears that this further deepening (and lowering) of the channel elevation allowed further upstream penetration of higher-salinity water. After the 2021 construction season, in March of 2022, the same ponds had maximum salinity values of 11.8, 22.8 and 20.3 ppt, respectively.

The project's Biological Assessment listed 9 purposes and goals, including "*provide habitat and benefits to multiple species by improving and increasing the diversity and amount of fresh and saltwater wetland/estuarine habitat**, particularly off-channel and side channel juvenile salmonid rearing and overwintering habitat***" (GHD 2017). Based on our biological sampling and water

quality monitoring in 2021-2022 (including November and December of 2022), the persistently high salinity readings in the off-channel ponds have failed to improve or increase the amount of off-channel habitat for juvenile salmonid rearing. If anything, there has been a substantial decrease in the quantity and quality of off-channel salmonid rearing and overwintering habitat in Martin Slough. In addition, pre-construction relocations in 2020 and 2021 documented ample amphibian breeding and rearing in Ponds D and G when these ponds were wholly freshwater. Significant loss of breeding and rearing habitat for red-legged frog, Pacific treefrog, rough-skinned newt, northwestern salamander, and coastal giant salamander has occurred post-construction.

RTA recommended that a meeting be convened with project partners and regulatory agencies to discuss the persistently high salinities in the Martin Slough off-channel ponds and feasible means to limit the upstream extent of brackish water; at a minimum allowing Pond G to function as high-quality overwintering habitat for juvenile coho. The pre-project water quality modeling predicted that salinities in the upper ponds (F and G) during the rainy season would be under 8 ppt and suitable for overwintering juvenile coho, yet on-the-ground monitoring has documented unsuitable conditions based on high salinities and the relative lack of coho presence in the ponds.

(See the *Martin Slough Enhancement Project-Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023. The complete report is attached as Appendix B.)

VEGETATION

Overview

The principal revegetation goal of the Martin Slough Enhancement Project is, through passive and active revegetation, to establish, rehabilitate, or re-establish native plant communities within the project area, including within tidal marsh, brackish marsh, freshwater marsh, riparian, and coastal prairie plant habitat zones. The active revegetation effort for this project originally included installation of >50,000 individual plants and direct seeding of approximately 1 acre of disturbed ground. Fifty species were planted including 18 obligate and facultative wetland species, 21 riparian tree and shrub species and 11 grass and forb species. Active planting occurred in upper channel banks, pond fringes and top of bank riparian areas. Grasses reseeding occurred in pastures and golf course rough. Passive revegetation was anticipated in salt and brackish wetlands in the mid- and lower channel where native seed and propagules move in the tidal water column and are naturally recruited (RCAA 2018).

Monitoring was designed to validate revegetation success considering total vascular plant cover (conversely the amount of bare earth) and native to non-native vascular plant ratios as well as species richness and diversity. Criteria also were developed specifically for 2 target invasive plants identified in the Annual Monitoring Plan (RCAA 2021, rev.), *Spartina densiflora* (dense-flowered cord grass) and *Phalaris arundinacea* (reed canary grass).

With all project phases vegetation monitoring began second-year post-construction, or Year 2. In 2020, construction occurred in project Phase 3, on the EMGC, from the eastern boundary of Phase 2 at the NRLT/golf course property line to immediately below Martin Slough

mainstem/Pond E and including the East Tributary/Pond D (Figure 1). In 2022, Phase 3 Year 2, revegetation was monitored by RCAA staff. When success criteria are met in Year 2 (first year monitoring) in a particular project phase, then monitoring of that phase should occur next in Year 5. However, if success criteria are not entirely met in Year 2 then monitoring should occur again in Year 3 and possibly Year 4 in that particular project phase. Tables 6 and 7 summarize success criteria for wetland and riparian plant communities.

Table 6. Revegetation success criteria in the Martin Slough Enhancement Project wetland zone.

Tidal, Brackish, and Freshwater Marsh Success Criteria	
Year 2	30 percent or greater total absolute vegetation cover 35 percent or greater relative cover of native wetland species. No more than 20 percent absolute cover of target invasive plants.
Year 3 (contingency)	40 percent or greater total absolute vegetation cover 40 percent or greater relative cover of native wetland species. No more than 15 percent absolute cover of target invasive plants.
Year 4 (contingency)	50 percent or greater total absolute vegetation cover 45 percent or greater relative cover of native wetland species. No more than 10 percent absolute cover of target invasive plants.
Year 5	60 percent or greater total absolute vegetation cover 50 percent or greater absolute cover of native wetland species. No more than 10 percent relative cover of target invasive plants. Plant vigor shall be "good" per the qualitative score for assessing the health and vigor of planted stock
All Years	Native wetland species consist of hydrophytic OBL/FACW/FAC species. No major erosional areas

Table 7. Revegetation success criteria in the Martin Slough Enhancement Project riparian zone.

Riparian Success Criteria	
Year 2	30 percent or greater total absolute vegetation cover 35 percent or greater relative cover of native riparian species No more than 20 percent absolute cover of target invasive plants.
Year 3 (contingency)	40 percent or greater total absolute vegetation cover 40 percent or greater relative cover of native species No more than 15 percent absolute cover of target invasive plants
Year 4 (contingency)	50 percent or greater total absolute vegetation cover 45 percent or greater relative cover of native species No more than 10 percent absolute cover of target invasive plants.
Year 5	60 percent or greater total absolute vegetation cover 50 percent or greater relative cover of native species No more than 10 percent absolute cover of target invasive plants. 90 percent total vegetation cover for areas within Golf Course more than 25 feet away from the channel and ponds planted using nonnative species
All years	Plant vigor shall be "good" per the qualitative score for assessing the health and vigor of planted stock No major erosional areas

Methods

Macroplots (polygons) were established in the Phase 3 project area that included ground directly disturbed by construction activities and adjacent channel top of bank areas. Within the macroplots 34 sample units were randomly established, with 17 in the wetland (tidal, brackish and freshwater marsh) zone and 17 in the riparian habitat zone (Figure 8). Vegetation was sampled using 1-m^2 quadrats and 3-m radius circular plots centered on the random point in wetland and riparian delineated zones, respectively.

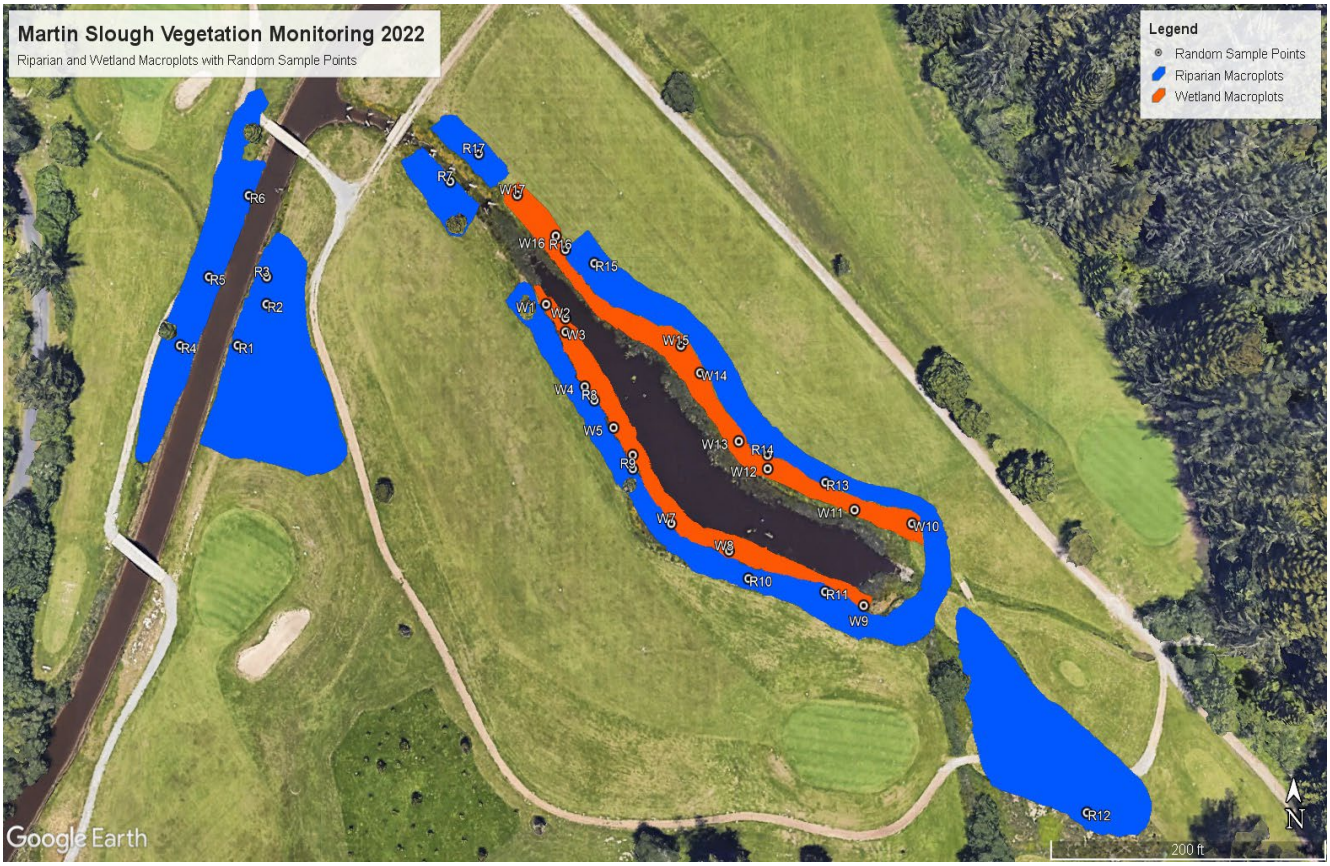


Figure 8. Macroplots in the Phase 3 area with wetland and riparian monitoring sample plots randomly located.

The RCAA (2021) Monitoring Plan included 3 vegetation strata: tree, shrub and herbaceous. The intent is to sample each of these strata separately over time as woody vegetation grows and cover increases to above 5% in each stratum. Currently, neither the tree nor shrub stratum meet the 5% standard, thus, cover estimates consist predominantly of herbaceous species within riparian plots.

Percent cover was visually estimated for each species within each sample unit. Each species was classified according to its native/nonnative status within its historic range and, in the wetland zone, wetland designation (OBL, FACW, FAC, FACU or UPL; USWS 1988). Absolute cover, relative cover, and species richness and diversity were calculated for both zones. Relative native wetland (FAC, FACW, and OBL) cover was calculated for the wetland (tidal, brackish and freshwater marsh) zone. Species richness and diversity were calculated using the Shannon-Weiner Diversity Index (Omayio and Mzungu 2019).

Planted trees and shrubs in riparian zones were maintained (weeded, mulched, watered and caged with deer fence) by RCAA staff throughout the entire project area. Although no plant viability success criteria were identified in the revegetation plan (RCAA 2018), field crews documented tree and shrub mortality throughout the project area in 2022. Replacements planting began in the riparian zone in December 2022.

Results and Discussion

Absolute Cover

Generally, plant cover was high throughout the Phase 3 area. Mean absolute cover was 72.4% (± 22.7 SD; range 43-129%) in the wetland zone and 93.1% (± 19.5 SD; range 58-115%) in the riparian zone. In the wetland zone, mean cover for wetland indicator species was estimated at 35% (± 22.7; range 13-90%). In the riparian zone, tree and shrub strata combined cover averaged 6.7%. Both zones surpassed the Year 2 success criteria of ≥30% absolute vegetation cover, however, the cover estimates in the riparian zone included all 3 strata, thus, represents primarily herbaceous vegetation.

Relative Cover

In the wetland zone relative cover of native wetland indicator species was 62.1% versus 36.8% relative cover for nonnative species (plants not identified to genus accounted for 1.1%). In the riparian zone, relative cover of native and nonnative species was 47.2% and 52.6%, respectively. Both zones surpassed the success criteria of in the wetland zone of ≥35% relative cover of native species. Only one sample unit, in the wetland zone, contained a target invasive species, reed canary grass, with 15% cover of the invasive species in that plot.

Table 8 below summarizes absolute and relative cover estimates.

Table 8. Cover estimates and success criteria for wetland and riparian zone vegetation and bare earth. (WI=wetland indicator; T&S=tree and shrub.) All values are percents.

Habitat Zone	Mean Absolute Percent Cover All Vegetation	Absolute Cover Success Criteria	Mean Relative Cover Native Vegetation	Relative Cover Success Criteria	Mean Cover Bare Earth
Wetland	**72** (35 WI)	**≥30**	**62**	**≥35**	**41**
Riparian	**93** (7 T&S)	**≥30**	**47**	**≥35**	**35**

Plant Vigor

Plant vigor was qualitatively assessed as good in the herbaceous stratum in both the wetland and riparian zones. However, at the time of sampling at least 2-dozen planted tree and shrub saplings in the riparian zone lacked vigor or were dead within the Phase 3 project area. Plant vigor was inventoried across the entire project area in the fall and actual mortality turned out to be

significantly greater in the Phase 3 area than was documented during sampling. Plant mortality likely was due to the dry summer conditions in recent years, coupled with insufficient watering.

Bare Earth

Bare earth was recorded in 41% (6) of wetland plots, averaging 20% in area per plot, or 6.9% of the area sampled. Bare earth was recorded in 35% (7) of riparian plots and averaged 19% in area per plot, or 7.6% of the area sampled.

Species Richness and Diversity

Wetlands
Plant species richness was moderate in the wetland zone, with 29 species identified; roughly 2/3 were native and 1/3 were nonnative. Eighty-seven percent of the wetland native species were classified as either obligate- or facultative wetland. One obligate native species, wire rush (*Juncus balticus)*, occurred in 94% of the plots, ranging from 5 to 90% cover and averaging 22% cover. Lyngbye's sedge (*Carex lyngbyei)* was recorded in 41% of plots with cover ranging from 3-15%. The naturalized nonnative birdsfoot trefoil (*Lotus corniculatus)* occurred in 59% of the plots, although cover was relatively low, ranging from 1-22%. A target invasive species, reed canary grass, occurred in one plot with 15% cover; cord grass, the second target invasive, was not detected in any of the wetland plots.

Riparian
Plant species richness was high in the riparian zone with 54 species identified, with approximately half native and half nonnative species. Native red fescue (*Festuca rubra*) occurred in 82% of plots with cover generally 20% or above. When combined with fescue recorded but not identified to species, this grass dominated plant cover in most riparian plots. Wire rush occurred in 59% of plots, although cover was minimal with about 5% per plot. Highly invasive Yorkshire grass (*Holcus lanatus*) occurred consistently, within 94% of plots; nonnative clover (*Trifolium* sp.) occurred in 88% of plots. Sixty-five percent of the plots contained either highly invasive grasses and/or species in the Asteraceae.

Species diversity was calculated for each zone using the Shannon-Wiener Diversity Index (Omayio and Mzungu 2019):

Diversity $= H/\ln(S)$, where:

$H = \Sigma[(p_i) \times \ln(p_i)]$,

p_i = proportion of the sample represented by the species $_i$

S = the total number of species

Species diversity was relatively high, well above 0 (when only 1 species is detected), in both zones. Diversity was higher in the riparian zone than in the wetland zone, with diversity indices at 3.55 and 2.42 in the riparian and wetland zones, respectively. However, between roughly ½-2/3 of the plots contained nonnative and, in some cases, highly invasive species. A species list of all species recorded during monitoring in the riparian and wetland zones is in Appendix C.

Recommendations

Revegetation of previously disturbed ground appears to be progressing rapidly and has either met or is close to meeting performance criteria as outlined in RCAA's Monitoring Plan (RCAA 2021, rev. and Tables 6 and 7 above). This is especially the case in the wetland zone where percent cover was 72%, of which 38% consisted of wetland indicator species and the ratio of native to non-native was approximately 2:1.

Vegetation in the riparian zone, although meeting performance criteria, is threatened with becoming dominated by invasive nonnative species, the ratio of native to nonnative species in the riparian zone hovering around 1:1. This threat is likely to persist until riparian tree and shrub saplings are able to grow enough to shade out undesirable understory species. As was evident from the mortality inventory in fall 2022, tree and shrub saplings require more frequent weeding, cage repair and regular watering to ensure survival. Although the RCAA field crew spent a fair amount of time weeding and watering over the course of 2022, it apparently wasn't enough to compensate for the recent seasonal drought. Additional watering, ideally via irrigation, is what is required during drought to promote survivability of tree and shrub plantings across the project area.

To a lesser extent, deer browsing caused mortality or reduced plant vigor. Regular inspections to ensure plants are properly caged with deer fence to protect them from browsing is important. Some of the mortality in 2022 was caused by damaged cages allowing deer and small mammalian herbivores to access plants. Gopher activity also appeared responsible for plant mortality, particularly in localized areas. RCAA suggests an ultrasonic pest repellant or other non-lethal form of gopher control where gopher activity is threatening the well-being of young plants.

The Hydrologic, Water Quality and Fisheries sections of this report describe monitoring results indicating that project modeling relative to salinity levels in the upper ponds and mainstem proved to be inaccurate. Reconstructing the channel has allowed the muted tide to enter farther upstream than was predicted and the increased salinity has not been diluted by freshwater inflow. Thus, salinity levels are currently too high in the upper reaches to function as juvenile salmonid rearing and amphibian habitat. In January of 2023, the project team met via teleconference to discuss this situation and agreed that lowering the tide gates and further restricting the muted tide is warranted as the only potential near-term solution to reducing the salinity levels within the slough. The tradeoff is likely to be that the brackish wetland plant community will be negatively impacted by less saltwater flowing into the upper ponds and main stem. Continued vegetation monitoring is important to determine impacts of a reduced muted tide to wetland vegetation and habitat in the near future.

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APPENDICES

Appendix A. *Martin Slough Enhancement Project, 2022 Physical Monitoring Report,* Michael Love and Associates 2022.

Appendix B. *Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022*, Ross Taylor and Associates 2023.

Appendix C. 2022 Martin Slough vegetation monitoring plant species list.

Appendix A.

Martin Slough Enhancement Project, 2022 Physical Monitoring Report

Michael Love and Associates 2022.

Martin Slough Enhancement Project
2022 Physical Monitoring Report

Eureka, California

December 2022

Prepared for:

Redwood Community Action Agency

Prepared by:

Michael Love & Associates
Hydrologic Solutions

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2022 Physical Monitoring Report
Martin Slough Enhancement Project

Eureka, California

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December 2022

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Appendices

1 INTRODUCTION

1.1 Purpose of Report

This report summarizes water year 2022 performance monitoring of hydrology and water quality conditions for the Martin Slough Enhancement Project in Eureka, California. It presents field observations and concludes with recommendations.

1.2 Background

Martin Slough is part of the Elk River watershed, which is part of the larger Humboldt Bay ecosystem. Martin Slough has been identified by the California Department of Fish and Wildlife as playing a key role in the life cycle of Coho Salmon, providing ideal rearing habitat for juvenile coho. In 2006 the Elk River watershed, including Martin Slough, was listed under the Clean Water Act as impaired for sediment and siltation, citing impaired water quality, impaired spawning habitat, and increased depth of flooding due to sediment. In response to these stressors, the Martin Slough Enhancement Project was developed with the goal of enhancing fish habitat for endangered Coho Salmon and reducing the extent and duration of flooding.

The project area encompasses two properties; 40 acres of pasture owned by the Northcoast Regional Land Trust (NRLT) and 120 acres upstream of the NRLT property owned by the City of Eureka and operated as the Eureka Municipal Golf Course. The project was initiated in 2001 when RCAA and partners began preparing a feasibility study, which was completed in 2006. Between 2007 and 2014, Michael Love & Associates, Inc. (MLA) and GHD Inc developed designs for new tide gates, enhanced slough channel, new tidal marshes, and off-channel brackish and freshwater ponds. Construction of the project has been phased, with the first phase implemented in 2014 and the last phase of implementation completed in October of 2021.

1.3 Project Purpose

While not much is known relative to the historical composition of the lower portions of Martin Slough prior to construction of the existing dikes, existing ground elevations relative to tidewater and remnant channel features reveal the lower portions of Martin Slough consisted of estuarine habitat, likely composed of some salt marsh and slough channels along with other more brackish and freshwater scrub/shrub and forested habitats. Existing limiting factors that have been identified in Martin Slough include obstructed fish access, poor fish habitat, poor sediment routing, lack of riparian habitat, and frequent prolonged flooding that has a negative economic impact on current land uses.

The purpose of the Martin Slough Enhancement Project is to improve aquatic and riparian habitat and reduce flooding of pasture and golf course greens throughout the project area. Specific goals of the project include the following:

1. Improve fish access from Swain Slough into Martin Slough,
2. Reduce flood impacts to current land use,
3. Improve sediment transport,
4. Increase the amount of riparian corridor and riparian canopy,
5. Improve water quality (increased circulation, decrease nutrient inputs, decrease sedimentation),

6. Increase the extent of the estuarine ecotone in Martin Slough, providing a gradual transition from brackish water to freshwater habitats, and
7. Enhance and create low-velocity off-channel/backwater habitats.

1.4 Project Phasing

Following completion of the project planning elements, implementation of the project occurred in phases to accommodate funding constraints and logistics of implementing the entire project. The project components and phases are shown in **Figure 1**.

1.4.1 Phase 1 – Tide Gate Replacement

Replacement of the Martin Slough tide gates was accelerated due to the dilapidated state of the existing gates. In 2014, the dilapidated tide gates at the confluence at Swain Sloughs were replaced with a new tide gate system that includes two Muted Tide Regulators (MTRs) designed to allow a limited amount of tidal water into the project area. This is considered Phase 1 of the project. With most of the project completed at the end of 2020, the MTR gates were adjusted in October 2020 to allow the intended muted tide into the upstream project reaches. The majority of the muted tide flows into Martin Slough through the 6 ft x 6 ft MTR side hinged gate. Once this larger MTR gate closes additional tidal inflow comes through the 2 ft x 2 ft auxiliary gate, which is set to close at a maximum tidal inundation elevation.

1.4.2 Phase 2- NRLT Property

Over the summer and fall of 2018 channel and off-channel enhancements were constructed on the NRLT property (Phase 2). The work included: enlarging approximately 3,000 feet of the Martin Slough channel to accommodate the design muted tidal prism (volume), constructing 3.05 acres of tidal marsh plains (Marsh Plain A and B), 1.7 acres of brackish marsh (Pond C), a new Southeast Tributary channel and terminal freshwater pond, replacing two undersized culverts to improve fish passage through the historical channel meander, installation of log weirs on the Southeast Tributary and woody instream habitat structures, and installation of a bridge over the mainstem of Martin Slough. Revegetation of native wetland and salt marsh plants in restored areas occurred over the winter/spring of 2019. The 2019 Physical Monitoring Report detailed the post project conditions.

1.4.3 Phase 3 – Downstream of Fairway Drive

Phase 3 of the project was constructed during the summer and fall of 2019 on the Eureka Municipal Golf Course downstream of Fairway Drive. Phase 3 consisted of enlarging approximately 1,000 feet of Martin Slough mainstem channel (Reach 4 and 5), enlarging an existing tributary pond (Pond D), installation of 8 log weirs on the tributary downstream of Pond D, installation of 7 woody instream habitat structures and a rock grade control structure in Pond D, and construction of one vehicle bridge across Martin Slough.

1.4.4 Phase 4 – Extending upstream to North Fork Tributary Confluence

Phase 4 of the project was constructed in summer and fall of 2020 and included enlarging and realigning 1,800 feet of the Martin Slough channel from just downstream of Fairway drive to the North Fork Tributary confluence (Reach 6 and lower portions of Reach 7), construction of Pond E and Pond F, and construction of one vehicle bridge across Martin Slough. A temporary rock grade control was installed immediately downstream of the North Fork confluence.

1.4.5 Phase 5 – Pond G and Upstream Limits of Project

The remaining project elements were constructed in 2021. This includes final grading of the North Fork channel, marshes, and Pond G and completion of the upstream-most portion of Reach 7 along the mainstem of Martin Slough which included installation of 6 log weirs. A temporary salinity barrier was installed immediately downstream of the North Fork confluence and is planned for removal once the golf course completes its planned irrigation water supply improvements.

Salinity Barrier

The Eureka Municipal Golf Course currently diverts surface water from Martin Slough for irrigation of turf using their riparian water right. The diversion is located in in the North Fork channel of Martin Slough, approximately 265 feet upstream from the confluence with the mainstem. Water pumped from the channel originates from both the North Fork and mainstem of Martin Slough due to the low gradient of the slough and resulting backwatering of the pond from the mainstem.

A seasonal "salinity barrier" was installed as part of Phase 5 as an interim measure to protect the irrigation system from brackish inflow when irrigating. This will allow for a year-round muted tidal regime downstream of the North Fork confluence with the Martin Slough mainstem following completion of Project construction in 2021. This temporary salinity barrier is operated during the irrigation season and will eventually be removed once the golf course irrigation system upgrades have been completed.

1.5 Physical Monitoring Goals

The goal of project monitoring is to ensure the project is functioning as intended and to provide a means of identifying any shortcomings in project performance to allow for adaptive management as needed.

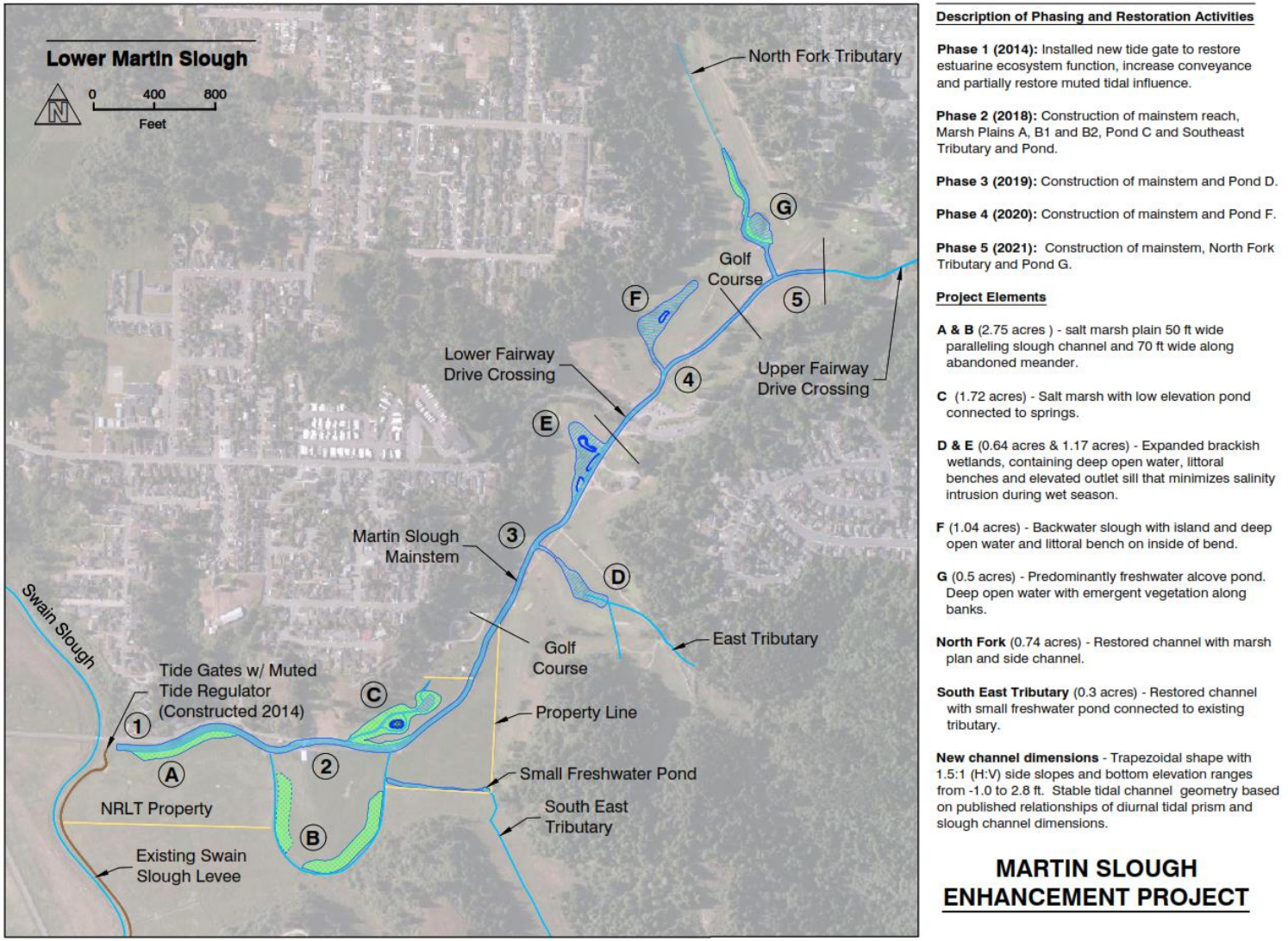


Figure 1. Overview of Martin Slough Enhancement Project. Phase 1 (2014) comprised of tide gate replacement, Phase 2 (2018) comprised of Mainstem channel, Marsh plain A, B, Pond C, and the Southeast tributary on NRLT Property, Phase 3 (2019) included Mainstem channel and Pond D on the Golf Course property, Phase 4 (2020) included mainstem channel and Ponds E and F, and Phase 5 (2021) included Pond G the mainstem and North Fork channel and a temporary Salinity Barrier.

2 MATERIALS AND METHODS

The following physical parameters, as defined by NOAA Restoration Center (NOAA, 2003), are being monitored as part of the Martin Slough Enhancement Project: (1) hydrology, (2) water quality, and (3) topography. Vegetation and fisheries-use are also parameters being monitored for the project and are reported in separately. The hydrologic and water quality results are generally organized by water years, which start October 1st and end September 30th. Topographic monitoring involves field survey and reoccupation of known benchmarks. The topographic component of monitoring is conducted every other year. This report provides monitoring results and findings for water year 2022 (October 1, 2021 to September 30, 2022). The topographic monitoring was not performed this year.

The Martin Slough Enhancement Project Monitoring Plan (RCAA 2021) provides performance and success criteria to evaluate whether the project is performing as intended. With the project fully completed at the end of water year 2021, and the introduction of the intended tidal amplitude, tidal prism, hydrologic circulation, and water quality conditions at the beginning of water year 2022, future monitoring results will be compared to the project performance and success criteria. For water year 2022, monitoring of two parameters (hydrology, and water quality) will be used to assess water quality conditions, evaluate inundation of revegetated wetland areas, and used to guide management.

2.1 Topographical Parameter

The objectives of monitoring the topography parameter are to monitor persistence of, and identify changes in, post-construction topographic conditions. As scheduled in the Martin Slough Enhancement Project Monitoring Plan (RCAA 2021), topographic monitoring occurs at the end of years 1, 3 and 5 as funding is available. Topographic monitoring was completed for water year 2019 for the portions of the project constructed on the NRLT (Phase 2) property. The 2021 report presented topographic monitoring for Phase 2 Year 3 and Phases 3-4 Year 1. Phase 5 Year 1 monitoring is being delayed one year to consolidate all the topographic monitoring for all the phases to occur on odd years. Topographic monitoring will be conducted for the entire project in the /fall of 2023.

Large wood features placed throughout the project were visually inspected at the conclusion of water year 2022. These included large wood cover structures on the North Fork tributary and log weirs installed in the mainstem at the upstream end of the project as part of Phase 5 construction. The inspection focused on determining if any of the wood had moved, if any steel anchors were loose or corroded, and if any undesirable scour induced by the structure had occurred.

2.2 Hydrology Parameter

The objectives of monitoring hydrology of the project are to measure water level fluctuations relative to tidal influence within the project area to:

- Evaluate the extent to which the project muted tides match the design muted tidal ranges
- Assess flow conveyance (in both directions) through the project reaches, and
- Assess whether the higher muted tides (spring tides) during the dry season are remaining within acceptable ranges and not inundating adjacent pasture (NRLT) and greens (Eureka Municipal Golf Course).

Results from the monitoring can be used to guide adjustments to the tide gate MTRs (Muted Tide Regulators) and identify if any flow constrictions are affecting project performance.

2.2.1 Water Level Monitoring

The methods used to monitor project hydrology consisted of installation of submersible water level loggers in four locations throughout the project reaches, three on the mainstem of Martin Slough and one on the North Fork tributary. The loggers measure the hydrostatic pressure above the sensor and are corrected using recorded atmospheric pressure to calculate the stage, or water level, in 15-minute intervals. Each monitoring station consists of a perforated PVC standpipe secured to a T-post or other stable feature. The data logger is placed at the bottom of the standpipe and connected with a cable or cord to the cap for retrieval. A reference benchmark was established at each site and surveyed to convert water levels to water surface elevations in North America Vertical Datum 1988 (NAVD88). The data loggers were downloaded approximately every two months by RCAA staff and serviced or repaired as needed. At least one water level observation was made during each download period to calibrate the recorded data to the reference benchmark, placing all water level data into the NAVD88 vertical datum.

Stage data was recorded after Phase 1 completion starting in March 2017, expanded after Phase 2 completion and expanded further following implementation of Phase 3 and 4 and following Phase 5 completion. The following monitoring stations/locations were maintained during water year 2022. Dates of gage installations and periods when data loggers were removed for servicing are provided in **Table 1**.

Phase 1

Property Line: Middle Reach of Martin Slough on NRLT property, near the property line with the Eureka Municipal Golf Course, a water level gage was installed in Martin Slough on March 14, 2017 and was in operation through July 11, 2018, when it was removed for construction of Phase 2. This gage has been discontinued and was replaced by the Hole 18 (MS-18) gage after construction in 2018.

Swain Slough: In Swain Slough near the tide gate a water level logger was installed on February 11, 2018 and remains operational.

Phase 2

MS-Pond C: Lower Martin Slough on NRLT property, a water level logger was installed in Martin Slough, upstream of the confluence with Pond C on December 17, 2018 and remains operational.

MS-18 (Hole 18): Middle reach of Martin Slough on the Golf Course property, a water level logger was installed in Martin Slough between Hole 17 and 18 (downstream of Pond E) on the golf course on November 19, 2018 and removed on October 22, 2019 for Phase 3 construction. Following Phase 3 construction this water level logger was reinstalled on November 5, 2019 to the newly constructed vehicle bridge and remains operational.

Phase 3

MS-NF: Upper reach of Martin Slough, a water level logger was installed in Martin Slough downstream of the North Fork tributary confluence on the golf course on November 5, 2019 and removed on September 9, 2020 for Phase 4 construction. They were reinstalled in December 2020, moving the station to a bridge on the North Fork tributary just downstream of the existing irrigation pond and future Pond G. The gage was removed from May of 2021 to November 2021 for maintenance and construction of Phase 5. When the gage was reinstalled, it was replaced with stage and surface salinity data logger, the bottom salinity logger was removed. The gage remains in the North Fork tributary and remains operational.

Table 1. Water year 2022 dates of water level logger installations and replacement.

Gaging Station	Data Type	Installation	Replaced	Purpose
Atmospheric	Stage	12/14/20	12/15/21	New Data Logger
Swain Slough	Stage	10/2/20	12/15/21	New Data Logger
Pond C	Stage	9/4/21 to present		Replaced cable for
	Salinity Surface	9/4/21 to present		all loggers on 5/4/22
	Salinity Bottom	9/4/21 to present		
MS-18	Stage	9/4/21 to present		
	Salinity Surface	9/4/21	4/14/2022	New Data Logger
	Salinity Bottom	9/4/21	4/14/2022	New Data Logger
MS-NF	Stage	11/12/21 to present		End Construction
	Salinity Surface	11/12/21	4/14/2022	New Data Logger

2.2.2 Tidal Datums

Humboldt Bay experiences semidiurnal tides: two high tides and two low tides per day. The tidal datums of Mean Higher High Water (MHHW), Mean Lower High Water (MLHW), Mean Higher Low Water (MHLW), Mean Lower Low Water (MLLW), and sometimes Mean Tide Level (MTL) are used for designing and evaluating performance of tidal restoration projects. A key metric in sizing and maintaining tidal channel geometry is the average tidal prism, which is defined as the volume of water that drains between MHHW and MLLW.

The tidal datums (in NAVD88) from the Humboldt Bay North Spit NOAA Station No. 9418767 were used as a reference for unmuted tidal conditions. Tidal datums for each monitoring station were calculated on a per-month basis and seasonally using the recorded water levels. A spreadsheet algorithm was used to identify the daily MHHW, MLHW, MLLW, and MHLW and calculate the monthly averages.

2.2.3 Tidal Prism

The volume of tidal water exchanged between MHHW and MLLW defines the tidal prism. It is a key parameter in the design and self-sustainability of the project. Though Martin Slough receives freshwater inflows, the hydraulic geometry of the tidal channel of Martin Slough will be governed by the daily tidal flux created by the muted tide rather than less frequent high flow events from

upstream. The daily tidal prism is a governing factor in the dimensions of the channel, and a significant reduction in the tidal prism could cause sedimentation and a decrease in the channel cross-sectional area. Changes in MHHW or MLLW during the dry season would suggest a change in tidal prism, and may require changes in tide gate settings to restore the intended tidal prism and maintain geomorphic stability of the tidal channels. Tidal prism is calculated based on the surveyed cross section and is therefore only presented for the years when topographic survey is completed.

2.3 Water Quality Parameter

The objectives of monitoring water quality parameters are to measure salinity, dissolved oxygen and water temperature to assess sufficiency of water quality for target habitat and species and ensure that salinity does not extend upstream to the golf course irrigation pump intake, when in use. The methods used to measure water quality parameters consisted of installation of temperature and salinity data loggers at the same locations as the water level loggers (salinity loggers were not installed at Swain Slough).

Salinity data loggers, which also record water temperature, were installed in each perforated standpipe. At most locations two were installed; one at the bottom coupled to the water level logger and one attached to a float that travels the height of the standpipe and measures conditions approximately 10 inches below the surface. At the MS-NF site only surface salinity was recorded. Salinity and temperature were recorded continuously on the same 15-minute interval as the stage data loggers. Salinity data loggers were not installed at the Swain Slough station, but Swain Slough water temperatures were recorded by the water level logger placed at the bottom of the water column. Spot measurements of salinity, temperature and dissolved oxygen were also taken using a YSI handheld meter and recorded on data sheets when the data loggers were downloaded, which typically occurs at a low tide. Additional water quality measurements were taken as part of the fisheries monitoring, as covered in a separate monitoring report.

Initially, the four salinity loggers installed at Pond C and MS-18 gage stations were loggers that record a range of salinity between 0 and ~12 ppt, much lower than is commonly found in marine environments. This was done to examine the lower salinity levels that impact salmonid usage. At the end of the WY 2021 monitoring season these loggers were exchanged for full range salinity loggers.

Figure 2. Overview of Phases 1 through 5, and location of stage and water quality monitoring stations (image from Google Earth, Oct. 2019).

3 RESULTS AND DISCUSSION

3.1 Visual Inspection

No topographic monitoring was conducted in 2022. Topography was visually assessed on December 7, 2022 from the channel bank as part of the visual inspection of logs weirs and large wood structures. Revegetation efforts appear to be completed following the 2021 construction season. Survival and success of planting efforts was not evaluated during this inspection and is part of a separate monitoring effort.

3.1.1 Mainstem Channel Condition

Bank at Weirs at Upstream End of Project

The channel alignment at the upstream end of the project had caused some scour along the right bank of the upstream most log weir (**Figure 3**), as noted in the 2021 monitoring report. This condition appears to be improving as the upstream channel adjusts to the downstream weir elevations. Based on observations of this location in December 2022, vegetation has grown on the eroded bank, helping stabilize it. No active erosion was observed. This location should continue to be visually monitored.

The downstream weirs have been partially buried by sediment, likely caused by backwater from the high-flow constriction created by the steel plates and brackets associated with the downstream salinity barrier.

Bank at Confluence with Pond F

During Phase 5 construction, the left bank upstream of the maintenance bridge at the confluence with Pond F was observed to have some bank sloughing into the channel. The cause was unknown at the time, possibly due to relic drainage pipes. As a first approach, RCAA planted vegetation along the bank for stabilization. During the visual inspection it was noted that the sedges have become well established and a few of the willow stakes have established. The bank does not appear to have eroded further and the toe of the bank has not spread further into the channel

Bank at NRLT Bridge

A high spot in the channel caused by a slumping bank was identified during the Year 1 survey of Phase 2. This is located immediately upstream of the new bridge and sheet pile retaining wall at the NRLT barn. A section of the right bank appears to be slumping into the channel when observed at low tide, and there are numerous seeps emerging from the adjacent hillside (**Figure 4**). High groundwater along the base of the adjoining hillslope appears to be driving the instability.

Observations made during low tide on December 7, 2022, confirm that the instability is still present and the extents of the slump appear to be relatively unchanged when compared to previous observations. The detailed survey planned for 2023 will be used to assess the condition further.

(a)

(b)

Figure 3. Upstream of the last weir where the project transitions to the undisturbed channel in (a) 2021 and (b) 2022. Alignment of the channel is creating some bank scour along the right bank.

(a)

(b)

Figure 4. Bank slumping along the right side of the channel immediately upstream of the new bridge and sheet pile retaining wall, as seen (a) in December 2020 and (b) in December 2022 at low tide.

3.1.2 Pond Sills

Shortly after construction it was noted that the inlet sill at Pond F was experiencing some erosion and rilling across the surface. A layer of 2x4-inch aggregate was placed on the sills of pond F and G and tamped into the surface to protect the sills from further erosion (**Figure 5**). The sills were inspected and found to be stable with no erosion or channelization occurring.

Figure 5. Inlet sill at Pond F with aggregate placed on the surface to prevent erosion and rilling across the sill surface.

3.1.3 Inspection of Large Wood Structures

The large wood structures were visually inspected from the bank on December 7, 2022 to ensure they were stable and functioning as intended. All structures (Log Cover Structures, Rood Wad Deflectors, and Root Wad Habitat Structures, Log Constrictors, Log Weirs) appeared stable and show no signs of shifting since constructed. No adverse scour along the banks was found in the proximity of the wood structures. The complex wood structures located in the open water of the ponds were partially or completely submerged during the low tide.

During the 2021 construction season RCAA staff filled and compacted voids that formed around the pile logs at the Pond D weirs. These areas appeared stable and no additional erosion or scour was noted. Cattails have colonized the shallow section of between Pond D and the most upstream weir where concrete mats are placed over the existing gas line crossing.

3.2 Hydrology

3.2.1 Muted Tide Regulator (MTR) Settings and Target Water Levels

During water year 2022 the muted tide in Martin Slough was controlled using the 6-foot by 6-foot side hinge gate and associated MTR in combination with the 2-foot by 2-foot auxiliary door (slide gate) connected to its MTR. Both MTR float-switches are located on the upstream side of the tide gate. The 6-foot by 6-foot MTR gate was set to close when water levels in Martin Slough reach approximately 3.25 feet (NAVD88). The auxiliary gate closes when the inside Martin Slough water

levels approached elevation 5.2 feet. This elevation appears to vary by several tenths of a foot from one tide cycle to the next.

3.2.2 Water Level Observations

Water level data, combined with salinity and water temperature data, were plotted for each month of the 2021 water year and are provided in **Appendix A**.

Swain Slough Water Levels

Swain Slough water levels fluctuated similar to those recorded at the NOAA North Spit tidal station (No. 9418767), except that the water level never dropped below 1.0 feet. Two conditions affect this; 1) The gage is located in an outlet scour pool below a drainage flap gate, and the pool becomes disconnected from Swain Slough at the lowest tides in Swain Slough (Figure 6), and 2) A tidal sill located on Elk River downstream of the confluence with Swain Slough results in the lowest tide levels being between elevation 0.5 to 1 foot (NAVD88). This tidal sill was noted in NOAA's historical Elk River tidal station.

Martin Slough near Pond C Water Levels

The plots of Martin Slough water levels at the Pond C gage show water level fluctuating as expected, with the distinct signature of a muted tide that peaks just above elevation 5 feet (NAVD88) and does not drop below an elevation of 1 foot. Higher high tides appear to peak at about 5.5 feet, with an occasional peak just above 6 feet and the highest peak of 6.44 feet on December 23, of 2021. Peaks above 5.5 feet typically occur over one or two days associated with elevated streamflows due to rainfall events.

Martin Slough near Hole 18 Water Levels

The Hole 18 monitoring station (MS-18) is located in Martin Slough, on the golf course vehicle bridge located approximately 500 feet downstream of Fairway Drive. The station is a short distance upstream of the confluence of Pond D and just downstream of the confluence with Pond E.

Tidal influence extends past the Hole 18 gage and is reflected in the water level observations for water year 2022. The water level typically peaks at 5.0 feet with occasional peaks near 5.5 feet. Water level approaching 6 feet is usually associated with an exceptionally high tide or rainfall event.

During water year 2022 the highest water level recorded at Gage MS-18 was 6.29 feet on April 19, 2022. The second highest water level was 6.26 feet recorded on December 23, 2021 and followed a similar pattern as recorded at Pond C. During the dry weather monitoring period (June through September) the Hole 18 monitoring station is tidally influenced with a muted tide pattern fluctuating between a low level of 1 foot and a high of 5.44 feet, closely corresponding to the water levels recorded at the Pond C gage.

North Fork Martin Slough Water Levels

The North Fork Tributary gage was installed and operational starting November 12, 2021 following Phase 5 construction. The baseflow water level during the period recorded is consistently between elevation 2 and 5 feet. The highest water level peak of 6.3 feet, was recorded on December 23, 2021. During the irrigation months (April to August), water level was controlled by the temporary salinity barrier (**Figure 8**). From mid-April through early June high tide peaks are visible above elevation 4 feet, indicating that the weirs are submerged during the peak high tide. From Early June through mid-august the barrier appears to have been raised to elevation 5.0 feet and flow was backed up

behind the barrier. Once the barrier was removed in mid-August water levels fluctuated daily with the tide between 2 feet and just above 5 feet.

Figure 6. Gage installation at Swain Slough.

Figure 7. Gage access at MS at Pond C.

Figure 8. Temporary salinity barrier installed to isolate the municipal golf course irrigation intake from the tidal prism. Located on the mainstem just downstream of the confluence with the North Fork. Photo taken June 29, 2022.

Field Observations of Water Level Conditions

The brackish marsh around Pond C was observed during a low tide (**Figure 9**) while conducting the visual inspection on Dec 7, 2022. The floodplain was wet from the previous high tide and brackish vegetation was established throughout the area. This indicates that brackish water is reaching the upper marshplains as intended by the design. Wood structures on the marshplains are partially submerged during high tide, creating cover habitat.

3.2.3 Tidal Datums

Stage data was analyzed and tidal datums were calculated relative to the NAVD88 vertical datum. Monthly values are provided in **Appendix C**, and averages for the dry season of July through September are provided in **Table 2**. This represents the period of minimal freshwater influence on the tidal channel. For reference, the yearly tidal datums calculated at the North Spit for the Epoch encompassing 1983 to 2001, July through September datums for water year 2022 and the design muted tidal datums are also included in Table 2. Tidal datums for the North Fork Tributary gage were not computed because data collection was interrupted by construction activities and by the seasonal installation of the salinity barrier.

Except for MLLW, which is influenced by a tidal sill in the Elk River Slough that limits draining of the tide, the Swain Slough data collected during this monitoring period appears similar to North Spit, but slightly higher. This is likely due to periods of elevated flows in the Elk River that raise water levels in Swain Slough. When compared to the previous water year (2021) the MMLW, MTL and MHHW decreased by 0.07 feet, 0.03 ft and 0.10 feet respectively.

At the Pond C gage, when compared to the water year 2021 datums, the MTL and MHHW decreased by 0.02 and 0.08 ft respectively while the MLLW increased by 0.07 feet. At the Hole 18 gage, the tidal datums for MLLW increased by 0.10 feet, the MHHW and MTL remained essentially the same as the previous year.

The tidal datums can be used to determine the inundation frequency of areas that have been revegetated with brackish-tolerant plant species. With completion of Phase 5 in 2021, the tide gate settings are no longer being operated based on interim conditions. However, further increasing the tidal range to meet MHHW design conditions of 5.5 feet was not implemented due to concerns with tidal flooding of low-lying greens and the resulting increase in salinity this would cause to the upstream ponds and channel reaches that were intended to provide seasonal freshwater habitat.

Figure 9. Brackish marshplain adjacent to the Pond C channel as seen in December 2022 showing brackish water from previous high tide.

Table 2. Tidal Datums for dry period of July through September 2022 and (2021) at each gage station.

Location	Water Level (NAVD88)			
	MLLW	**MTL**	**MHHW**	**Ave. Diurnal Range**
North Spit (for epoch 1983-2001)	-0.34 ft	3.36 ft	6.51 ft	6.85 ft
North Spit (July -Sept. WY 2022)	0.27 ft	3.95 ft	7.13 ft	6.86 ft
Swain Slough	1.48 ft (1.55 ft)	3.95 ft (3.98 ft)	6.69 ft (6.79 ft)	5.21 ft (5.24 ft)
Martin Slough				
MS Design	1.50 ft	Not Provided	5.50 ft	4.00 ft
MS at Pond C	1.46 ft (1.39 ft)	3.43 ft (3.45 ft)	5.11 ft (5.19 ft)	3.65 ft (3.80 ft)
MS at Hole 18	1.32 ft (1.22 ft)	3.26 ft (3.26 ft)	4.92 ft (5.01 ft)	3.61 ft (3.79 ft)

3.3 Water Quality

Surface and bottom salinity concentrations and water temperatures recorded at each gaging location in water year 2022 are plotted with water level and provided in **Appendix A**. The plots include daily rainfall totals measured at the NWS office on Woodley Island for reference. A table of water quality spot measurements recorded during each data download is presented in **Appendix B**. These include water temperature, salinity, and dissolved oxygen concentrations. Plots of daily average and daily maximum water temperatures are provided in **Figure 10**.

3.3.1 Water Quality Performance Criteria

The project monitoring plan defines performance criteria for salinity, water temperature, and dissolved oxygen (DO). The project monitoring plan defines performance criteria for DO concentrations as being no lower than 4 mg/l when salmonids are anticipated to be present. This is generally applied to surface DO concentrations, as bottom concentrations can be substantially lower when fish are present. For Pond G and the North Fork tributary this is applied year-round, as they were intended to provide over-summering habitat for rearing salmonids. The other ponds and channel are expected to provide seasonal over-wintering salmonid habitat and the water quality criteria apply from late fall into mid to late spring.

Water temperature performance criteria are based on daily values. Water temperature should maintain a daily average at or below 18° C and daily maximum at or below 21°C during periods when salmonids are expected to be present.

For salinity, the threshold is 4 ppt, and is generally applied to the surface salinity concentrations due to higher DO and lower salinity concentrations near the surface where fish would be expected.

3.3.2 Salinity and Water Temperature

The project, when completed, is intended to create a longitudinal gradient of salinity, with highest salinity near the tide gate transitioning to freshwater conditions at the upstream end, with each pond having different concentrations of brackish water. Additionally, stratification is expected to provide a vertical gradient from more saline waters at the bottom to less brackish water near the surface. During rainfall-runoff events the entire project channel length and all the ponds are anticipated to be predominately freshwater. With completion of the project's upstream reach in 2021, the water year 2022 salinity data show brackish conditions have moved upstream as expected.

Water temperatures within the project area are dependent on air temperature, temperature of freshwater inflow from upstream, and temperatures of inflow from Swain Slough. During winter months temperatures are expected to be similar to freshwater streams around Humboldt Bay. During the dry season, areas with brackish water should experience higher water temperatures due to influence from Humboldt Bay and Swain Slough. These can well exceed 20 degrees Celsius due to shallow inundation of mudflats during rising tides in the daytime. Water temperature data from water year 2019 through 2022 show these trends.

Data Logger Reliability

During the end of water year 2021 and start of water year 2022, many of the data loggers that had been in use for the duration of the project had begun to fail due to battery exhaustion. Data loggers were returned to Onset for replacement batteries and data is recovered when possible. When data is not recovered there is a gap in the data plots.

RCAA staff reported that periodically the surface salinity data loggers that are attached to a float would become tangled in the standpipe and remain stuck in the pipe when the water recedes. Downloading the data and reinstalling the loggers resets the logger's position. When this occurs the data is unusable and it can be difficult to parse the data to determine when it became stuck. When obvious the data for that time period has been removed from the data set. Recommendations for improving reliability of the data collection are presented in Section 4.

Swain Slough Temperature

Salinity was not recorded in Swain Slough. Water temperatures in Swain Slough during the fall of 2021 and early winter of 2022 were similar to those measured in the freshwater reach of Martin Slough near Hole 18 gage and upstream at the North Fork Tributary gage, with small diurnal temperature fluctuations (**Appendix A** and **Figure 10)**. However, by mid-April 2022, water temperatures become elevated and both diurnal and tidal influenced temperature fluctuations become more apparent.

Martin Slough near Pond C Salinity and Temperature

In Martin Slough at Pond C, the salinity was highly correlated to precipitation, and stratification was present during periods not dominated by freshwater inflows. During periods between rainfall events the bottom salinity would fluctuate dramatically with incoming verses outgoing tides, while the surface salinity generally fluctuated less and was less brackish. During periods with precipitation, salinity concentrations became close to zero for days at a time. Several days following the cessation of rainfall, the bottom salinity would increase relatively rapidly, while the surface salinity slowly increased with each tide cycle. This pattern was most pronounced in January 2022.

Water temperatures in Martin Slough near Pond C remained low throughout the fall and early winter months. Surface and bottom temperatures were nearly identical much of the time, with periods where the surface water temperature was colder and fluctuated much more with tidal cycles than along the bottom. This is assumed to be associated with stratification during flood tide and then mixing during ebb tide. By May 2022, temperatures at this location began to rise, as did salinity, due to the lack of rainfall. During the summer months water temperatures were between 18° and 22° C and were consistently warmer than Swain Slough.

Martin Slough near Hole 18 Salinity and Temperature

Salinity measurements in Martin Slough near Hole 18 show that during winter and early spring both surface and bottom salinity fluctuated between 0 ppt and 22 ppt almost daily with the tidal cycle. However, starting in April, salinity decreases dramatically with the onset of rainfall. Water temperatures in Martin Slough near Hole 18 fluctuated with tides, and showed diurnal fluctuation with changes associated with precipitation and ambient air temperature. These fluctuations grew more exaggerated in the warmer months starting in April and continuing through September.

All of the loggers at this site were replaced in April with units with refurbished batteries.

North Fork Martin Slough Salinity and Temperature

Salinity measurements are recorded at the surface only for the North Fork Tributary gage, located just upstream of the confluence with the mainstem. Data show that saline water is reaching the upper reach of the Martin Slough project area. When the salinity barrier was installed surface salinity dropped to less than 0.5 ppt. With its removal in August the salinity fluctuated with the tide between 0 and 18 ppt.

Temperature values show normal diurnal fluctuations, with warming during the summer months. This is the area of the project that the performance criteria for water temperature is applied year-round, due to the desire to provide year-round conditions suitable for rearing salmonids. The installation of the salinity barrier influences water temperatures by increasing surface temperature and decreasing bottom temperatures, presumably due to the lack of mixing that occurs when the barrier is installed.

3.3.3 Comparison to Performance Criteria

Salinity

Spot measurements of salinity (**Appendix B**) were almost always above the 4 ppt threshold unless there was rainfall, with the exception in the North Fork tributary which recorded low values of 0.1 and 0.4 ppt during time that the salinity barrier was installed. The continuous data (**Appendix**) show that during the winter months surface salinity at all three gage stations fluctuate with the tide cycle often dropping below the 4 ppt threshold during low tide and for extended periods during precipitation events. During the warmer and drier summer months the Pond C and Hole 18 surface salinity levels show less fluctuation. Starting in May for Pond C and June for the Hole 18 gage, the salinity levels generally remain above 16 ppt and 12 ppt respectively.

During the spring, prior to installation of the salinity barrier in mid-April, North Fork Tributary gage salinity levels periodically exceeded 4 ppt. Following the removal of the salinity barrier in early August salinity climbed to between 12 and 18 ppt. The data shows that, with the temporary salinity barrier not installed the project fails to meet its objective of providing low salinity habitat in the North Fork and Pond G during the summer months. Instead, the salinity concentrations far exceed those suitable for rearing salmonids due to the substantial amount of tidal inflow to the North Fork combined with a lack of freshwater inflow to keep the reach fresh.

The 2022 water year experienced 25.48 inches of rainfall based on the NWS Woodley Island gage in Eureka, CA. The normal recorded rainfall for 1991 to 2020 in Eureka was 41.40 inches. The 2022 water year is 62% of normal and this drier than normal year is one likely cause of the high salinity levels due to the lack of freshwater flowing through the project area or from Swain Slough via Elk River.

Water Temperature

Temperature values recorded during the water year are shown in **Figure 10**. During the months of October through April maximum daily and average daily water temperatures are well below the thresholds of 21° C and 18° C respectively. During the summer months daily average temperature increases to between 18° C and 25° C. From June to August Swain Slough temperatures are also above the average daily threshold of 18° C, with the North Fork recording the lowest values of the three gage stations during the summer months (although the North Fork data set is not complete due to construction in fall of 2021). The data suggests the inflow of tidal water from Swain Slough governs the water temperatures in Martin Slough due to the large degree of tidal cycling. The drier than normal water year and resulting low base flow is one likely cause of the higher temperatures.

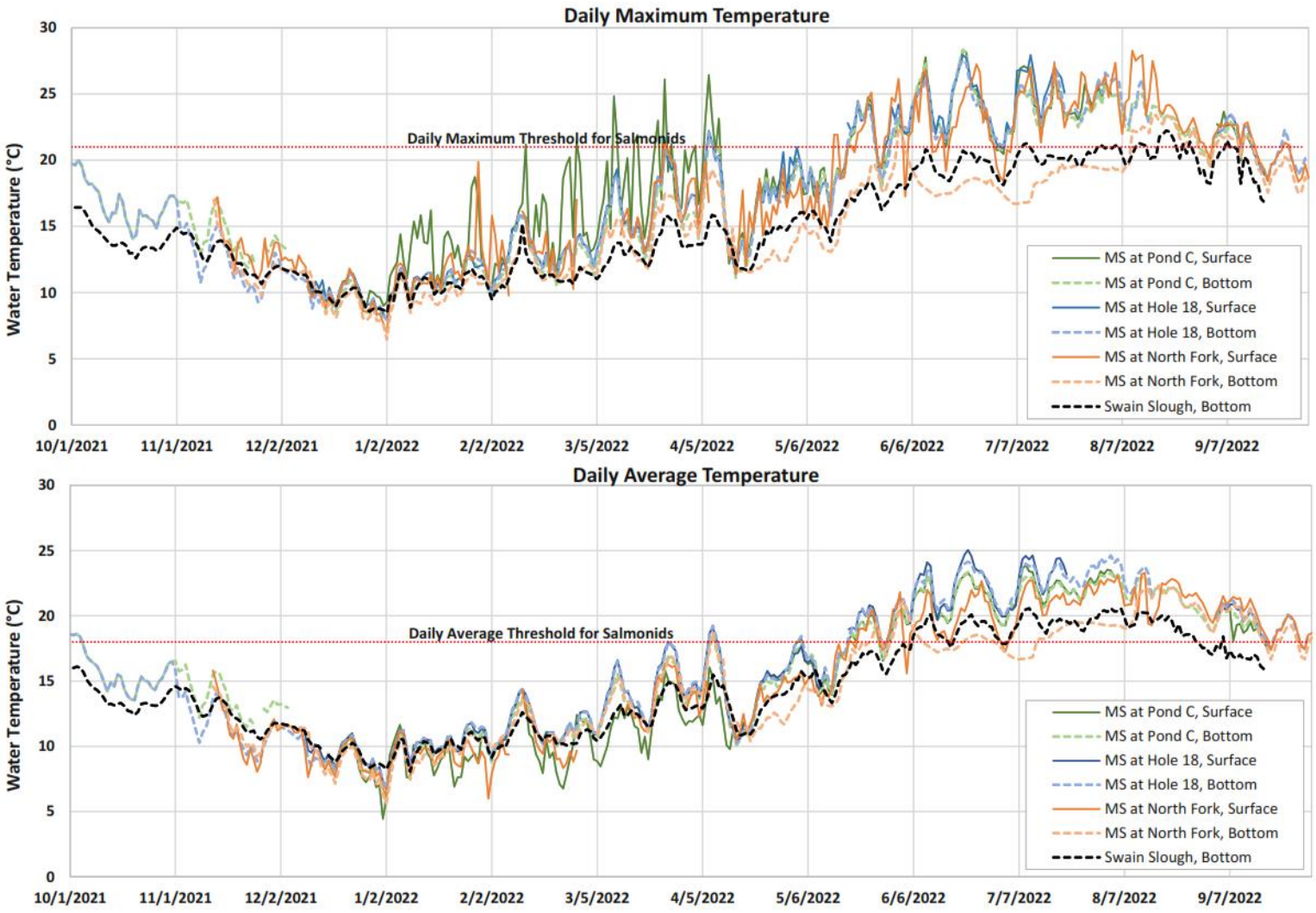


Figure 10. Daily maximum and daily average water temperatures for water year 2022 recorded at the Swain Slough, Martin Slough at Pond C, Martin Slough at Hole 18 and the North Fork Tributary gaging stations. Summer salmonid usage assumed to be in the vicinity of the MS at North Fork station.

Dissolved Oxygen Spot Measurements

Spot measurements of dissolved oxygen (DO) by RCAA staff during each download are provided in **Appendix C**. The measured DO levels at the four sites were generally above the minimum performance criteria of 4 mg/l on the surface, and were often substantially higher. These DO levels are considered acceptable for rearing salmonids and other aquatic organisms.

4 RECOMMENDATIONS

The Martin Slough Enhancement Project has been implemented in phases with the final construction phase completed in 2021. While the restoration project has been completed, the Eureka Municipal Golf Course is still working on establishing an alternative irrigation supply. In the interim the golf course is using the temporary salinity barrier to maintain freshwater at its screened pump intake on the North Fork. When installed, it affects the upstream hydrologic and water quality conditions. However, it does not appear to be influencing downstream water quality.

4.1 Channel Conditions

The high point identified along the thalweg profile around Station 14+00 near the NRLT Bridge is still present. It originated from a slumping bank associated with high groundwater and saturated soils close to the base of the adjoining hillslope. Material may continue to slump at this location, but currently is not significantly constricting the channel or influencing the tidal amplitude. The project manager and project engineer should continue to inspect this site to detect if any additional slumping occurs, and/or if the channel is scouring this material.

The second area of sedimentation noted in the 2019 survey at the property line near the previous grade control should also continue to be monitored to see if this material scours-out or causes a reduction in tidal exchange or outflow of freshwater. This will be evaluated as part of the topographic monitoring in 2023.

The previously noted eroding bank at the upstream end of the project may continue to adjust and should be monitored to ensure the upstream-most log weir adjacent to this location remains stable. Minor bank armoring might be needed to protect the upstream weir and piles. Future channel surveys should include the channel immediately upstream of the project on the mainstem to assess changes to bed elevation and width.

4.2 Water Levels

The 2022 water level data shows that the tidal amplitude and MHHW in Martin Slough are both less than the design values (**Table 2**). Further increasing the muted high tide by adjusting the tide gate settings to better achieve the design condition was discussed but considered undesirable, as it would further increase salinity concentrations in the upper portions of the project, which was intended to provide low salinity aquatic habitat during the dry season. Additionally, there are low areas on the golf course adjacent to the channel that could become inundated during spring tides if the gate is adjusted to increase tidal amplitude. Even with the current lower than design setting, the tidal amplitude and MHHW water levels are inundating the constructed surfaces (i.e. marsh plains) and vegetation is becoming established as intended.

4.3 Water Quality Conditions

The water quality monitoring shows that water temperatures and salinity concentrations in the North Fork are exceeding the performance thresholds during summer and early fall. When the salinity barrier was in place, the salinity concentrations were within criteria, but the water temperature remained above the performance thresholds (**Figure 10**). The higher salinity concentrations are likely due to lower summer streamflows and more tidal-freshwater mixing than assumed during the design. Drought conditions resulting in below average streamflows during 2022

are likely to further influence water quality. Adaptive management options to reduce salinity and water temperatures in the upper reaches of the project should be explored but appear to be limited.

4.4 Monitoring Protocols

The water quality and stage motoring equipment has been in operation since 2017 and as such some equipment require servicing or replacement, especially in the corrosive brackish water environment. Battery levels should continue to be monitored and replaced when the voltage is consistently falling below 3.4 to 3.3 volts.

The monitoring stations should be examined to ensure that the t-posts are sufficiently embedded and the straps holding the pipe are sound. The stainless steel cables inside the standpipes have corroded and were replaced with nylon cord and should be examined during each download.

Access to the Pond C gage is along a log that extends from the toe of the bank into the channel (**Figure 7**). An additional length of metal safety grating should be installed along the log to provide sure footing when accessing the standpipe. A rope staked into the bank would also be helpful for traversing the steep bank.

Increasingly, the floats in the standpipes that keep the upper salinity data logger at the water surface have become stuck after high tides, leaving them dry until the next high tide event. This unfortunately leaves portions of the upper salinity dataset unusable. The floats should be changed-out for a smaller spherical float that allows for unfettered movement as the tide rises and falls. The standpipes are 4-inch diameter and a 3-inch diameter or smaller ball float should improve the performance. Additional weight applied to the existing data loggers may also help.

5 REFERENCES

NOAA, 2003. Science-based restoration monitoring of coastal habitats, Volume 1: A framework for monitoring plans under the Estuaries and Clean Water Act of 2000.

RCAA, 2021. Martin Sough Enhancement Project Monitoring Plan. August 2013, Revised November 2021. By Redwood Community Action Agency Natural Resources Services Division.

Appendix A

Martin Slough Water Level and Water Quality Data
Water Year 2022:

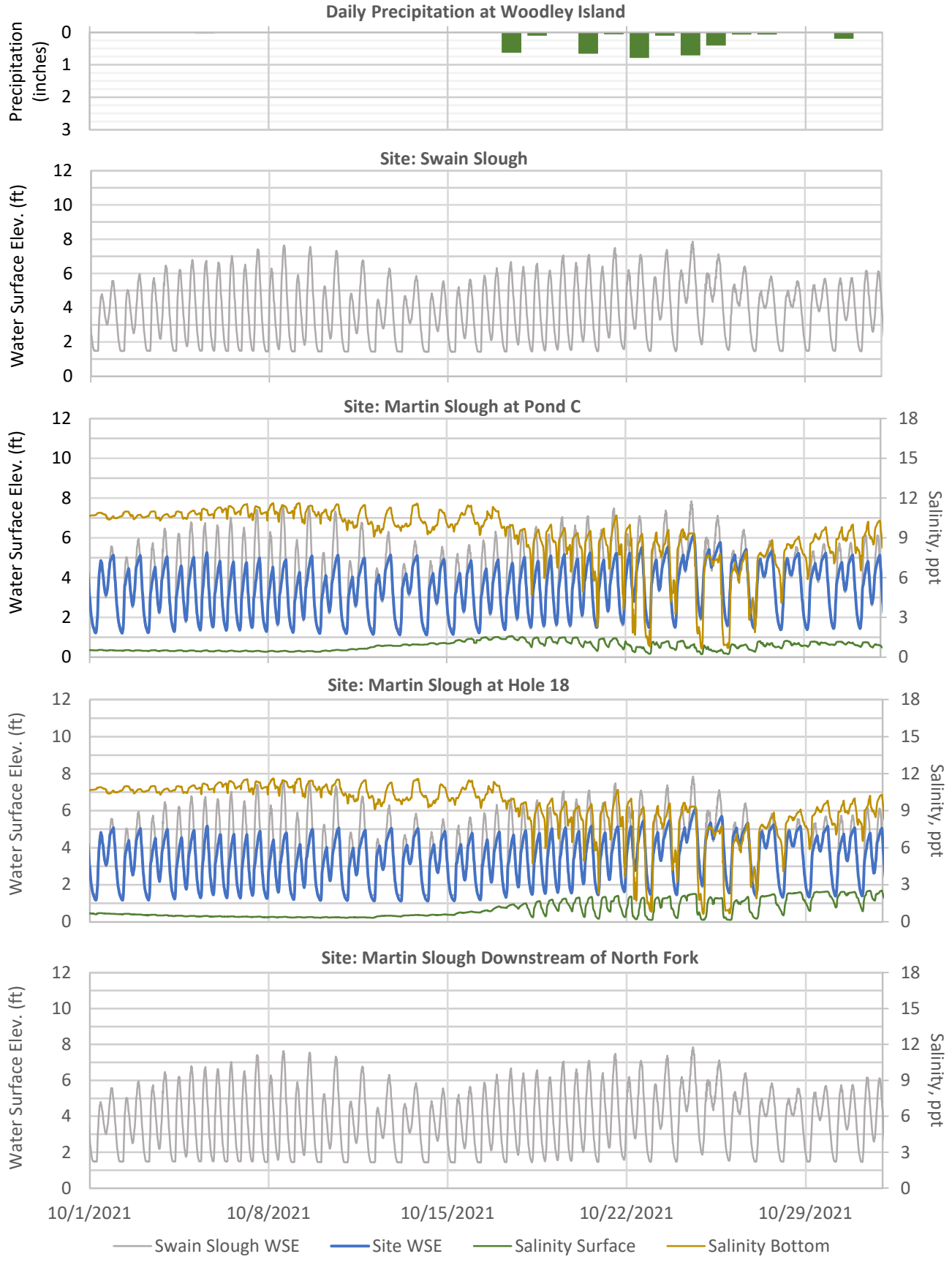
1) Stage and Salinity Plots

2) Stage and Temperature Plots

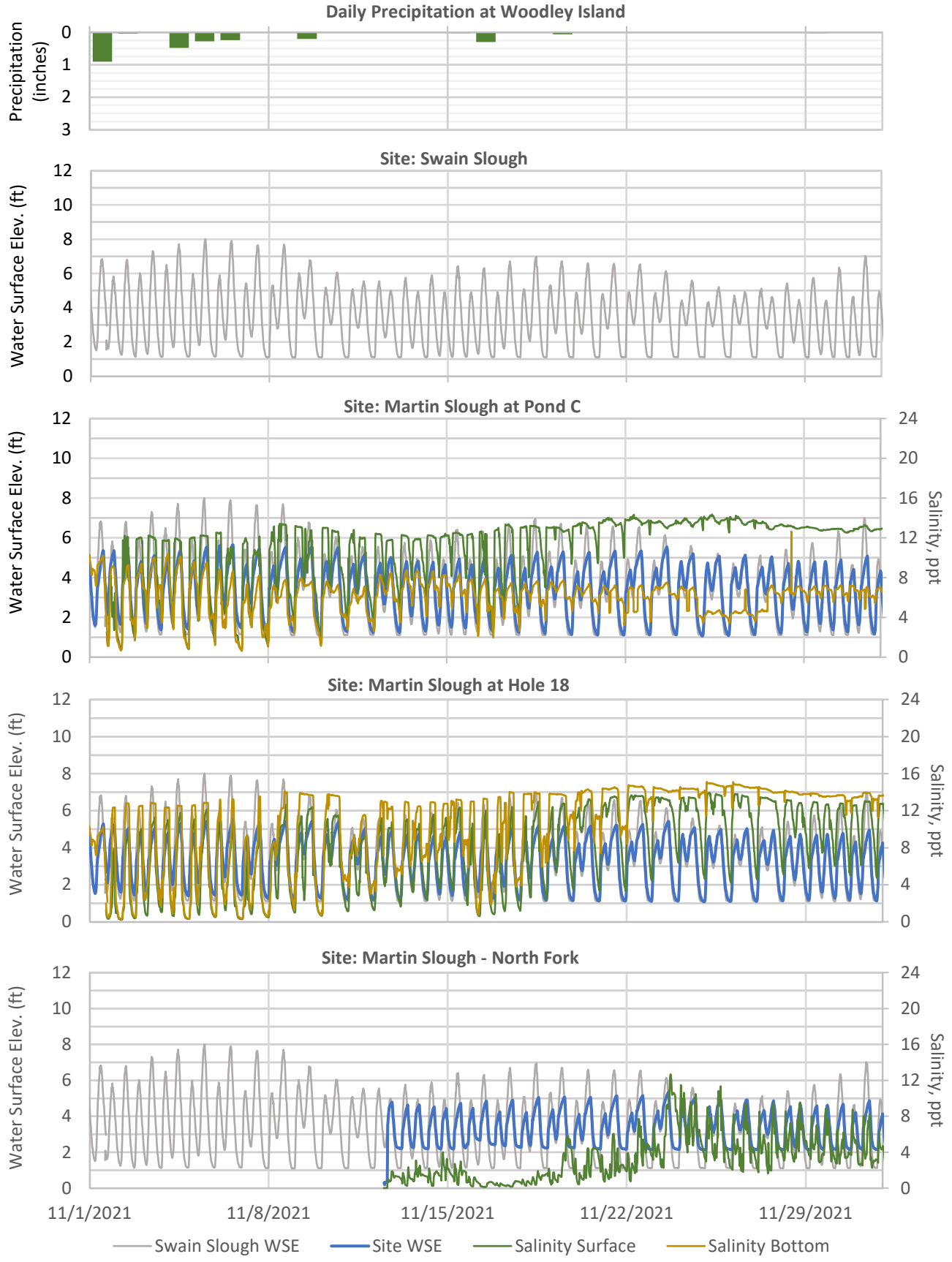
Martin Slough Water Level and Water Quality Data:

Stage and Salinity Plots

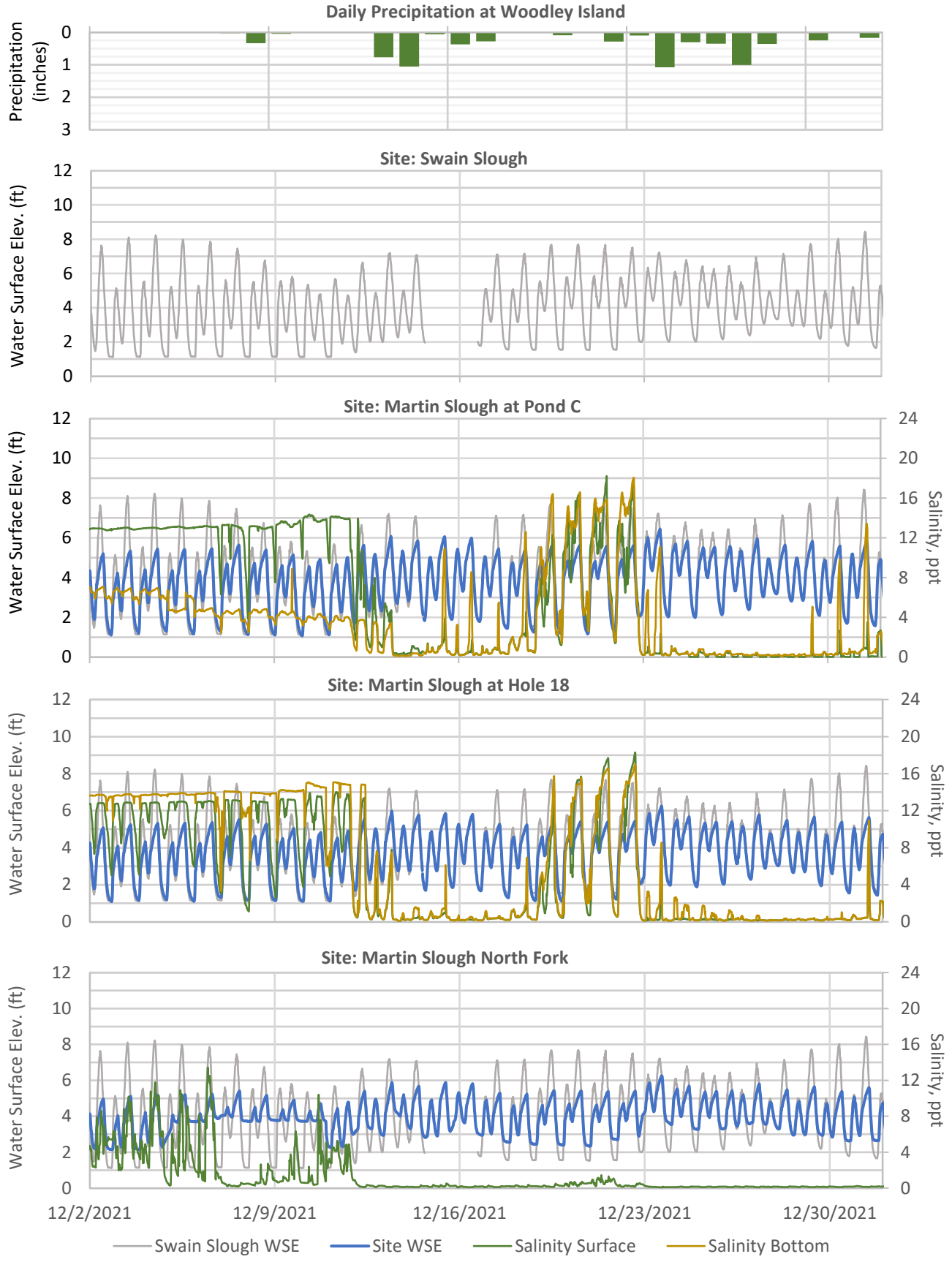
Martin Slough **October 2021**



Martin Slough **November 2021**



Martin Slough **December 2021**



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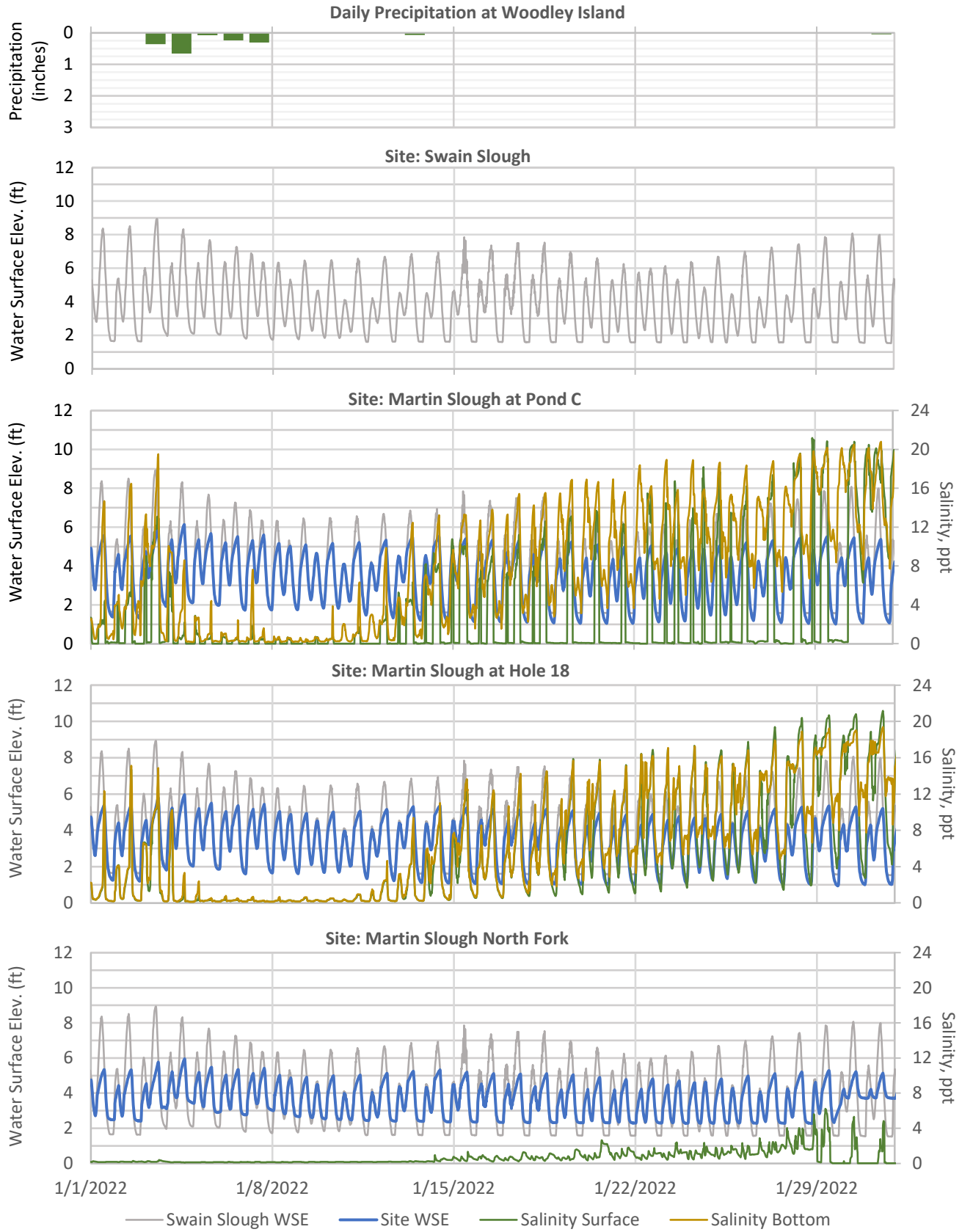

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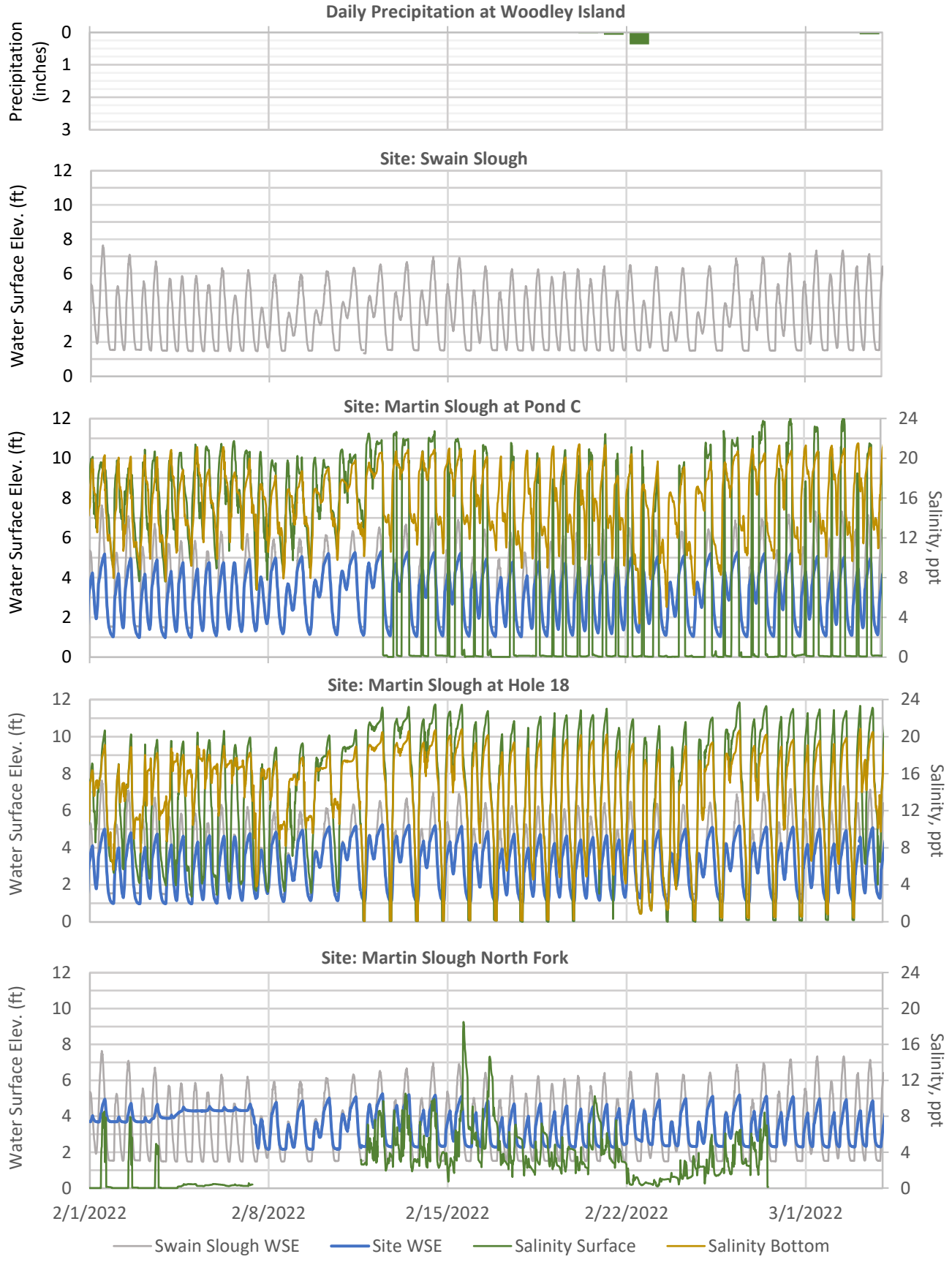

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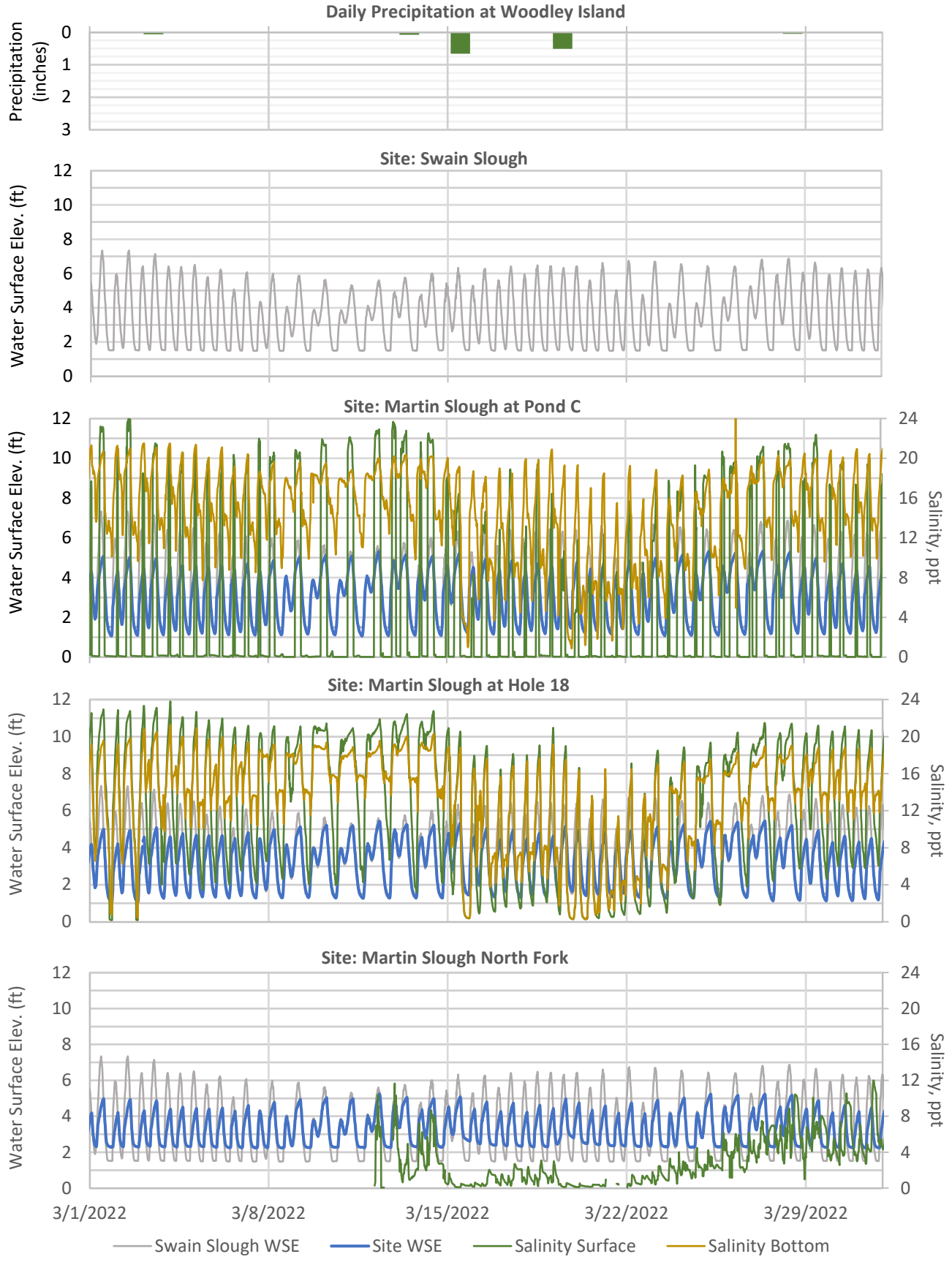

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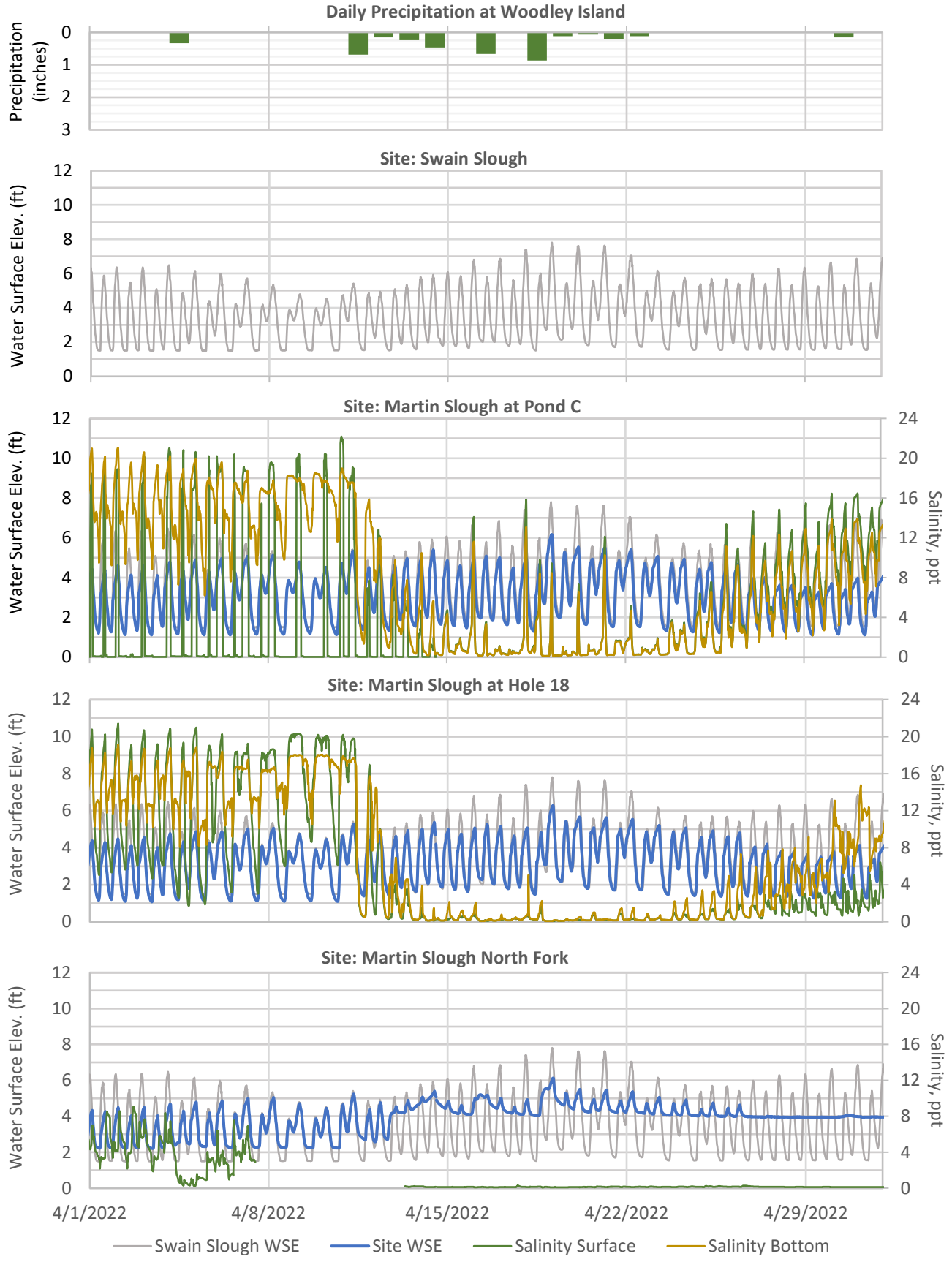

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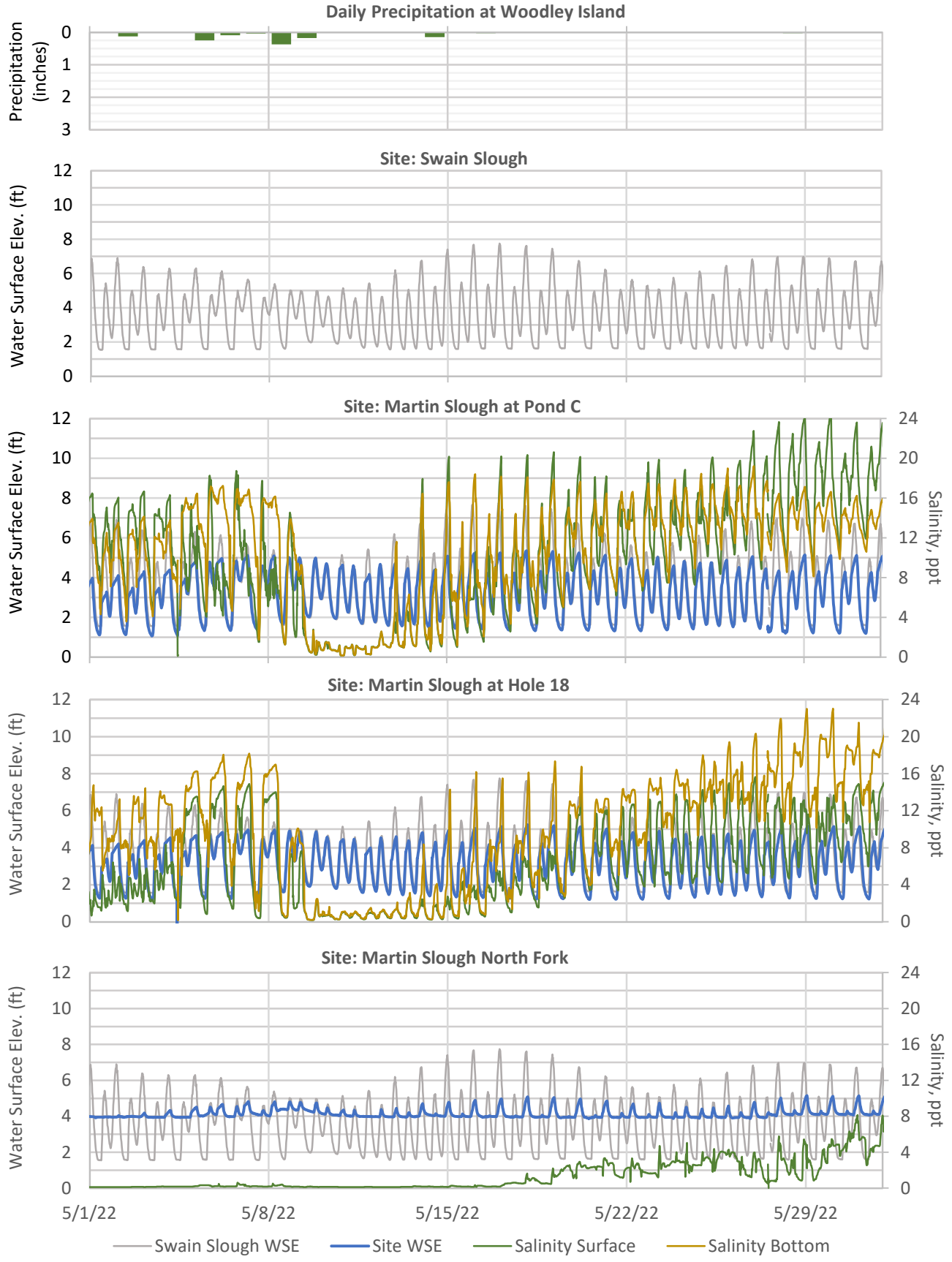

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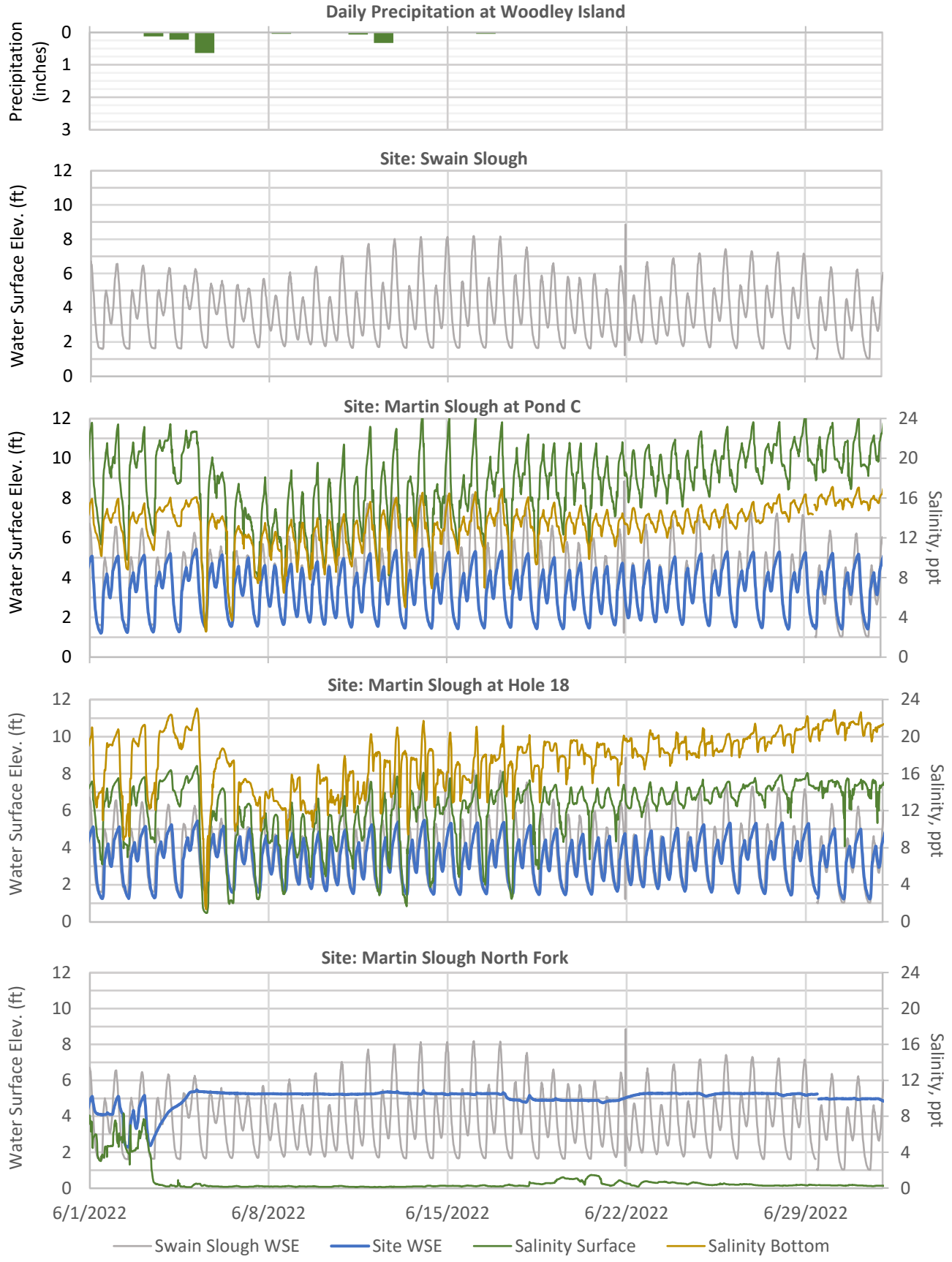

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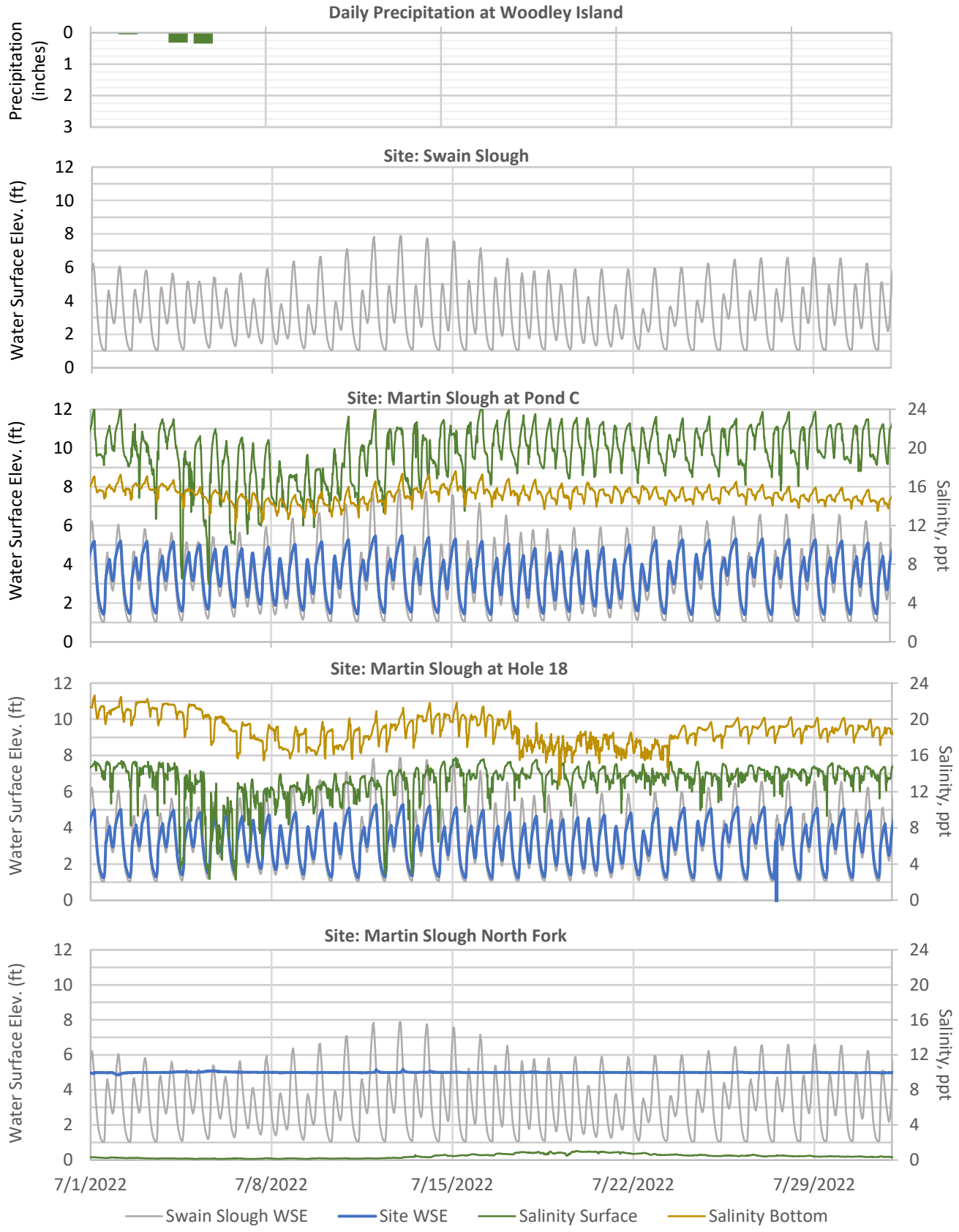

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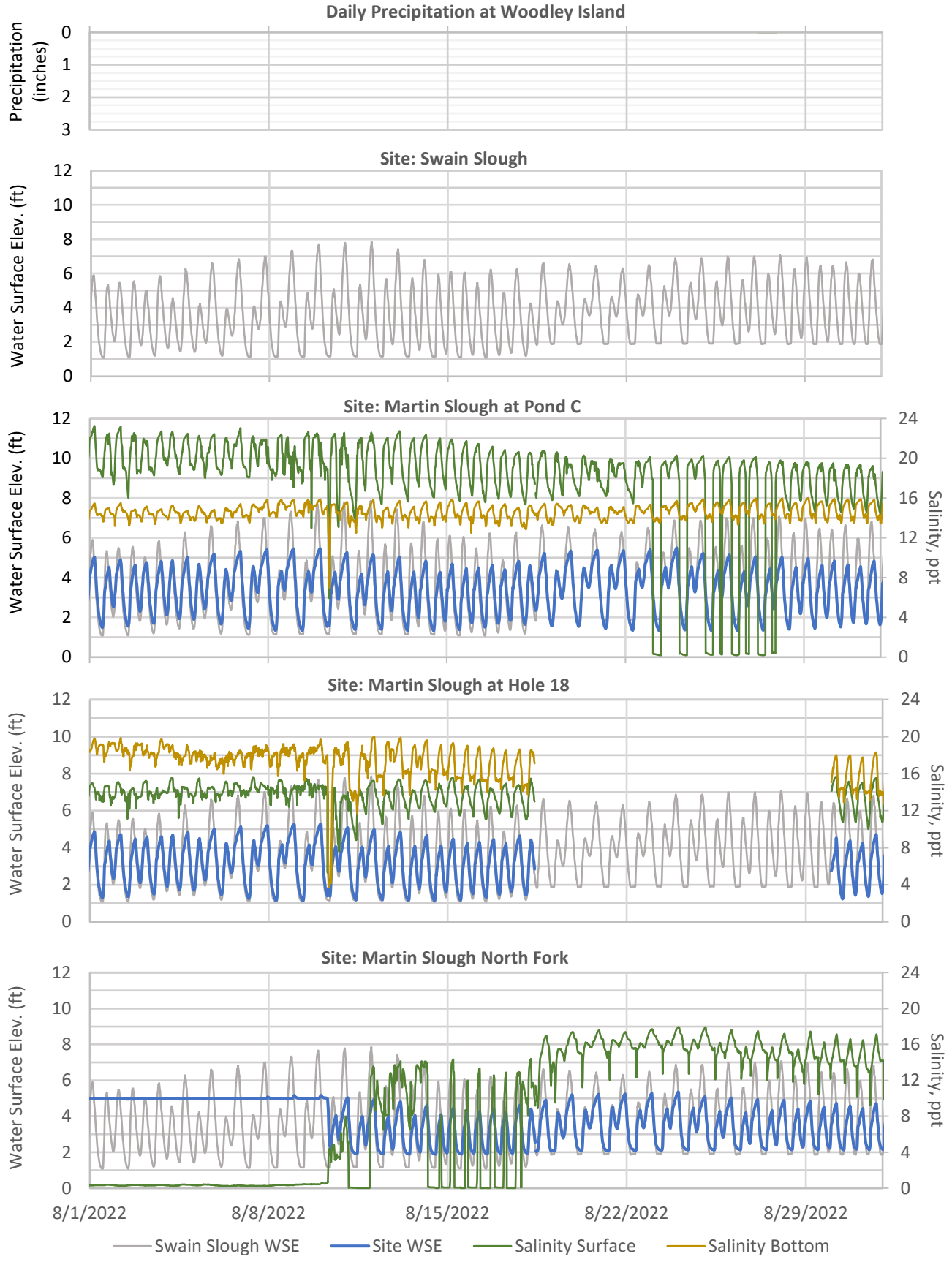

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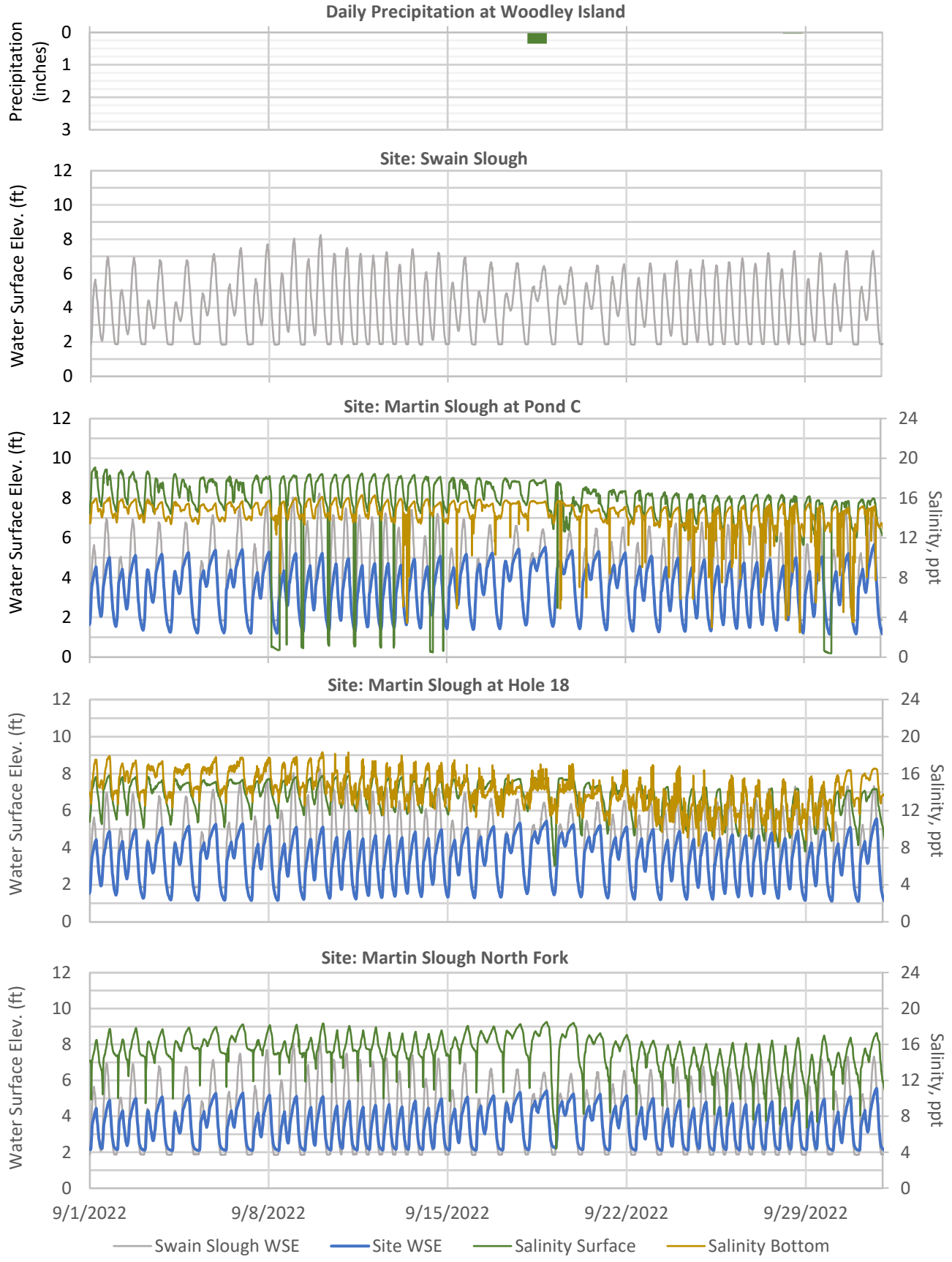

Martin Slough Water Level and Water Quality Data:

Stage and Temperature Plots

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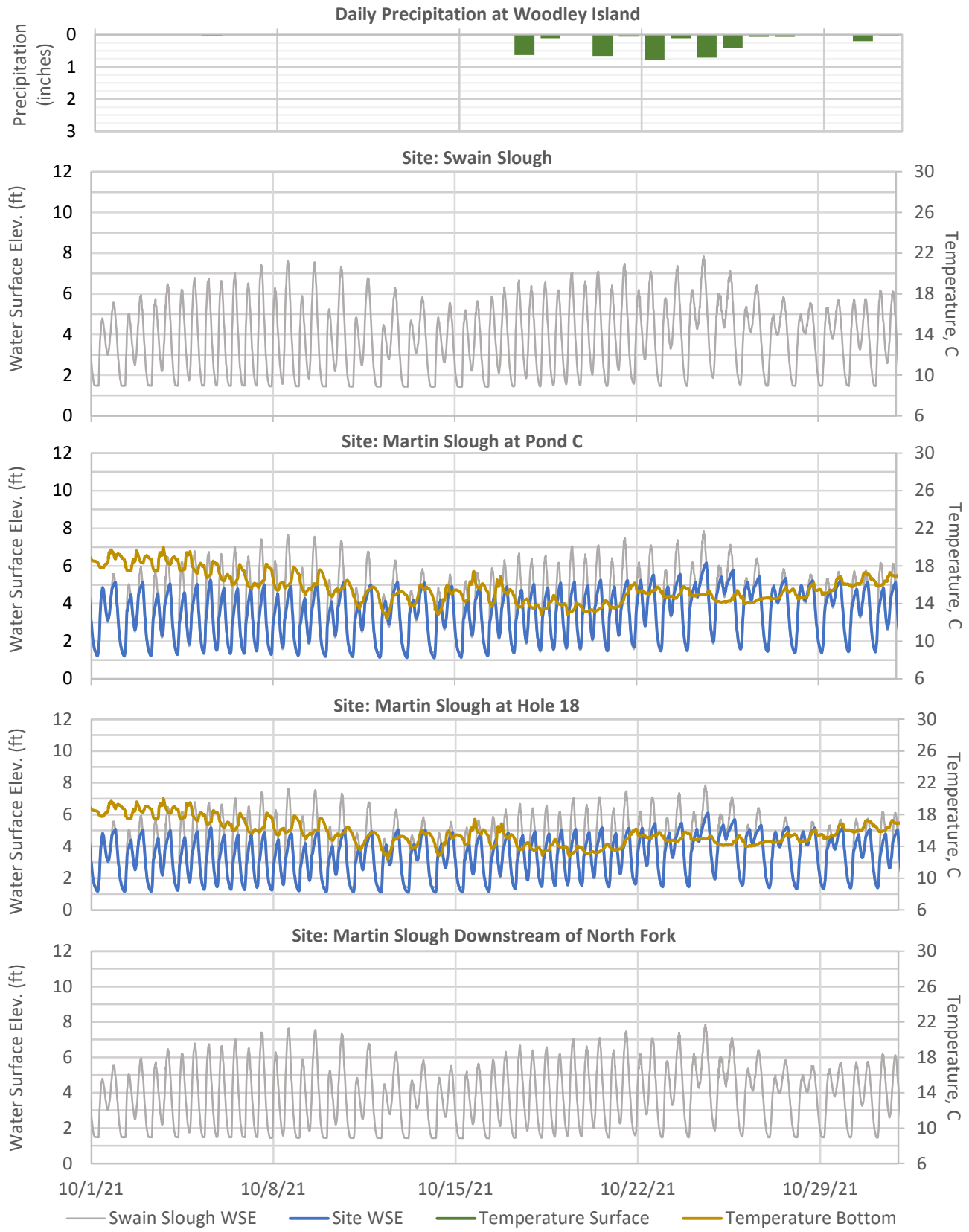

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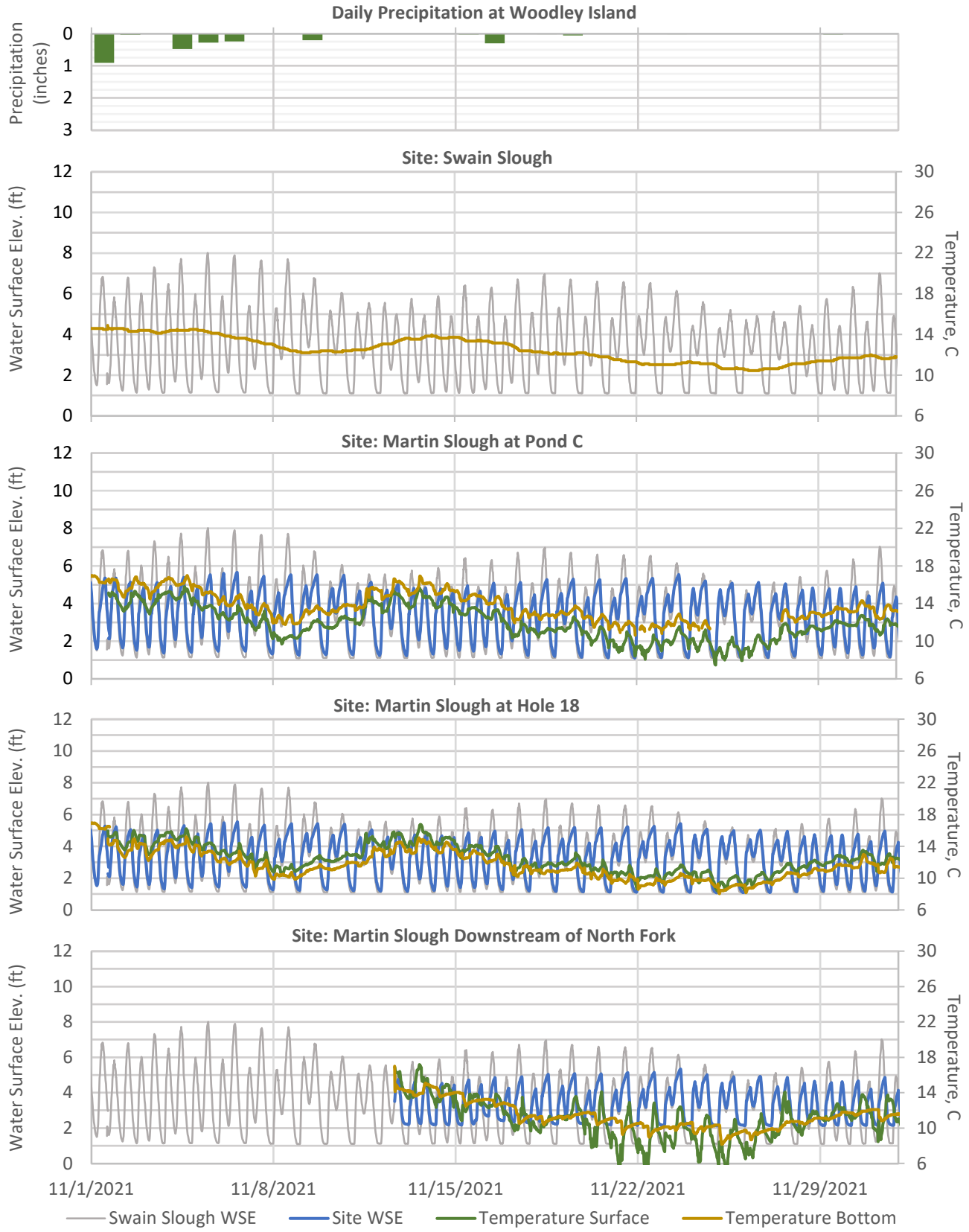

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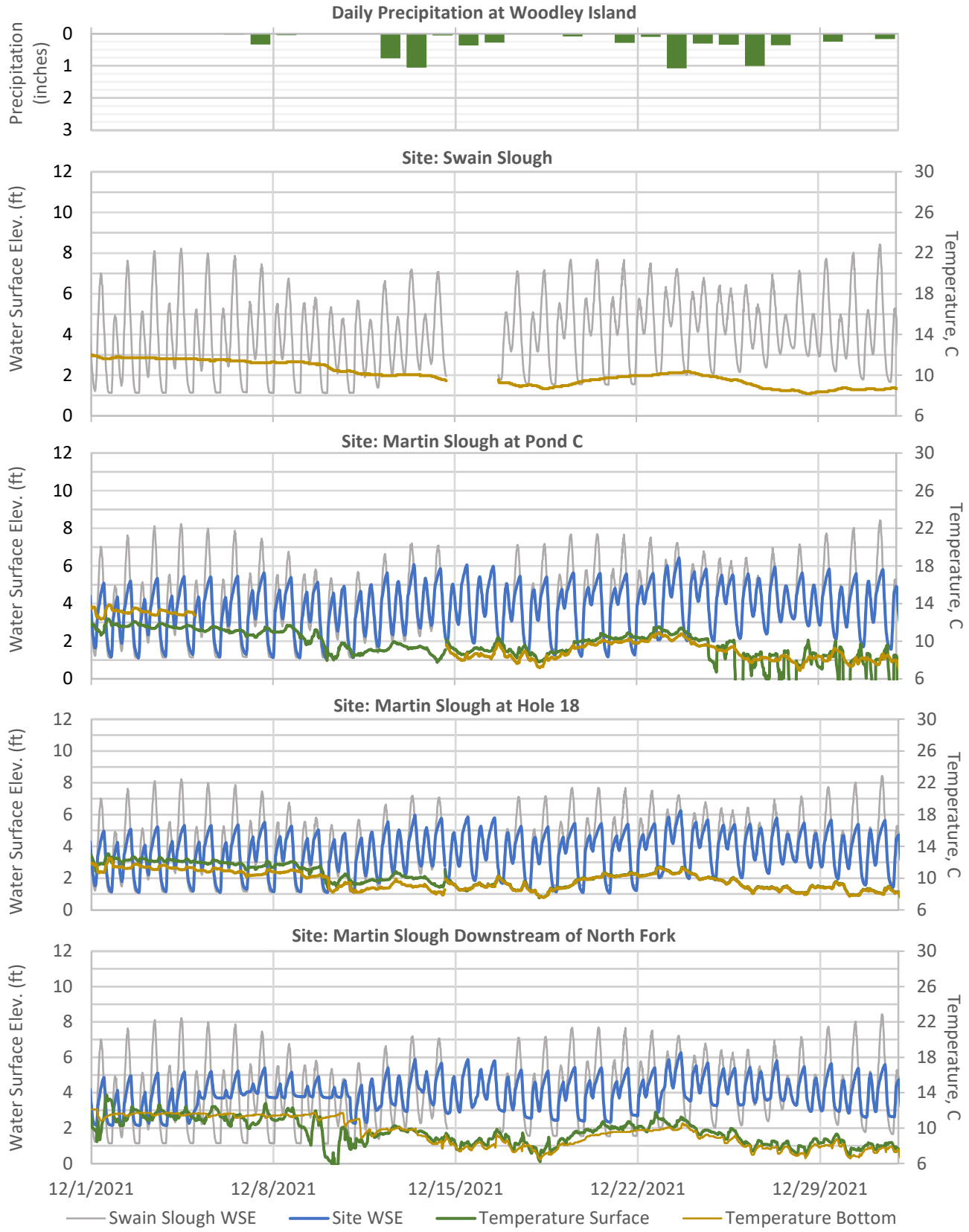

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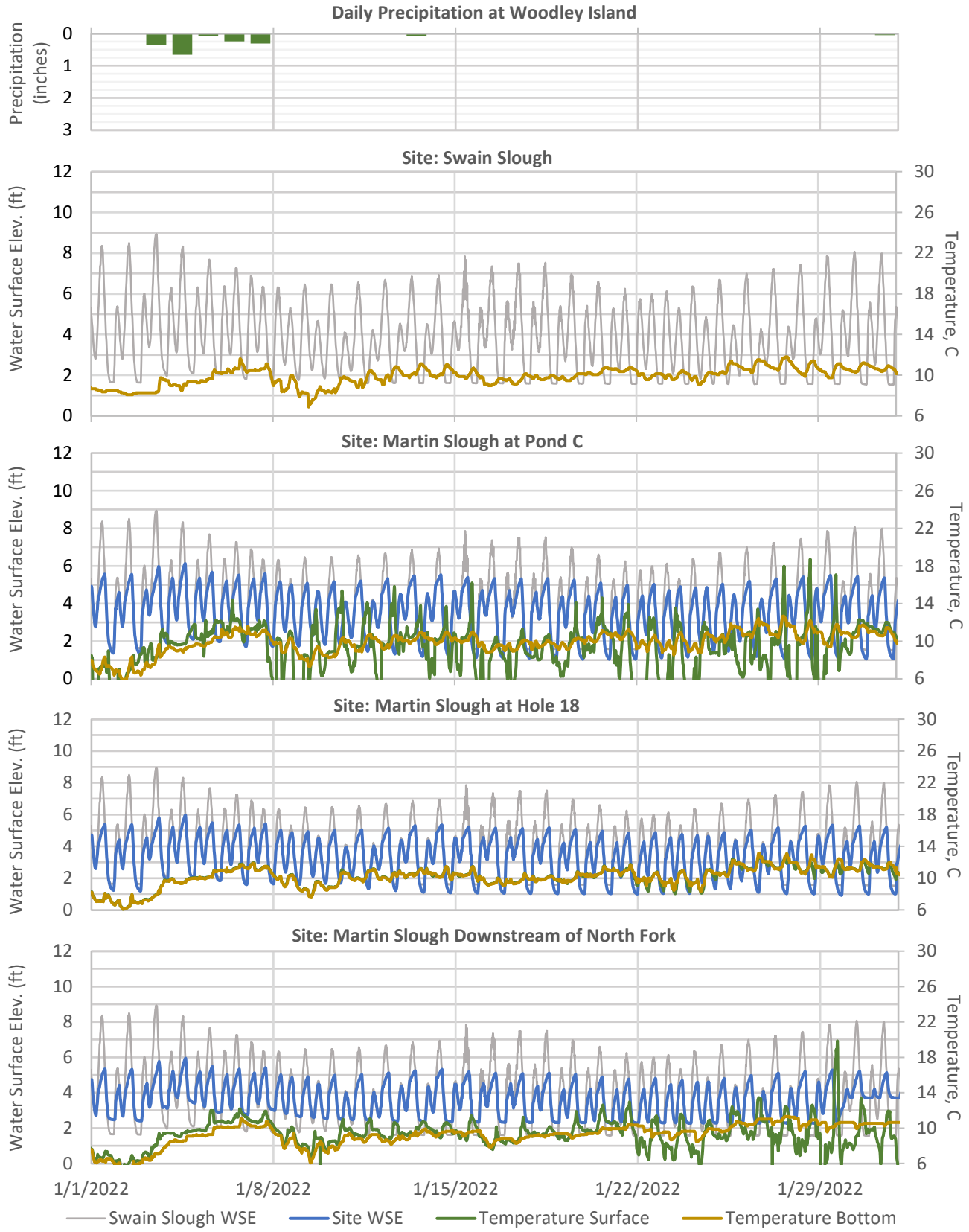

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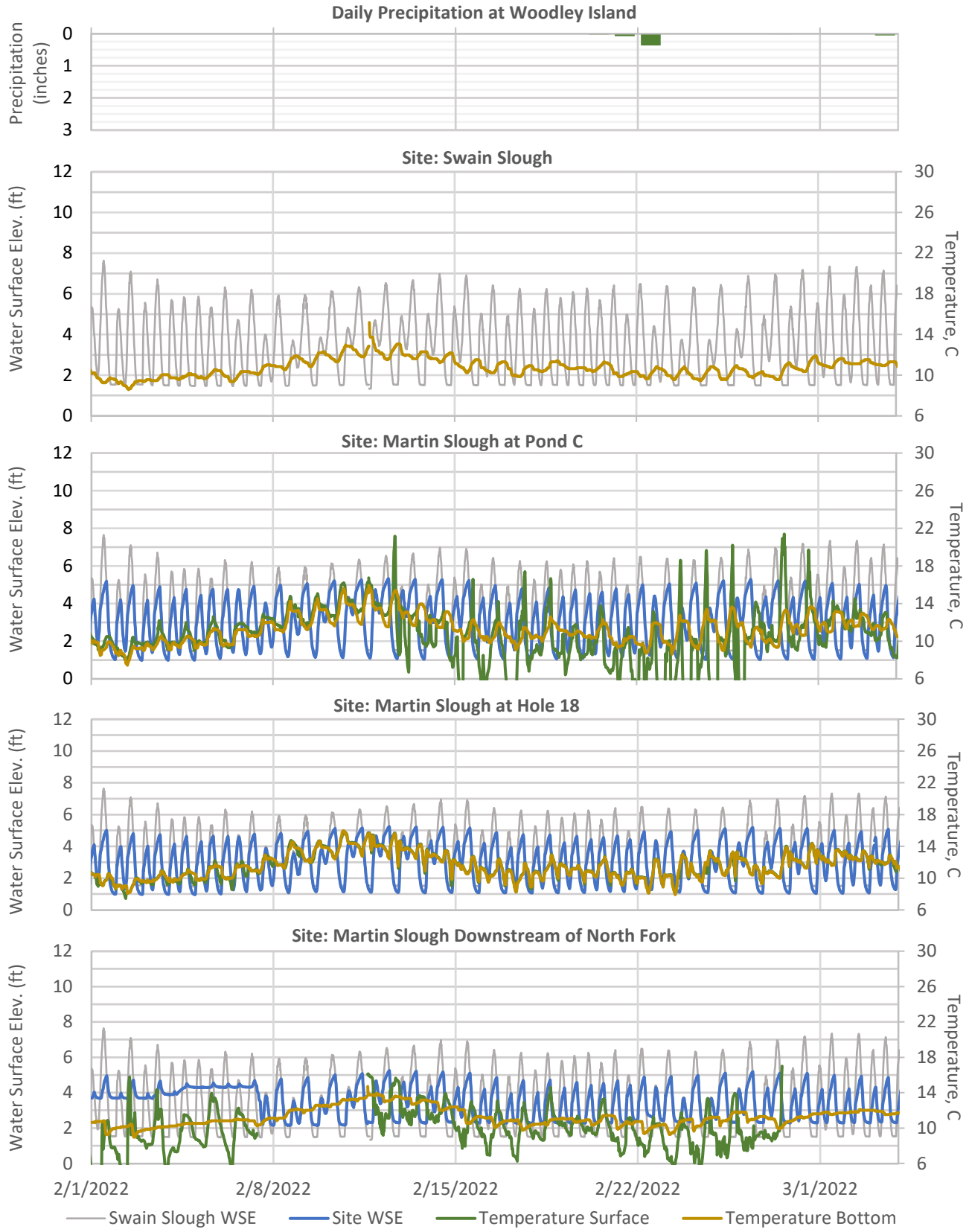
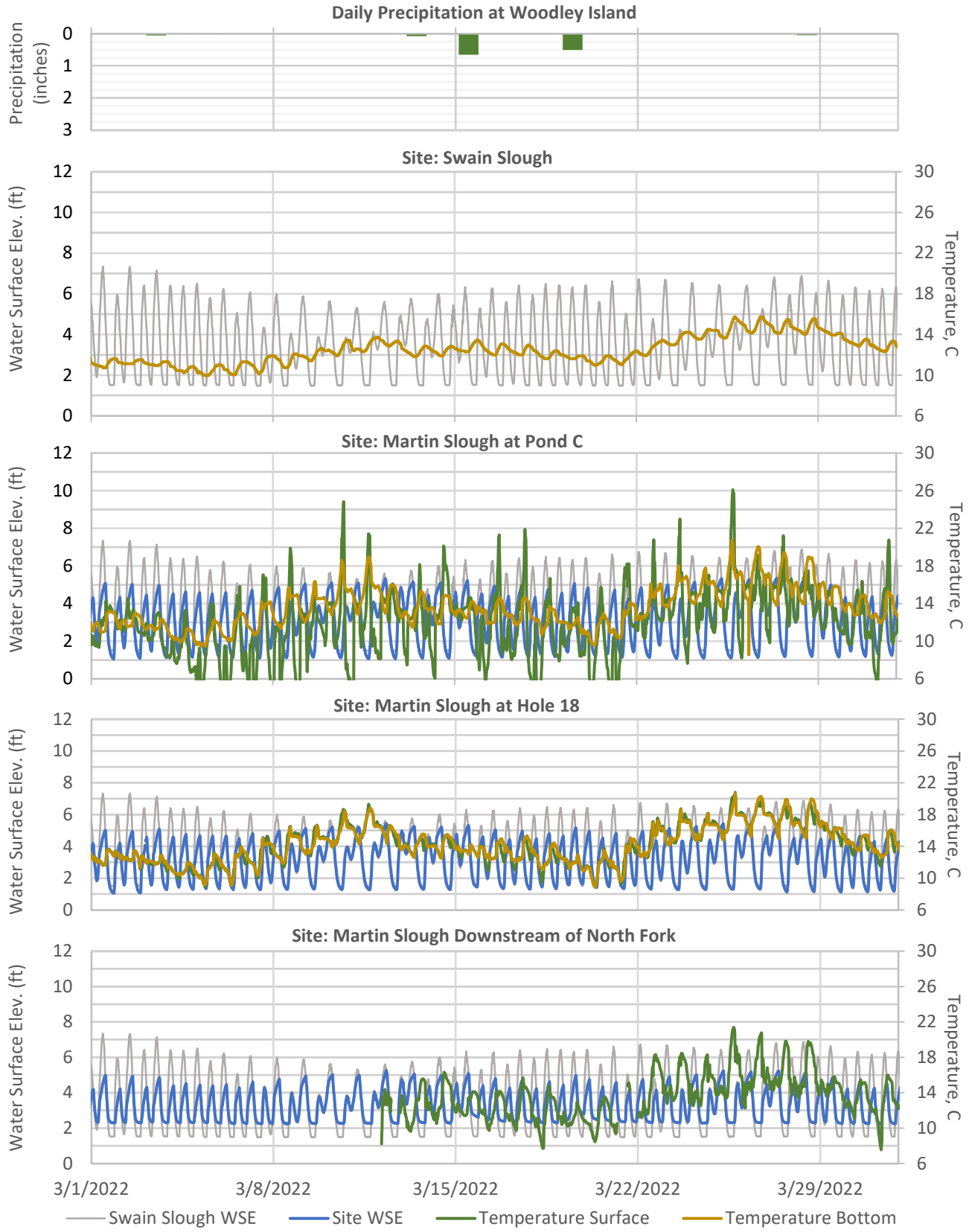


Martin Slough **March 2022**



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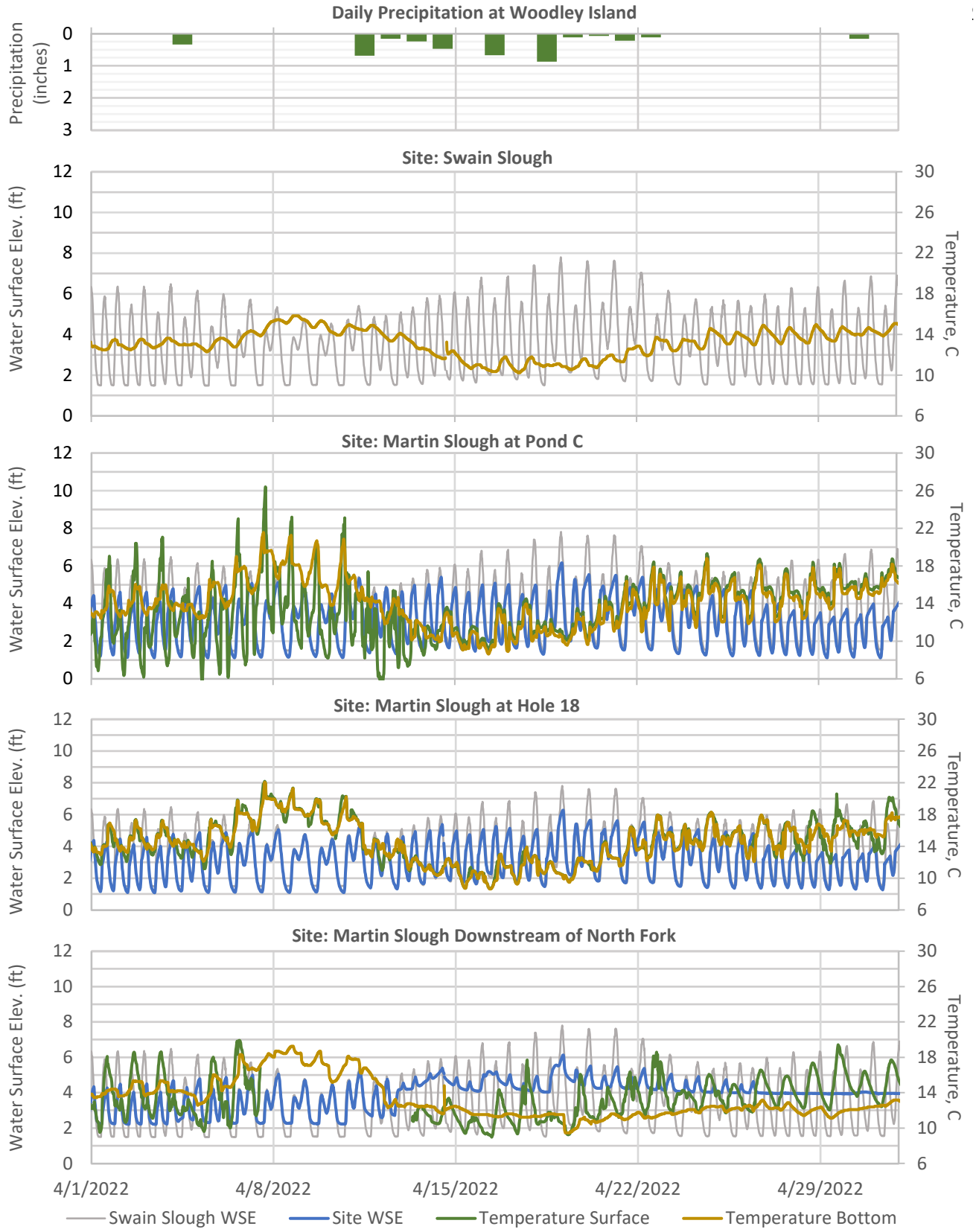
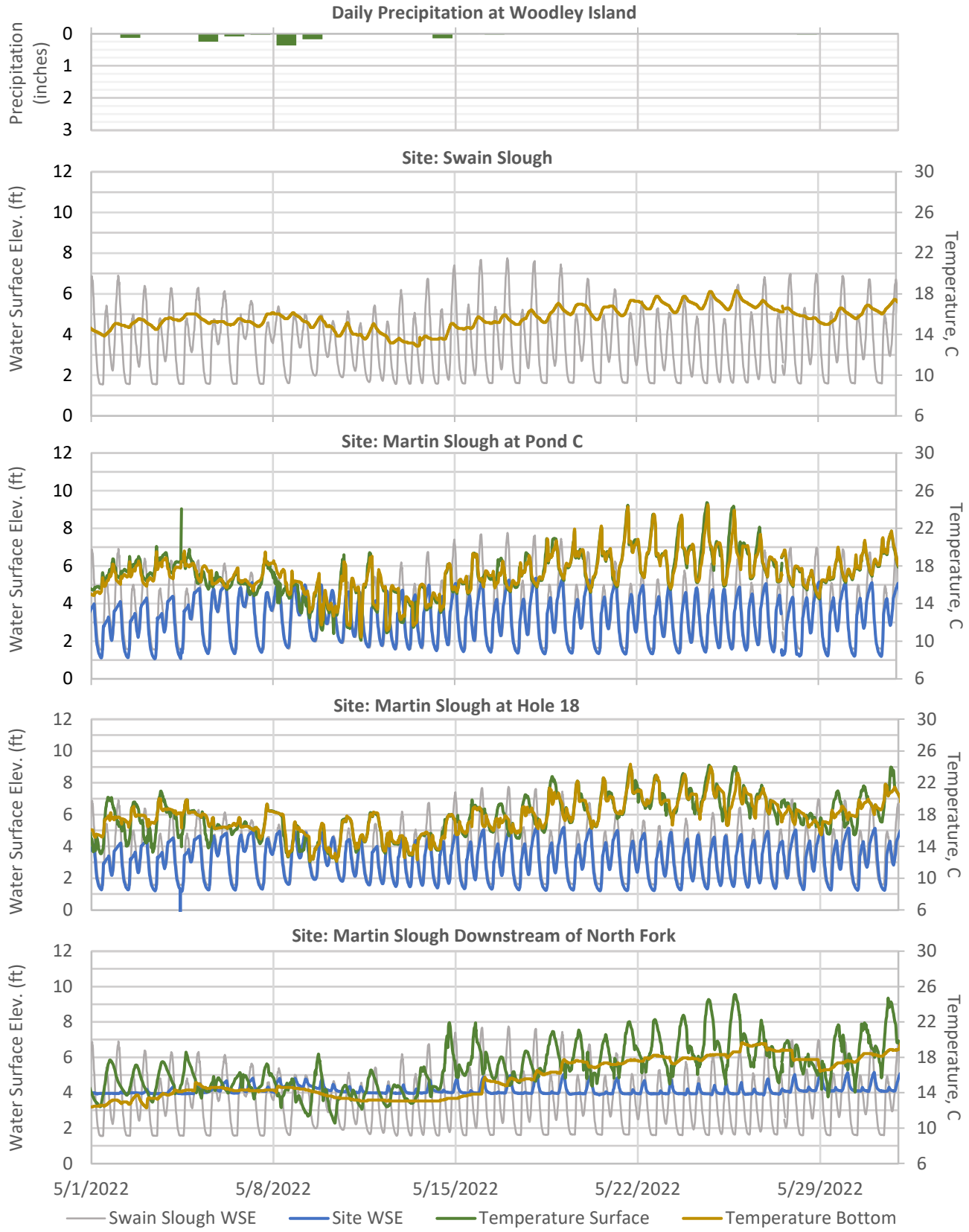
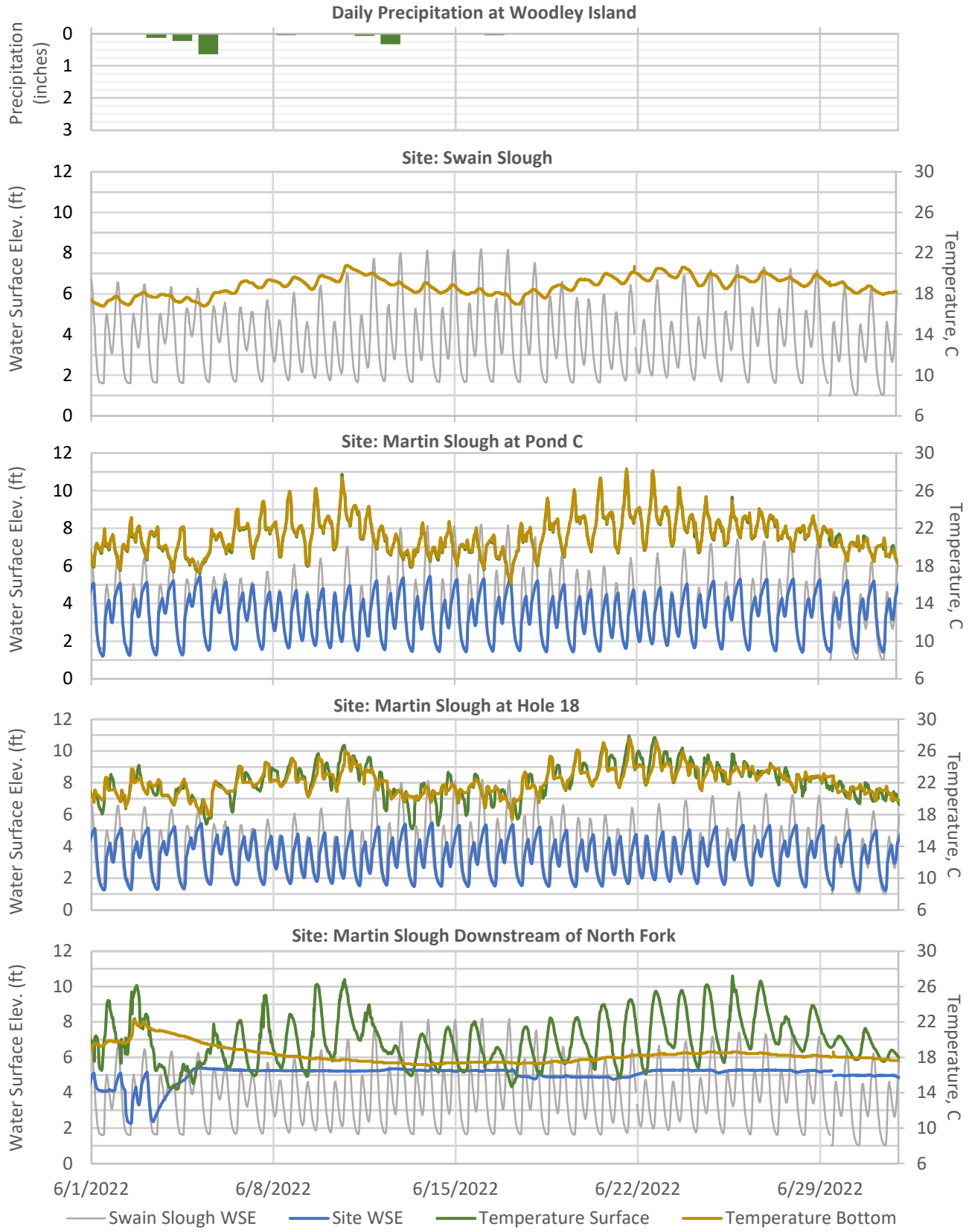


Martin Slough **May 2022**



Martin Slough **June 2022**



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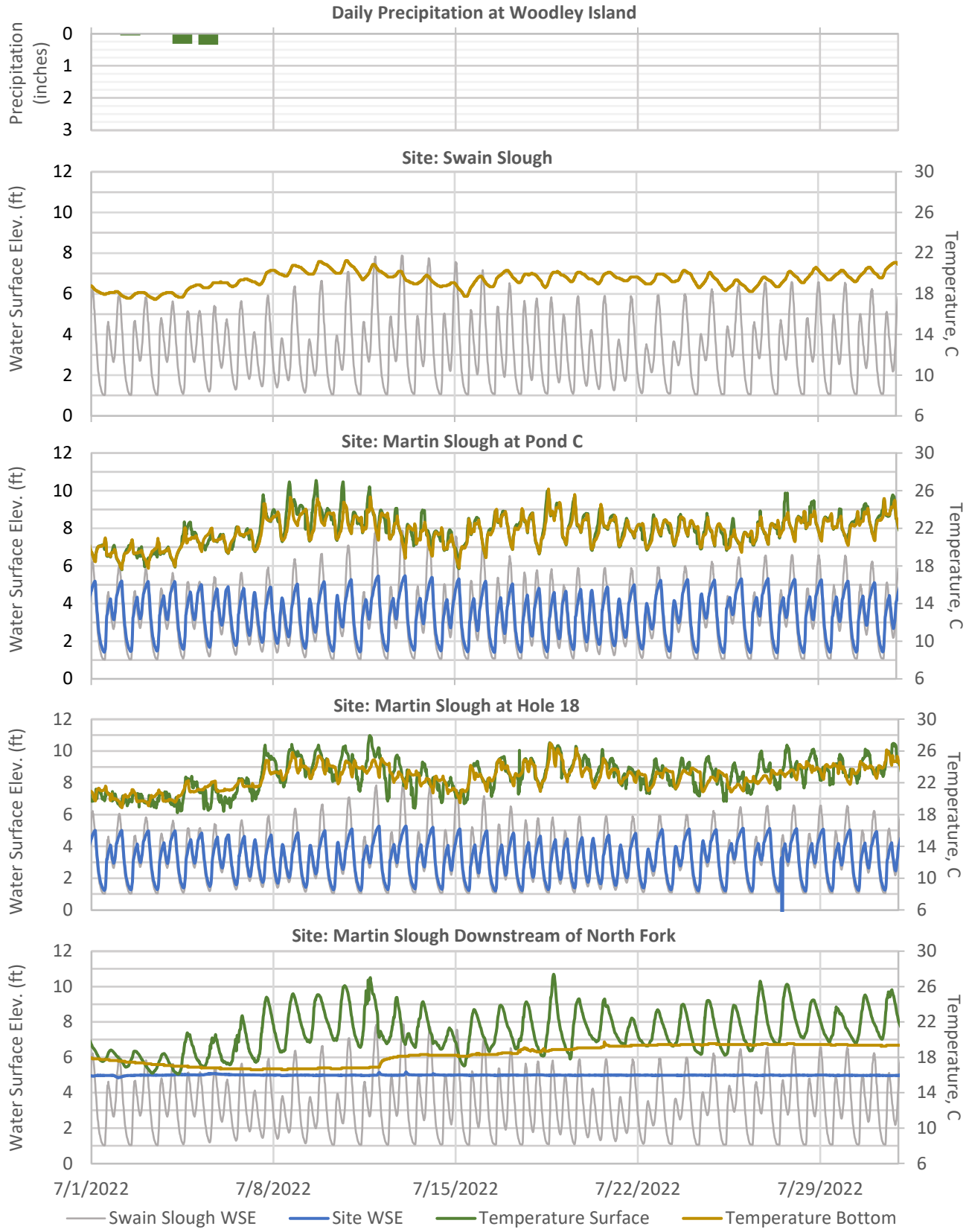

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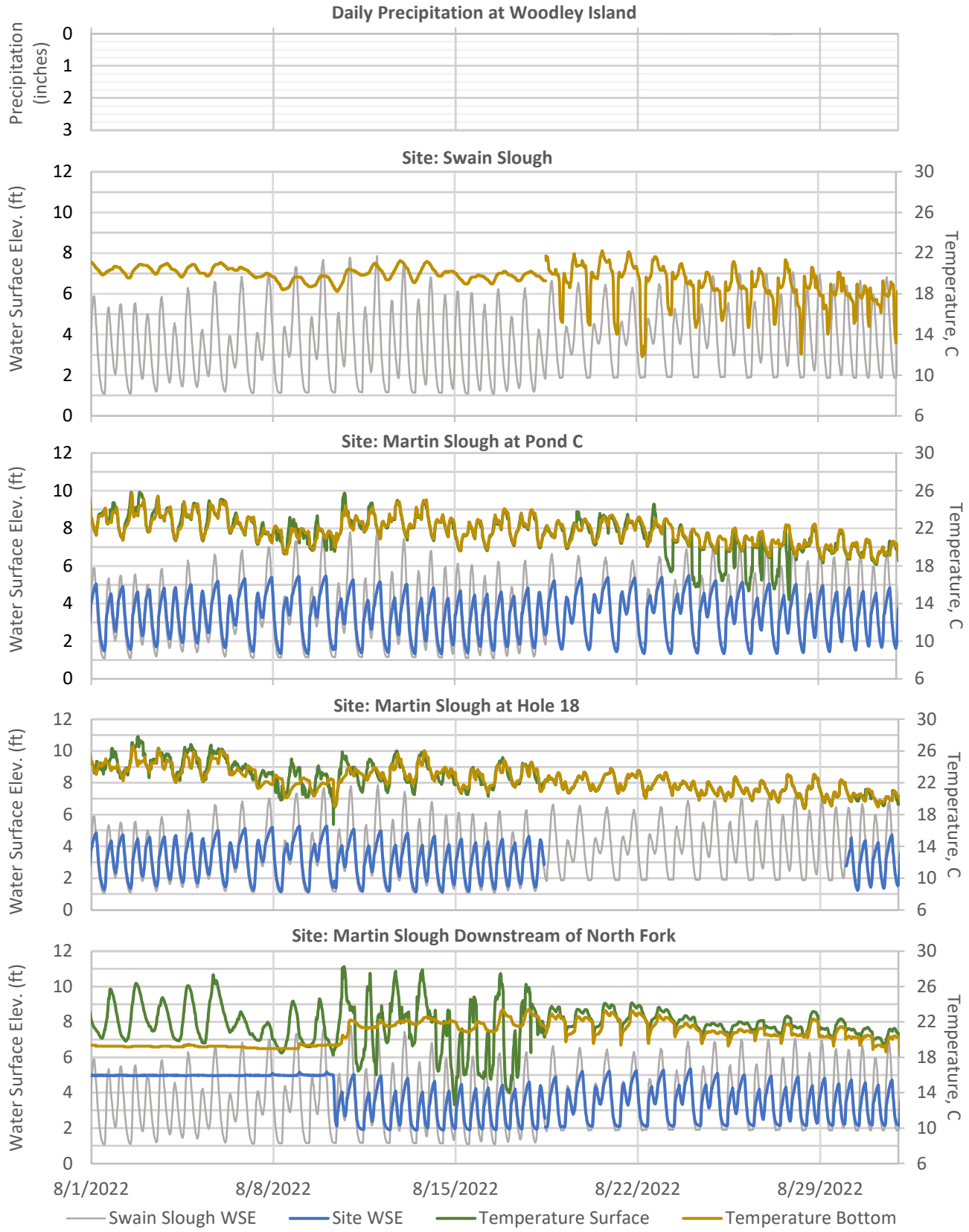

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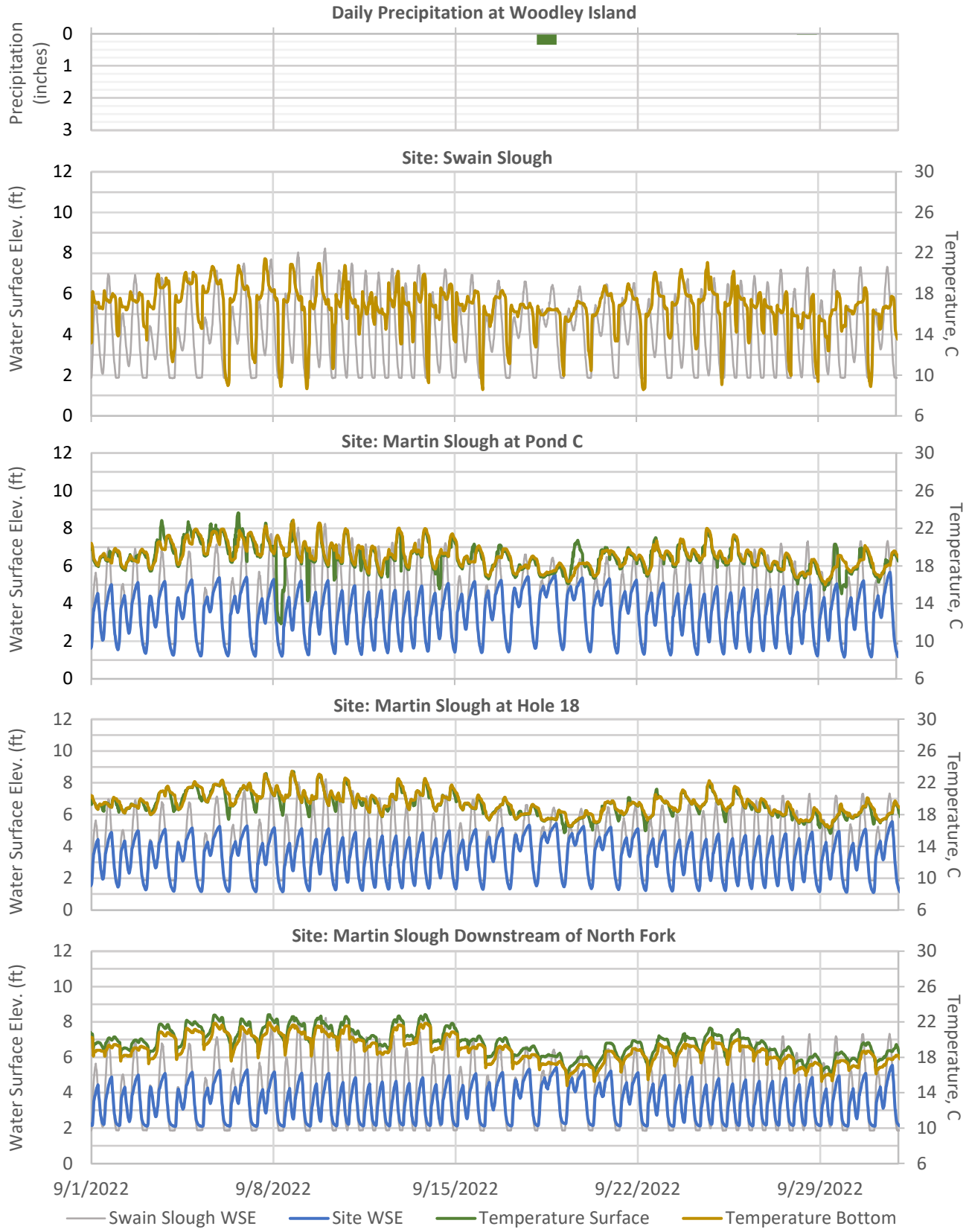

Appendix B

Martin Slough Water Quality Spot Measurements

Martin Slough Channel Enhancement 2022

Discrete Measurements of Water Surface Elevations (WSE) and Water Quality Parameters

Date: December 14, 2021			Period: Post Project						
		WSE	Surface			Bottom			
Gage Location	Time (PST)	NAVD88 (ft)	D.O. (mg/L)	Salinity (ppt)	Temp (°C)	D.O. (mg/L)	Salinity (ppt)	Temp (°C)	Tide at Gage
Swain Slough	4:15 PM	1.96	5.4	23.0	8.6	0.0	0.0	0.0	
MS POND C	3:30 PM	2.14	7.2	0.5	8.8	7.3	0.6	8.7	
MS-18	2:00 PM	2.79	7.1	0.5	8.6	7.1	0.5	8.6	
MS-NF	2:45 PM	2.97	6.6	0.2	8.4	6.2	0.2	8.4	

Date: February 11, 2022			Period: Post Project						
		WSE	Surface			Bottom			
Gage Location	Time (PST)	NAVD88 (ft)	D.O. (mg/L)	Salinity (ppt)	Temp (°C)	D.O. (mg/L)	Salinity (ppt)	Temp (°C)	Tide at Gage
Swain Slough	4:45 PM	1.53	9.9	26.8	14.0	0.0	0.0	0.0	
MS POND C	4:00 PM	1.25	12.7	20.6	15.9	0.0	0.0	0.0	
MS-18	2:00 PM	1.71	11.0	15.2	14.7	11.7	16.7	14.6	
MS-NF	2:30 PM	2.25	10.8	20.5	13.9	11.7	19.3	13.8	

Date: April 14, 2022			Period: Post Project						
		WSE	Surface			Bottom			
Gage Location	Time (PST)	NAVD88 (ft)	D.O. (mg/L)	Salinity (ppt)	Temp (°C)	D.O. (mg/L)	Salinity (ppt)	Temp (°C)	Tide at Gage
Swain Slough	4:15 PM	2.26	8.9	2.7	13.8	0.0	0.0	0.0	
MS POND C	12:00 AM	0.00	8.6	0.4	11.9	8.5	0.4	11.9	
MS-18	1:15 PM	4.70	8.6	0.2	10.8	8.4	0.5	10.9	
MS-NF	2:00 PM	5.08	7.3	0.1	11.6	7.0	0.1	11.1	

Date: May 27, 2022			Period: Post Project						
		WSE	Surface			Bottom			
Gage Location	Time (PST)	NAVD88 (ft)	D.O. (mg/L)	Salinity (ppt)	Temp (°C)	D.O. (mg/L)	Salinity (ppt)	Temp (°C)	Tide at Gage
Swain Slough	3:45 PM	2.62	6.4	0.3	17.4	0.0	0.0	0.0	
MS POND C	2:30 PM	3.46	10.1	15.8	18.0	10.2	21.8	16.3	
MS-18	12:45 PM	4.27	8.5	13.5	18.5	8.6	19.5	16.2	
MS-NF	1:15 PM	4.16	6.5	1.0	18.7	5.4	5.9	18.3	

Date: June 29, 2022			Period: Post Project						
		WSE	Surface			Bottom			
Gage Location	Time (PST)	NAVD88 (ft)	D.O. (mg/L)	Salinity (ppt)	Temp (°C)	D.O. (mg/L)	Salinity (ppt)	Temp (°C)	Tide at Gage
Swain Slough	10:30 AM	1.05	11.2	29.5	17.6	0.0	0.0	0.0	
MS POND C	9:30 AM	1.56	4.8	22.2	20.5	4.1	22.5	20.5	
MS-18	11:00 AM	1.49	7.5	19.8	20.7	2.9	26.6	22.0	
MS-NF	11:45 AM	5.25	15.0	0.4	18.4	12.1	0.4	18.2	

Martin Slough Channel Enhancement 2022

Discrete Measurements of Water Surface Elevations (WSE) and Water Quality Parameters

Date: August 18, 2022			Period: Post Project						
		WSE	Surface			Bottom			
Gage Location	Time (PST)	NAVD88 (ft)	D.O. (mg/L)	Salinity (ppt)	Temp (^oC)	D.O. (mg/L)	Salinity (ppt)	Temp (^oC)	Tide at Gage
Swain Slough	12:00 PM	1.85	2.3	30.9	20.6	2.3	30.5	19.8	
MS POND C	11:15 AM	2.36	7.2	22.5	21.1	7.0	29.0	20.5	
MS-18	9:30 AM	2.85	4.6	19.9	21.0	2.1	26.0	20.5	
MS-NF	10:15 AM	2.56	9.1	9.0	19.7	7.4	19.7	21.6	

Date: October 13, 2022			Period: Post Project						
		WSE	Surface			Bottom			
Gage Location	Time (PST)	NAVD88 (ft)	D.O. (mg/L)	Salinity (ppt)	Temp (^oC)	D.O. (mg/L)	Salinity (ppt)	Temp (^oC)	Tide at Gage
Swain Slough	9:15 AM	2.91	7.3	27.4	12.9	0.0	0.0	0.0	
MS POND C	10:15 AM	3.39	8.3	27.7	14.3	8.4	28.5	14.2	
MS-18	11:00 AM	3.80	6.3	0.2	14.7	4.7	27.8	14.5	
MS-NF									

Appendix C

Martin Slough Calculated Tidal Datums

Martin Slough Tidal Datums

Gage: Swain Slough

Year	Month	MLLW	MLW	MW	MHW	MHHW	MTL	DIURNAL RANGE	MINIMUM STAGE	MAXIMUM STAGE
2021	10	1.48	2.05	3.84	6.10	6.60	4.08	5.13	1.42	7.85
2021	11	1.13	1.67	3.45	5.80	6.43	3.73	5.29	1.09	8.01
2021	12	1.59	2.26	4.03	6.32	7.20	4.29	5.61	1.11	8.43
2022	1	1.66	2.18	3.93	6.26	7.20	4.22	5.54	1.53	8.94
2022	2	1.49	1.80	3.47	5.69	6.48	3.75	4.99	1.33	7.64
2022	3	1.50	1.82	3.52	5.83	6.38	3.83	4.88	1.48	7.34
2022	4	1.58	1.95	3.51	5.68	6.18	3.81	4.60	1.49	7.81
2022	5	1.62	2.04	3.57	5.71	6.38	3.88	4.77	1.55	7.75
2022	6	1.64	2.25	3.84	6.02	6.84	4.13	5.20	1.00	8.19
2022	7	1.11	1.69	3.32	5.50	6.36	3.60	5.24	1.03	7.88
2022	8	1.48	1.90	3.66	5.95	6.66	3.92	5.19	1.07	7.86
2022	9	1.86	2.28	4.07	6.41	7.05	4.34	5.19	1.85	8.23
WY 2022	**Annual**	1.51	1.99	3.68	5.94	6.65	3.96	5.14	1.00	8.94
2022	**July to Sept**	1.48	1.95	3.68	5.95	6.69	3.95	5.21	1.31	7.99

Martin Slough Tidal Datums

Gage: MS-Pond C

Year	Month	MLLW	MLW	MW	MHW	MHHW	MTL	DIURNAL RANGE	MINIMUM STAGE	MAXIMUM STAGE
2021	10	1.38	2.05	3.46	4.91	5.19	3.48	3.82	1.12	6.17
2021	11	1.30	1.95	3.41	5.00	5.20	3.48	3.90	1.06	5.66
2021	12	1.64	2.35	3.77	5.27	5.61	3.81	3.97	1.07	6.44
2022	1	1.35	2.03	3.49	5.02	5.35	3.52	4.00	1.01	6.13
2022	2	1.09	1.59	3.08	4.66	5.03	3.13	3.93	0.99	5.33
2022	3	1.14	1.62	3.09	4.69	4.98	3.16	3.83	1.06	5.35
2022	4	1.31	1.78	3.10	4.63	4.85	3.20	3.53	1.12	6.17
2022	5	1.40	1.91	3.18	4.69	4.90	3.30	3.49	1.07	5.36
2022	6	1.50	2.15	3.36	4.79	5.10	3.47	3.60	1.21	5.46
2022	7	1.53	2.15	3.39	4.77	5.14	3.46	3.60	1.40	5.48
2022	8	1.49	2.03	3.40	4.79	5.07	3.41	3.58	1.33	5.50
2022	9	1.36	1.99	3.45	4.87	5.12	3.43	3.77	1.16	5.54
WY 2022	**Annual**	1.38	1.97	3.35	4.84	5.13	3.41	3.75	0.99	6.44
2022	**July to Sept**	1.46	2.06	3.41	4.81	5.11	3.43	3.65	1.30	5.51

Martin Slough Tidal Datums

Gage: MS-18

Year	Month	MLLW	MLW	MW	MHW	MHHW	MTL	DIURNAL RANGE	MINIMUM STAGE	MAXIMUM STAGE
2021	10	1.34	1.99	3.40	4.84	5.12	3.42	3.79	1.12	6.11
2021	11	1.25	1.88	3.31	4.88	5.11	3.38	3.87	1.08	5.56
2021	12	1.57	2.25	3.64	5.13	5.46	3.69	3.90	1.06	6.26
2022	1	1.26	1.90	3.35	4.86	5.19	3.38	3.93	0.94	5.97
2022	2	1.09	1.54	3.00	4.56	4.92	3.05	3.83	0.98	5.25
2022	3	1.27	1.73	3.17	4.76	5.05	3.24	3.78	1.06	5.45
2022	4	1.39	1.85	3.16	4.67	4.89	3.26	3.50	1.08	6.29
2022	5	1.36	1.87	3.12	4.62	4.84	3.24	3.48	-0.41	5.25
2022	6	1.52	2.13	3.38	4.82	5.13	3.47	3.61	1.23	5.49
2022	7	1.34	1.96	3.20	4.59	4.95	3.27	3.61	1.19	5.28
2022	8	1.34	1.78	3.14	4.58	4.79	3.18	3.46	1.12	5.29
2022	9	1.27	1.90	3.35	4.76	5.02	3.33	3.74	1.12	5.44
WY 2022	**Annual**	1.33	1.90	3.27	4.76	5.05	3.33	3.71	-0.41	6.29
2022	**July to Sept**	1.32	1.88	3.23	4.64	4.92	3.26	3.61	1.14	5.34

Appendix B.

Martin Slough Enhancement Project- Coho Salmon Monitoring Report for Fall/Winter/Spring of 2021-2022

Ross Taylor and Associates 2023.

MARTIN SLOUGH ENHANCEMENT PROJECT – COHO SALMON MONITORING REPORT FOR FALL/WINTER/SPRING OF 2021-2022

Introduction and Background:

A multi-phase program to restore the lower reaches of Martin Slough has been ongoing since the initiation of a feasibility study in 2001. The on-the-ground work started in 2014 with the installation of a muted tide gate where Martin Slough enters Swain Slough. The Martin Slough Enhancement Project is located in, and adjacent to, the southern portion of the City of Eureka and terminates at its confluence with Swain Slough (Figure 1). Martin Slough is the last (most downstream) tributary to Elk River via Swain Slough. Martin Slough has a watershed area of approximately 5.4 square miles and natural channel length of over 10 miles, with approximately 7.5 miles of potential fish habitat. Focal species include Coho Salmon (*Oncorhynchus kisutch*), Chinook Salmon (*O. tshawytscha*), Tidewater Goby (*Eucyclogobius newberryi*), steelhead (*O. mykiss*), and numerous other non-listed estuarine species. The lower portion of the watershed flows through low gradient bottomland containing the Eureka Municipal Golf Course and historic pastureland that is now managed by the Northcoast Regional Land Trust (NRLT). Many of the stream channels flow from gulches that contain mature second-growth redwood forests. The upper portions of the watershed are either in urban settings, or recently harvested timber lands slated for future residential and commercial development.

The Martin Slough channel enhancement and off-channel pond enhancement and construction occurred over a four-year period between 2018 and 2021. The four summer seasons of channel work proceeded in an upstream direction, starting at the tide gate in 2018 and finishing in Reach 7 with the construction of Pond G and the North Fork excavation work during the summer of 2021 (Figure 2).

Ross Taylor and Associates (RTA) contracted with Redwood Community Action Agency (RCAA) to conduct monthly fisheries monitoring in Martin Slough during 2019-2021. Bob Pagliuco (NOAA Fisheries) assisted in selecting sites that included previously monitored sites and new sites within channel reaches and habitat features constructed during the summer of 2018 (Figure 2). Although Figure 2 describes sampling methods as either “seine” or “seine and trap”, since May of 2020 only seine nets were used by RTA for their fisheries sampling.

Since January of 2019, biological monitoring has continued every fall/winter/spring season, with RTA and graduate students from Cal Poly Humboldt (CPH) independently conducting the field work. RTA’s sampling occurred in all habitat types and was focused on documenting fish presence, species diversity and associated water quality. RTA’s work included PIT tagging of juvenile Coho Salmon and generation of growth rates from recaptures of previously tagged fish.

Josh Cahill's graduate work with CPH was focused on assessing off-channel habitat use by juvenile Coho Salmon and included PIT tagging to determine growth rates, residency times and timing of smolt out-migrations.

The latest round of Martin Slough biological monitoring is funded by CDFW Grant #Q2010531, to conduct two fall/winter/spring seasons (2021-2022 and 2022-2023) of monthly sampling from November through June. The primary objective of this monitoring is an extension of Cahill's work on juvenile Coho Salmon over-wintering and habitat utilization in Martin Slough. Sampling occurs two days per month and effort is targeted in habitats most likely occupied by Coho Salmon. Recaptures of previously tagged fish will continue to provide growth information, movement and residency times in specific habitats. Installation of a PIT tag antenna array and data logger in lower Martin Slough allows for determination of out-migration timing of Coho Salmon smolts.

The remainder of this report summarizes the methods and results of the biological monitoring conducted by RTA during the 2021-2022 fall/winter/spring season.

Methods and Materials

Fisheries monitoring occurred two days per month, starting in November 2021 and ending in June 2022. The use of beach seine nets was consistent with methods developed by Mike Wallace/CDFW for sampling juvenile Coho Salmon in Humboldt Bay tributaries and the methods described in RTA's project-specific Scientific Collector's Permit ID# S-200360010-20073-001 for Martin Slough and lower Elk River biological monitoring. We used a variety of net sizes, depending on the site, tide levels and water depths; including nets with lengths of 10, 20, 22, 30, 80 and 100 feet. The 10-foot through 30-foot nets were four feet tall and the 80-foot and 100-foot nets were six feet tall. When sampling most locations, the nets used had ¼-inch meshes; however, for areas known to support Tidewater Goby, the nets used had 1/8-inch meshes. The 10-foot through 30-foot nets were set by wading through the sampling sections and anywhere from one to three passes were made (Figure 3). Because the 80-foot and 100-foot nets were typically used in deeper water, these nets were set with a kayak, with the net stacked accordion fashion in a 100-quart cooler with the back end removed. The kayak was paddled in a semi-circle to deploy the net and then the net was pulled to the shoreline (Figure 4). In the off-channel ponds, multiple sets were made with the kayak to cover the pond's perimeter.

For each sampling location, we recorded a start and end time, and also measured the water temperature, dissolved oxygen and salinity from the near-surface to a maximum depth in one-

foot intervals. The number of passes made and the length and mesh size of the net used was also recorded for each section sampled.

Depending on location and the species caught, fish were processed differently. For example, common species such as Threespine Stickleback and Pacific Staghorn Sculpin were counted out of the seine net and immediately released. When large numbers of Threespine Stickleback were encountered, we typically batch-counted these in visual estimates of 25 fish per aquarium net-scoop. We also avoided holding Tidewater Goby and smelt species in buckets due to either their ESA-listing status (goby) or their rather fragile nature (smelt). All Coho Salmon and other salmonids were temporarily held in dark-colored 5-gallon pails with lids and battery-powered aerators for further processing: anesthetizing, measuring, weighing, scanning and/or tagging.

Procedures for processing juvenile Coho Salmon included anesthetize, measure and weigh, and PIT tag implantation. To anesthetize fish, no more than three juvenile Coho Salmon at a time were placed in a container holding approximately two quarts of water with one fully-dissolved tab of Alka-Seltzer Gold (aspirin-free). Once the fish were immobilized, they were scanned for previously implanted PIT tags, had their fork length (FL) measured to the nearest millimeter and were weighed on a digital scale to the nearest 0.1 g. The scale had a small plastic pan attached to it, to prevent fish from flopping off of the scale. Both the scale pan and measuring board were wetted down prior to placing a fish on these objects. In addition, the fish handler's hands were wetted prior to processing fish. Tag numbers were recorded for fish with previously implanted PIT tags. On new Coho Salmon, a fine-tipped scalpel was used to make a small incision on the fish's ventral side between the pectoral and pelvic fins and slightly off-centered. Then either a 9 mm or 12 mm Biomark® PIT tag was inserted by hand into the incision. The 9 mm tags were implanted into fish between 65-75 mm in FL and the 12 mm tags were inserted in fish >75 mm in FL. All tags were pre-soaked in a diluted solution of betadine and water, and the scalpel blade was also sanitized in the diluted betadine between each surgical procedure. Processed juvenile Coho Salmon were then placed in an aerated recovery bucket and monitored until all fish appeared upright and swimming. Fish were released back into their capture locations and were carefully observed during their post-surgery release. When large numbers of fish were processed, both the anesthetizing bath and recovery container water were changed (as needed) to avoid subjecting fish to increases in water temperatures.

In the field, sampling data were written into a bound waterproof notebook and then entered into Excel spreadsheets at the RTA Office. Spreadsheets were created for: general fish catch, juvenile Coho Salmon catch, growth rate calculations of recaptured Coho Salmon, Tidewater Goby catch (for meeting USFWS permit requirements), and water quality measurements. Data from the handheld PIT tag reader were downloaded in the office and then transferred into the

juvenile Coho Salmon spreadsheet. For recaptures of previously tagged fish, growth rates were computed by subtracting the fish's most recent length and weight from its previously recorded length and weight, and then dividing these increases by the number of days between capture events (aka number of days at large). When individual fish were recaptured multiple times, the month-to-month growth rates depicted how growth changed over the course of the fall/winter/spring season.

Documenting the out-migration timing of Coho Salmon smolts in Martin Slough was another objective of this current monitoring project. To accomplish this objective, a PIT tag antenna array and data logger system were installed in the lower reach of Martin Slough near the barn on the property owned and managed by the NRLT (Figure 5). This system consisted of a Biomark® IS1001 Multiplexing Transceiver system and two 10' x 3' pass-through antennas. The antennas were arranged side-by-side to cover the channel cross-section. This side-by-side arrangement was done to provide better coverage of tagged fish migrating downstream, at the expense of having the antennas set above and below each other to allow detection of direction of movement (direction is documented by a fish passing by one antenna and then by passing the next antenna). The rationale for our side-by-side antenna arrangement was that all of our juvenile Coho Salmon were tagged upstream of the array and because the array was located in the lower end of Martin Slough, all detections of our tags would be out-migrating Coho smolts. Any unknown tags or tags attributed to fish tagged in other Humboldt Bay drainages would be assumed to be moving in an upstream direction through our array because these fish would be entering Martin Slough through the tide gate located approximately 1,200 feet downstream of the array. The side-by-side orientation of the two antennas also provided better coverage during the wide variations in channel depth and width as a result of tide changes (Figures 5 and 6). The Biomark® IS1001 Multiplexing Transceiver also had the ability to auto-tune the antennas, which was important in a tidally-influenced area with not only changes to water depths, but frequent changes in salinity levels.

The PIT tag array and transceiver system was powered by four solar panels which charged a bank of four 12-volt deep-cycle batteries. The IS1001 unit, solar inverter and deep-cycle batteries were stored in a steel lockbox to deter theft. The system was originally designed to run off of electrical power located in the NRLT barn, however, after extensive testing and adjustments, we were unable to reduce electrical interference to low enough levels for proper tag detection. At first, we were concerned that the electrical interference was caused by metallic structures near the barn, such as the metal supports of the cattle bridge, the electric cattle fence and possibly overhead power lines. Through the process of elimination and moving the array upstream of the barn, cattle bridge, and overhead power lines; it appeared that any type of extension cord plugged into the IS1001 unit from the barn created unacceptable levels

of electrical interference. The barn's wiring was also re-grounded and this didn't reduce the electrical interference. We also tried a variety of extension cords and each one created too much electrical interference. Due to numerous delays in obtaining the proper equipment from Biomark, a fully functioning system with two antennas was operational by late April 2022, probably a month after the commencement of the Coho Salmon smolt out-migrations. PIT tag detection data from the IS1001 unit were downloaded in approximately one-month intervals and the site was also visited two or three times monthly to clear debris off of the antennas and make sure the IS1001 unit was running properly.

Results – Sampling Dates and Locations

Martin Slough fisheries sampling for the fall/winter/spring season of 2021-2022 occurred on the following dates: November 16th and 18th, 2021; December 17th and 20th, 2021; January 25th and 26th, 2022; February 23rd and 24th, 2022; March 21st and 28th, 2022; April 25th and 26th, 2022; May 19th and 20th, 2022; and June 23rd, 2022.

In a downstream-to-upstream direction, the locations sampled during the 2021-2022 season included: Pond C, Pond C Terminal Channel, Oxbow Channel, South-East Tributary, SE Tributary Pond, Pond D Log Sill Pools, Pond D, Pond E, Pond F, North Fork Channel, Pond G, Main Channel near Salinity Weir, Main Channel Upstream of North Fork Confluence, and Main Channel near Upper Fairway Drive. We typically sampled one day per month in the upper reaches of Martin Slough, followed by a day lower in the watershed (Table 1). The number of sites sampled per day varied between eight and three, and varied depending on tides, ease of access, and/or numbers of juvenile Coho Salmon to process (Table 1).

Table 1. Martin Slough sample sites and dates that sites were sampled, between November 2021 and June 2022.

Sampling Location	Nov. 16th	Nov. 18th	Dec. 17th	Dec. 20th	Jan. 25th	Jan. 26th	Feb. 23rd	Feb. 24th	Mar. 21st	Mar. 28th	April 25th	April 26th	May 19th	May 20th	June 23rd
Pond C				X			X							X	
Pond C Terminal Channel				X			X							X	
Oxbow Channel				X			X								
South-East Tributary		X		X		X	X					X			
SE Tributary Pond				X		X	X					X			
Pond D Log Sill Pools	X			X		X				X				X	
Pond D	X			X		X				X				X	
Pond E	X			X		X				X		X		X	X
Pond F		X	X		X			X	X			X		X	
North Fork Channel					X			X	X	X	X		X		
Pond G		X	X		X			X	X	X	X		X		X
Main Channel - near Salinity Weir													X		X
Main Channel – above North Fork					X			X	X				X		X
Main Channel – Upper Fairway Dr.			X		X			X	X		X		X		X

Results – Species Caught – Numbers and Locations

Martin Slough fisheries sampling for the fall/winter/spring season of 2021-2022 caught a total of 14 fish species, two crustacean species, one reptile and two amphibian species. The species list included:

1. Coho Salmon (1,691 fish captured).
2. Tidewater Goby (1,355 fish captured).
3. Coastal Cutthroat Trout (one fish captured).
4. Pacific Staghorn Sculpin (290 fish captured).
5. Sculpin spp. (likely Prickly Sculpin)(36 fish captured).
6. Threespine Stickleback (7,950 fish captured).
7. Juvenile smelt (not identified to species)(661 fish captured).
8. Jack Smelt (seven fish captured).
9. Surf Smelt (one fish captured).
10. Shiner Surfperch (17 fish captured).
11. California Roach (21 fish captured).
12. Starry Flounder (eight fish captured).
13. Bay Pipefish (three fish captured).
14. Pacific Herring (two fish captured).
15. Green Shore Crab (one crab captured).
16. Dungeness Crab (one crab captured).
17. Western Pond Turtle (three turtles captured).
18. Red-legged Frog (112 tadpoles and five frogs captured).
19. Northwestern Salamander (four larvae captured).

The 14 fish species captured in Martin Slough varied both in abundance and in distribution amongst the 14 sampling locations (Table 2). Threespine Stickleback was the most common species encountered, with both the highest abundance (7,950 captured) and was present at all 14 sampling locations (Table 2). Tidewater Goby continued to be a common and abundant species in Martin Slough, and their distribution increased over the four years of project construction as the upstream extent of brackish water was increased. Tidewater Goby were captured in 12 of the 14 sampling locations, and were absent from the two sampling sites located upstream of brackish water intrusion (Table 2). The upstream distribution of Pacific Staghorn Sculpin increased similarly as Tidewater Goby's, as the brackish water extended farther upstream, so did the presence of Pacific Staghorn Sculpin (Table 2).

Table 2 also provided insight to the species diversity within the sampling locations. Pond F was the most diverse and supported 12 of the 14 fish species captured in Martin Slough; whereas the East Tributary Pond was the least diverse, with only two fish species captured during the 2021-2022 sampling (Table 2).

Table 2. Martin Slough sample sites and fish species sampled, between November 2021 and June 2022. Left-to-right, fish species are arranged by frequency of occurrence at the 14 sampling locations.

Sampling Location	Three-spine SB	Stag-horn Sculpin	Tide-water Goby	Coho Salmon	Sculpin Spp.	Juv. Smelt Spp.	Starry Flounder	Shiner Surf-perch	Bay Pipe-fish	Pacific Herring	CC Trout	Jack Smelt	Surf Smelt	CA Roach
Pond C	X	X	X		X	X	X	X						
Pond C Terminal Channel	X	X	X											
Oxbow Channel	X	X	X											
South-East Tributary	X	X	X											
SE Tributary Pond	X													X
Pond D Log Sill Pools	X	X	X	X	X									
Pond D	X	X	X	X										
Pond E	X	X	X	X	X	X	X	X	X		X	X	X	
Pond F	X	X	X	X	X	X	X	X	X	X				
North Fork Channel	X	X	X	X	X	X	X							
Pond G	X	X	X	X	X	X				X				
Main Channel - near Salinity Weir	X	X	X	X										
Main Channel – above North Fork	X	X	X	X	X	X								
Main Channel – Upper Fairway Dr.	X	X		X	X									

Results – Coho Salmon Catch and Growth Rates

The total number of 1,691 Juvenile Coho Salmon sampled in 2021-2022 included 1,519 fry caught in May and June, which were suspected progeny of adults that successfully spawned in Martin Slough and 173 captures of age-0 and age-1+ fish that most likely migrated into Martin Slough from the Elk River during the late-fall/early-winter juvenile redistribution period. Most of the newly emerged fry were caught in the main channel, above or near the confluence with the North Fork of Martin Slough. In May 2022, a sub-sample of these fish were measured and weighed, and were between 46 and 54 mm in FL and weighed 0.6 to 1.6 g (too small to tag) (Figure 7).

We implanted a total of 133 PIT tags in Coho Salmon and had 36 recaptures of previously tagged fish (169 captures). We also caught two Coho Salmon in Pond D in November and in December of 2021 that were smolts that failed to out-migrate earlier in 2021. One of these fish had been tagged by Josh Cahill/CPH and we caught both of these fish twice, thus these four captures brought our total up to the 173 fish reported in the previous paragraph. Most of the juvenile Coho Salmon were tagged in pools at the Upper Fairway Drive sampling location (117 fish) and most of the recaptures of previously tagged fish were also caught at this sampling location (34 of the 36 recaptures). The remaining tags were implanted in juvenile Coho Salmon captured at the following locations: Pond G (18 fish), North Fork Channel below Pond G (eight fish), Main Channel near the North Fork confluence (eight fish), Pond E (seven fish), Pond F (six fish), and the Main Channel near the East Fork confluence (three fish). Besides the 34 recaptures in pools at the Upper Fairway Drive sampling location, the remaining two recaptures occurred in Pond G (of a fish tagged at Upper Fairway Drive) and in the North Fork Channel immediately below Pond G.

Daily growth rates were computed for all previously PIT tagged fish that were recaptured in February, March, April and May. In February, computing daily growth rates of recaptured fish was straightforward because there were only recaptures of fish tagged the previous month. In March through May, we recaptured fish with varying “number of days at large” and also recaptured the same fish multiple times. Tables with all of the daily growth computations from PIT tag recaptures are provided in Appendix A.

Recaptures of previously tagged fish were made in February (six recaptures), March (13 recaptures), April (12 recaptures), and May (six recaptures). By month, the recaptures documented the following growth rates:

February: on 2/24/22, the six Coho Salmon recaptures were at large for 30 days and growth in length averaged 0.16 mm/day and ranged from 0.07 mm/day to 0.27 mm/day. Growth in weight averaged 0.08 g/day and ranged from 0.05 g/day to 0.11 g/day. All six recaptures were initially tagged in the Upper Fairway Drive sampling location and were also recaptured at this location.

March: on 3/21/22, 11 previously tagged Coho Salmon were recaptured and all 11 of these fish were also caught in February. The time at large between the February and March sampling equaled 25 days and growth in length for these 11 fish averaged 0.32 mm/day and ranged from 0.12 mm/day to 0.44 mm/day. Growth in weight averaged 0.11 g/day and ranged from 0.06 g/day to 0.15 g/day. All 11 recaptures were initially tagged in the Upper Fairway Drive sampling location and were also recaptured at this location.

On 3/28/22, two previously tagged Coho Salmon were recaptured. One of these fish was initially caught and tagged on 1/25/22 and during its 61 days at large, its growth rates were 0.26 mm/day and 0.09 g/day. This fish was initially tagged at the Upper Fairway Drive site and was recaptured in Pond G. The other fish recaptured on 3/28/22 was caught on 2/24/22 and during its 32 days at large, its growth rates were 1.06 mm/day and 0.51 g/day. This fish was 94 mm in FL on 2/24/22 and was 128 mm in FL on 3/28/22 and was our only juvenile Coho Salmon that was tagged and recaptured in a brackish water area (in the North Fork channel just below Pond G).

April: on 4/25/22, 12 previously tagged Coho Salmon were recaptured and eight of these fish were also captured on 3/21/22. The time at large between these dates equaled 34 days and the growth in length for these eight fish averaged 0.55 mm/day and ranged from 0.50 mm/day to 0.77 mm/day. Growth in weight of these eight fish averaged 0.14 g/day and ranged from 0.10 g/day to 0.19 g/day. One of the 4/25/22 recaptures was previously captured on 2/24/22 and was at large for 59 days; during this period this fish had average growth rates of 0.56 mm/day and 0.17 g/day. The final two fish recaptured on 4/25/22 were in initially tagged on 1/25/22 and these fish were at large for 89 days. During this period, these two fish had average growth rates of 0.40 mm/day and 0.17 g/day.

May: on 5/19/22, six previously tagged Coho Salmon were recaptured and two of these fish were also captured on 4/25/22. The time at large between these dates equaled 24 days and the growth in length for these two fish were averaged 0.35 mm/day (0.29 mm/day and 0.42 mm/day). Growth in weight of these two fish averaged 0.14 g/day and ranged from 0.10 g/day to 0.19 g/day. Three of the 5/19/22 recaptures were previously caught on 3/21/22 and were at large for 58 days. During this 58-day period, the growth rates of these three fish averaged 0.51

mm/day and 0.15 g/day. The sixth fish recaptured on 5/19/22 was last captured on 1/25/22 and was at large for 113 days between capture events. This fish's growth rates were 0.14 mm/day and 0.08 g/day.

Looking at differences in growth rates throughout the 2021-2022 monitoring season, rates tended to increase as the rearing season progressed and water temperatures generally increased (Table 2). The individual fish with the highest growth rate was tagged and recaptured in a brackish water location of the North Fork, just below Pond G, and provided our only documentation of growth rates in brackish water. At this location, the salinity measurements on 2/24/22 equaled 2.2 ppt at the near-surface and 8.8 ppt at a depth of 1.0 feet. On the day of its recapture on 3/28/22, the salinity measurements were 0.5 ppt at the near-surface, 0.7 ppt at a depth of one-foot, and 1.8 ppt at a bottom depth of 1.5 feet.

Our 36 recaptures of previously tagged juvenile Coho Salmon documented minimal movement of fish between capture events. One fish tagged in the pools at Upper Fairway Drive on 1/25/22 was recaptured in Pond G on 3/28/22. Other than that, all recaptures occurred at the location of their initial captures. In regards to the length of residency in the Upper Fairway Drive pools, we had one fish (#989.00102914529) with 113 days between its initial capture and final recapture; four fish with 89 days between initial captures and final recaptures; one fish with 83 days between initial capture and final recapture; one fish with 61 days between initial capture and final recapture; and eight fish with 59 days between initial captures and final recaptures. The fish with the most recaptures was tag ID #982.126058677526, which was tagged on 1/25/22 and was recaptured three times (in February, March and April). This fish's growth rates increased each time it was recaptured: in length, its growth rates were 0.20 mm/day between January and February, 0.40 mm/day between February and March, and 0.56 mm/day between March and April.

Table 3. Average month-to-month growth rates for juvenile Coho Salmon in Martin Slough, January through May of 2022. Water temperature measured in lower pool at Upper Fairway Drive when Coho Salmon were sampled.

Growth Period	Number of Recaps	Average Growth - length	Average Growth - weight	Water Temp at Upper FW Drive
January to February	6 fish	0.16 mm/day	0.08 g/day	Jan = 9.0°C
February to March	11 fish	0.32 mm/day	0.11 g/day	Feb = 5.9°C
March to April	8 fish	0.55 mm/day	0.14 g/day	March = 8.8°C
March to May	3 fish	0.51 mm/day	0.15 g/day	April = 10.3°C
April to May	2 fish	0.35 mm/day	0.14 g/day	May = 13.0°C

Results – Coho Salmon out-migration and Antenna Array Detections

The PIT tag antenna array system located in lower Martin Slough was operating with one functional antenna on 4/8/22 and was fully operational (two antennas) on 4/25/22. Between 4/9/22 and 6/21/22 a total of 50 individual tags were detected by the array and 49 of these were tags we implanted in juvenile Coho Salmon. One of the tags detected was a juvenile Coho Salmon from Freshwater Creek. The 49 tags detected by the array comprised 37% of the 133 fish we tagged in Martin Slough. During the month of April, 13 tagged fish were detected, in May 29 fish were detected, and in June eight fish (including the Freshwater Creek fish) were detected. The final download of the array's data logger occurred on 7/27/22, yet the final tag was detected on 6/21/22. We assumed that we missed a portion of the out-migration season since our array was non-functional until April 8th and wasn't fully functional until late April. Research spanning nearly a 70-year period has confirmed that April into May are the peak months in California for Coho Salmon smolt out-migration (Shapovalov and Taft 1954; Drucker 1972; Ettlinger et al. 2021).

Most of the Martin Slough detections (33 of 49) occurred during periods of darkness and of the 16 detections that occurred during daylight hours, seven of these occurred between 6:00AM and 7:00 AM, and three of these detections occurred later than 4:00PM. Twenty of the 49 detections (40%) occurred between 10:00PM and 4:00AM. Our results regarding diel timing of out-migration movement were consistent with other studies that documented most movement occurring at night. Meehan and Siniff (1962) found that on the Taku River the peak migration of Coho smolts occurred between 11:00PM and 3:00AM. Mace (1983) reported that Coho smolts were rarely observed out-migrating during daylight hours, and they appeared in the transition zone between freshwater and the estuary only in the afternoon and evening hours.

The transit time of tagged fish passing the antenna array was highly variable, from a single detection to several detections over a relatively short time period (several minutes up to an hour), to numerous detections over time periods spanning several hours to several days. One fish (tag #989.001029145441) accumulated 159 detections between 4/17/22 and 4/24/22. Another fish (tag #989. 001029145466) had 52 detections between 5/1/22 and 5/7/22 and was detected on both antennas. Without a second pair of antennas, we lacked directional movement information to determine if these fish were moving back and forth with the tide or were spending an extended period in lower Martin Slough before leaving the system.

Results – Water Quality Measurements

The dissolved oxygen, water temperature and salinity measurements are provided in Appendix B. The overall trend observed during the 2021-2022 monitoring was the persistently high salinity readings in all of the off-channel ponds, including Pond G, the uppermost pond on the golf course. During the four years of project construction, salinity readings in the Martin Slough ponds increased each year as more of the channel was excavated, the muted tide gate became fully operational in the fall of 2020, and the upstream extent of high tides increased (Table 4). Ponds D, E, F, and G were all constructed with high tailwater controls which prevented the ponds from fully draining; yet this feature also impeded more dense brackish water from draining out of the ponds. It also appeared that rain events created a low-salinity lens on the near-surface to one-to-two feet of depth, then deeper than two-feet remained highly brackish, too salty to support over-winter rearing of juvenile Coho Salmon.

Table 4. Salinity readings in parts per thousand (ppt) in four off-channel ponds. The 2021 data were collected by Cahill/CPH and the 2020 and 2022 data were collected by RTA. First value is near-surface and second value is salinity at the pond's maximum depth.

Sampling Date	Pond D	Pond E	Pond F	Pond G
4/23/20	0.2 – 0.2	0.2 – 0.2	Not sampled	Not constructed
5/26/20	0.2 – 0.2	0.2 – 0.2	Not sampled	Not constructed
1/31/21	0.3 - 5.1	0.1 – 0.4	0.1 – 0.2	Not constructed
2/24/21	0.1 – 0.7	0.2 – 0.2	0.2 – 0.8	Not constructed
3/17/21	0.1 – 0.1	0.2 – 0.7	Not sampled	Not constructed
4/14/21	0.2 – 0.4	1.4 – 1.8	2.5 – 4.6	Not constructed
5/17/21	0.3 – 0.3	5.5 – 6.2	7.4 – 8.1	Not constructed
1/25-26/22	0.3 – 18.3	11.1 – 15.7	7.1 – 15.3	1.0 – 19.1
2/24/22	Not sampled	Not sampled	7.1 – 20.2	Not sampled
3/28/22	0.3 – 11.8	21.7 – 22.8	3.4 – 20.3	5.3 – 16.2
4/25-26/22	Not sampled	1.9 – 3.6	0.6 – 15.2	0.8 – 14.8
5/19-20/22	10.3 – 11.1	10.3 – 11.1	7.6 – 11.2	2.0 – 15.2

Discussion and Recommendations

The sampling conducted between November 2021 and June 2022 was successfully completed using a variety of seine nets. During this eight-month sampling period a total of 14 locations were sampled and each site was sampled multiple times. During the second sampling season in the fall/winter/spring of 2022-2023 we intend to continue sampling at a similar frequency and effort. The only change in effort may be to sample more intensively in freshwater and low-

salinity areas where more juvenile Coho Salmon are likely to be present, with an objective to tag as many fish as possible. We also intend to sample less frequently in areas of known high densities of Tidewater Gobies, specifically to reduce potential impacts to these ESA-listed fish, and these areas include Pond C and the Pond C terminal channel.

One juvenile Coho Salmon detected at the Martin Slough originated in Freshwater Creek. This fish was captured and tagged at the Freshwater Creek downstream outmigrant trap on 6/5/22 and 12 days later it was detected in Martin Slough. The distance between these two locations is approximately 11 miles; however, the fish's path through Humboldt Bay was unknown and the 11-mile distance assumed a pathway hugging the eastern shore of the bay, which may not be the preferred pathway of out-migrating smolts (Pinnix et al. 2013). Movements of juvenile Coho Salmon between freshwater various tributaries within Humboldt Bay have been previously documented; however, this is a relatively rare occurrence (Halloran 2020). Acoustic tagging and tracking of Coho Salmon smolts in Humboldt Bay determined that smolts spent between 15-22 days in the bay prior to out-migrating to the ocean (Pinnix et al. 2013). This acoustic tagging study observed that Coho smolts used deep channels with narrow intertidal margins, as opposed to shallow channels, intertidal mudflats and eelgrass meadows (Pinnix et al. 2013). Finally, this acoustic tagging study determined that out-migrating Coho smolts spent from less than one day to up to four days in the lower estuary of Freshwater Creek, which could explain the multiple detections over several days we had with some of our tagged fish in lower Martin Slough. A second pair of antennas would allow us to better determine movement patterns of Coho Salmon smolts in lower Martin Slough; unfortunately, we lack budget for purchases of additional equipment.

The presence of newly emerged Coho Salmon fry in Martin Slough in May and June of 2022 was a pleasant surprise. Discussion with CDFW biologists who conducted numerous years of sampling in Martin Slough prior to the channel enhancement project, large numbers of newly emerged fry were never documented (Wallace, pers. comm.) We assumed that these fish were the result of successful spawning of adult Coho Salmon in upper Martin Slough during the winter of 2021-2022. As far as we know, this is the first time that adult salmon may have recently spawned in Martin Slough.

The persistently high salinity levels in the off-channel ponds during the fall/winter/spring of 2021-2022 coincided with very few juvenile Coho Salmon sampled in off-channel habitats. Between December 2021 and April 2022, a total of 140 juvenile Coho Salmon were caught and 29 of these were in off-channel ponds (21% of the fish caught). By pond, the numbers of Coho Salmon caught were: Pond D = 2 fish; Pond E = 7 fish; Pond F = 1 fish; and Pond G = 19 fish. As provided in the results section, in 2021 the salinity levels were relatively low in Ponds D-F when

Cahill conducted his off-channel habitat sampling. At this time, the muted tide gate was fully operational, yet these ponds still remained only slightly brackish. Cahill's catches in 2021 included relatively high numbers of juvenile Coho Salmon. For example, on 3/17/21 his catch of Coho Salmon was 36 fish in Pond D, 26 fish in Pond E and 41 fish in Pond F; all when the maximum salinity readings were less than 1.0 ppt. The channel excavation work was completed during the summer of 2021 and it appears that this further deepening (and lowering) of the channel elevation allowed further upstream penetration of higher salinity water. Such that, after the summer of 2021 construction season, these same ponds had maximum salinity values of 11.8, 22.8 and 20.3 ppt in March of 2022, respectively.

The project's Biological Assessment listed nine purposes and goals, including "*provide habitat and benefits to multiple species by improving and increasing the diversity and amount of fresh and saltwater wetland/estuarine habitat**, particularly off-channel and side channel juvenile salmonid rearing and overwintering habitat***" (GHD 2017). Based on our biological sampling and water quality monitoring in 2021-2022 (including November and December of 2022), the persistently high salinity readings in the off-channel ponds have failed to improve or increase the amount of off-channel habitat for juvenile salmonid rearing. If anything, we have documented a substantial decrease in the quantity and quality of off-channel salmonid rearing and overwintering habitat in Martin Slough. In addition, pre-project relocations in 2020 and 2021 documented ample amphibian breeding and rearing in Ponds D and G when these ponds were wholly freshwater. Thus, project completion has also led to significant losses of breeding and rearing habitat for Red-legged Frog, Pacific Treefrog, Rough-skinned Newt, Northwestern Salamander, and Pacific Giant Salamander.

RTA recommends that RCAA convene a meeting with project partners and regulatory agencies to discuss the persistently high salinities in the Martin Slough off-channel ponds and if there are feasible means to limit the upstream extent of brackish water to at least have Pond G function as high-quality overwintering habitat for juvenile Coho Salmon. The pre-project water quality modeling predicted that salinities in the upper ponds (F and G) during the rainy season would be under 8 ppt and suitable for overwintering juvenile Coho Salmon, yet on-the-ground monitoring has documented unsuitable conditions based on high salinities and the relative lack of Coho Salmon presence in the ponds. Project objectives should be reviewed and discussed at the start of this meeting.

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Personal Communications

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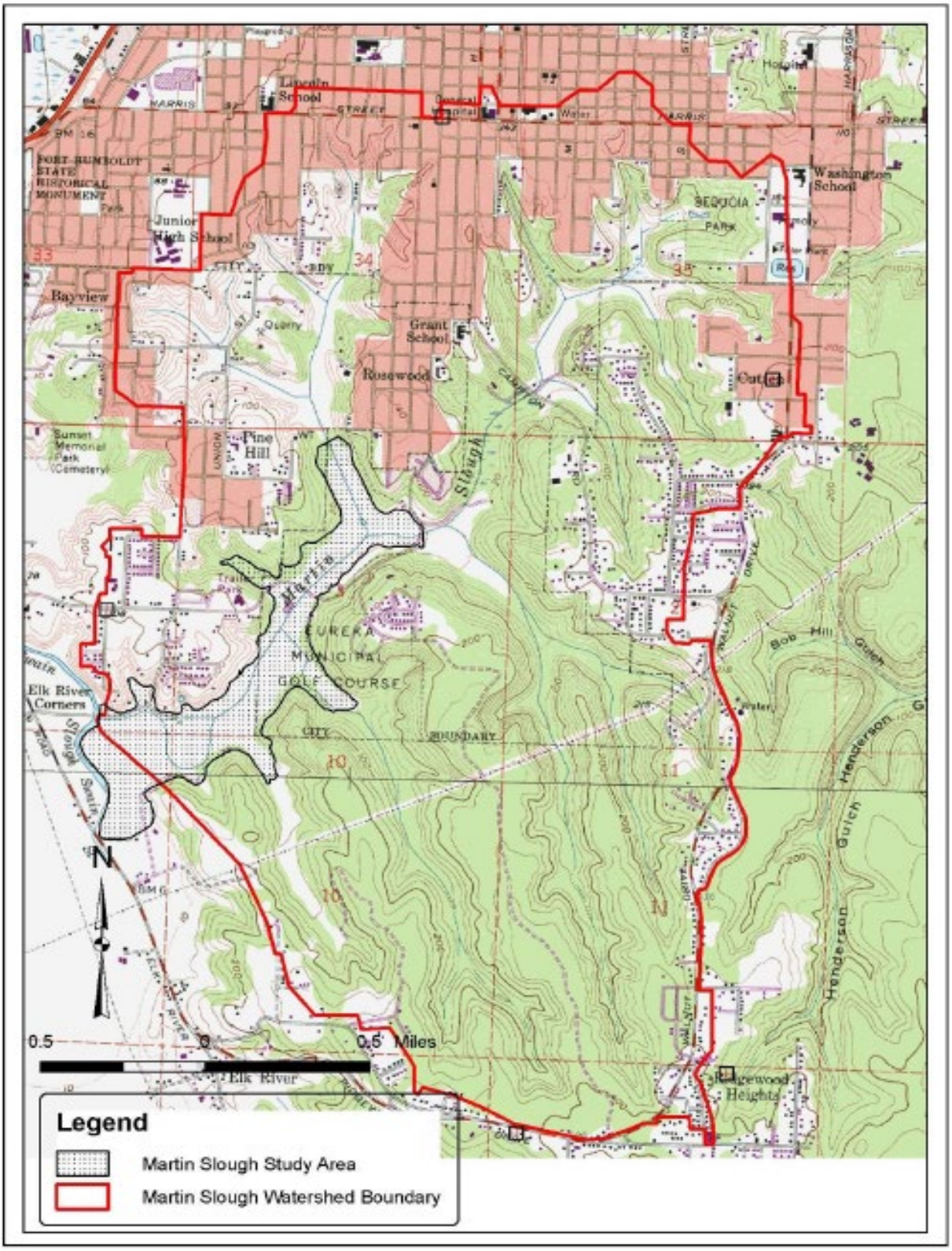
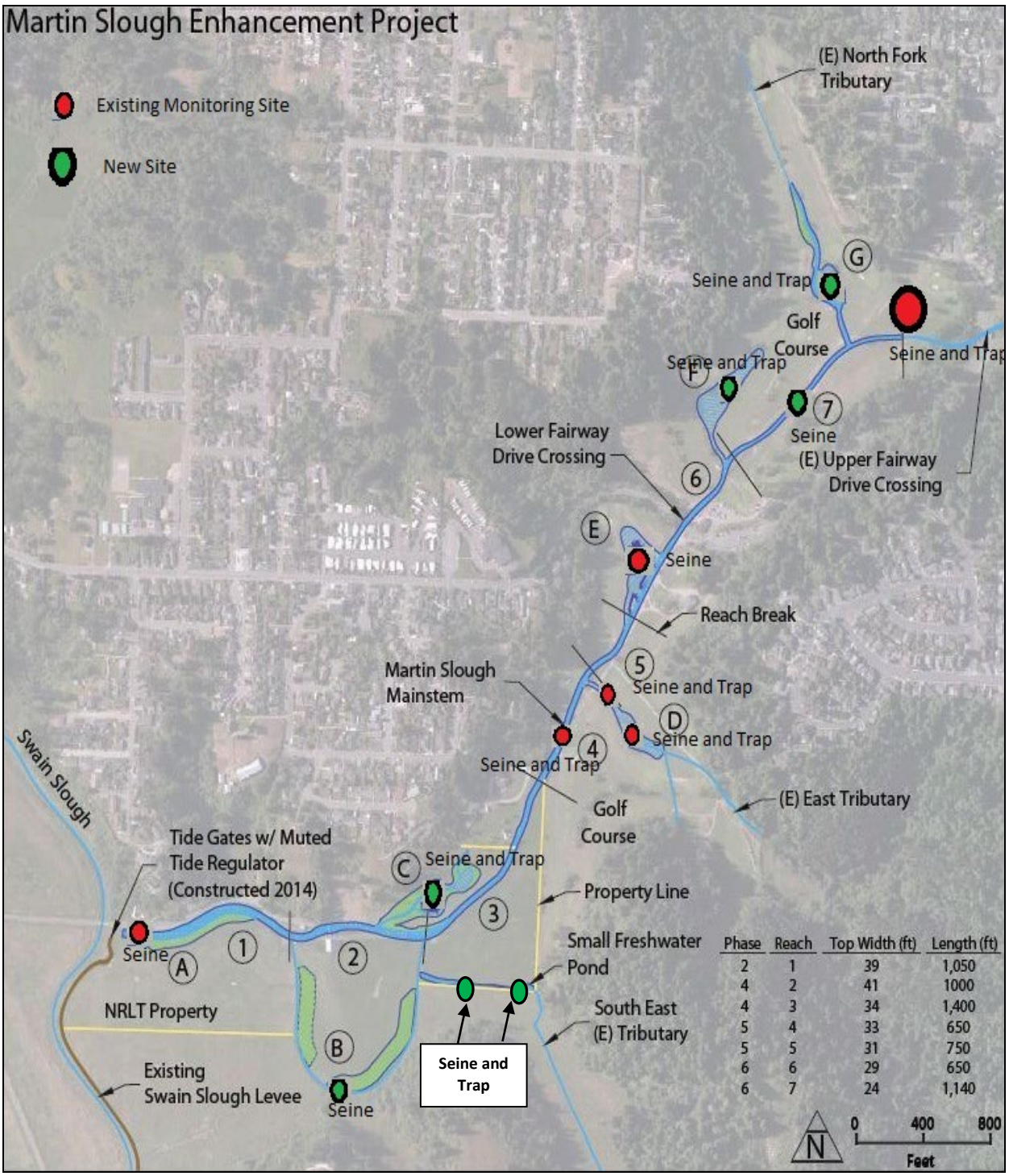


Figure 1. Martin Slough enhancement project area and watershed boundary (map is from GHD's Biological Assessment report, March 2017).



Phase	Reach	Top Width (ft)	Length (ft)
2	1	39	1,050
4	2	41	1000
4	3	34	1,400
5	4	33	650
5	5	31	750
6	6	29	650
6	7	24	1,140

Figure 2. Lower Martin Slough enhancement project – reaches and fisheries monitoring locations – existing sites and proposed new sites.

Figure 3. Martin Slough main channel sampling with the 30-foot seine net.

Figure 4. Setting the 80-foot seine net in Pond C with the kayak.

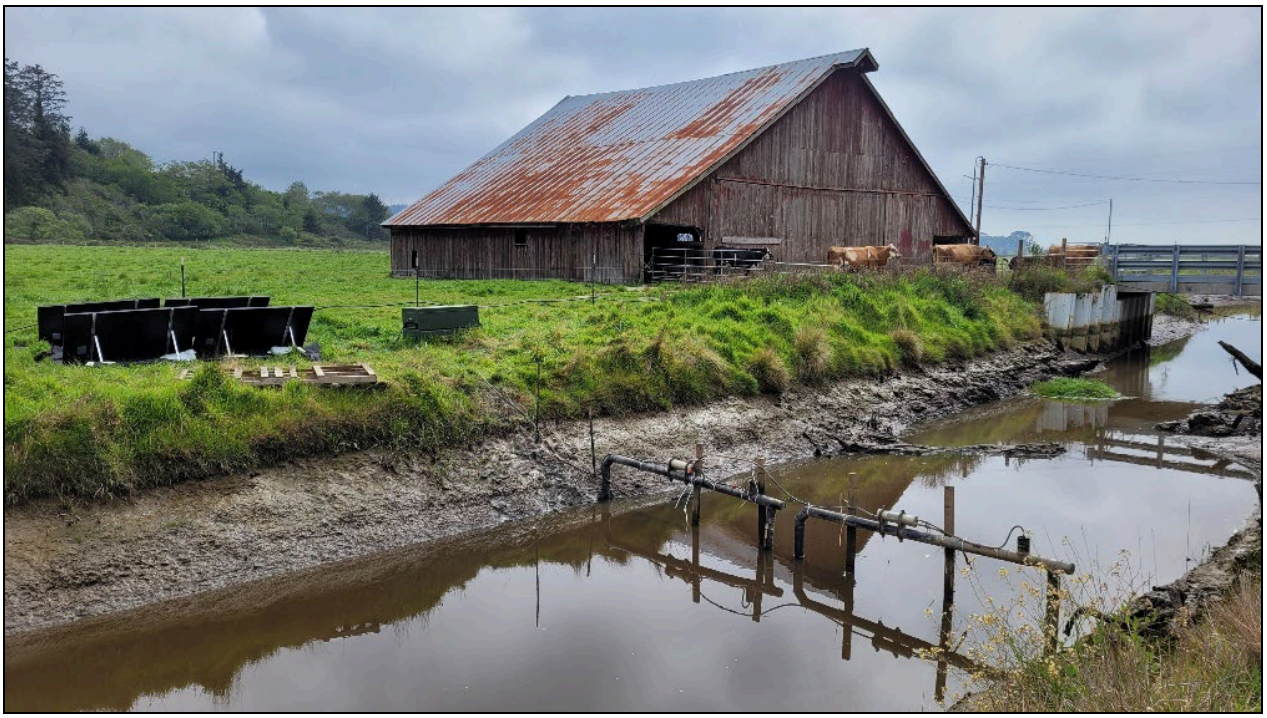


Figure 5. PIT tag antenna array system in lower Martin Slough at low tide on 4/25/22.

Figure 6. PIT tag antenna array system in lower Martin Slough at high tide on 4/27/22.

Figure 7. Coho salmon smolt and six fry caught at the Upper Fairway Drive site on 5/19/22.

APPENDIX A: GROWTH INFORMATION FROM PIT TAG RECAPTURES FROM MARTIN SLOUGH; FEBRUARY 2022 THROUGH MAY 2022

GROWTH OF JUVENILE COHO SALMON FROM FEBRUARY 24, 2022 RECAPTURES

DATE	FORK LENGTH (mm)	WEIGHT (g)	PIT TAG #	RECAP.	LOCATION	DAYS AT LARGE	GROWTH (mm/day)	GROWTH (g/day)
1/25/2022	63	2.3	982.126058677526		Upper FW Drive			
2/24/2022	69	4.0	982.126058677526	Yes	Upper FW Drive	26	0.19	0.04
1/25/2022	126	22.1	989.001029145303		Upper FW Drive			
2/24/2022	128	24.4	989.001029145303	Yes	Upper FW Drive	26	0.00	-0.01
1/25/2022	78	4.2	989.001029145326		Upper FW Drive			
2/24/2022	82	5.9	989.001029145326	Yes	Upper FW Drive	26	0.15	0.02
1/25/2022	86	6.0	989.001029145511		Upper FW Drive			
2/24/2022	90	9.4	989.001029145511	Yes	Upper FW Drive	26	0.15	0.01
1/25/2022	74	4.2	989.001029145521		Upper FW Drive			
2/24/2022	82	7.2	989.001029145521	Yes	Upper FW Drive	26	0.12	0.02
1/25/2022	110	11.9	989.001029145531		Upper FW Drive			
2/24/2022	114	13.4	989.001029145531	Yes	Upper FW Drive	26	0.15	0.02

GROWTH OF JUVENILE COHO SALMON FROM MARCH 21ST AND 28TH, 2022 RECAPTURES

DATE	FORK LENGTH (mm)	WEIGHT (g)	PIT TAG #	RECAP.	LOCATION	DAYS AT LARGE	GROWTH (mm/day)	GROWTH (g/day)
2/24/2022	68	3.2	982.126058677500		Upper FW Drive			
3/21/2022	77	4.7	982.126058677500	Yes	Upper FW Drive	25	0.36	0.06
1/25/2022	63	2.3	982.126058677526		Upper FW Drive			
2/24/2022	69	4.0	982.126058677526	Yes	Upper FW Drive	30	0.20	0.06
3/21/2022	79	6.1	982.126058677526	Yes	Upper FW Drive	25	0.40	0.08
1/25/2022	83	5.2	989.001029145258		Upper FW Drive			
3/21/2022	94	9.9	989.001029145258	Yes	Upper FW Drive	55	0.20	0.09
1/25/2022	126	22.1	989.001029145303		Upper FW Drive			
2/24/2022	128	24.4	989.001029145303	Yes	Upper FW Drive	30	0.07	0.08
3/21/2022	131	27.3	989.001029145303	Yes	Upper FW Drive	25	0.12	0.12
1/25/2022	78	4.2	989.001029145326		Upper FW Drive			
2/24/2022	82	5.9	989.001029145326	Yes	Upper FW Drive	30	0.13	0.06
3/21/2022	93	8.6	989.001029145326	Yes	Upper FW Drive	25	0.44	0.11
2/24/2022	72	4.1	989.001029145445		Upper FW Drive			
3/21/2022	80	6.4	989.001029145445	Yes	Upper FW Drive	25	0.32	0.09
2/24/2022	78	4.7	989.001029145446		Upper FW Drive			
3/21/2022	88	7.8	989.001029145446	Yes	Upper FW Drive	25	0.40	0.12
2/24/2022	102	13.1	989.001029145465		Upper FW Drive			
3/21/2022	107	16.1	989.001029145465	Yes	Upper FW Drive	25	0.20	0.12
2/24/2022	75	4.0	989.001029145478		Upper FW Drive			
3/21/2022	83	6.9	989.001029145478	Yes	Upper FW Drive	25	0.32	0.12

GROWTH OF JUVENILE COHO SALMON FROM MARCH 21ST AND 28TH, 2022 RECAPTURES

DATE	FORK LENGTH (mm)	WEIGHT (g)	PIT TAG #	RECAP.	LOCATION	DAYS AT LARGE	GROWTH (mm/day)	GROWTH (g/day)
2/24/2022	87	7.1	989.001029145484		Upper FW Drive			
3/21/2022	97	10.9	989.001029145484	Yes	Upper FW Drive	25	0.40	0.15
2/24/2022	83	5.9	989.001029145505		Upper FW Drive			
3/21/2022	92	9.8	989.001029145505	Yes	Upper FW Drive	25	0.36	0.16
1/25/2022	85	5.7	989.001029145264		Upper FW Drive			
3/28/2022	101	11.4	989.001029145264	Yes	POND G	61	0.26	0.09
2/24/2022	94	9.3	989.001029145449		North Fork MS			
3/28/2022	128	25.7	989.001029145449	Yes	North Fork MS	32	1.06	0.51

GROWTH OF JUVENILE COHO SALMON FROM APRIL 25TH, 2022 RECAPTURES

DATE	FORK LENGTH (mm)	WEIGHT (g)	PIT TAG #	RECAP.	LOCATION	DAYS AT LARGE	GROWTH (mm/day)	GROWTH (g/day)
2/24/2022	68	3.2	982.126058677500		Upper FW Drive			
3/21/2022	77	4.7	982.126058677500	Yes	Upper FW Drive	25	0.36	0.06
4/25/2022	96	9.3	982.126058677500	Yes	Upper FW Drive	34	0.56	0.14
1/25/2022	63	2.3	982.126058677526		Upper FW Drive			
2/24/2022	69	4.0	982.126058677526	Yes	Upper FW Drive	30	0.20	0.06
3/21/2022	79	6.1	982.126058677526	Yes	Upper FW Drive	25	0.40	0.08
4/25/2022	98	10.8	982.126058677526	Yes	Upper FW Drive	34	0.56	0.14
3/21/2022	80	5.9	989.001029145332		Upper FW Drive			
4/25/2022	96	11.0	989.001029145332	Yes	Upper FW Drive	34	0.47	0.15
3/21/2022	90	8.5	989.001029145442		Upper FW Drive			
4/25/2022	106	13.9	989.001029145442	Yes	Upper FW Drive	34	0.47	0.16
2/24/2022	72	4.1	989.001029145445		Upper FW Drive			
3/21/2022	80	6.4	989.001029145445	Yes	Upper FW Drive	25	0.32	0.09
4/25/2022	100	10.4	989.001029145445	Yes	Upper FW Drive	34	0.59	0.12
3/21/2022	78	5.4	989.001029145490		Upper FW Drive			
4/25/2022	97	10.2	989.001029145490	Yes	Upper FW Drive	25	0.76	0.19
2/24/2022	70	4.1	989.001029145492		Upper FW Drive			
4/25/2022	100	11.3	989.001029145492	Yes	Upper FW Drive	59	0.51	0.12
2/24/2022	83	5.9	989.001029145505		Upper FW Drive			
3/21/2022	92	9.8	989.001029145505	Yes	Upper FW Drive	25	0.36	0.16
4/25/2022	109	15.4	989.001029145505	Yes	Upper FW Drive	34	0.50	0.16

GROWTH OF JUVENILE COHO SALMON FROM APRIL 25TH, 2022 RECAPTURES

DATE	FORK LENGTH (mm)	WEIGHT (g)	PIT TAG #	RECAP.	LOCATION	DAYS AT LARGE	GROWTH (mm/day)	GROWTH (g/day)
1/25/2022	86	6.0	989.001029145511		Upper FW Drive			
2/24/2022	90	9.4	989.001029145511	Yes	Upper FW Drive	25	0.16	0.14
4/25/2022	121	19.2	989.001029145511	Yes	Upper FW Drive	59	0.53	0.17
3/21/2022	76	5.6	989.001029145514	Yes	Upper FW Drive	25		
4/25/2022	93	9.0	989.001029145514	Yes	Upper FW Drive	34	0.50	0.10
1/25/2022	83	6.1	989.001029145515		Upper FW Drive			
4/25/2022	117	17.9	989.001029145515	Yes	Upper FW Drive	89	0.38	0.13
1/25/2022	84	5.6	989.001029145525		Upper FW Drive			
4/25/2022	122	23.2	989.001029145525	Yes	Upper FW Drive	89	0.43	0.20

GROWTH OF JUVENILE COHO SALMON FROM MAY 19TH, 2022 RECAPTURES

DATE	FORK LENGTH (mm)	WEIGHT (g)	PIT TAG #	RECAP.	LOCATION	DAYS AT LARGE	GROWTH (mm/day)	GROWTH (g/day)
1/25/2022	112	14.0	989.001029145292		Upper FW Drive			
5/19/2022	128	23.6	989.001029145292	Yes	Upper FW Drive	83	0.19	0.12
3/21/2022	87	9.4	989.001029145440		Upper FW Drive			
5/19/2022	114	16.3	989.001029145440	Yes	Upper FW Drive	58	0.47	0.12
3/21/2022	75	5.1	989.001029145451		Upper FW Drive			
5/19/2022	109	13.7	989.001029145451	Yes	Upper FW Drive	58	0.59	0.15
2/24/2022	70	4.1	989.001029145492		Upper FW Drive			
4/25/2022	100	11.3	989.001029145492	Yes	Upper FW Drive	59	0.51	0.12
5/19/2022	107	12.0	989.001029145492	Yes	Upper FW Drive	24	0.29	0.03
3/21/2022	76	5.6	989.001029145514		Upper FW Drive			
4/25/2022	93	9.0	989.001029145514	Yes	Upper FW Drive	34	0.50	0.10
5/19/2022	103	12.6	989.001029145514	Yes	Upper FW Drive	24	0.42	0.15
3/21/2022	94	12.9	989.001029145523		Upper FW Drive			
5/19/2022	121	22.7	989.001029145523	Yes	Upper FW Drive	58	0.47	0.17

APPENDIX B: WATER QUALITY MEASUREMENTS FROM MARTIN SLOUGH; NOVEMBER 2021 THROUGH MAY 2022

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
11/16/2021	12:30	POND E	0.5	6.82	14.5	8.2	Mid-pond from kayak
11/16/2021	12:30	POND E	1.0	6.14	13.2	10.9	Mid-pond from kayak
11/16/2021	12:30	POND E	2.0	5.12	13.3	12.6	Mid-pond from kayak
11/16/2021	12:30	POND E	3.0	2.15	13.8	14.7	Mid-pond from kayak
11/16/2021	14:30	POND D	0.5	9.11	14.3	1.1	Mid-pond from kayak
11/16/2021	14:30	POND D	1.0	10.43	14.4	2.1	Mid-pond from kayak
11/16/2021	14:30	POND D	2.0	9.90	17.9	18.9	Mid-pond from kayak
11/16/2021	14:30	POND D	3.0	8.71	18.2	22.1	Mid-pond from kayak
11/16/2021	15:30	POND D - LOG SILL	0.5	9.12	13.8	1.1	Pool formed by uppermost log sill
11/16/2021	15:30	POND D - LOG SILL	1.0	9.10	13.8	1.1	Pool formed by uppermost log sill
11/16/2021	15:30	POND D - LOG SILL	2.0	9.08	13.8	1.1	Pool formed by uppermost log sill

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
11/18/2021	12:30	POND F	0.5	6.48	10.9	5.6	Lower end of pond from kayak - very few TWG
11/18/2021	12:30	POND F	1.0	6.02	10.7	6.5	Lower end of pond from kayak - very few TWG
11/18/2021	12:30	POND F	2.0	5.93	10.8	10.6	Lower end of pond from kayak - very few TWG
11/18/2021	12:30	POND F	3.0	5.82	11.1	12.7	Lower end of pond from kayak - very few TWG
11/18/2021	12:30	POND F	4.0	5.91	11.2	13.9	Lower end of pond from kayak - very few TWG
11/18/2021	12:30	POND F	5.0	5.88	11.3	15.7	Lower end of pond from kayak - very few TWG
11/18/2021	12:30	POND E	6.0	2.18	14.2	20.8	Lower end of pond from kayak - very few TWG
11/18/2021	12:45	POND E	0.5	6.58	11.1	5.5	Upper end of pond from kayak - abundant TWG
11/18/2021	12:45	POND E	1.0	6.14	11.2	6.6	Upper end of pond from kayak - abundant TWG
11/18/2021	12:45	POND E	2.0	5.64	11.6	10.1	Upper end of pond from kayak - abundant TWG
11/18/2021	12:45	POND E	3.0	5.45	11.5	13.4	Upper end of pond from kayak - abundant TWG
11/18/2021	12:45	POND E	4.0	5.28	11.6	13.9	Upper end of pond from kayak - abundant TWG
11/18/2021	12:45	POND E	4.5	2.37	14.0	16.3	Upper end of pond from kayak - abundant TWG
11/18/2021	14:00	POND G	0.5	6.78	10.9	0.7	Mid-pond from kayak
11/18/2021	14:00	POND G	1.0	6.15	11.4	1.3	Mid-pond from kayak
11/18/2021	14:00	POND G	2.0	2.76	14.3	5.6	Mid-pond from kayak
11/18/2021	14:00	POND G	3.0	0.79	16.4	18.8	Mid-pond from kayak
11/18/2021	14:00	POND G	4.0	0.38	16.8	20.0	Mid-pond from kayak
11/18/2021	14:00	POND G	4.5	0.27	16.7	20.8	Mid-pond from kayak
11/18/2021	15:45	SE TRIB POND	0.5	3.38	12.1	0.1	Mid-pond - waded out
11/18/2021	15:45	SE TRIB POND	1.0	3.42	12.1	0.1	Mid-pond - waded out
11/18/2021	15:45	SE TRIB POND	2.0	3.35	11.8	0.1	Mid-pond - waded out
11/18/2021	15:45	SE TRIB POND	3.0	2.79	11.5	0.1	Mid-pond - waded out
11/18/2021	15:45	SE TRIB POND	3.5	2.44	11.5	0.1	Mid-pond - waded out
11/18/2021	16:00	SE TRIBUTARY	0.5	5.42	11.7	1.9	In pool below culvert
11/18/2021	16:00	SE TRIBUTARY	1.0	3.82	11.7	15.7	In pool below culvert

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
12/17/2021	12:30	POND G	0.5	8.25	8.5	0.1	Mid-pond from kayak
12/17/2021	12:30	POND G	1.0	8.21	7.8	0.2	Mid-pond from kayak
12/17/2021	12:30	POND G	2.0	8.91	8.7	1.5	Mid-pond from kayak
12/17/2021	12:30	POND G	3.0	9.71	10.7	4.3	Mid-pond from kayak
12/17/2021	12:30	POND G	4.0	9.31	13.5	14.5	Mid-pond from kayak
12/17/2021	12:30	POND G	5.0	1.25	15.5	18.3	Mid-pond from kayak
12/17/2021	12:30	POND G	6.0	0.67	15.9	19.7	Mid-pond from kayak
12/17/2021	12:55	UPPER FW DRIVE	0.5	7.21	8.4	0.1	Mid-pool waded out
12/17/2021	12:55	UPPER FW DRIVE	1.0	6.73	8.1	0.1	Mid-pool waded out
12/17/2021	12:55	UPPER FW DRIVE	2.0	5.57	7.9	0.1	Mid-pool waded out
12/17/2021	15:30	POND F	0.5	7.92	9.4	0.5	Lower end of pond from kayak
12/17/2021	15:30	POND F	1.0	7.77	9.0	0.5	Lower end of pond from kayak
12/17/2021	15:30	POND F	2.0	1.71	10.7	8.3	Lower end of pond from kayak
12/17/2021	15:30	POND F	3.0	0.54	11.8	22.6	Lower end of pond from kayak

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
12/20/2021	11:05	POND E	0.5	8.97	9.3	3.8	Mid-pond from kayak, by lower log structure
12/20/2021	11:05	POND E	1.0	8.95	9.2	3.8	Mid-pond from kayak, by lower log structure
12/20/2021	11:05	POND E	2.0	8.79	9.2	4	Mid-pond from kayak, by lower log structure
12/20/2021	11:05	POND E	3.0	7.69	9.0	6.5	Mid-pond from kayak, by lower log structure
12/20/2021	11:05	POND E	4.0	6.14	9.1	8.1	Mid-pond from kayak, by lower log structure
12/20/2021	11:05	POND E	4.5	6.04	9.1	9.4	Mid-pond from kayak, by lower log structure
12/20/2021	12:50	POND D	0.5	8.85	9.9	0.2	Mid-pond from kayak, by mid log structure
12/20/2021	12:50	POND D	1.0	8.56	9.7	0.2	Mid-pond from kayak, by mid log structure
12/20/2021	12:50	POND D	2.0	8.44	9.6	2.8	Mid-pond from kayak, by mid log structure
12/20/2021	12:50	POND D	3.0	2.17	11.8	7.8	Mid-pond from kayak, by mid log structure
12/20/2021	12:50	POND D	4.0	0.71	13.5	20.7	Mid-pond from kayak, by mid log structure
12/20/2021	15:00	SE TRIB POND	0.5	3.91	9.6	0.2	Waded out, mid-pond
12/20/2021	15:00	SE TRIB POND	1.0	2.54	9.2	0.2	Waded out, mid-pond
12/20/2021	15:00	SE TRIB POND	2.0	2.41	9.2	0.2	Waded out, mid-pond
12/20/2021	15:00	SE TRIB POND	3.0	2.24	9.1	0.2	Waded out, mid-pond
12/20/2021	15:00	SE TRIB POND	4.0	1.74	8.9	0.2	Waded out, mid-pond
12/20/2021	15:15	SE TRIBUTARY	0.5	9.71	10.1	5.9	Taken in pool below culvert
12/20/2021	15:15	SE TRIBUTARY	1.0	9.24	9.8	10.4	Taken in pool below culvert
12/20/2021	15:15	SE TRIBUTARY	2.0	8.93	9.6	16.5	Taken in pool below culvert
12/20/2021	16:00	POND C	0.5	11.20	10.5	6.6	Waded out to take measurements
12/20/2021	16:00	POND C	1.0	9.29	9.5	15.3	Waded out to take measurements
12/20/2021	16:00	POND C	2.0	8.91	9.5	18.2	Waded out to take measurements
12/20/2021	16:00	POND C	3.0	8.28	9.7	18.8	Waded out to take measurements

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
1/25/2022	12:05	POND G	0.5	8.49	10.2	1.0	Mid-pond from kayak
1/25/2022	12:05	POND G	1.0	8.46	10.3	1.5	Mid-pond from kayak
1/25/2022	12:05	POND G	2.0	7.92	10.7	1.8	Mid-pond from kayak
1/25/2022	12:05	POND G	3.0	4.75	12.4	8.9	Mid-pond from kayak
1/25/2022	12:05	POND G	4.0	0.86	13.7	16.5	Mid-pond from kayak
1/25/2022	12:05	POND G	4.5	0.43	13.9	19.1	Mid-pond from kayak
1/25/2022	14:50	UPPER FW DRIVE	0.5	7.29	9.1	0.1	Mid-pool waded out
1/25/2022	14:50	UPPER FW DRIVE	1.0	7.24	9.0	0.1	Mid-pool waded out
1/25/2022	14:50	UPPER FW DRIVE	2.0	7.09	9.0	0.1	Mid-pool waded out
1/25/2022	14:50	UPPER FW DRIVE	2.5	7.03	8.9	0.1	Mid-pool waded out
1/25/2022	15:50	POND F	0.5	8.84	12.0	7.1	Lower end of pond from kayak
1/25/2022	15:50	POND F	1.0	8.76	11.8	7.2	Lower end of pond from kayak
1/25/2022	15:50	POND F	2.0	7.54	11.5	8.1	Lower end of pond from kayak
1/25/2022	15:50	POND F	3.0	6.39	10.9	13.2	Lower end of pond from kayak
1/25/2022	15:50	POND F	4.0	5.59	10.9	15.3	Lower end of pond from kayak

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
1/26/2022	13:40	POND E	0.5	8.91	13.0	11.1	Mid-pond from kayak, lower log structure
1/26/2022	13:40	POND E	1.0	8.08	12.2	12.4	Mid-pond from kayak, lower log structure
1/26/2022	13:40	POND E	2.0	7.31	11.1	13.6	Mid-pond from kayak, lower log structure
1/26/2022	13:40	POND E	3.0	4.55	10.9	15.1	Mid-pond from kayak, lower log structure
1/26/2022	13:40	POND E	3.5	3.38	11.0	15.7	Mid-pond from kayak, lower log structure
1/26/2022	14:25	POND D	0.5	8.74	12.0	0.3	Mid-pond from kayak, middle log structure
1/26/2022	14:25	POND D	1.0	8.32	12.1	0.5	Mid-pond from kayak, middle log structure
1/26/2022	14:25	POND D	2.0	7.16	12.9	2.4	Mid-pond from kayak, middle log structure
1/26/2022	14:25	POND D	3.0	6.18	13.7	6.7	Mid-pond from kayak, middle log structure
1/26/2022	14:25	POND D	3.5	4.98	13.9	18.3	Mid-pond from kayak, middle log structure
1/26/2022	16:00	SE TRIB POND	0.5	7.51	11.4	0.2	Waded out, mid-pond
1/26/2022	16:00	SE TRIB POND	1.0	4.14	9.5	0.2	Waded out, mid-pond
1/26/2022	16:00	SE TRIB POND	2.0	3.11	8.4	0.2	Waded out, mid-pond
1/26/2022	16:00	SE TRIB POND	3.0	2.78	8.2	0.2	Waded out, mid-pond

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
2/23/2022	10:20	POND C	0.5	8.26	9.9	8.7	Waded out, mid-pond
2/23/2022	10:20	POND C	1.0	7.48	10.2	22.0	Waded out, mid-pond
2/23/2022	10:20	POND C	1.5	7.21	10.2	23.3	Waded out, mid-pond
2/23/2022	14:25	SE TRIB POND	0.5	5.16	8.8	0.1	Waded out, mid-pond
2/23/2022	14:25	SE TRIB POND	1.0	3.77	7.7	0.1	Waded out, mid-pond
2/23/2022	14:25	SE TRIB POND	2.0	3.52	7.4	0.1	Waded out, mid-pond
2/23/2022	14:25	SE TRIB POND	3.0	3.49	7.3	0.1	Waded out, mid-pond
2/23/2022	14:25	SE TRIB POND	4.0	3.31	7.3	0.1	Waded out, mid-pond
2/23/2022	14:25	SE TRIB POND	4.5	2.96	7.3	0.1	Waded out, mid-pond

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
2/24/2022	10:15	POND F	0.5	10.21	10.7	7.1	Mid-pond waded out
2/24/2022	10:15	POND F	1.0	10.17	11.0	13.5	Mid-pond waded out
2/24/2022	10:15	POND F	2.0	10.03	10.9	16.3	Mid-pond waded out
2/24/2022	10:15	POND F	3.0	9.56	12.7	18.9	Mid-pond waded out
2/24/2022	10:15	POND F	4.0	8.92	13.1	20.2	Mid-pond waded out
2/24/2022	12:30	UPPER FW DRIVE	0.5	8.62	6.0	0.1	Mid-pool waded out
2/24/2022	12:30	UPPER FW DRIVE	1.0	8.48	5.9	0.1	Mid-pool waded out
2/24/2022	12:30	UPPER FW DRIVE	2.0	5.89	5.9	0.1	Mid-pool waded out
2/24/2022	14:50	NORTH FORK	0.5	9.66	12.0	2.2	Just downstream of Pond G outlet
2/24/2022	14:50	NORTH FORK	1.0	9.39	11.8	8.1	Just downstream of Pond G outlet
2/24/2022	15:00	NORTH FORK	0.5	9.98	12.3	2.8	Near confluence with main channel
2/24/2022	15:00	NORTH FORK	1.0	9.32	12.1	9.3	Near confluence with main channel
2/24/2022	15:00	NORTH FORK	2.0	8.72	12.0	14.2	Near confluence with main channel

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
3/21/2022	12:15	UPPER FW DRIVE	0.5	7.43	8.9	0.1	Mid-pool waded out
3/21/2022	12:15	UPPER FW DRIVE	1.0	7.31	8.8	0.1	Mid-pool waded out
3/21/2022	12:15	UPPER FW DRIVE	2.0	7.21	8.8	0.1	Mid-pool waded out
3/21/2022	13:45	NORTH FORK	0.5	7.78	10.7	0.1	Near confluence with main channel
3/21/2022	13:45	NORTH FORK	1.0	7.68	10.7	0.2	Near confluence with main channel
3/21/2022	13:45	NORTH FORK	2.0	6.94	10.8	1.3	Near confluence with main channel
3/21/2022	13:50	NORTH FORK	0.5	8.36	11.6	0.5	Just downstream of Pond G outlet
3/21/2022	13:50	NORTH FORK	1.0	8.07	11.3	0.7	Just downstream of Pond G outlet
3/21/2022	13:50	NORTH FORK	1.5	7.79	11.2	1.8	Just downstream of Pond G outlet
3/21/2022	14:45	POND G	0.5	9.36	16.5	1.5	Mid-pond waded out
3/21/2022	14:45	POND G	1.0	9.72	16.2	2.2	Mid-pond waded out
3/21/2022	14:45	POND G	2.0	7.71	18.1	9.1	Mid-pond waded out
3/21/2022	14:45	POND G	3.0	6.69	18.7	12.1	Mid-pond waded out
3/21/2022	14:45	POND G	4.0	3.93	18.5	16.8	Mid-pond waded out
3/21/2022	15:45	POND F	0.5	7.85	14.5	3.2	Mid-pond waded out
3/21/2022	15:45	POND F	1.0	7.51	14.0	3.4	Mid-pond waded out
3/21/2022	15:45	POND F	2.0	7.09	13.8	3.9	Mid-pond waded out
3/21/2022	15:45	POND F	3.0	3.71	13.7	6.5	Mid-pond waded out
3/21/2022	15:45	POND F	4.0	3.55	14.3	20.3	Mid-pond waded out

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
3/28/2022	12:15	POND G	0.5	8.78	17.4	5.3	Mid-pond from kayak
3/28/2022	12:15	POND G	1.0	8.45	17.4	6.5	Mid-pond from kayak
3/28/2022	12:15	POND G	2.0	8.36	17.6	8.7	Mid-pond from kayak
3/28/2022	12:15	POND G	3.0	7.67	17.6	10.0	Mid-pond from kayak
3/28/2022	12:15	POND G	4.0	6.73	17.6	11.7	Mid-pond from kayak
3/28/2022	12:15	POND G	5.0	4.78	18.8	16.2	Mid-pond from kayak
3/28/2022	14:40	POND E	0.5	9.98	19.4	21.7	Mid-pond waded out
3/28/2022	14:40	POND E	1.0	8.89	18.0	22.0	Mid-pond waded out
3/28/2022	14:40	POND E	2.0	6.71	16.9	22.4	Mid-pond waded out
3/28/2022	14:40	POND E	2.5	4.77	16.7	22.8	Mid-pond waded out
3/28/2022	16:15	POND D	0.5	10.05	18.8	0.3	Mid-pond from kayak
3/28/2022	16:15	POND D	1.0	9.86	14.5	0.5	Mid-pond from kayak
3/28/2022	16:15	POND D	2.0	6.68	16.2	8.4	Mid-pond from kayak
3/28/2022	16:15	POND D	3.0	4.85	16.5	11.2	Mid-pond from kayak
3/28/2022	16:15	POND D	4.0	3.27	16.7	11.8	Mid-pond from kayak
3/28/2022	16:45	EAST FK STEP-POOLS	0.5	9.71	17.7	2.3	Measured in 2nd pool above cart bridge
3/28/2022	16:45	EAST FK STEP-POOLS	1.0	9.69	17.9	2.5	Measured in 2nd pool above cart bridge
3/28/2022	16:45	EAST FK STEP-POOLS	2.0	8.62	17.0	3.1	Measured in 2nd pool above cart bridge
3/28/2022	16:45	EAST FK STEP-POOLS	2.5	7.97	16.3	18.4	Measured in 2nd pool above cart bridge

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
4/25/2022	11:15	UPPER FW DRIVE	0.5	6.87	10.4	0.1	Mid-pool waded out
4/25/2022	11:15	UPPER FW DRIVE	1.0	6.82	10.3	0.1	Mid-pool waded out
4/25/2022	11:15	UPPER FW DRIVE	2.0	6.67	10.3	0.1	Mid-pool waded out
4/25/2022	13:30	POND G	0.5	8.82	15.5	0.8	Mid-pond waded out
4/25/2022	13:30	POND G	1.0	8.06	16.6	1.3	Mid-pond waded out
4/25/2022	13:30	POND G	2.0	7.63	16.6	4.9	Mid-pond waded out
4/25/2022	13:30	POND G	3.0	6.73	20.1	8.4	Mid-pond waded out
4/25/2022	13:30	POND G	4.0	5.17	20.6	14.8	Mid-pond waded out
4/25/2022	13:40	NORTH FORK	0.5	7.38	14.1	0.3	Just downstream of Pond G outlet
4/25/2022	13:40	NORTH FORK	1.0	6.92	14.3	0.5	Just downstream of Pond G outlet
4/25/2022	13:40	NORTH FORK	2.0	6.62	13.9	0.6	Just downstream of Pond G outlet
4/25/2022	13:40	NORTH FORK	3.0	6.01	13.4	0.6	Just downstream of Pond G outlet
4/25/2022	13:40	NORTH FORK	3.5	5.73	13.3	1.3	Just downstream of Pond G outlet

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
4/26/2022	12:30	SE TRIB POND	0.5	4.51	13.5	0.2	Mid-pond waded out
4/26/2022	12:30	SE TRIB POND	1.0	3.22	11.9	0.2	Mid-pond waded out
4/26/2022	12:30	SE TRIB POND	2.0	2.84	11.6	0.2	Mid-pond waded out
4/26/2022	12:30	SE TRIB POND	3.0	2.21	11.1	0.2	Mid-pond waded out
4/26/2022	12:30	SE TRIB POND	4.0	1.39	10.7	0.2	Mid-pond waded out
4/26/2022	12:30	SE TRIB POND	5.0	0.62	10.3	0.2	Mid-pond waded out
4/26/2022	12:40	SE TRIBUTARY	0.5	9.74	16.0	2.0	In pool below culvert
4/26/2022	12:40	SE TRIBUTARY	1.0	7.94	13.5	4.6	In pool below culvert
4/26/2022	14:45	POND F	0.5	7.56	17.3	0.6	Mid-pond waded out
4/26/2022	14:45	POND F	1.0	7.39	17.1	0.8	Mid-pond waded out
4/26/2022	14:45	POND F	2.0	6.43	15.2	1.2	Mid-pond waded out
4/26/2022	14:45	POND F	3.0	3.29	14.5	15.2	Mid-pond waded out
4/26/2022	16:10	POND E	0.5	6.81	18.8	1.8	Upper bend where coho were caught
4/26/2022	16:10	POND E	1.0	6.37	16.7	2.1	Upper bend where coho were caught
4/26/2022	16:10	POND E	2.0	5.48	15.5	3.0	Upper bend where coho were caught
4/26/2022	16:15	POND E	0.5	6.92	18.1	1.9	Lower end near log structure
4/26/2022	16:15	POND E	1.0	6.73	16.5	2.1	Lower end near log structure
4/26/2022	16:15	POND E	2.0	6.38	15.0	2.5	Lower end near log structure
4/26/2022	16:15	POND E	3.0	6.18	14.4	3.1	Lower end near log structure
4/26/2022	16:15	POND E	3.5	4.75	14.3	3.6	Lower end near log structure

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
5/19/2022	11:30	UPPER FW DRIVE	0.5	5.75	13.0	0.1	Mid-pool waded out
5/19/2022	11:30	UPPER FW DRIVE	1.0	5.68	13.0	0.1	Mid-pool waded out
5/19/2022	11:30	UPPER FW DRIVE	1.5	5.47	12.9	0.1	Mid-pool waded out
5/19/2022	12:30	MAINSTEM above N FK	0.5	6.21	13.6	0.1	2nd log structure d.s. cart bridge
5/19/2022	12:30	MAINSTEM above N FK	1.0	6.15	13.5	0.1	2nd log structure d.s. cart bridge
5/19/2022	12:30	MAINSTEM above N FK	2.0	6.03	13.5	0.1	2nd log structure d.s. cart bridge
5/19/2022	13:50	MAINSTEM below weir	0.5	7.44	17.1	0.6	right below salinity intrusion weir
5/19/2022	13:50	MAINSTEM below weir	1.0	7.42	17.1	0.7	right below salinity intrusion weir
5/19/2022	13:50	MAINSTEM below weir	2.0	7.32	17.1	0.8	right below salinity intrusion weir
5/19/2022	14:40	POND G	0.5	10.58	20.2	2.0	Mid-pond waded out
5/19/2022	14:40	POND G	1.0	10.56	20.2	2.0	Mid-pond waded out
5/19/2022	14:40	POND G	2.0	9.95	19.6	2.5	Mid-pond waded out
5/19/2022	14:40	POND G	3.0	8.87	20.4	5.9	Mid-pond waded out
5/19/2022	14:40	POND G	4.0	7.69	22.2	15.2	Mid-pond waded out
5/19/2022	15:30	NORTH FORK	0.5	9.26	19.2	2.7	Below Pond G outlet
5/19/2022	15:30	NORTH FORK	1.0	9.24	19.3	2.7	Below Pond G outlet
5/19/2022	15:30	NORTH FORK	2.0	9.21	19.2	2.8	Below Pond G outlet
5/19/2022	15:30	NORTH FORK	3.0	9.26	18.5	5.0	Below Pond G outlet

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
5/20/2022	11:15	POND F	0.5	9.86	17.9	7.6	lower end where most coho fry were caught
5/20/2022	11:15	POND F	1.0	9.92	18.1	7.8	lower end where most coho fry were caught
5/20/2022	11:15	POND F	2.0	9.26	18.0	10.4	lower end where most coho fry were caught
5/20/2022	11:15	POND F	3.0	8.83	18.0	11.2	lower end where most coho fry were caught
5/20/2022	11:30	POND F	0.5	10.07	19.4	9.8	near upper log structures
5/20/2022	11:30	POND F	1.0	9.92	19.5	10.0	near upper log structures
5/20/2022	11:30	POND F	2.0	9.82	19.5	10.7	near upper log structures
5/20/2022	13:10	POND E	0.5	10.18	20.1	10.3	Lower end near log structure
5/20/2022	13:10	POND E	1.0	9.32	20.2	10.4	Lower end near log structure
5/20/2022	13:10	POND E	2.0	8.65	19.0	10.9	Lower end near log structure
5/20/2022	13:10	POND E	2.5	7.91	18.8	11.1	Lower end near log structure
5/20/2022	14:20	POND D	0.5	10.18	20.1	10.3	by lowermost log structure
5/20/2022	14:20	POND D	1.0	9.32	20.2	10.4	by lowermost log structure
5/20/2022	14:20	POND D	2.0	8.65	19.0	10.9	by lowermost log structure
5/20/2022	14:20	POND D	3.0	7.91	18.8	11.1	by lowermost log structure
5/20/2022	14:20	POND D	3.5	7.91	18.8	11.1	by lowermost log structure
5/20/2022	15:45	POND C	0.5	10.15	22.5	9.3	Mid-pond waded out
5/20/2022	15:45	POND C	1.0	9.46	25.2	18.6	Mid-pond waded out

DATE	TIME (24 HRS)	LOCATION	DEPTH OF READING (ft)	DISSOLVED OXYGEN (mg/L)	TEMP (Celsius)	SALINITY (ppt)	COMMENTS AND NOTES
6/23/2022	10:50	UPPER FW DRIVE	0.5	4.25	14.3	0.1	Mid-pool waded out
6/23/2022	10:50	UPPER FW DRIVE	1.0	4.03	14.2	0.1	Mid-pool waded out
6/23/2022	10:50	UPPER FW DRIVE	2.0	3.47	14.2	0.1	Mid-pool waded out
6/23/2022	10:50	UPPER FW DRIVE	2.5	3.26	14.1	0.1	Mid-pool waded out
6/23/2022	12:00	MAINSTEM above N FK	0.5	4.47	15.4	0.1	uppermost pool by cart bridge
6/23/2022	12:00	MAINSTEM above N FK	1.0	4.05	14.8	0.1	uppermost pool by cart bridge
6/23/2022	12:00	MAINSTEM above N FK	2.0	3.82	14.6	0.1	uppermost pool by cart bridge
6/23/2022	12:00	MAINSTEM above N FK	2.5	3.76	14.5	0.1	uppermost pool by cart bridge
6/23/2022	12:10	MAINSTEM above N FK	0.5	5.84	19.7	0.3	Log structure pool nearest salinity barrier
6/23/2022	12:10	MAINSTEM above N FK	1.0	4.57	17.1	0.3	Log structure pool nearest salinity barrier
6/23/2022	12:10	MAINSTEM above N FK	2.0	3.48	16.1	0.3	Log structure pool nearest salinity barrier
6/23/2022	12:10	MAINSTEM above N FK	3.0	3.47	16.1	1.1	Log structure pool nearest salinity barrier
6/23/2022	12:10	MAINSTEM above N FK	4.0	2.89	17.2	2.6	Log structure pool nearest salinity barrier
6/23/2022	12:10	MAINSTEM above N FK	4.5	1.45	17.5	12.8	Log structure pool nearest salinity barrier
6/23/2022	13:10	POND G	0.5	8.49	24.5	14.2	Mid-pond waded out
6/23/2022	13:10	POND G	1.0	7.76	24.4	15.2	Mid-pond waded out
6/23/2022	13:10	POND G	2.0	7.09	23.8	16.9	Mid-pond waded out
6/23/2022	13:10	POND G	3.0	6.49	23.8	17.5	Mid-pond waded out
6/23/2022	13:10	POND G	3.5	4.57	23.8	18.2	Mid-pond waded out
6/23/2022	11:30	POND E	0.5	9.54	25.6	18.3	near upper log structures
6/23/2022	11:30	POND E	1.0	9.07	25.4	18.7	near upper log structures
6/23/2022	11:30	POND E	2.0	8.78	24.8	19.2	near upper log structures

Appendix C.

2022 Martin Slough Vegetation Monitoring Plant Species List.

Plant species detected in wetland and/or riparian vegetation monitoring plots in Martin Slough in 2022. Wetland indicator status is provided only for those species detected within plots in the wetland zone.

Scientific Name	***Common Name***	***Wetland Indicator Status***	***Native (N) Nonnative (NN)***
Alnus rubra	Red alder	FAC	N
Argentina anserina	Silverweed	FACW	N
Atriplex prostrata	Fat hen	FAC	NN
Baccharis pilularis	Coyote brush	--	N
Bolboschoenus maritimus	Alkali bulrush	OBL	N
Bromus carinatum	California brome	FACU	N
Carex lyngbyei	Lyngby sedge	OBL	N
Carex obnupta	Slough sedge	OBL	N
Ceanothus thyrsiflorus	Blue blossom	--	N
Cirsium vulgare	Bull thistle	FACU	NN
Cirsium sp.	Thistle	--	NN
Cornus sericea	Red osier dogwood	--	N
Cotula coronopifolia	Brass buttons	FACW	NN
Distichlis spicata	Saltgrass	FACW	N
Eleocharis macrostachya	Pale spikerush	OBL	N
Elymus glaucus	Blue wild rye	--	NN
Elymus repens	Quack grass	--	NN
Epilobium ciliatum	Willowherb	--	N
Euphorbia sp	Spurge	--	NN
Festuca microstachys	Small fescue	--	N
Festuca rubra	Red fescue	FAC	N

Scientific Name	*Common Name*	*Wetland Indicator Status*	*Native (N) Nonnative (NN)*
Festuca sp.	Fescue	--	N
Frangula purshiana	Cascara buckthorn	--	N
Helichrysum luteoalbum	Jersey cudweed	FACW	NN
Holcus lanatus	Yorkshire fog	FAC	NN
Hordeum brachyantherum	Meadow barley	FACW	N
Hypochaeris glabra	Smooth cat's ear	--	NN
Hypchaeris radicata	Rough cat's ear	--	NN
Juncus balticus	Wire rush	OBL	N
Juncus effusus	Soft rush	OBL	N
Juncus patens	Spreading rush	FAC	N
Leucanthemum vulgare	Ox eye daisy	--	NN
Lotus corniculatus	Birdsfoot trefoil	FAC	NN
Lonicera involucrate	Twinberry	FAC	N
Lupinus sp.	Lupine	--	--
Morella cerifera	Wax myrtle	--	N
Oenanthe sarmentosa	Water parsley	OBL	N
Phalaris arundinacea	Reed canary grass	OBL	NN
Picea sitchensis	Sitka spruce	FAC	N
Plantago lanceolata	Ribwort plantain	FAC	NN
Plantago major	Broadleaf plantain	FACW	NN
Poa pratensis	Kentucky blue grass	FACU	NN
Rubus armeniacus	Himalaya berry	FACU	NN
Ranunculus repens	Creeping buttercup	FACW	NN
Ribes sanguineum	Red flowering current	--	N
Rubus parviflorus	Thimbleberry	FAC	N

Scientific Name	***Common Name***	***Wetland Indicator Status***	***Native (N) Nonnative (NN)***
Rubus spectabilis	Salmonberry	FAC	N
Rumex salicifolius	Willow dock	OBL	N
Salix lasiandra	Pacific willow	OBL	N
Sequoia sempervirens	Coast redwood	--	N
Salix sitchensis	Sitka willow	FACW	N
Spiraea douglasii	Western spiraea	OBL	N
Taraxacum officinale	Dandelion	FACU	NN
Trifolium dubium	Lesser trefoil	FACU	NN
Trifolium repens	White clover	FACU	NN
Trifolium sp.	Clover	--	NN
Triglochin maritima	Arrowgrass	OBL	N
Typha latifolia	Broadleaf cattail	OBL	N