TIDAL EXCHANGE AND WATER QUALITY MONITORING
SALT RIVER ECOSYSTEM RESTORATION PROJECT
PHASE 1 & 2
YEAR 3 – 2016

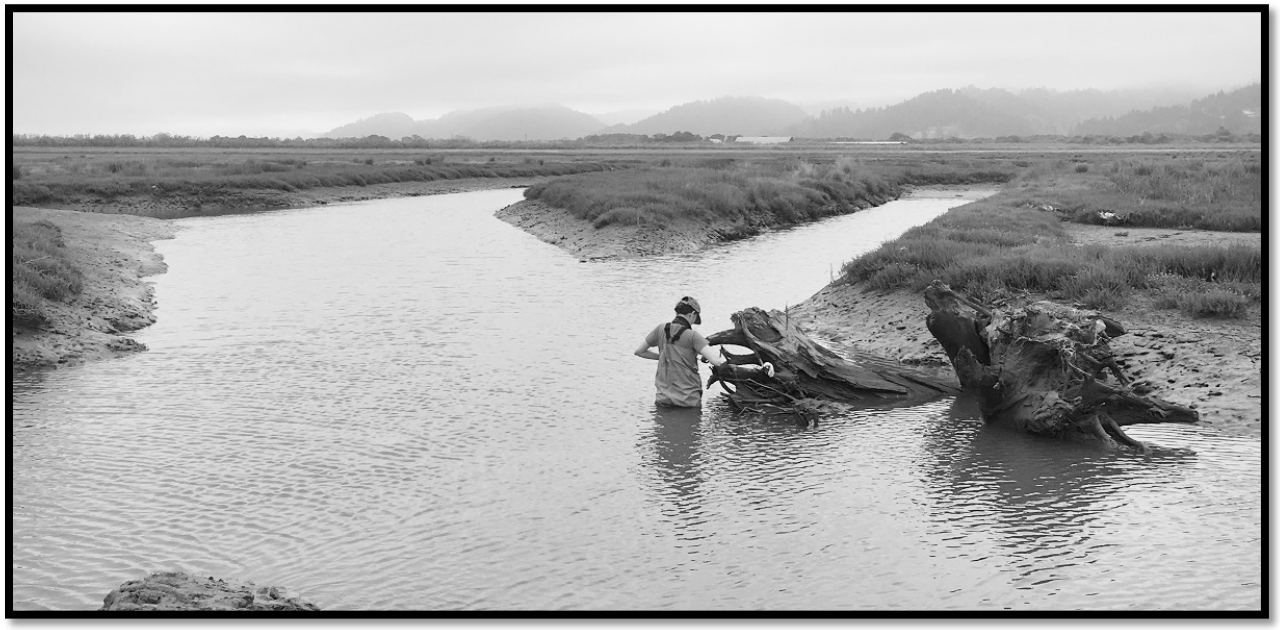

Photo: Summer Daugherty

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PURPOSE

In 2013 restoration work was completed to re-convert over 300 acres of reclaimed pasture back to a variety of tidal marsh habitats and restore 2.5 miles of Salt River channel. This work represents the first phase (Phase 1) of a watershed-scale restoration effort known as the Salt River Ecosystem Restoration Project. In 2014, an additional 1.2 miles of Salt River channel was restored/enhanced from the restored estuary (Phase1) to the upper extent of tidal inundation (portion of Phase 2). Presented in this Tidal Exchange and Water Quality Monitoring Report are the results of three months of continuous sampling for water quality parameters including salinity, dissolved oxygen, temperature, and water-level within the Phase 1 and portion of Phase 2 restoration footprint.

INTRODUCTION

The Salt River Ecosystem Restoration Project is located in Humboldt County, California near the City of Ferndale. The purpose of the Salt River Ecosystem Restoration Project (SRERP) is to restore hydrological processes and functions to the Salt River watershed. These processes and functions are necessary to re-establish a functioning riverine, riparian, wetland and estuarine ecosystem as part of a land use, flood alleviation, and watershed management program.

An essential element to the design of the SRERP is the restoration, or re-conversion, of 330 acres of tidal estuary on the former Riverside Ranch dairy. This work was largely completed in 2013 and represents the first phase (Phase 1) of a multi-year, multi-phase ecosystem restoration effort. This component of the larger project was also known as the Riverside Ranch Tidal Marsh Restoration for the purposes of some grant funds secured for the project.

In 2014, an additional 1.2 miles of main stem Salt River channel was excavated and enhanced immediately upstream of the 2013 effort. The extent of the 2014 restoration terminated within feet of the expected tidal inundation (just above Dillon Road Bridge). This portion of the restoration efforts constitutes a portion of the project footprint known as Phase 2.

Restoration work re-established intertidal connection between the Eel River Estuary and the Salt River and substantially enhanced wetland habitat. The restored marsh area in combination with expansion of the Salt River channel and creation of an extensive internal slough network has increased tidal exchange and enhanced tidal prism (i.e. increasing the volume of water exchanged on each tidal cycle). These restored features are intended to help sustain the Salt River channel's width and depth.

Some primary objectives of the tidal marsh restoration include specific items to help attain the following project goals:

- Use the increase in tidal prism to help maintain the constructed Salt River channel geomorphology and hydrologic conveyance.
- Improve drainage and water quality in the lower Salt River and Eel/Salt River estuary.

- Restore tidal connectivity to historic tidal wetlands to allow for the natural evolution of diverse and self-sustaining salt- and brackish water tidal marshes, intertidal mudflat and shallow water habitats.
- Create a template for the natural evolution of a complex tidal drainage network. The network will maximize subtidal and intertidal habitats beneficial to marine and anadromous fish and wildlife species. This includes the enhancement of rearing and migration conditions for estuarine-dependent species including: coho salmon, Chinook salmon, steelhead trout, coastal cutthroat trout, tidewater goby, and commercially and recreationally valuable species such as redtail perch.
- Provide winter habitat for migratory waterfowl and shorebirds.

METHODS

An Adaptive Management Plan (AMP) was developed and adopted for the SRERP. The AMP describes the organizational structure for the adaptive management process, identifies key players and their roles, and provides a range of management thresholds and triggers. The process is intended to ensure that project goals and objectives are attained while also providing for on-going, long-term input from local property owners and other stakeholders. The AMP defines numerous monitoring requirements that encompass erosion, geomorphic, sediment, and habitat conditions. This report's monitoring effort focuses on the tidal prism and water quality objectives on Phase 1 and the lower portion of the Phase 2 restoration of the SRERP.

To measure tidal prism, multi-parameter recorders are deployed to determine tidal exchange, functional tidal prism, and a healthy salinity structure. These recorders measure water quality parameters such as water level, temperature, dissolved oxygen, and salinity levels. Recorders are deployed at four sites across Riverside Ranch (Figure 1). The 2016 sites include: 1) immediately downstream of the confluence of the southern slough channel on the Salt River; 2) at a large wood structure located midway upstream on the southern slough channel network, associated with a fish sampling site (modified from previous years due to degradation of original site); 3) immediately downstream of the confluence of the northern slough channel on the Salt River; 4) at a terminal end of the northern slough channel network, associated with a fish sampling site. Two additional sites were established outside of the Phase 1/Riverside Ranch footprint, which included a site near the confluence of the Salt River and Eel River and further upstream on the main stem Salt River channel near the upstream tidal extent (at Dillon Road Bridge). In 2016, the site near the confluence of the Salt River and Eel River was abandoned due to repeated loss of equipment in the highly dynamic system.

In 2014 (Year 1), data loggers were deployed in PVC housings. However, the PVC housing may have inflated temperature data due to the housing heating up during low tide events during daylight hours. Therefore data loggers are currently attached to the outside of PVC covered rebar. Each recorder was programed to take samples every hour, on the hour, each day of deployment. This sampling regimen provides a high enough resolution to determine the

changing habitat conditions. Dissolved oxygen (DO) loggers are only required to be at two interior slough sites (Sites #2 and #4) on Riverside Ranch. These sites are associated with two fish sampling sites. DO loggers are deployed for only two weeks in July/August to determine DO levels in the slough channels during the warmest part of the year.

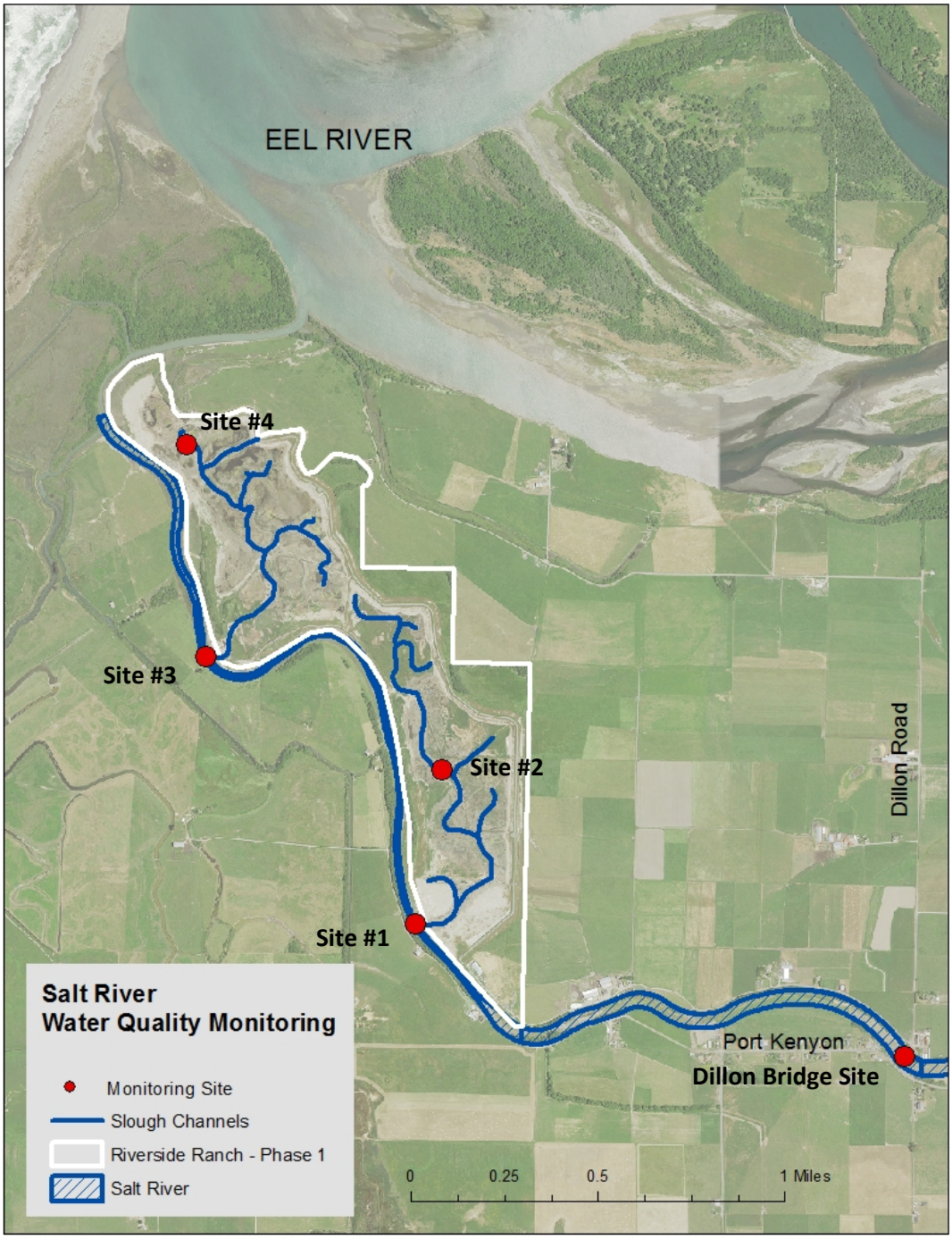


Figure 1: 2016 Water Quality Sampling Sites across the Salt River Ecosystem Restoration Project.

RESULTS

The previous two years of data collection indicates that the loggers foul quickly over time, thus providing possible erroneous data. Salinity and Dissolved Oxygen loggers appear to be impacted by algal and microorganism growth on the sensors. Additionally, the loggers deployed at Site #3 in 2016 (at the confluence of the Salt River and the northern slough channel) were unable to be collected due to persistent early rains which raised Salt River levels and frequent day time high tides.

The following results will present summarized data by site for water level, comparison of water level and tidal height (Humboldt Bay), temperature, salinity, and dissolved oxygen.

Site 1 – Southern Salt River Channel Adjacent to Riverside Ranch

Site 1 is located in the main stem Salt River in the estuary portion of the project area (Riverside Ranch), immediately downstream of the confluence of the southern slough channel network. In 2016, the site is influenced by tidal waters and fresh water inputs which are directly upstream (Reas Creek) and downstream (Smith Creek). The loggers were stationed on the right side of the channel, above the thalwag, to keep the equipment out of the way of any boat traffic. At extreme low tides, the site is often completely dewatered; thus water quality loggers are exposed to the air. The loggers were deployed on July 29th, 2016. Water level and salinity loggers were retrieved on November 1st, 2016.

The following figures present the collected data graphically.

Figure 1A. Site 1 Water Depth

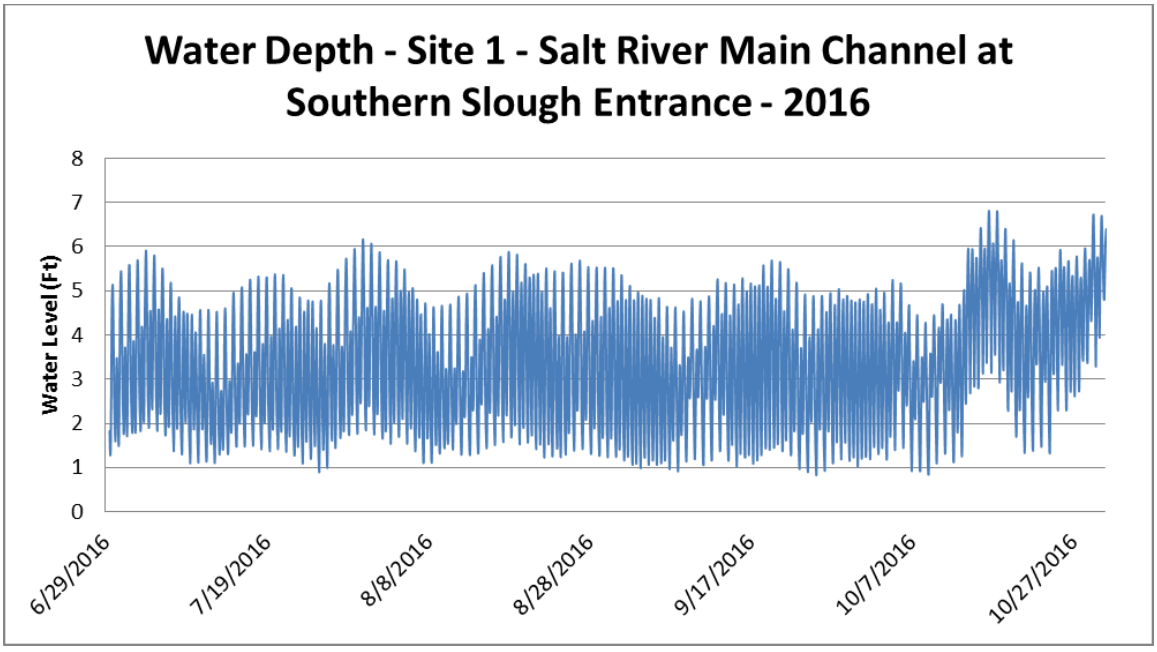


Figure 1B. Site 1 Water Level and Humboldt Bay Tidal Height Comparison

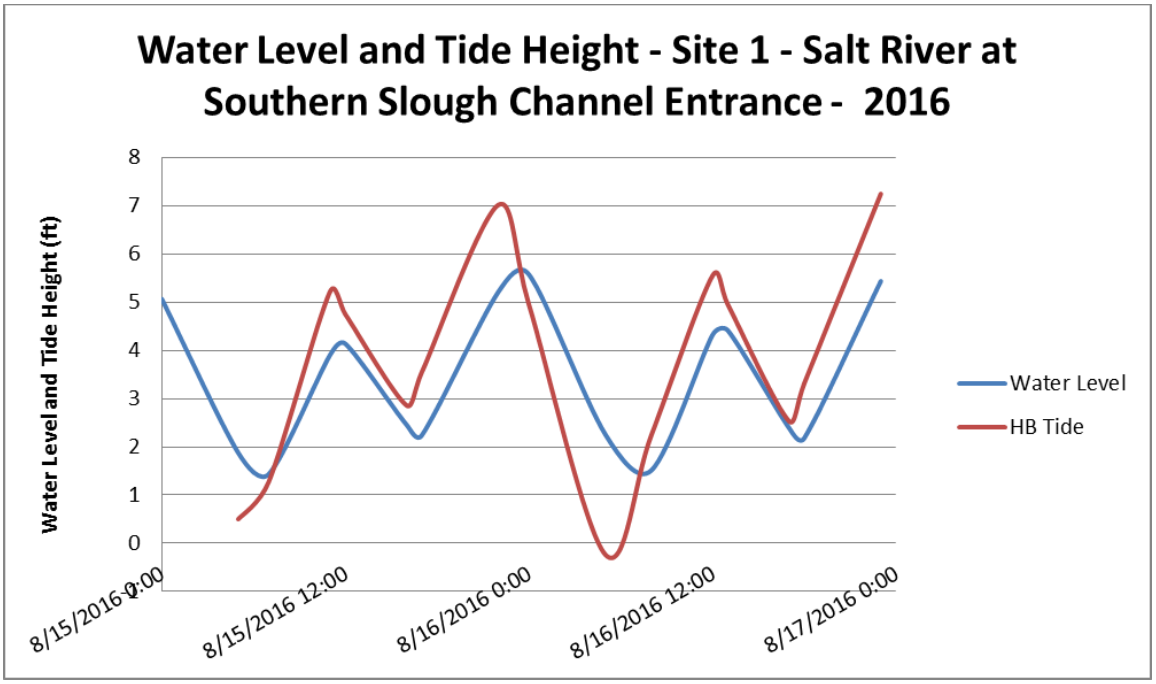


Figure 1C. Site 1 Temperature

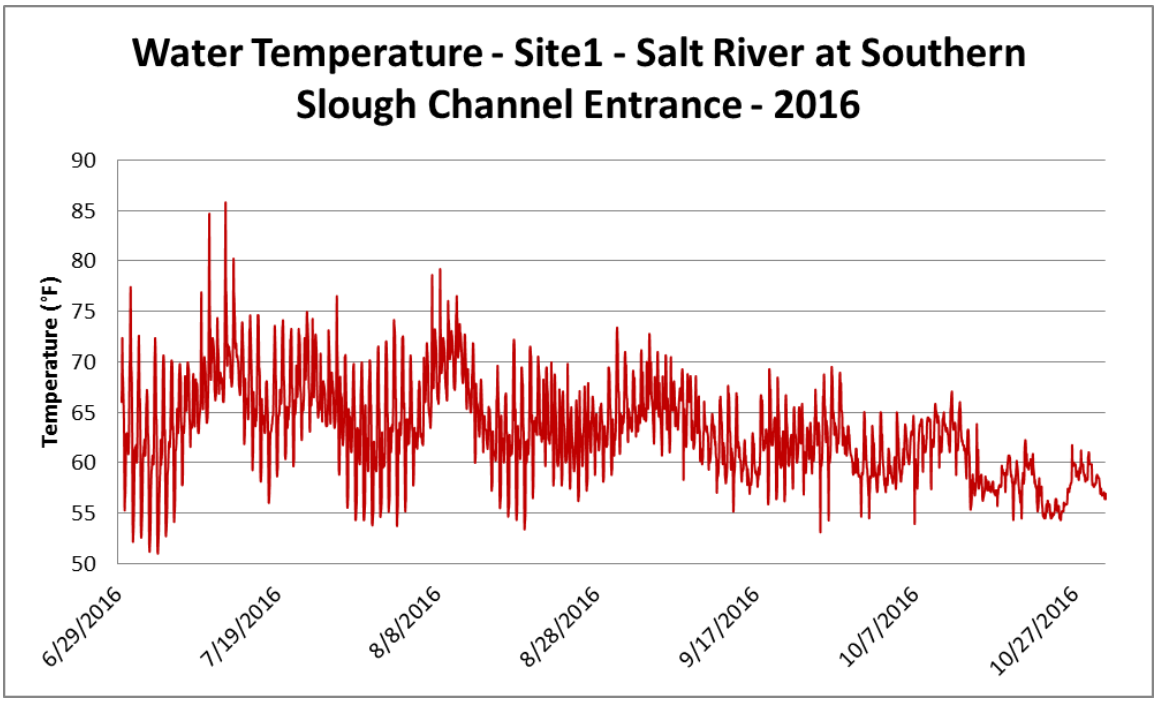
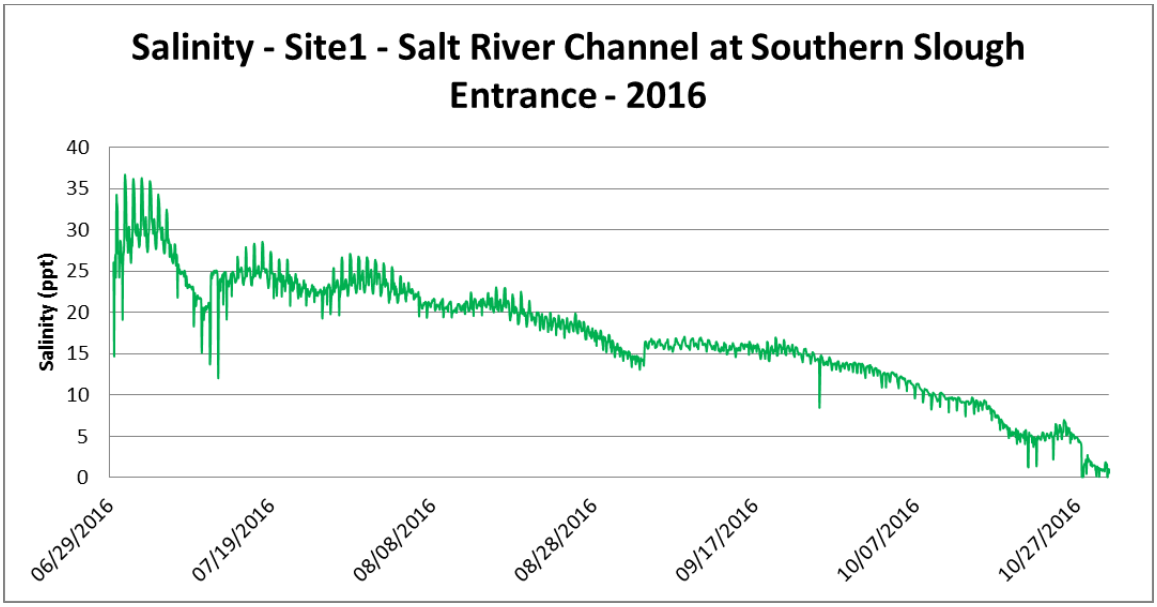


Figure 1D. Site 1 Salinity



** Removed salinity values corresponding below 1.2' of water level (when water loggers were likely out of the water at low tide)

Table 1. 2016 Water Parameter Statistics for Site 1

	Water Parameter - Site 1			
	Water Level (ft)	Temperature (°F)	Salinity (ppt)	Dissolved Oxygen (mg/L)
Maximum	7.6	85.7	36.6	N/A
Minimum	0.8	51	0.05	N/A
Average	3.3	63.1	17.1	N/A

Water Level – Site 1

Site 1 is located in the Eel River estuary and is directly affected by tidal water inundation. Large fluctuations in water level, as depicted by the data and graph above (Figure 1A), are due to the diurnal high and low tides. The tides are muted at the site compared to actual ocean conditions. Maximum water level during the sampling period (July through October) reached 7.6 feet and decreased to a minimum of 0.8 feet, with an average 3.3 feet (Table 1).

Water levels at Site 1 are compared to tide heights at the Humboldt Bay North Spit tide station for two days in August (15th and 16th) (Figure 1B). Though tides heights in the Humboldt Bay and water levels at Site 1 should not be strictly equated to each other since the site is not at a 0.0

ft elevation, tides and water levels can be correlated to determine the lag time of tidal waters entering the site. Reviewing the two day interval in the Figure 1B and the associated data, it appears at this site, the high tide lag is between 1 to 2 hours and the low tide lag is generally 1 hour, though upwards to 3 hours when the preceding high tide is above 7 feet.

Temperature – Site 1

Temperature readings were collected from the water level recorder (Figure 1C). This recording device was likely exposed to air temperature during lower tides, thus recording large temperature spikes.. The average temperature during the sampling period is calculated at 63.1 °F (Table 1). The maximum temperature reached 85.7 °F and the minimum temperature dropped to 50.1 °F. The Water Temperature graph above shows a slightly decreasing and less variable temperature trend from July to October. This is consistent with colder atmospheric and ocean temperatures developing as the seasons turn from summer to fall.

Salinity – Site 1

Recorded salinity values ranged from 36.6 (ppt) to nearly zero (0.01 ppt) (Table 1 and Figure 1D). The low salinity values correspond to the logger being out of the water (low tide) during the logging time. If the outliers are neglected, salinity appears to still have a similar range between 36.6 (ppt) and 0.05 (ppt). In 2014, salinity logger sensors proved to foul quickly. Thus the data collected may be erroneous. However, the data collected at this site (1) appears probable. The decreasing salinity values from late September to the end of the collection period (November), coincides with increasing rain events. These rain events produced increased fresh water inputs not only in the Salt River tributaries, but also in the Eel River which pushes up into the estuary at high tides.

Dissolved Oxygen – Site 1

A dissolved oxygen logger was not deployed at this site. Dissolved oxygen loggers are only deployed in the interior slough channels of Riverside Ranch.

Site 2 – Southern Slough Network on Riverside Ranch

Site 2 is located in the southern slough network in the estuary portion of the project area (Riverside Ranch), midway up the slough channel from the confluence of the Salt River. This site is not the same as Site 2 in 2015. Staff relocated the site due to sedimentation aggradation and the erosion of a downstream channel feature barrier at the original Site 2. This site is almost exclusively tidally influenced. Fresh water inputs are incidental, and come in with the high tides. The loggers were stationed at a large wood structure that has a scour pool. The loggers were deployed on June 29th, 2016. The dissolved oxygen logger was deployed on July 20th and retrieved on August 4th, 2016. Water level and salinity loggers were retrieved on November 10th, 2016.

The following figures present the collected data graphically.

Figure 2A. Site 2 Water Depth

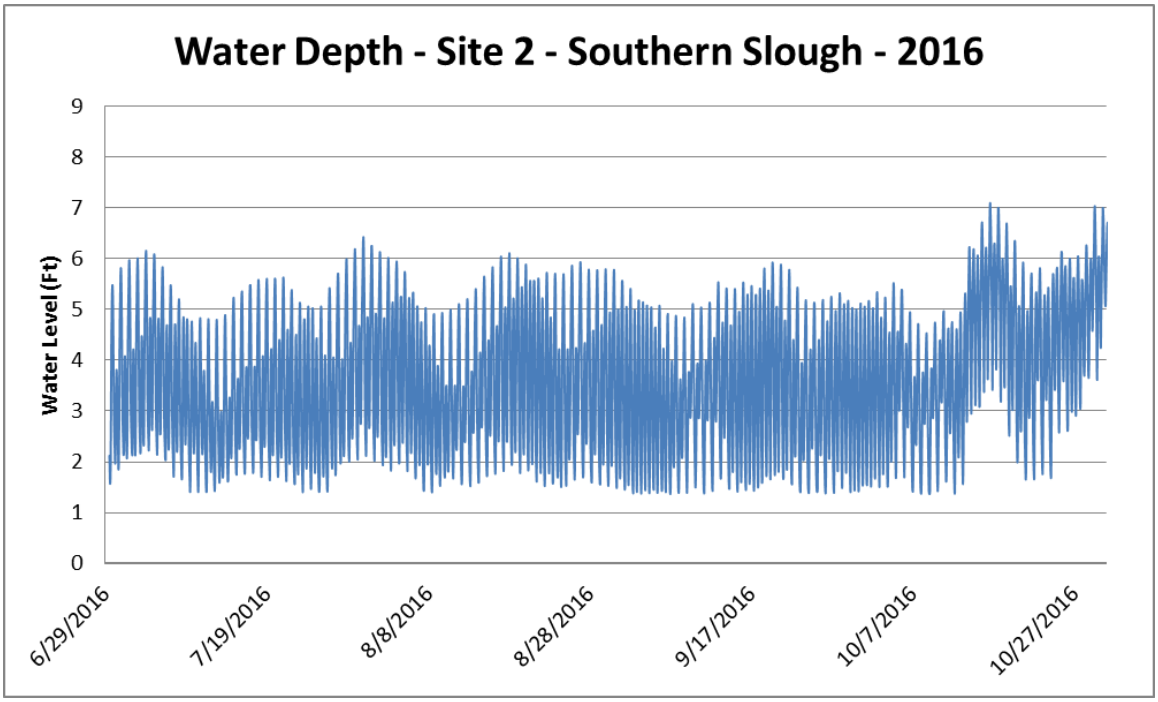


Figure 2B. Site 2 Water Level and Humboldt Bay Tidal Height Comparison

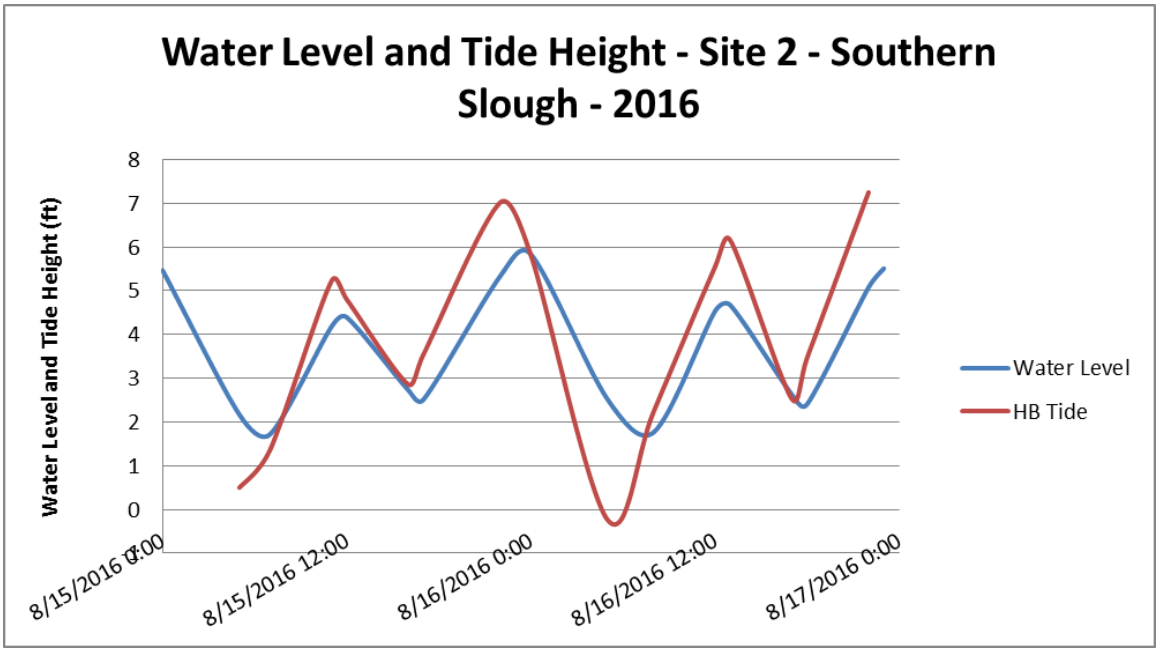


Figure 2C. Site 2 Temperature

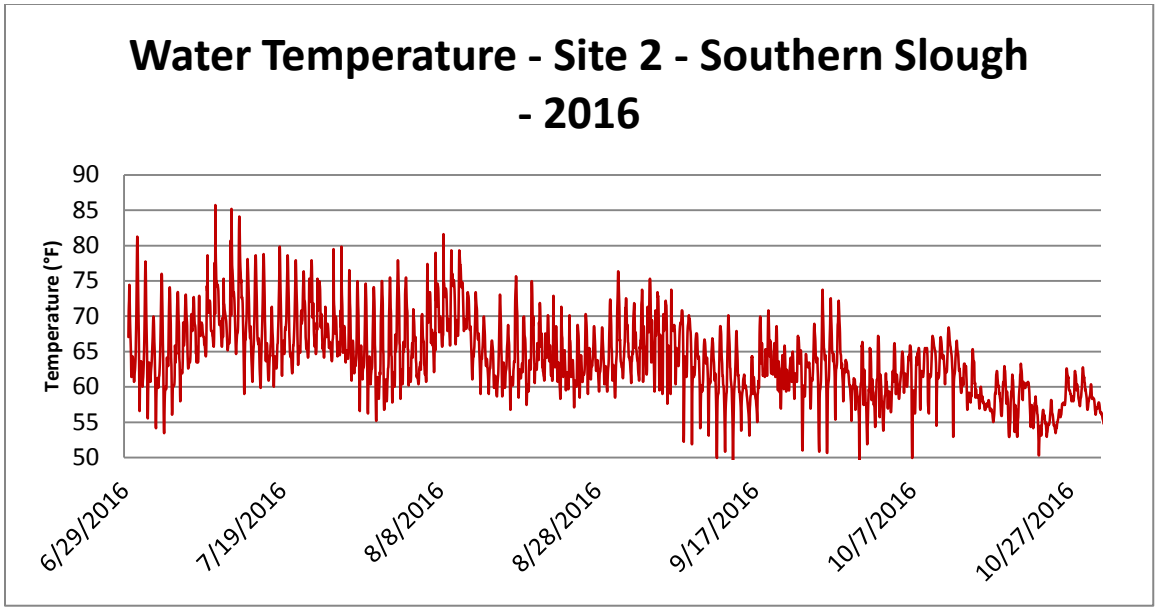
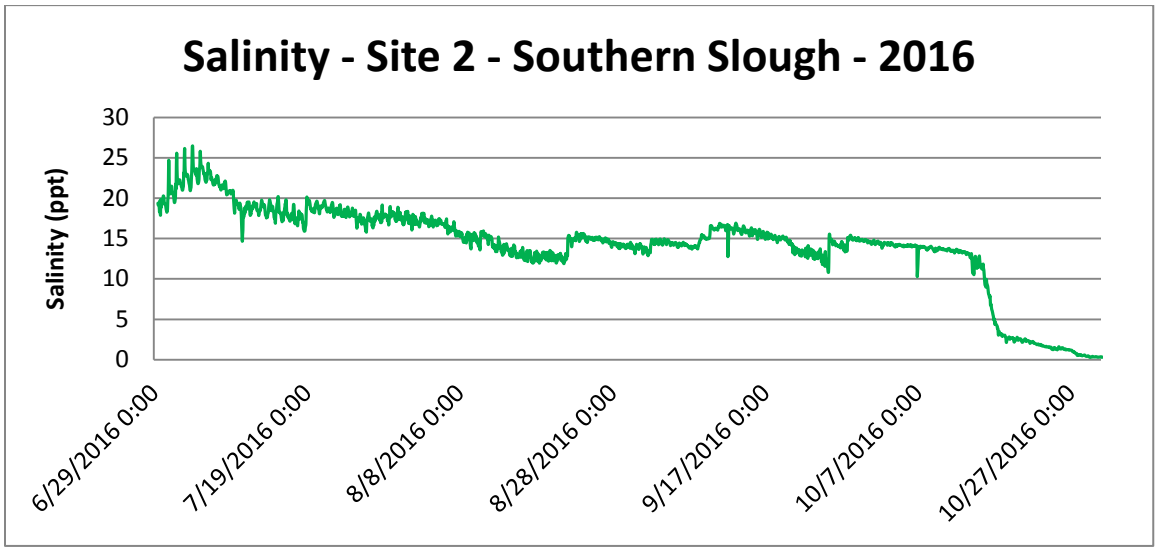


Figure 2D. Site 2 Salinity



*Removed salinity data when water levels were at 1.7' or below, when loggers were likely out of water

Figure 2E. Site 2 Dissolved Oxygen

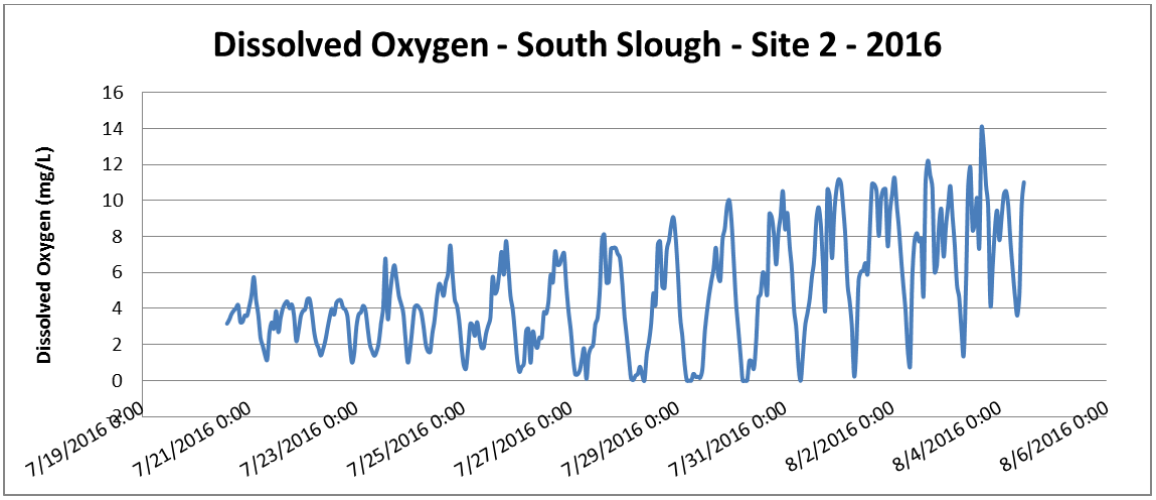


Table 2. 2016 Water Parameter Statistics for Site 2

	Water Parameter - Site 2			
	Water Level	Temperature	Salinity	Dissolved Oxygen
	(ft)	(°F)	(ppt)	(mg/L)
Maximum	7.9	85.7	26.5	14.0
Minimum	1.4	49.2	0.3	0.0
Average	3.6	63.9	14.0	4.9

Water Level – Site 2

Site 2 is located in the Eel River estuary and is directly affected by tidal water inundation. Fluctuations in the water level, as depicted by the data, are due to the diurnal high and low tides (Figure 2A). The tides are muted at the site compared to actual ocean conditions. Maximum water level during the sampling period (July through October) reached 7.9 feet and decreased to a minimum of 3.6 feet, with an average 1.4 feet (Table 2).

Water levels at Site 2 are compared to tide heights at the Humboldt Bay North Spit tide station for two days in August (15th and 16th) (Figure 2B). Tides heights in the Humboldt Bay and water levels at Site 2 should not be strictly equated to each other since Site 2 is not at a 0.0 ft elevation. Tides and water levels can be correlated to determine the lag time of tidal waters entering the site. Reviewing the two day interval graph above and associated data, it appears at this site, the high tide lag is between 1 to 2 hours depending on the tide level (larger tides take longer to peak

in the system) and the low tide lag is generally 1 hour, though upwards to 3 hours when the preceding high tide is above 7 feet.

Temperature – Site 2

Temperature readings were collected from the water level recorder (Figure 2C). The average temperature during the sampling period is calculated at 63.9 °F. The maximum temperature recorded is 85.7 °F and the minimum temperature is 49.2 °F (Table 2). The Water Temperature graph above shows a decreasing temperature trend from July to October. This is consistent with colder atmospheric and ocean temperatures setting in from summer to fall.

Salinity – Site 2

In 2014, salinity logger sensors proved to foul quickly. The Salinity graph above shows readings begin to gradually decrease after the first week (Figure 2D). Though the data begins to level off in mid-August then decline dramatically mid-October. Recorded salinity values ranged between 26.5 (ppt) and 0.3 (ppt). Spot salinity measurements, taken with a hand held meter, were at 19.03 (ppt) at deployment and 8.22 (ppt) at retrieval (Table 2). The spot salinity measurements appear to indicate that sensors were compromised and did not record accurately the last half of October.

Dissolved Oxygen – Site 2

A dissolved oxygen (DO) logger was deployed between July 20th and August 4th, 2016. The DO levels recorded at this site indicate that DO is positively correlated with temperature. That is, as temperature peaks, DO peaks; as temperatures decrease, DO decreases. This is contrary to rule that cold water contains higher DO levels than warm water. Further analyzing the data, DO is not correlated with high tides or changing tides; unless it is coincides with temperature. For example, the highest DO recorded at the end of the sampling period is correlated with high temperatures and a high water levels from a high tide. After further analysis, it was determined that DO is directly and positively correlated with daylight, where DO concentrations are highest during midday (thus during the warmest part of the day). This is likely due to the increased photosynthesis of aquatic microbes in the water (e.g. phytoplankton). Though DO levels positively correlate with daylight, it doesn't explain the increase in variance over time. Colonies of microorganisms covered the DO logger and its sensor which may impact DO levels present during logger readings.

Typically, the amount of dissolved oxygen at 100% saturation is around 10 mg/L. However, water can become supersaturated (>100%) due to the photosynthesis of aquatic microbes. This could explain the maximum DO level of 14.0 mg/L. The recorded minimum DO level is0.0(Table 2 and Figure 2E). It is unknown if these values are indicative of true levels. DO meters tend to read inaccurately. However spot DO measurements during fish surveys at the same site indicate supersaturated DO concentrations (approximately 3.16 mg/L and 9.71 mg/L in June and July respectively).

Site 3 – South Salt River Channel Adjacent to Riverside Ranch

Site 3 is located in the main stem Salt River in the estuary portion of the project area (Riverside Ranch), immediately downstream of the confluence of the northern slough channel network's confluence. In 2016, the site is influenced by tidal waters and fresh water inputs directly upstream (Reas Creek and Smith Creek). The loggers were stationed on the right side of the channel, above the thalwag to keep the equipment out of the way of any boat traffic. At low tides, the site is often dewatered; thus water quality loggers are exposed to the air. The loggers were deployed on June 29th. Unfortunately, due to persistent day-time high tides and early rains, which raised Salt River levels, data loggers from Site 3 were unable to be recovered in time for this report write-up.

Table 3. Water Parameter Statistics for Site 3 – Results are unavailable

	Water Parameter - Site 3			
	Water Level	Temperature	Salinity	Dissolved Oxygen
	(ft)	(°F)	(ppt)	(mg/L)
Maximum	N/A	N/A	N/A	N/A
Minimum	N/A	N/A	N/A	N/A
Average	N/A	N/A	N/A	N/A

Site 4 – Northern Slough Network on Riverside Ranch

Site 4 is located in the northern slough network in the estuary portion of the project area (Riverside Ranch), at one of the terminal arms furthest away from the confluence of the Salt River. This site is almost exclusively tidally influenced. Fresh water inputs are incidental, and come in with the high tides. The loggers were stationed behind a channel feature that creates backwater at low tides. Therefore, at low tides, the loggers are continuously submerged. The loggers were deployed on June 29th, 2016. The DO logger was not deployed as the sensor became damaged at deployment. Water level and salinity loggers were retrieved on November 1st, 2016.

The following figures present the collected data graphically.

Figure 3A. Site 4 Water Depth

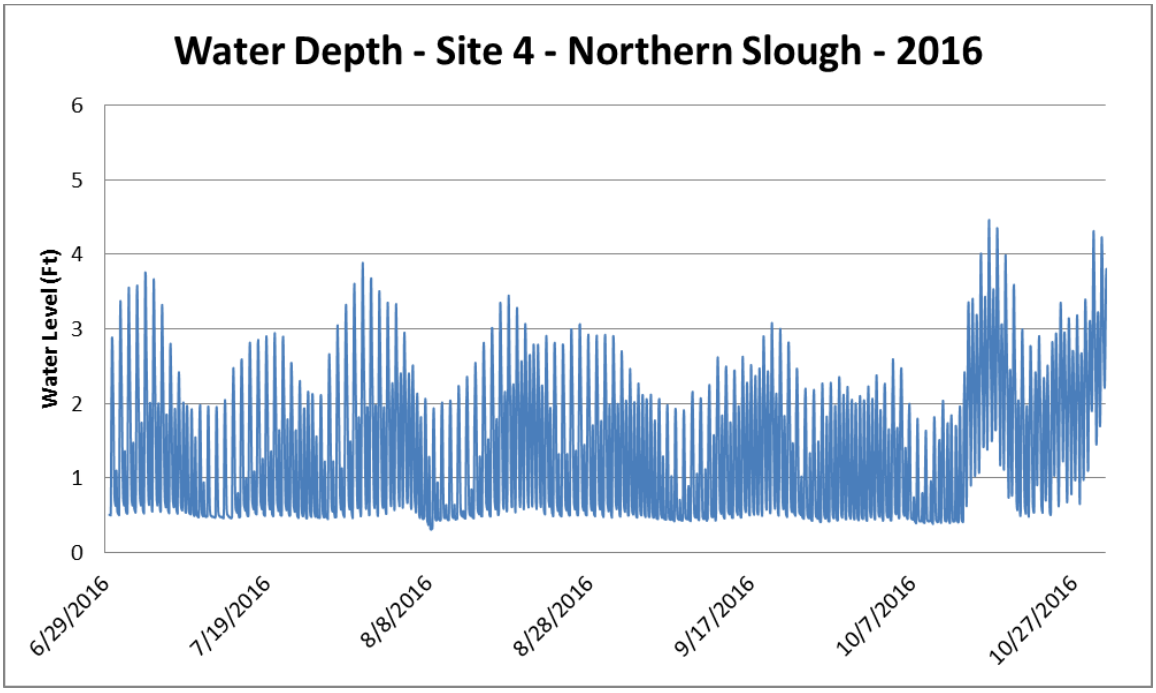


Figure 3B. Water Level and Humboldt Bay Tidal Height Comparison

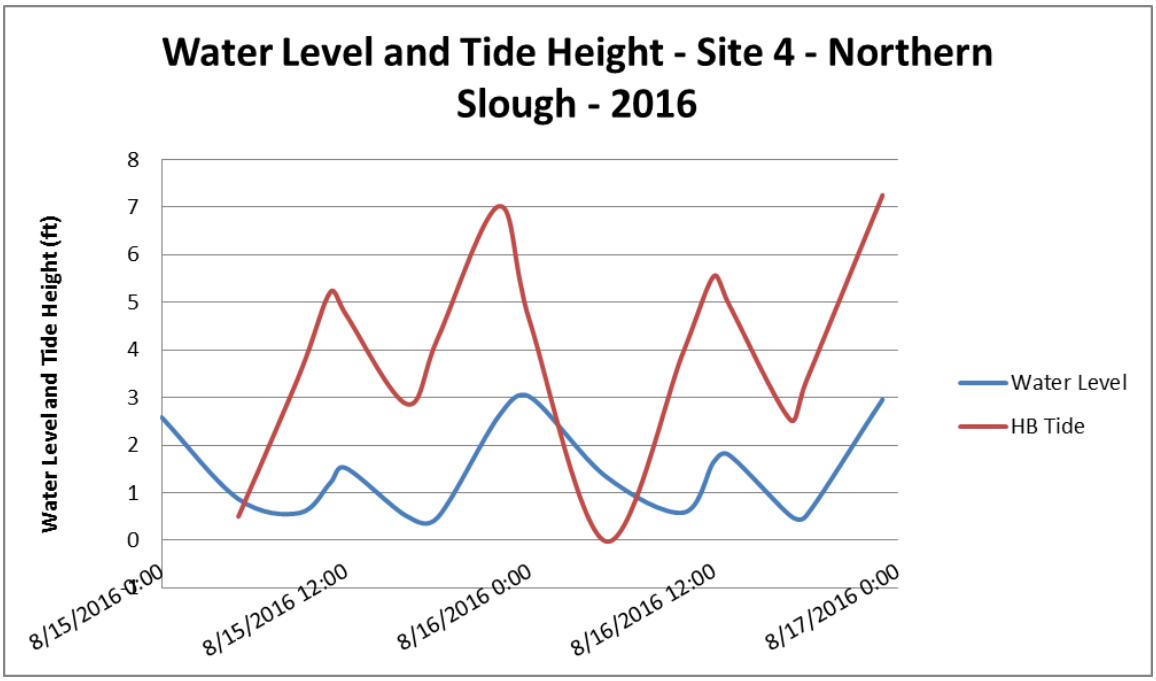


Figure 3C. Site 4 Temperature

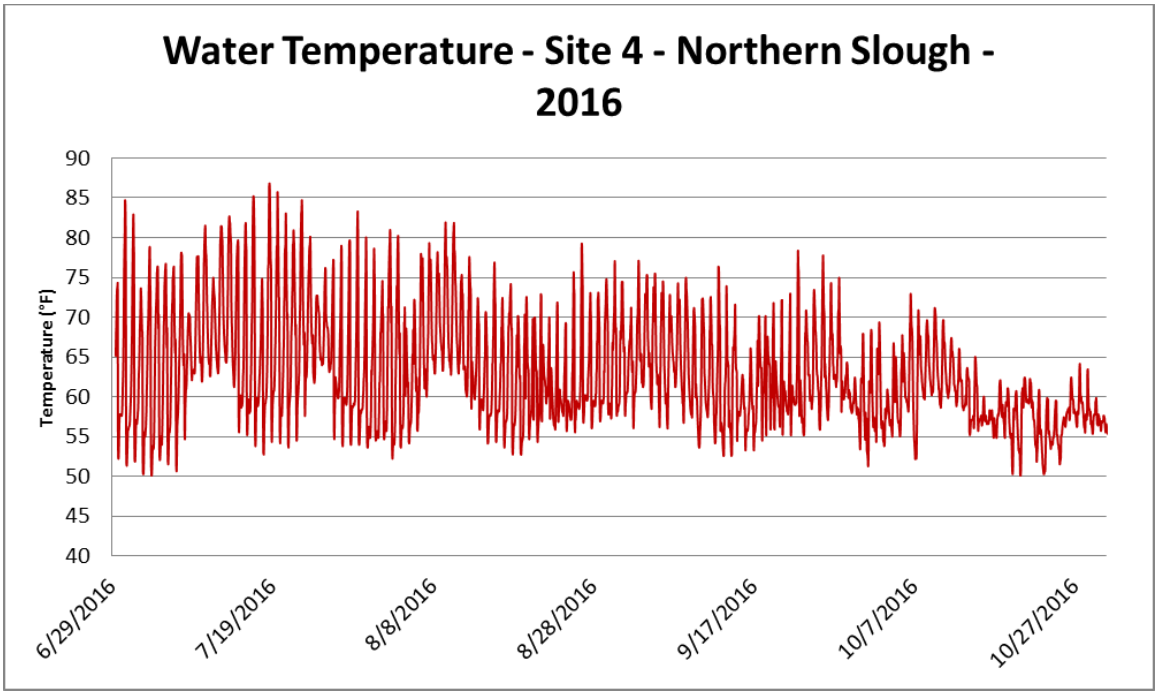


Figure 3D. Site 4 Salinity

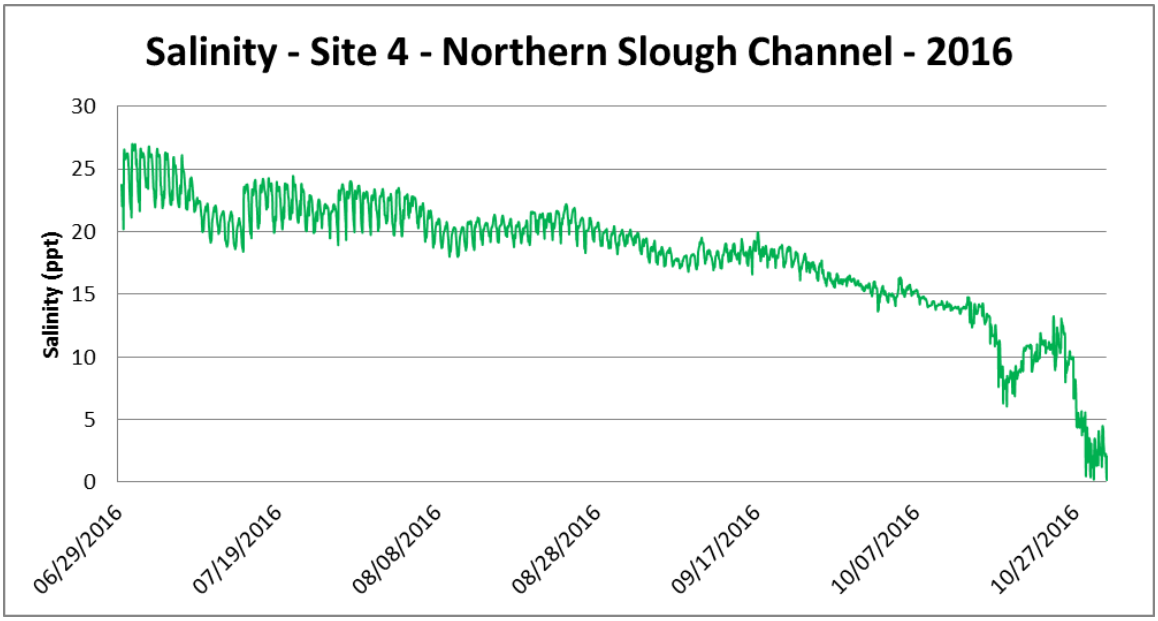


Table 4. Water Parameter Statistics for Site 4

	Water Parameter - Site 4			
	Water Level	Temperature	Salinity	Dissolved Oxygen
	(ft)	(°F)	(ppt)	(mg/L)
Maximum	5.0	86.8	27.0	N/A
Minimum	0.3	50.1	0.2	N/A
Average	1.3	63.0	18.0	N/A

Water Level – Site 4

Site 4 is located in the Eel River estuary and is directly affected by tidal water inundation. Fluctuations in the water level, as depicted by the data, are due to the diurnal high and low tides. The tides are muted at the site compared to actual ocean conditions. Maximum water level during the sampling period (July through October) reached 5.0 feet and decreased to a minimum of 0.3 feet, with an average 1.3 feet (Table 4 and Figure 3A).

Water levels at Site 4 are compared to tide heights at the Humboldt Bay North Spit tide station for two days in August (15th and 16th) (Figure 3B). Tides heights in the Humboldt Bay and water levels at Site 4 should not be strictly equated to each other since the site is not at a 0.0 ft elevation. Tides and water levels can be correlated to determine the lag time of tidal waters entering the site. Reviewing the graph above and data, it appears this site's high tide lag is 1 to 2 hours and the low tide lag is between 1 and 5 hours within the two day interval. These lag times indicate that the internal slough network fills quickly, but drains very slowly.

Temperature – Site 4

Temperature readings were collected from the water level recorder. No temperature spikes should have been recorded since the logger was continuously submerged. However, on average, this is a very shallow site and temperatures can rise dramatically during sun exposure. The average temperature during the sampling period is calculated at 63.0 °F. The maximum temperature recorded is 86.8 °F and the minimum temperature is 63.0 °F (Table 4 and Figure 3C). The Water Temperature graph above shows a decreasing temperature trend and less variability from July to October. This is consistent with colder atmospheric and ocean temperatures setting in from summer to fall.

Salinity – Site 4

In 2014, salinity logger sensors proved to foul quickly, however in 2016 the sensor appears to have recorded correctly. The salinity graph above shows relatively stable readings where salinity gradually decreases over the deployment time (Figure 3D). Intermittent rains in September and heavier rains in October likely affected the salinity in the estuary. The maximum salinity value

is 26.7 ppt and the minimum is 0.2 ppt (the minimum value occurring at the end of October). Average salinity is calculated to be 18.0 ppt.

Dissolved Oxygen – Site 4

The DO logger was not deployed as the sensor became damaged at deployment.

Site – Dillon Bridge – Salt River Channel

The Site at Dillon Bridge is located in the constructed Salt River channel, approximately 3.7 miles upstream from the lowest end of the restored portion of the Salt River. This site still receives tidal water at high tide events and is considered to be at the upper extent of tidal inundation. Fresh water inputs exist above the site during the monitoring period, only during wetter weather. Downstream fresh water inputs are incidental from lower tributaries, and come in with the high tides. The loggers were deployed in a shallow scour pool. The loggers were deployed on June 29th, 2016. Water level and salinity loggers were retrieved on November 1st, 2016.

The following figures present the collected data graphically.

Figure 4A. Dillon Bridge Site Water Depth

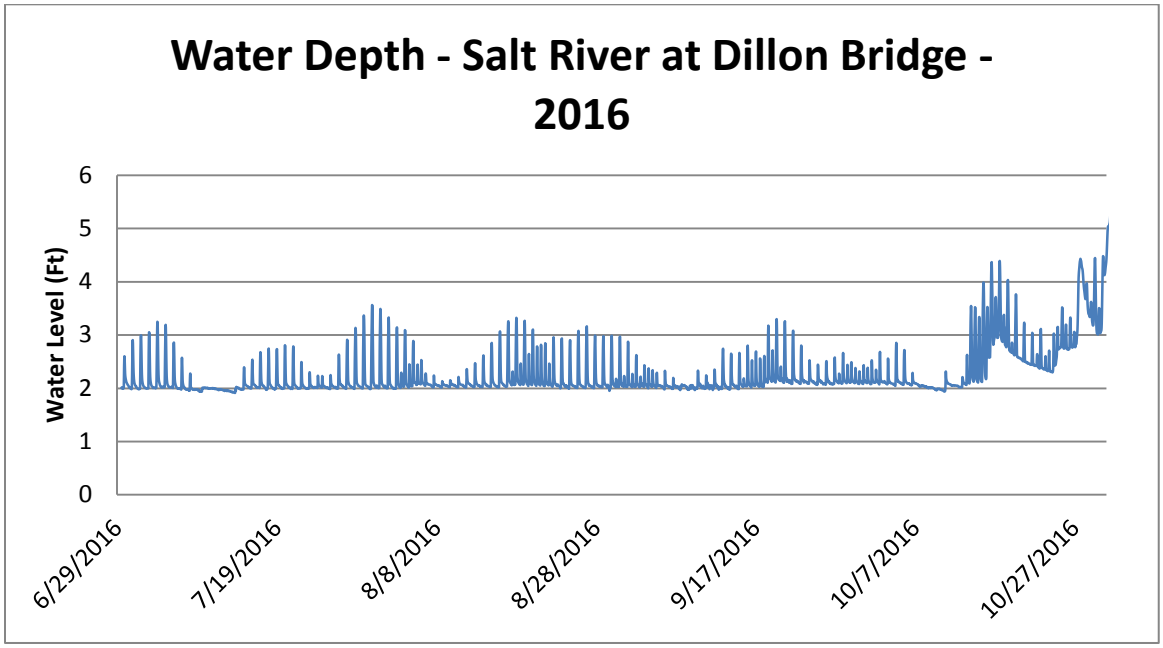


Figure 4B. Dillon Bridge Water Level and Humboldt Bay Tidal Height Comparison

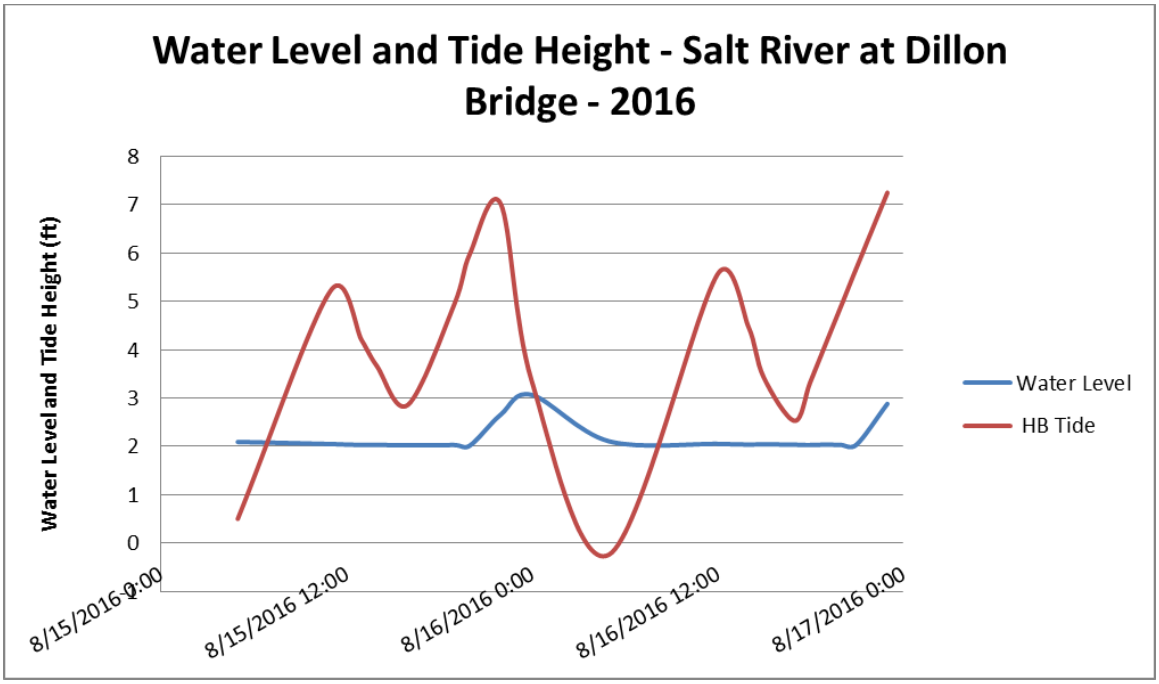


Figure 4C. Dillon Bridge Site Temperature

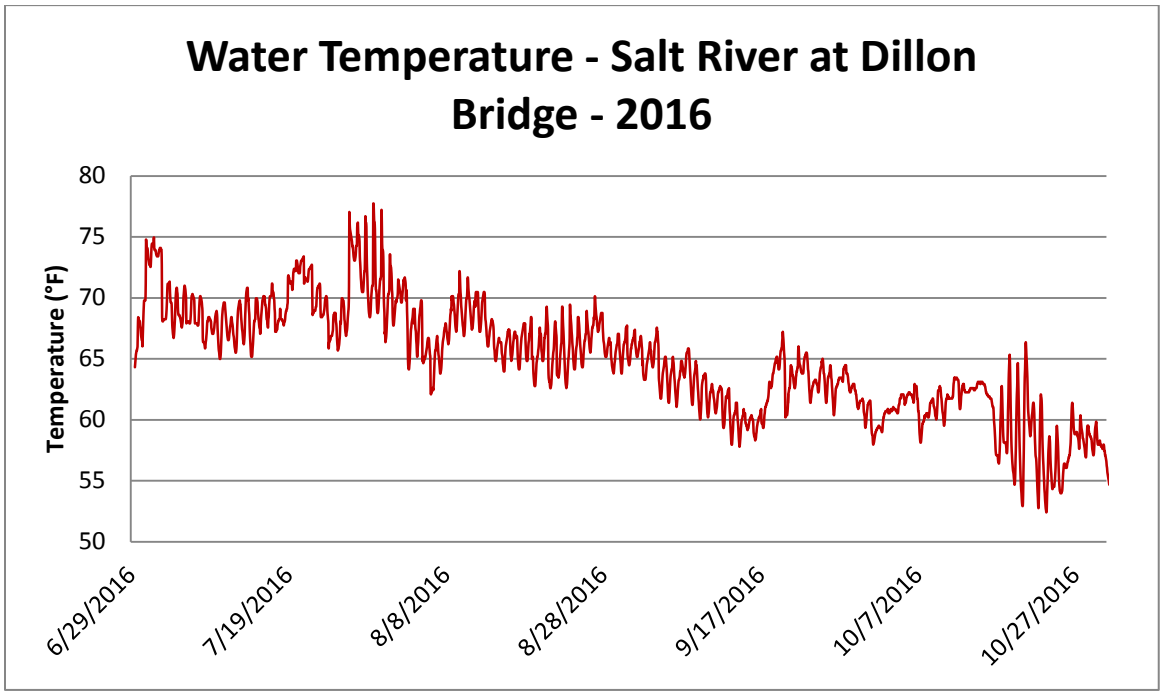


Figure 4D. Dillon Bridge Site Salinity

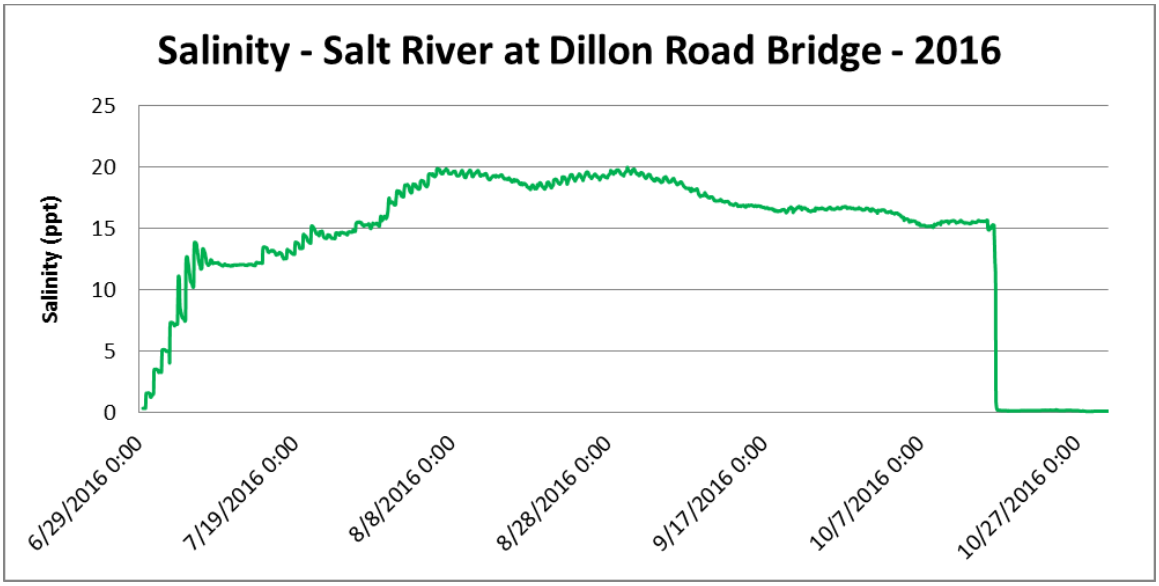


Table 5. Water Parameter Statistics for Site Dillon Bridge – Salt River Channel

	Water Parameter - Dillon Bridge			
	Water Level	Temperature	Salinity	Dissolved Oxygen
	(ft)	(°F)	(ppt)	(mg/L)
Maximum	5.6	87.7	20.0	N/A
Minimum	1.9	50.8	0.1	N/A
Average	2.3	63.1	14.1	N/A

Water Level – Site - Dillon Bridge – Salt River Channel

The Site at Dillon Bridge is located in the constructed Salt River channel and is directly affected by tidal water inundation. Fluctuations in the water level, as depicted by the data, are due to the diurnal high and low tides. The tides are muted at the site compared to actual ocean conditions. Maximum water level during the sampling period (July through October) reached 5.6 feet and decreased to a minimum of 1.9 feet, with an average of 2.3 feet (Table 5 and Figure 4A).

Water levels at the Dillon Road Bridge site are compared to tide heights at the Humboldt Bay North Spit tide station for two days in August (15th and 16th). Tides heights in the Humboldt Bay and water levels at this site should not be strictly equated to each other since the site is not at a 0.0 ft elevation. Tides and water levels can be correlated to determine the lag time of tidal waters entering the site. Reviewing the two day interval graph above and the associated data, it

appears that high tides reach this site if it is greater than 6' to 7', where the low high tides of 5.2' and 5.' that took place over the two day period did not rise the water level at the site (Figure 4B). The lag time for the larger high tides is approximately 2 hours. Low tide lag times are difficult to determine from the data, but low tides lag times have been documented at 3 to 4 hours in 2015.

Temperature – Site - Dillon Bridge – Salt River Channel

Temperature readings were collected from the water level recorder. The average temperature during the sampling period is calculated at 64.8 °F. The maximum temperature recorded is 77.7 °F and the minimum temperature is 52.4 °F (Table 5 and Figure 4C). The Water Temperature graph above shows a decreasing temperature trend from July to October. This is consistent with colder atmospheric and ocean temperatures setting in from summer to fall.

Salinity – Site - Dillon Bridge – Salt River Channel

In 2016, salinity was very low at deployment (0.4 ppt (spot salinity measurements confirm)) and rose quickly over a period of seven days and stayed within a range of 12.0 ppt and 20.0 ppt (Table 5 and Figure 4D). It is unknown why salinity was so low at this site given that freshwater inputs ceased by the date of deployment and tides would have inundated the site. The recorders show that salinity reached a maximum of 20.0 ppt and a minimum of 0.1 ppt and had an average of 14.1 ppt. The precipitous plunge of salinity values in mid-October coincided with a 4.6 inch rain event that occurred between October 13th and 16th. This rain event likely contributed large and persistent freshwater inputs for the rest of the recording season. The purpose of siting this probe at this location is to determine whether tidal inundation reaches this far up the channel. The average salinity is 14.1 ppt at the Dillon Bridge site; which is similar to the average values found at Sites 1, 3, and 4 in the estuary. Also, personal observations have noted that the tide extends just over 100' upstream of this site.

CONCLUSIONS

Water quality parameters measurements were recorded in Year 3 after post restoration activities on Phase 1 (Riverside Ranch) and at the extent of tidal inundation in the Salt River channel (Phase 2 Dillon Road Bridge). Accurate sampling of some of the parameters proved challenging due to the tidal environment of the restoration site. The challenges faced during the sampling period include unrecovered equipment and sensors being fouled by suspended sediment, biological marine fauna, and algae production. These impediments render some of the collected data questionable with water level data likely the most robust data recorded.

Although some of the data collected does not provide a clear description of the environment occurring on the current project footprint, it does reflect that water quality parameters reached expected levels at most sites during the sampling period and shows that tidal inundation occurs across all sites. Observations also confirmed that tidal water reaches the upper extents of the

newly-created internal slough channels and upstream portions of the Salt River channel (Dillon Bridge) daily. These results and observations indicate the project is functioning as designed and expected.