RUSSIAN RIVER ESTUARY
ADAPTIVE BEACH MANAGEMENT PLAN
2020

Prepared for

Sonoma Water

Prepared by

ESA

with

Bodega Marine Laboratory, University of California at Davis

May 15 2020

ESA REF. # DW01958

Services provided pursuant to this Agreement are intended solely for the use and benefit of the Sonoma Water.

No other person or entity shall be entitled to rely on the services, opinions, recommendations, plans or specifications provided pursuant to this agreement without the express written consent of ESA, 550 Kearny Street, Suite 800, San Francisco, CA 94108.

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

DEFINITIONS

Several key terms that are used throughout the management plan are defined here, in alphabetical order, to assist the reader.

Barrier beach, beach berm – The sand ridge that separates the Russian River estuary from the Pacific Ocean. Sometimes shortened to just 'beach'. The Russian River Biological Opinion uses 'sandbar' as a synonym.

Breaching – Removal of sand from the barrier beach that forms a channel for water to flow between the estuary and ocean. 'Natural' refers to breaches that occur without human intervention and 'artificial' to describe breaches that are the result of human sand excavation. 'Self-breach' refers to breaches caused by the estuary's own rising water levels that scour the beach open.

Brackish – Salinity levels between ocean salt water and fresh water.

Closed – When there is no open water connection across the beach, between the estuary and the ocean. See also the other two beach states, 'open' and 'perched'.

Estuary – The section of Russian River that can be affected by ocean tides and salinity, which extends from the river mouth at the ocean, upstream approximately seven miles along the river to the river's junction with Austin Creek.

Flood stage – The water level above which significant inundation begins for areas not typically covered with water. In the Russian River estuary, flood stage is 9 ft NGVD.

Inlet – A channel across the barrier beach, at the mouth of the Russian River, that provides hydraulic connection between the estuary and the ocean. Flows through the inlet are a function of riverine inflows, ocean tides, and ocean waves. A tidal inlet state allows for flows in both directions, whereas the outlet channel form of the inlet only allows water to flow from the estuary to the ocean.

Lagoon – As per the Biological Opinion definition (p. 248), "when ocean waves build up a sandbar across the river's mouth, the Russian River estuary forms a lagoon that is hydraulically isolated from the marine environment, except for occasional wave overwash." When lagoon conditions occur, the mouth can be either closed or perched.

Mouth – The location where the Russian River can connect to the ocean, depending on the inlet state. As per this definition, the mouth always exists, as it refers to a physical region where connection can happen, as opposed to the state of the connection. The mouth includes a portion of the beach within Goat Rock State Beach and the parts of the estuary and ocean immediately adjacent to the beach.

National Geodetic Vertical Datum (NGVD) – An established point of reference relative to the earth's surface that serves as a reference point for making measurement of elevation relative to the earth's surface.

Open – When beach conditions allow for flows in both directions between the estuary and the ocean. See also the other two beach states, 'closed' and 'perched'.

Outlet channel – A channel across the barrier beach, at the mouth of the Russian River, which has a bed elevation above the elevation of ocean high tide, such that water only flows from the estuary out to the ocean. When an outlet channel exists, the estuary is in a lagoon state and 'perched'.

Perched – The Biological Opinion (p. 92) "defines a perched lagoon as having water surface elevation above mean high tide. Although this definition can include freshwater lagoons with closed sandbars, when we use the term perched lagoon in this Biological Opinion, we are referring to lagoons where freshwater flows out to the ocean over the sandbar at the lagoon's mouth." Contrast with the other two states, 'closed' and 'open'.

Salmonids – A group of fish, which includes salmon and trout that can inhabit freshwater and marine environments. For the purposes of this document, Chinook salmon, coho salmon, and steelhead trout collectively make up Russian River salmonids.

EXECUTIVE SUMMARY

The Sonoma County Water Agency (Sonoma Water) has developed an adaptive management plan for the Russian River Estuary Management Project. The Plan was developed in response to a 2008 Biological Opinion (Biological Opinion) from the National Marine Fisheries Service (NMFS).

Before the Biological Opinion, estuary management focused on minimizing flood risk through artificial breaching of the closed river mouth. The Biological Opinion requires the addition of adaptive beach management from May 15th to October 15th (the lagoon management period) to support the improvement of estuary rearing habitat for young salmonids (Figure 1-1). To improve rearing habitat by promoting fresh and brackish water habitat, the Biological Opinion proposes actions to facilitate lagoon conditions in the estuary, with water levels above tidal elevations. The estuary changes from tidal to lagoon conditions when beach sand fills in the inlet that connects the estuary with the ocean. With tidal inflows blocked, river inflow increases the depth and area of freshwater habitat, improving young salmonid rearing habitat. However, with the beach blocking the inlet, water levels would rise high enough to flood low-lying structures and property along the estuary. One option for managing higher lagoon water levels but below flood stage requires an outlet channel to move water from the estuary over the beach berm.

The current management plan is described in this document, which is updated annually by Sonoma Water in collaboration with resource agency stakeholders. Stakeholders include NMFS, California Department of Fish and Wildlife (CDFW), and California State Parks (CSP).

The approach of the 2020 plan is to meet the objective of the Biological Opinion's Reasonable and Prudent Alternative (RPA), Alterations to Estuary Management, to the greatest extent possible while complying with existing permits and minimizing impacts to visual, biological, and recreational resources. The adaptive approach includes tailoring beach management actions to conditions at the time of the action, monitoring to assess beach and estuary responses, and annual revisions to the plan.

HABITAT OBJECTIVES

To improve rearing habitat by promoting fresh and brackish water conditions, the Biological Opinion proposes actions to facilitate a lagoon with water levels above tidal elevations. According to the Biological Opinion, tidal water level changes and saline water reduce habitat quality for juvenile salmonids rearing by reducing the amount of freshwater habitat, elevating salinity above optimal levels for young salmonids and their invertebrate prey, and flushing young salmonids into the ocean. Drawing on monitoring in the Russian River Estuary and similar estuaries in California, the Biological Opinion assumes that habitat under lagoon conditions would be strongly influenced by the presence of salt stratification. Lagoon water levels would be higher than the ocean tide range, and thereby increase the extent and duration of inundated or floodplain type shallow freshwater habitat areas within the estuary. The Biological Opinion concluded that the larger extent of freshwater habitat during lagoon conditions would benefit rearing salmonids in the estuary. The benefits include a larger extent of freshwater habitat for rearing salmonids not yet acclimated to oceanic salinity, higher rates of invertebrate prey production, and reduced risk of flushing to the ocean. In addition, Boughton et al. (2017) reviewed existing literature, focusing on young steelhead behavioral and physiologic responses to various estuarine conditions. The study characterized the interconnected roles of foraging opportunity, predation risk, and water quality. Based on fish habitat studies in lab settings, other lagoons, and the Russian River, the tech memo developed a rating scheme that identified how changes in temperature, salinity, and dissolved oxygen affect young steelhead growth potential. While water quality is not the sole indicator of habitat, the rating scheme provided a qualitative approach for assessing habitat. It is intended to help resource managers interpret observations and model predictions of estuary rearing habitat conditions.

MANAGEMENT CRITERIA

To evaluate the goal of improving estuary habitat conditions for juvenile steelhead rearing, beach management has the following performance criteria for the lagoon management period:

- **Estuary water levels**. The estuary water level target set by the Biological Opinion for May 15-October 15 is at least 7 ft in elevation, but not exceeding flood stage of 9 ft. Lagoon water levels greater than 4 ft are expected to accompany reduced marine influence, improved fresh and brackish water conditions, and would likely improve juvenile salmonid rearing habitat.
- **Minimize artificial breaching**. Although the beach management plan seeks to avoid breaching, the Biological Opinion recognizes that artificial breaching during the lagoon management season may occasionally be necessary.

Additional criteria for evaluating overall plan success include:

- **Sand channel**. Outlet channel will be a temporary feature, created only by excavating a sand channel. No new structures or mechanical devices, temporary or permanent, will be a part of outlet channel implementation.
- **Economic feasibility**. Operations and maintenance requirements will not place undue burden on Sonoma Water in terms of cost. In particular, Sonoma Water will consider cost as it relates to frequency or duration of maintenance activities.
- **Public Safety**. The outlet channel management plan will not reduce public safety for floodplain property owners, visitors and employees of the State Beach, and Sonoma Water maintenance staff.

In addition to these criteria, Sonoma Water must manage the estuary's mouth in accordance with permits from state and federal agencies. Key aspects of these permits that affect 2020 outlet channel management include: limits on channel dimensions and volume; scheduling to minimize interference with public access; limiting beach actions to no more than two consecutive days; and constraining access during marine mammal pupping season.

CONCEPTUAL MODEL OF MOUTH CONDITIONS

The beach at the mouth of the Russian River Estuary is continually changing due to scour, transport, and deposition of sand. These changes result from ocean tides, ocean waves, and river inflows.
The river usually passes through the beach through a tidal inlet. A tidal inlet is an open channel in the beach that allows reversing exchange between the ocean and estuary as tides change (Figure 4-1). When

the ocean waves strengthen as compared to the tides, waves deposit sand into the inlet faster than flowing tidal currents scour and remove sand. This net sand deposition can fill and close the inlet, creating a barrier beach and lagoon conditions (Figure 4-2). Lagoon conditions are characterized by reduced marine influence, estuarine water levels that no longer fluctuate with the tides, and increased fresh and brackish water conditions in the estuary.

At times, the lagoon can become perched. When perched, water only flows from the estuary to the ocean (Figure 4-3). Flow in the outlet channel adds to the seepage through the beach from the lagoon to the ocean. Typically, these seepage and outlet channel flows are less than river inflows into the estuary.

The net inflows during closed or perched conditions cause lagoon water surface levels to rise. Rising water levels either overflow the beach crest and cause self-breaching, or, when the beach crest has built higher by ocean waves, the water levels threaten to flood low-lying properties along the estuary. As lagoon water levels approach flood stage, Sonoma Water plans for and, when conditions on the beach are safe, implements artificial breaching of the beach to create a tidal outlet channel. The channel drains water from the lagoon and returns the estuary to tidal conditions.

The ongoing monitoring, analyses, and management of the beach and estuary have demonstrated that the natural variability in ocean tides and waves, river inflows, and beach morphology, both individually and in combination, are the primary drivers of beach change. Long-term monitoring demonstrates that the combination of these processes tends to cause either an open tidal inlet or closed lagoon, and perched conditions are infrequent.

IMPLEMENTATION OF BEACH MANAGEMENT

Beach management selected for implementation will be based on site conditions at the time of closure and discussion with the resource agency management team. Monitoring of the beach and estuary response will be used to inform adaptive management during the lagoon management period, in accordance with specified decision-making process and communication protocols.

Sonoma Water monitors the river mouth and estuary water levels year-round. The possibility of beach management action occurs once the inlet closes. Pending specific conditions of a closure during this year’s management period, Sonoma Water, in consultation with the resource management agencies, will likely seek to extend the duration of deeper fresh and brackish habitat conditions for salmonids rearing by implementing beach management at higher water surface elevations, while maintaining the estuarine water levels described above.

1. INTRODUCTION

Sonoma Water is required to develop a management plan for the beach at the mouth of the Russian River Estuary in response to a 2008 Biological Opinion (Biological Opinion) from the National Marine Fisheries Service (NMFS). As part of its overall goal of aiding the survival and recovery of salmonids, this Biological Opinion strives to improve salmonid rearing habitat in the estuary.

Prior to the Biological Opinion, estuary management focused on minimizing flood risk through artificial breaching of the closed river mouth to prevent flooding. The Biological Opinion requires adaptive management of the barrier beach and estuary water surface elevations to enhance the quality of estuary rearing habitat for juvenile salmonids in the Russian River Estuary (Figure 1-1) during the lagoon management period, May 15th to October 15th. To enhance estuary rearing habitat and promote brackish/freshwater habitat, the Biological Opinion proposes actions to facilitate a lagoon with water levels above tidal elevations. The estuary converts from tidal to lagoon conditions when beach sand fills in the inlet that connects the estuary with the ocean. With tidal inflows blocked, river inflows to the lagoon extends the depth and area of freshwater habitat for the benefit of juvenile salmonid rearing. However, with the beach blocking the inlet, water levels can continue to rise high enough to flood structures adjacent to the estuary. One option for managing the lagoon water levels in a perched state that is also below flood stage requires an outlet channel to convey water from the estuary to the ocean over the beach berm.

The Biological Opinion stipulates several phases of estuary planning and management over fifteen years. The phases provide an adaptive process for monitoring, analyzing, and refining management actions to enhance estuarine salmonid habitat. If earlier phases are successful in meeting the performance criteria, subsequent phases will not be needed. The current management plan is described in this document, which is revised annually by Sonoma Water with input from resource agency stakeholders.

The approach of the 2020 plan is to meet the objective of the Reasonable and Prudent Alternative (RPA), Alterations to Estuary Management, to the greatest extent feasible while staying within the constraints of existing regulatory permits and minimizing the impact to aesthetic, biological, and recreational resources of the site. Sonoma Water, in collaboration with the resource management agencies, conducted an extensive review of the plan in 2018. This update resulted in a substantial update to the 2019 plan, and the plan continues to be revised each year. The measures developed in the 2020 management plan, when implemented, may not fully meet the objective established by the RPA. The concept of this approach has been developed and continues to evolve in coordination with NMFS, California Department of Fish and Wildlife (CDFW)[1], and California State Parks (CSP). Estuary management for 2020 was discussed at a meeting on March 24, 2020, that included representatives from NMFS and CDFW, as well as Sonoma Water, Bodega Marine Laboratory, the U.S. Army Corps of Engineers, the North Coast Regional Water Quality Control Board, and ESA. A draft of the 2020 plan was provided to the Estuary Management Team (Section 9) on March 23,

[1] CDFW's CESA tracking number is 2080-2009-016-03 and 1600 Notification number is III-1176-96

2020, for review. Comments on the draft plan from these representatives informed the revision of the draft plan to create the final plan.

1.1 SUMMARY OF PLAN DEVELOPMENT AND IMPLEMENTAITON

This beach management plan was first developed in 2009 to address the Phase 1 objectives in the Biological Opinion and then updated annually in 2010 through 2019. The current management plan for 2020, is based on the plan drafted in 2019.

A brief summary of the management plan's implementation is as follows:

- Because of permitting issues, the management plan was not implemented in 2009.
- In 2010, an outlet channel naturally established itself for about one a week at the end of June, and was then closed by ocean waves. After this closure, Sonoma Water mechanically re-created the outlet channel. However, waves closed the outlet channel less than a day after implementation. Before the outlet channel could be re-established by Sonoma Water, the lagoon's barrier beach breached, returning the estuary to tidal conditions for the remainder of the summer. Additional closures occurred in September and October, but large wave conditions and imminent flooding prevented efforts to create an outlet channel.
- In 2011, the inlet never closed long enough to warrant management action. Wave events caused a series of closures between the end of September and into November. However, the closures lasted a week or less, ending when rising lagoon water levels overtopped the beach berm and naturally scoured a new tidal channel.
- In 2012, the inlet experienced several closures, but none resulted in water surface elevations above 5.5 ft NGVD before self-breaching. During much of June and July, the inlet was closed or limited to conditions with the estuarine tide range muted to about one foot or less. There was no beach management during these months as the inlet naturally cycled through closure and self-breaching. From the second part of July until after mid-September, the estuary was fully tidal. Then, in the last month of the management period, two more closures occurred and ended with self-breaches.
- 2013 was similar to 2011 and 2012, with early summer and early fall closures ending when overtopping naturally scoured a new channel.
- In 2014, instream flows on the Russian River were low due to drought conditions. So when the inlet closed in September and October, these lower inflows slowed the rate of lagoon water surface elevation rise, enabling two back-to-back closures. The September closure lasted more than a month and the October closure lasted about three weeks. These closures persisted beyond the lagoon management period, and were artificially breached.
- Instream flows in 2015 were also low due to drought conditions. After nearly three weeks of closure, an early season event ended in June via self-breaching. A closure starting in the first week of September and lasting almost a month also self-breached at the start of October. Although outside of the management period, a closure in December 2015 was notable for causing water levels to reach more than 12 ft NGVD in the Estuary, well above flood stage, until self-breaching occurred. Sonoma Water could not artificially breach before then because of hazardous wave overtopping conditions on the beach berm.

- In 2016, Sonoma Water excavated an outlet channel twice, on June 8th and June 27th. In both instances, water flowing through the outlet channel scoured the channel and, within a day, caused self-breaching of the barrier beach after about one week of closure.
- In 2017, a natural outlet channel started in late June and lasted for nearly a week before ending in closure. An outlet channel was implemented during this closure, but lasted for less than a day before self-breaching with the falling tide. After two other closures lasting two-three weeks, another outlet channel implementation was attempted in September, but ended with an apparent artificial breach by unknown members of the public.
- In 2018, the inlet did not migrate to the northern part of the beach, probably because riverine flows were not large enough during the wet season to cause such a migration. During a period of high waves and neap tides in early May, the estuary's tides became muted, but this muting only lasted for a few days before the estuarine tide range returned to its larger, more typical range. No closures occurred during the management period. At the end of the management period, a series of closures occurred, culminating in water surface elevation nearly two feet above flood stage because construction equipment could not safely access the beach due to wave overwash. When water surface elevations reached 10.92 ft NGVD, self-breaching occurred.
- The revisions between the 2018 and 2019 plan were more extensive than in prior years, and were developed over a series of monthly meetings with the Estuary Management Team over the course of 2018-2019 to incorporate the information and lessons learned over the last 10 years of Estuary monitoring and studies. The revisions included: revising and expanding the conceptual model of physical processes (Section 4), updating the channel configuration analysis (Section 6), clarifying the decision-making process for beach management actions (Section 7.2), and adding additional data graphics to the implementation scenario (Attachment B).
- In 2019, substantial winter river discharges fully opened the mouth, and the mouth started the management period in the northwest part of the beach. A two-week period of muted tides in July ended with a closure. Planning was conducted for beach management in response to the closure, but the mouth self-breached in early August and no beach management action was taken. Another week of muted tides occurred in September, but evolved naturally to an open inlet. Two more closures occurred after the end of the management period.

1.2 PLAN OVERVIEW

The remainder of this adaptive beach management plan is organized as follows. Conclusions and recommendations of this plan are described in Section 2. Sections 3-6 describe the planning and analysis steps: (a) defining project performance criteria (Section 3), (b) developing a conceptual model of relevant physical processes (Section 4), and (c) conducting technical analysis to quantify hydraulic and geomorphic conditions (Sections 5 and 6). The resulting operations and management plan derived from these planning steps is also documented in this report (Section 7). Section 8 describes the monitoring and adaptive management. The communication protocol for planning and implementing beach management is covered in Section 9. The adaptive management strategy will continue via implementation of this plan, then monitoring and evaluating the outlet channel response to refine the plan for subsequent years.

1.3 FIGURES

Source: Sonoma County Orthophotography (April-May, 2000)

0 120 240 480 Feet

figure 1-1

Russian River Estuary Beach Management Plan

Russian River Estuary Site Location

ESA Ref# DW0 1958

PWA

G:\1958.01_Russian_River\Projects

2. CONCLUSIONS AND RECOMMENDATIONS

Conclusions about the physical processes affecting outlet channel behavior and recommendations for 2020 management are summarized below.

2.1 CONCLUSIONS: PHYSICAL PROCESSES AFFECTING BEACH AND INLET BEHAVIOR

1. The location of beach, at the interface of the Russian River estuary and the surf zone of the Pacific Ocean, is a dynamic system influenced by river inflows, ocean tides, ocean waves, and sand transport. As such, the beach will be subject to variable forcing at hourly, tidal, and monthly timescales. Natural variability in these forcing processes, both individually and in combination, are the primary causes of beach change. The ongoing monitoring, analyses, and management of the beach and estuary have demonstrated the limited capacity for beach management to override these natural forcing processes.
2. In order for an outlet channel to preserve its function in this active transport zone, the net sediment transport must be small, even though the gross sediment transport is large. To sustainably meet the performance criteria, an outlet channel must be resilient in the face of this variable forcing. This resiliency is difficult to predict.
3. Under current management of the Russian River watershed and estuary, there have been two documented occurrences of outlet channel conditions naturally occurring during the proposed management season of May 15 to October 15 for the eighteen-year period of record (1999 to 2019). Persistent outlet channel conditions occurred in June 2010 and June-July 2017 and lasted for about one week before closing. More typically, as a result of natural processes and existing artificial breaching practice, the connection between the estuary and the ocean has been observed in one of two states: bi-directional tidal exchange (88% of the time during the 1999-2008 management periods) or fully closed with no exchange (12% of the time).
4. Naturally-occurring conditions similar to an outlet channel were observed outside the management period five times between 1999 and 2019. These events appeared to be extended transitions to fully tidal conditions rather than stable conditions. Estuary water levels steadily declined throughout all events and the estuary typically returned to tidal exchange within 48 hours.
5. Beach management to facilitate an outlet channel has been implemented five times since 2009. Three of the implemented outlet channels ended with self-breaching, one ended with closure, and one ended with breaching, probably due to additional excavation by an unknown party.
6. To meet the performance criteria, an outlet channel geometry must simultaneously meet two key constraints: (1) convey sufficient discharge from the estuary to the ocean to preserve water levels in the estuary below flood stage and (2) preserve channel function by avoiding closure or breaching. These two constraints can be in conflict, since both conveyance capacity to preserve estuary water levels and the potential for breaching increase with flow rates but closure is more likely for lower flow rates.

7. An outlet channel is subject to two failure modes: (1) closure caused by deposition, leading to estuary water levels to rise and possibly cause flooding, and (2) breaching caused by scour, leading to tidal exchange and marine conditions in the estuary. Of the two failure modes, breaching is more detrimental to the Biological Opinion's juvenile salmonid habitat objectives through the loss of freshwater and brackish water habitat that develops under lagoon conditions and restoration of the marine influences of tidal water levels and saline water that enter the estuary. Once breaching occurs, the estuary may persist in a breached state for weeks or months before the target outlet channel can re-form. The immediate impact of closure is only increasing estuary water levels, which allows time for management action to prevent habitat loss.
8. Based on engineering calculations, an outlet channel's bed slope must be essentially flat (slope on the order of 0.0001) and water depths less than 2 ft, preferably 0.5 to 1 ft, to reduce the likelihood of channel scour at likely May to October flows.
9. Based on the results of hydrologic modeling and observations over the last decade, it may be difficult to convey sufficient discharge to maintain estuary water levels while simultaneously keeping the bed shear stress in an outlet channel below the threshold for scour. Even with dry-year reductions to instream flows, the predicted local bed shear stress during the management period is almost always greater than the critical bed shear stress threshold for erosion.
10. Discharge conditions are a significant source of hydraulic uncertainty for assessing an outlet channel. Discharge measurements are made at the USGS Hacienda gaging station[2], 21 miles upstream from the Russian River's mouth, and changes in flow (losses/gains) are known to occur between the Hacienda station and the mouth. A water balance model for the estuary indicates that net losses between the Hacienda gaging station and the mouth vary from 10% to 53% and average 37%. Limited USGS and Sonoma Water discharge measurements at other locations suggest that most losses occur in the lower 6 miles of the river; probably in large part due to seepage through the beach berm.

2.2 RECOMMENDATIONS: 2020 MANAGEMENT ACTIONS

Based on conclusions about the physical processes affecting the estuary and beach, estuarine habitat objectives, and ongoing adaptive management refinements in conjunction with the natural resource agencies, the recommended Sonoma Water beach management actions are:

1. The beach management selected for implementation will be based on site conditions at the time of closure and discussion with the resource agency management team. Monitoring of the beach and estuary response will be used to inform adaptive management during the management period.
2. Initial management actions may be more frequent, and include maintenance actions that are corrections to the existing channel configuration. Based on experience from these initial efforts, larger and less frequent actions may be undertaken.

[2] Located just downstream of Hacienda Bridge, USGS station ID 11467000.

3. Once the estuary closes, implement the channel so that when reconnecting the channel, the estuary water levels are no more than 0.5 to 1 ft above the constructed channel bed elevation. This approach reduces the potential for scour. When the beach crest elevation is less than 9 ft NGVD, an outlet channel may be implemented for a lower range of water levels (5-7 ft NGVD). When the beach crest elevation is greater than 9 ft NGVD, implementation should be deferred to preserve the closed lagoon habitat as long as possible while still not exceeding flood stage. Under some conditions, the outlet channel may be excavated above lagoon water levels, up to an elevation of 8.5 ft NGVD, to serve as a 'release valve' before water levels exceed flood stage of 9 ft NGVD.
4. Two outlet channel location and planform alignment will be considered for implementation:
    - a wide and short channel that seeks to minimize scour potential; or
    - a narrow and long channel aligned to the north that seeks to minimize closure potential.
5. Channel excavation activities should be completed (i.e. the temporary sand barrier removed) coincident with high tides in the ocean. This will reduce the scour potential associated with the initial outflow at the time of breaching.
6. A communication protocol, as described in Section 9, will provide guidance between Sonoma Water and identified points of contact representing key resource management agencies in the estuary.
7. Because of uncertainty about the system and its response to beach management, the adaptive management approach specified in the Biological Opinion and being pursued by Sonoma Water is critical. A year-end evaluation to assess actual channel performance and revised management for subsequent years is also recommended.

3. MANAGEMENT CRITERIA

The criteria for beach management are intended to assist in meeting the estuarine habitat objective specified in the Biological Opinion. The Biological Opinion requires adaptive management of the barrier beach and estuary water surface elevations to enhance the quality of estuary rearing habitat for juvenile salmonids in the Russian River Estuary (Figure 1-1) during the management period, May 15th to October 15th. To enhance estuary rearing habitat and promote brackish/freshwater habitat, the Biological Opinion proposes actions to facilitate a lagoon with water levels above tidal elevations. According to the Biological Opinion, marine influence includes tidal water level oscillations and saline water. The NMFS Biological Opinion (2008) states that marine conditions diminish habitat quality for salmonid rearing by reducing the habitat extent, elevating salinity above optimal levels for salmonid juveniles and their invertebrate prey, and flushing juveniles into the ocean following breach events.

Section 3.1 summarizes the habitat objectives which the plan is trying to achieve through beach management. Section 3.2 then presents the plan's performance and additional criteria for beach management, and minor modifications to these criteria for 2020 management.

Performance criteria for water quality and ecological values in the lagoon are addressed separately (Boughton et al., 2017) and are only summarized in this document's Section 3.1.2. Sonoma Water's water quality monitoring plan is described in Sonoma County Water Agency (2013a), with the monitoring results described in Sonoma County Water Agency (2013b).

3.1 HABITAT OBJECTIVES

3.1.1 Biological Opinion

The Biological Opinion characterizes the historical (pre-settlement) estuarine habitat conditions by examining recent (1996-2007) mouth and beach conditions, gathering information on the pre-settlement hydrology (RREITF 1994; SEC 1996), and reviewing historical records of mouth closure. These sources suggest that the mouth was historically open during the wet season (October through May) and was more frequently closed to ocean tides in the dry season (May through October). This finding is based on the observation that the mouth had closed in late spring or early summer in most of the years from 1996 to 2007, even with augmented summer flows. Because historical flows were lower in dry season when not supported by dam releases, the mouth would have been less likely to breach after closure, and salmonids in the estuary probably experienced a closed lagoon for several months at a time.

Drawing on monitoring in the Russian River Estuary and similar estuaries in California, the Biological Opinion assumes that habitat conditions in the closed lagoon would be strongly influenced by the presence of salt stratification, with a lower saltwater layer underlying an upper fresh layer. With seepage through the beach gradually removing the trapped saltwater, the lagoon presumably became fresher over the course of the closure (Smith 1990). When natural perched conditions ever occurred, with water spilling over the beach, this process was also thought to contribute to freshening of lagoon conditions. In both closed and perched cases, the estuary water levels would have been higher than the oceanic tide range, and thereby increase the extent of shallowly inundated areas within the estuary. The Biological Opinion concluded that the larger extent of freshwater conditions during lagoon conditions would have benefits for rearing salmonids in the estuary. The benefits are thought to include: larger extent of freshwater habitat for rearing salmonids not yet acclimated to oceanic salinity, higher rates of invertebrate prey production, and reduced risk of flushing to the ocean. Both dam releases to augment dry season flows and artificial breaching to prevent flooding of low-lying properties cause tidal connectivity to the estuary more often in the dry season. The resulting marine influences, in the form of tidal water level oscillations at lower elevations and oceanic salinity, were a departure from the historical conditions – fresher and greater inundated area – than salmonids would have experienced during more frequent closed or perched lagoon conditions.

To avoid jeopardizing listed salmonids and their critical habitat as a result of flood risk management through artificial breaching, the Biological Opinion calls for adaptive management that reduces marine influences on estuarine habitat, via management of estuarine water surface elevations and the beach, the management described in this report. This management applies to the estuary from May 15 to October 15 (lagoon management season).

3.1.2 Habitat Blueprint Study

To extend the understanding of estuarine habitats, the Russian River has been selected as a habitat focus area under NOAA's Habitat Blueprint framework. With this support, NOAA and Sonoma Water staff and collaborators have built on the findings of the Biological Opinion to further characterize the habitat needs of steelhead in the estuary. As part of this work, Boughton et al. (2017) developed a rating scheme to characterize estuarine rearing habitat requirements for juvenile steelhead as a function of key water quality parameters.

Boughton et al. (2017) is based on a thorough literature review and studies of the Russian River, which focused on salmonid behavioral and physiologic responses to estuarine conditions. The review characterizes the interconnected roles of foraging opportunity, predation risk, and water quality. The rating scheme identifies how variations in temperature, salinity, and dissolved oxygen affect juvenile steelhead growth potential. It also notes that water quality is not the sole indicator of habitat, since tolerances vary by life stage and that the ability to withstand less favorable conditions for limited periods can be augmented by abundant prey and/or habitat refugia. As a result, the rating scheme is qualitative, and intended to help fisheries managers interpret observations and model predictions of estuary conditions.

The study focuses on two juvenile life stages of steelhead: freshwater-acclimated and marine-acclimated juveniles, that use the estuary during the dry season (roughly coinciding with the management season). Temperature, salinity, and dissolved oxygen conditions are considered within a bio-energetics framework, i.e. how water quality supports or detracts from steelhead juveniles' capacity to convert food energy into growth. The study's rating scheme for the three key water quality parameters is:

- The physiological implications of water temperature apply to both life stages. In general, fastest growth occurs for temperatures between 14-18º C and positive growth occurs for temperatures below 14º C and as high as roughly 21º C. From 21-25º C, temperature has metabolic impacts that limit growth or negate growth, and temperatures above 25º C are likely lethal.
- Salinity tolerance varies as juveniles grow, and as they are exposed to different salinities. While juveniles can tolerate salinities outside of their optimal range for short periods (i.e. to avoid predation or pursue prey), the physiological mechanisms that regulate internal salinity require energy to be expended. For both life stages, salinities below 15 ppt allow for high growth potential, with 10-15 ppt allowing for the most efficient growth. For freshwater-acclimated residents, salinities from 15-28 ppt incur an energy cost as they adjust to saltier conditions (limiting growth potential for several weeks), while marine salinities, greater than 28 ppt, can be lethal after extended periods of time. For marine-acclimated residents, 15-28 ppt incurs low energy cost and positive growth potential, whereas salinities above 28 ppt incurs moderate energy demand and somewhat impairs growth potential.
- Dissolved oxygen levels, when greater than 6 mg/L, have minimal or no impairment on growth potential. Levels from 4-6 mg/L moderately impair positive growth potential, and levels from 3-4 mg/L severely impair or negate growth. Below 3 mg/L, habitat cannot support metabolic demand and will cause death.

The study also reviewed monitoring of invertebrate prey, fish abundance, and fish foraging by Sonoma Water, University of Washington, Humboldt State University, and others. Analysis of juvenile Russian River steelhead diets from 2009 to 2015 indicate that epibenthic crustaceans are a key component, consistent with earlier findings from Fuller (2011). Concurrent fish tagging studies combined this information with spatial data, showing that juveniles tend to occupy the upper 3 meters of the water column, with the subsurface epibenthic zone offering very good growth opportunities, due to high prey availability and lower predation risk. However, the predation risk is inferred, since actual predation data is lacking for the estuary. This information was used to define five habitat zones as a function of zone water depth and total water depth, with each zone offering variations in foraging habitat and predation risk.

Ongoing work is combining the Boughton et al. (2017) rating scheme with water quality monitoring for a range of hydrologic scenarios. This work is facilitated by a visual interface that maps the habitat conditions in the Estuary (in the depth and along-stream directions). This 'Habitat Mapping Tool' is being developed as part of the ongoing habitat focus area grant under NOAA's Habitat Blueprint framework. The goal is to better understand connections between estuary mouth conditions (including beach management actions) and the resulting steelhead habitat, to inform the adaptive management process.

3.2 MANAGEMENT CRITERIA

To evaluate the goal of improving estuary rearing for salmonids rearing, beach management has the following performance criteria for the May 15 to October 15 management period:

- **Estuary water levels**. The estuary water level management target is "[a]n average daily water surface elevation of at least 7 feet [NGVD] from May 15 to October 15" (Biological Opinion, p. 249). Higher estuary water levels, but not exceeding Sonoma Water's flood stage management target of 9 ft NGVD, would be preferred by NMFS. However, water levels greater than 4 ft NGVD are expected to accompany reduced marine, improved fresh and brackish water conditions, and would likely improve juvenile salmonid rearing habitat.
- **Minimize artificial breaching**. Though the overall goal is to enhance freshwater and brackish water habitat in the estuary, and therefore avoid artificial breaching, in light of natural variability of river discharge and nearshore wave conditions, ongoing experience managing the estuary may be required to develop operational procedures that minimize the need for artificial breaching. As such, NMFS estimates "that [Sonoma Water] will need to artificially breach the lagoon using methods that do not create a perched lagoon twice per year between May 15 and October 15 during the first three years covered by this opinion, and once per year between May 15 and October 15 during years 4-15 covered by this opinion" (Biological Opinion, p. 302).

Additional criteria for evaluating overall plan success include:

- **Sand channel**. Beach management will be a temporary feature, created only by excavating a sand channel. No new structures or mechanical devices, temporary or permanent, will be a part of beach management.
- **Economic feasibility**. Operations and maintenance requirements will not place undue burden on Sonoma Water in terms of cost, particularly as it relates to frequency or duration of maintenance activities.
- **Public Safety**. The outlet channel management plan will not diminish public safety as it pertains to floodplain property owners, visitors and employees of the State Beach, and Sonoma Water maintenance staff.

To meet the criterion for estuary water level (#1 above), the estuary will function with "water surface elevation above mean high tide … where freshwater flows out to the ocean over the sandbar at the lagoon's mouth" (Biological Opinion, p. 92). This implies uni-directional flow in the outlet channel, from the estuary to the ocean, to minimize marine influence, and minimal sediment transport within the outlet channel to prevent the channel bed from scouring and transforming into a tidal channel. This water level criterion can also be met when the inlet is closed and there is no surface flow across the beach. Artificial breaching may be required when estuarine water levels exceed flood stage of 9 ft NGVD. With this management plan, Sonoma Water seeks to minimize or avoid such breaches during the management period, but recognizes that they may be needed to avoid flooding of low-lying properties along the estuary.

NMFS (2008) introduced the terminology 'natural' to describe breaches that occur without human intervention and 'artificial' to describe breaches that are the result of human sand excavation. This terminology was used in the management plan through 2013. However, inlet and beach observations in 2012 (Attachment G), 2013 (Attachment H), and 2014 (Attachment I) suggest that the jetty groin, a human intervention, may indirectly facilitate breaching. The jetty groin appears to encourage some breaches sooner than natural conditions because the groin shelters a portion of the beach immediately to its north, limiting sand deposition and resulting in a low point in the beach berm. In 2012-2014, this low point was often the location where rising lagoon water levels scoured a new inlet. Therefore, starting with the 2014 plan, the term 'self-breach' is used to describe breaches caused by the estuary's own rising water levels. This term is used to include all breaches of this type, since the extent of the jetty's influence has not been fully determined. 'Artificial' breach continues to refer to instances involving human excavation, covering both authorized Sonoma Water contractors with mechanical equipment or unauthorized members of the public with hand tools.

Note that each time the lagoon breaches, the Biological Opinion hypothesizes that the lagoon is subject to less favorable water quality conditions not just during the breached period, but also for some period of time following the subsequent closure. "NMFS anticipates 3-4 weeks of adverse water quality conditions after the sandbar closes at the mouth of the estuary" (Biological Opinion p. 302). As discussed in the Biological Opinion (p. 188), the presence of low dissolved oxygen and higher salinities may initially degrade salmonid habitat and reduce food availability, particularly in the bottom layers. Conditions then typically improve, as the fresh, well-oxygenated surface layer increases in depth. Thus the management plan seeks to minimize self, as well as artificial breaching events.

The Biological Opinion requires Sonoma Water to petition the State Water Resources Control Board (SWRCB) to change minimum instream flow requirements to improve rearing habitat for steelhead. Permanent changes in instream flow requirements will take years to accomplish, therefore, the Biological Opinion also requires Sonoma Water to petition the SWRCB to change minimum instream flow requirements on an interim (temporary) basis to facilitate management of the estuary as a summer lagoon. Petitions have been filed with the SWRCB by Sonoma Water since 2010 as required by the Biological Opinion, however in some years, petitions were filed due to drought conditions in the watershed. The expected reduction in minimum instream flow help to provide more favorable conditions for outlet channel management.

For channel location, the Biological Opinion suggests the use of "a lagoon outlet channel cut diagonally to the northwest. … Alternative methods may include … use of a channel cut to the south if prolonged south west swells occur" (Biological Opinion p. 250).

3.3 2020 MODIFICATIONS

As discussed above (Section 1), the approach of the 2020 plan is to meet the objective of the RPA to the greatest extent feasible while staying within the constraints of existing regulatory permits. It is recognized that the measures developed in the 2020 management plan, when implemented, may not fully meet the objective established by the RPA as summarized in Section 3.2 above. The concept of this approach was developed in coordination with NMFS and CDFW.

Because of the estuary's coastal location and hydrologic significance, Sonoma Water must manage the estuary's mouth in accordance with multiple land use permits from various state and federal agencies. A table summarizing all these permits is provided in Attachment C. Key aspects of these permits which directly affect 2020 outlet channel management include:

- Excavation is limited to 2,000 cubic yards of sand per event to create a channel 25 to 100 ft wide. The channel width range is consistent with historic widths observed within the management covered by existing permits (Behrens, 2008).
- Management actions are permitted only on Monday-Thursday to minimize interference with public use. Management actions on Friday, Saturday, Sunday and holidays requires specific permission from State Parks staff.
- Management actions cannot be longer than two consecutive days (unless flooding is threatened).
- Access is constrained during marine mammal pupping season (March 15 – June 30) to reduce incidental harassment of neonate seals.

Pending specific conditions of a closure, during this year's management period, Sonoma Water, in consultation with the resource management agencies, will seek to extend the duration of deeper fresh and brackish habitat conditions for salmonid rearing by implementing beach management during the management season at higher water surface elevations to promote higher water levels, so long as water levels are not anticipated to exceed 9 ft. Under some conditions, instead of implementing an outlet channel at lower water levels, an outlet channel could be excavated with its bed elevation at 8.5 ft before water levels reach this elevation, to serve as a 'release valve' as water levels approach 9 ft. Additional information about possible outlet channel adaptive management can be found in Section 7.

4. CONCEPTUAL MODEL

The conceptual model of Russian River Estuary and the beach separating the estuary from the ocean describes the management plan's working understanding about relationships between beach conditions, external conditions (e.g. river inflows, ocean tides and waves), and target estuarine habitat conditions. This model focuses on the essential physical processes and linkages between these processes, as well as possible beach management actions.

The conceptual model is described in the following sections as follows:

- A simplified overview of the conceptual model (Section 4.1)
- Target conditions for the beach and estuary, based on the Biological Opinion and in accordance with the performance criteria in Section 3 (Section 4.2)
- The morphological processes which lead to the shifts between the two primary beach states: inlet closure and lagoon breaching (Sections 4.3 and 4.4)
- Details of specific physical processes, including littoral sediment transport, planform alignment, beach dimensions, and, seepage (Sections 4.6, 4.7, and 4.8)
- Implications of the conceptual model for water quality, flooding, and sea level rise (Sections 4.9 and 4.10)
- Assumptions and limitations of the conceptual model (Section 4.11)

4.1 OVERVIEW OF THE CONCEPTUAL MODEL

At the mouth of the Russian River Estuary, where the estuary meets the Pacific Ocean, the beach is continually evolving through scour, transport, and deposition of the sand. These geomorphic changes are the result of ocean tides, ocean waves, and river inflows.

Most of the time, the river passes through the beach through a tidal inlet, an open channel incised in the beach which allows reversing exchange between the ocean and estuary in response to tidal oscillations (Figure 4-1). When the ocean waves strengthen as compared to the tides, waves transport and deposited sand into the inlet faster than flowing tidal currents can scour and remove sand. This net sand deposition can completely fill and close the inlet, creating a barrier beach and lagoon conditions in the estuary (Figure 4-2). Lagoon conditions are characterized by reduced marine influence from the ocean; estuarine water levels no longer fluctuate with the tides, and fresh and brackish water expand their extents within the estuary.

This enhancement of freshwater and brackish water conditions is an objective of the Biological Opinion, so that juvenile salmonids benefit from lagoon conditions: greater freshwater extent, increased prey, and reduced risk of flushing to the ocean. At times, the lagoon can become perched, which the Biological Opinion defines as lagoon conditions with an outlet channel through the beach that is higher than ocean tides, so water only flows from the estuary to the ocean (Figure 4-3). When present, flow in the outlet channel augments the seepage through the beach from the lagoon to the ocean. Typically, these seepage and outlet channel flows are less than riverine inflows at the head of the estuary.

The resulting net flows causes lagoon water surface levels to rise. Rising water levels either overflow the beach crest and cause self-breaching, or, when the beach crest has built higher by ocean waves, the water levels threaten flooding to low-lying structures around the estuary. As lagoon water levels approach flood stage, Sonoma Water plans for and, when conditions on the beach are safe, implements artificial breaching of the beach to create a tidal outlet channel that drains off water from the lagoon, and returns the estuary to tidal conditions.

The purpose of the beach management plan is to identify and facilitate implementation of beach management actions that encourage lagoon conditions for a greater portion of the management period, May 15 – October 15, and thereby improve salmonid rearing habitat in the estuary.

The ongoing monitoring, analyses, and management of the beach and estuary have demonstrated the dominant role of natural processes in creating dynamic conditions, as well as the limited capacity for beach management to override these dynamic conditions. Natural variability in ocean tides, ocean waves, riverine inflows, and beach morphology, both individually and in combination, are the primary hydrologic and geomorphic drivers of beach change. Long-term monitoring demonstrates that the combination of these natural processes tends to cause either an open tidal inlet or closed lagoon.

Conditions that support a third state, an outlet channel, require combinations of waves, inflows, and beach morphology that occur infrequently. For instance, since the Biological Opinion has been in place (2009-present), outlet channels have occurred naturally twice and been implemented as a beach management action five times since 2009. The two naturally-occurring outlet channels ended after about a week with closure. Three of the implemented outlet channels ended with self-breaching, one ended with closure, and one ended with breaching, probably due to additional excavation by an unknown party.

4.2 TARGET BEACH AND ESTUARY CONDITIONS

In the Biological Opinion, the principal estuarine habitat goal of the Reasonable and Prudent Alternative's second element, Alterations to Estuary Management, is "to reduce marine influence (i.e., high salinity and tidal inflow) in the estuary"[3] from May 15 to October 15. The Biological Opinion further hypothesizes that marine conditions diminish habitat quality for salmonid rearing by reducing the habitat extent, elevating salinity above optimal levels for salmonid juveniles and their invertebrate prey, and flushing juveniles into the ocean due to breaching events. The target beach and estuary conditions to facilitate the target condition are beach conditions that impede tides from conveying marine waters into the estuary and estuarine water levels higher than the oceanic tide range.

Ideally, during the management period, estuary water levels can be maintained elevated above the ocean high tide range. The intent of these conditions are a greater extent of freshwater inundation in

3 NMFS (2008), p. 242

the estuary to enhance salmonid rearing habitat. A key performance criterion of this non-tidal state is that the water levels in the estuary fall within the range of 4 to 9 ft NGVD, with elevations above 7 ft NGVD preferred. When water levels exceed 9 ft NGVD, flooding threatens properties adjacent to the estuary and the beach will be breached to reduce water levels and minimize flood risk. The estuary water levels will not be managed directly, e.g. by pumping. Instead, they will be managed indirectly by adaptively managing the barrier beach as described in the Biological Opinion, to facilitate lagoon conditions.

When perched, he lagoon water level is determined by the balance between river inflows (Q_r) and three outflows: outlet channel flow (Q_c), evaporation (Q_e), and seepage through the beach berm (Q_s). For estuary water levels to remain within the target range, the inflows and outflows must sum to zero when averaged over a period of several days. As indicated by the width of the arrows depicting these flows in Figure 4-3, the river inflows, seepage, and the outlet channel flow are the three largest flows; evaporation and possibly loss to adjacent groundwater aquifers are minor factors in the water balance. As such, the sum of the seepage and outlet channel discharge capacity needs to nearly match the river inflows. If the combined outflows are too low, the lagoon water level will rise to flood stage and artificial breaching will be necessary. If the discharge is too high, the channel will scour and deepen, breaching to allow tidal flows to enter through the inlet. The discharge is determined in part by the beach and inlet width, bed elevation, slope, and planform alignment. These parameters can be managed to a certain degree, but are likely to evolve in response to the natural variability of the discharge and wave forcing, and the effects of tide range. Seepage is determined by the beach berm's permeability (LBNL, 2015), the water level difference between the lagoon and the ocean, and the ambient conditions of the regional water table (Largier and Behrens, 2010). The Jetty Study (ESA PWA, 2017) indicated that while portions of the jetty reduce seepage, jetty modifications or complete removal would have a relatively small effect on estuary water levels.

River inflows are another management parameter. As described in the Russian River Estuary Management Project Draft Environmental Impact Report (ESA, 2010), closure events due to barrier beach formation have occurred over a wide range of river inflows. During the lagoon management period, the outlet channel may need to be implemented over the range of river inflows that can occur between May and October. However, as discussed below in Section 4.4, higher river inflows increase the potential for flooding and the subsequent need for breaching. Correspondingly, reduced river inflows cause estuarine water levels to rise more slowly when the inlet is closed, so the fresh and brackish habitat associated with closure may persist longer before breaching. Beach management has to respond to whatever river inflows are present at the time of a river mouth closure and barrier beach formation.

4.3 TIDAL INLET CLOSURE

The processes which lead to inlet closure are likely caused by elevated water levels and waves in the ocean (z_{wave}), as shown on the right side of Figure 4-2. Elevated ocean water levels and waves will move the active transport zone further into the inlet, increasing deposition to raise the channel bed, z_{out}. Once deposition rates exceed the capacity of the inlet discharge to scour sediment, a berm will build within the inlet, causing it to close. This process is thought to occur over one to several high tides, corresponding to one to several days.

As offshore waves interact with the coastline and nearshore, they are transformed such that the wave conditions on the beach are a function of the wave direction, magnitude, period, beach geometry, and wave runup. While the tides fluctuate with a predictable schedule, ocean waves vary according to the variable weather and wind patterns over the ocean. The combined effect of water levels and waves can be characterized by the total water level, the height to which waves can reach on the beach face for given water level and wave conditions. Since both water levels and waves vary, total water level is often characterized as a frequency distribution that is based on observed tide and wave data.

When the inlet closes and flow through the inlet stops, a lagoon forms. The lagoon water level will increase since the continuing river inflows cannot all be exported through evaporation and seepage alone. Although seepage rates are likely to increase as a result of increasing water levels, it is assumed that the combined evaporation and seepage rate will remain below river inflow. As the water level rises, it will again overflow the beach berm when it reaches the minimum elevation of the berm crest. Early in the management season, the lowest point on the beach crest may allow the flow to overtop the berm below flood stage of 9 ft NGVD. However, as the berm crest elevation rises over the course of the management period, the water levels can rise above flood stage. If beach management actions do not address this rising water level, a full artificial breach, as is currently practiced, will be necessary to prevent flooding of property above 9 ft NGVD.

4.4 LAGOON BREACHING

The self-breaching considered as part of the conceptual model can occur when an outlet channel exists (Figure 4-3) or when estuary water levels overtop the low point on the beach crest. Breaching is likely to result from two processes: (1) fast-moving surface flow which scours the beach sands or (2) seepage-induced bed mobilization. In practice, other factors sometimes preclude beach management action before self-breaching occurs. A frequently observed cause of self-breaching has been the low point of the barrier beach being at or below target water levels. In most other cases, the beach has been inaccessible for the construction equipment needed for beach management, due to beach topography, wave overwash, or, in rare instances, the presence of neonate seals (pups less than one week old). Additionally, breaching by wave overtopping or strong river inflows are not considered because these processes are associated with winter storm events, which are rare during the management period.

Because the beach is composed of unconsolidated sand particles, it is susceptible to scour by the discharge flowing through the outlet channel or over the beach crest. Sand scoured from the channel will be conveyed to the ocean, with limited potential to be transported back into the inlet, and there is not a significant upstream source to replace scoured sand. Typically, scour will be extensive and enlarge the channel to the point of breaching and tidal inflows. To prevent scour, flow conditions (u_c) must be below the threshold for scouring sand (u_{crit}). This threshold is a function of the sand grain size, which has been observed to be coarse sand, narrowly distributed around 1 mm at the

Russian River mouth (EDS, 2009a). Further north on the beach, large rocks imbedded in the beach berm may provide grade control and limit scour. Whether the flow velocity is below the threshold depends on the type of bed material and hydraulic conveyance of the outlet channel or over the beach crest, particularly the bed slope.

The beach face slope is set by wave action in the surf zone and is sufficiently steep that flow velocity exceeds threshold for sand movement for all expected discharge rates. Under infrequent outlet channel conditions, the sand scoured by this process could be replaced by wave action on high tides, yielding no net change in the channel mouth morphology. However, if the scour is larger than deposition on the beach face, the active scour zone may move landward, into the outlet channel. This upstream movement is similar to nick point migration or head-cutting observed in streams and rivers. It is also the process thought to occur for self-breaching and observed by Sonoma Water's maintenance staff when the beach berm is artificially breached under current practice. The breaching typically happens relatively quickly, usually within a few hours, before wave-induced sand transport can close off the breach in subsequent higher tides.

A second possible mechanism of breaching is seepage-induced sand mobilization, represented in Figure 4-3 as an arrow associated with Q_s. If seepage rates are sufficiently large, the movement of water through the sand can mobilize sand particles where the seepage flow daylights at the ground surface. Piping of groundwater along preferred pathways, which may exist within or adjacent to the jetty, might encourage this process by increasing flow rates through portions of the beach. Although seepage failure has not been observed at the Russian River Estuary, it has been observed at other estuaries including Crissy Field (Battalio et al 2006) and others (Kraus et al 2002). Seepage failure may simultaneously accompany other breach mechanisms and hence be difficult to identify on its own. Or, seepage failure may require a larger head difference between the estuary and the ocean than what occurs at the Russian River mouth because of artificial breaching to prevent flooding or self-breaching when lagoon water levels exceed the beach berm's crest elevation.

In contrast to closure, which can be managed with further intervention, breaching can immediately and negatively impact NMFS's juvenile salmonid habitat objectives through the loss of freshwater and brackish water habitat that develops under lagoon conditions and restoration of the marine influences of tidal water levels and saline water that enter the estuary. Breaching may have greater impact on habitat during the first part of the management season (mid-May to early July), because juvenile salmonids are less acclimatized to salinity and because the next closure is unlikely to occur before wave energy picks up towards the end of the management period (September-October).

4.5 INTERACTIONS WITH LITTORAL SEDIMENT TRANSPORT

Several decades of monitoring demonstrate that the stretch of Goat Rock State Beach between the jetty groin and the northern cliffs, where the Russian River mouth is located (Figure 1-1), is an active zone for sediment transport. Waves move sand up onto the beach, and can build the beach's crest elevation. When waves approach to the shoreline at oblique angles, they generate net motion of sand along shore, known as 'littoral drift'. The strength of these influences varies along this region of the beach, with implications for beach management: when the tidal inlet or outlet channel is in exposed locations (northwest of the shielding effect of the jetty groin or during strong wave events), waves will more often result in closure from wave-generated transport and deposition. Beach management actions, such as breaching and outlet channel implementation, may influence the local sediment transport patterns, although this effect is less clear.

Beach monitoring, including monthly Water Agency surveys and autonomous photographs, combined with nearshore wave modeling, have indicated the following about sediment transport patterns north of the jetty groin:

- wave power is weakest at the jetty and increases with distance north.
- the section of beach north of Haystack Rock is exposed to both southerly swells in summer and northwesterly swells in spring and fall.
- the 50-100 ft segment of beach immediately north of the jetty groin is shielded from southerly and some westerly waves, which sometimes prevents the beach from growing as high as in other locations farther north.
- high riverine inflows, which typically shift the inlet north, also carry high sediment loads; a portion of these riverine sediments deposit in the ocean just offshore of the mouth and can play a role in tidal inlet and outlet channel dynamics for several months, either as nearshore sandbar or as an extension of the inlet
- wave power is strongest in winter, moderate in spring and fall, and reaches a minimum in July and August.
- beach growth is fastest at the beginning of the management season (May-June) and at the end (September-October), in response to these periods' stronger wave conditions.

These patterns suggest that a tidal inlet or outlet channel will be most vulnerable to closure when located away from the jetty and at the beginning and end of the management season.

4.6 PLANFORM ALIGNMENT

Because of the presence of hard barriers at the extents of the mouth's range (the jetty groin to the south and cliffs to the north), a tidal inlet or outlet channel are expected to occupy an alignment within a fixed region (Figure 1-1). Since implementation of the Biological Opinion, a range of seasonal planform migration conditions have been observed, which have helped to better understand migration (initially outlined in Behrens et al. 2009), and to understand how migration and planform alignment can influence changes in state. The following section describes some of the typical alignments that were observed since 2009.

When breaching or beach management occurs, the initial alignment of the channel (either a tidal inlet or an outlet channel) is typically straight across the beach and set by one of four factors, depending on the breaching processes or beach management. These four factors include: (1) the river inflows at the time of breach, (2) the location of the low point in the beach berm, (3) response of the channel to wave conditions immediately after breach, and (4) the selection of location by Sonoma Water during an artificial breach event. The following section elaborates on each of these factors.

High river inflow events:

- When breached or scoured by high river inflow events, the channel can align itself along the northern edge of the beach, primarily in response to the direction of the river inflows during these events, and possibly due to wave-breaking displaced from the shoreline by a nearshore sandbar created from riverine sediment.
- Monitoring data collected since 2009 indicate that an inflow event needs to exceed approximately 40,000 cubic feet per second (cfs) for the inlet to migrate into the northern-most section of the beach.
- From 2011 to 2016, peak annual riverine inflow rate remained below 40,000 cfs due to multi-year drought conditions, and the inlet never migrated to the far northern edge of the beach. As a result of peak inflows of 55,000 cfs in 2017, the channel once again occupied the far northern alignment. However, after peak inflows of only 14,800 cfs in 2018, the inlet again remained on the southern portion of the beach.

Self-breach at the lowest point in the berm crest:

- When a self-breaches of the barrier beach occurs, its location and alignment depend primarily on the location where the beach berm crest elevation is lowest.
- As water levels rise in the closed lagoon, the location where water begins to spill over the beach is often the prior location of the channel, which had the lowest elevation prior to closure and hence lags in elevation relative to the rest of the beach crest. During some closures, wave-induced beach building is sufficient to raise the entire beach crest to similar elevations, thereby eliminating the remnant low point from the prior channel.
- Sometimes the location of the lowest point is set by the wave refraction patterns, with nearshore wave modeling indicating that the weakest wave energy is located just north of the jetty groin (see Figure 4-6 in Jetty Study, ESA PWA, 2017). This minimum in wave energy occurs in the nearshore, before waves reach the groin, due to the shape and aspect of Goat Rock State Beach relative to the wave climate. In fact, this nearshore minimum was the basis for the groin's location.
- The groin further reduces wave energy in the surf zone, and can cause lower beach berm elevations in its lee than would otherwise be present. Particularly if the channel was located next to the groin prior to closure, the groin can reduce wave-induced beach berm building. Combined with the multi-year drought that limited northward inlet migration due to low peak annual river inflows, there was a persistent low point just north of the groin that limited opportunities for outlet channel implementation in 2014 and 2015.

Inlet migration due to waves after breach:

- Once the barrier beach is breached, the channel typically changes alignment because the ocean-side mouth migrates laterally in response to wave and littoral transport processes (Behrens et al., 2009).
- Observations by Behrens et al. (2009) show that the channel can move both northward and southward during the management period.
- The direction and magnitude of wave energy and the resultant littoral sand transport are thought to determine the direction and extent of inlet migration.

- The channel typically moves in the direction of the littoral transport (Dean and Dalrymple, 2002). However, several mechanisms have been identified at other locations that enable an inlet to move updrift, opposite to the direction of the littoral transport. These can include bar welding events, orientation of the mouth, or interaction of refracted waves with the outflows at ebb tide (Aubrey and Speer 1984; Pranzini 2001; J.McKeon, personal communication).

Pilot channel to initiate artificial breaching - location selection:

- Beach management actions take place between the jetty groin and the north end of Goat Rock State Beach. Sonoma Water has attempted beach management actions in several locations in this area; under current practice, the initial alignment is perpendicular to the beach and, when accessible, the preferred location is just to the north of the large rock ("Haystack Rock") at the northwest corner of the estuary.

After the channel has been open for some time, it tends to migrate in response to wave action, unless it is located at the far north end of the beach or at the southern extent next to the jetty groin. Over the course of weeks or months, this migration can result in the alignment developing one or more bends. More complex alignments with multiple bends can occur in response to changes in wave direction during El Niño years (Allan and Komar 2006; Behrens et al. 2009), or if the channel migrates to a location with a local reversal in wave direction, which are known to occur along the pocket beaches in this section of the coast (de Graca 1976). An additional factor which may affect the complexity of the channel alignment is landward migration of the offshore bar. This bar, which is created by sand eroded off the beach during winter storms and/or riverine inflows, can move landward with summer waves. If this bar moves sufficiently close to the inlet mouth, it may force the mouth to either side, which was observed during March and April 2017.

The alignment of the channel can effect on the water levels in the estuary, and sometimes support the formation of ephemeral outlet channel conditions. Lateral migration by the mouth while the upstream channel lags behind tends to create a sinuous channel over time, especially if the channel develops multiple channel bends in response to the mouth reversing directions. This tends to mute the tides in the estuary (Behrens et al. 2009), and, in some instances, can encourage the channel to naturally form an outlet channel. Cases when the channel is either an outlet channel or muted with less than a one-foot tide range are rare, but have occurred in July 2010, with the channel meandering through the north end of the beach, in 2016 when the channel was oriented toward the jetty groin before taking a sharp turn toward the ocean, and in June 2017, when the mouth was again elongated toward the far northern edge of the beach. In all of these cases, the effect of the channel alignment on estuary water levels was an ephemeral feature lasting only several days or about a week before closure.

Channel migration and its effect on conditions in the estuary were included in the lagoon quantified conceptual model (QCM) for the Russian River, which is described below in Section 6 and in Behrens et al. (2015). The modeling assumes that the migration rate is proportional to and in the direction of the along-shore component of the wave power, which becomes significant when waves approach the shore at an angle. Including migration in the model resulted in a more realistic prediction of muted tides and seasonal mouth closures in the model.

Lastly, when the channel is located at the northern end of the beach, it sometimes flows around a number of rocks embedded in that part of the beach, which might have the effect of limiting scour and slowing flows to the ocean. The channel flowed around these rocks during the July 2010 natural perched outlet condition, and also during the June 2017 perched condition.

4.7 BEACH WIDTH AND CREST ELEVATION

As part of the Jetty Study (ESA PWA, 2017), long-term beach width trends were quantified using a series of historic aerial photographs and maps of Goat Rock State Beach (GRSB) and other nearby beaches. The earliest mapping dated from the 19^{th} century, when a naturally-occurring tombolo connected Goat Rock and the mainland. This tombolo, or low sand bar perpendicular to the shoreline, was filled as part of the jetty construction and now is a parking lot. This assessment showed that:

- Beach widths have been increasing north of Goat Rock by approximately 1 foot per year since the tombolo was filled.
- Beach widths have been decreasing at the beach immediately to the south of Goat Rock.
- Beach widths have been relatively steady at Wright's Beach, a control site further to the south.
- The trend in width north of the jetty groin is more variable, since the inlet often erodes this section of the beach.
- The change in beach width was greatest in the 1950s and 1960s, and has more recently become slower.

Overall, the assessment indicated substantial widening of GRSB beach after the tombolo behind Goat Rock was filled. This beach widening occurred because the wave-driven transport of sand from north to south is blocked by the fill on the former tombolo, causing the sand to accumulate on the north side of Goat Rock. This trend is counter to the assumed trend in the Biological Opinion, that the jetty and artificial breaching caused a reduction in beach width as compared to pre-development conditions and that a reduction in beach width is partially responsible for less frequent perched conditions.

In addition to the effect that filling the tombolo behind Goat Rock has had on increasing beach width, riverine sediment supply may be a contributing factor to beach width. Sediments that wash through the estuary and into the ocean can contribute to beach building. Development occurred in the watershed in the 1950s and 1960s, potentially leading to elevated riverine sediment loads discharged through the mouth, which may have encouraged beach width to grow. However, this relative significance of this mechanism is harder to identify clearly.

4.8 SEEPAGE THROUGH BEACH

As discussed above, the rate of seepage from the estuary to the ocean through the beach berm affects estuary water levels during closed and outlet channel conditions. During a closure, larger seepage rates reduce the rate of water level rise, potentially extending the duration of closure. For an outlet channel, larger seepage rates mean that less water needs to be discharged by the outlet channel, which would decrease the chance of erosion and breaching. The historically narrower beach (see section above) fronting the estuary may have had larger seepage rates. The current wider beach could potentially reduce the rate of seepage losses from the lagoon, by making the seepage pathway longer.

The potential impacts of the jetty on seepage rates were investigated as part of the Jetty Study (ESA PWA, 2017). Sonoma Water coordinated an effort that included:

- Installation of two arrays of groundwater wells on the beach: to monitor groundwater elevations and salinity
- A seismic refraction study: to determine bedrock depths
- Ground penetrating radar: to determine the presence of jetty elements in the beach
- Electromagnetics (EM): to determine whether some portions of the beach conveyed more water than others
- Electrical resistivity tomography (ERT): to identify flow paths through the beach sediments.

The study determined that portions of the jetty buried in the beach reduce seepage rates. Areas without buried jetty elements had more rapid salinity and groundwater level responses to variations in the ocean tide, whereas areas with buried elements showed slower responses. This finding from the well arrays was consistent with observations from the EM and ERT methods. The results were less clear for the jetty groin, where it was difficult to collect data due to the presence of the inlet. Although the groin could also presumably slow seepage, there have also been several anecdotal observations of piping and sand liquefaction near the eroded tip of the groin that suggest at least some parts of it may increase local groundwater flow.

The net impact of the jetty on seepage rates from the lagoon is difficult to quantify. The jetty may reduce these rates compared with the historical beach. This would increase the likelihood of failure due to breaching and decrease the duration of closures. However, when changes in seepage rate due to jetty removal were modeled with the QCM, the change in number of closures, total number of days closed, and water level distribution were all relatively minor. The increased seepage out of the lagoon due to jetty removal was partially offset by the increased wave overtopping into the lagoon because the jetty had supported a high-than-natural beach crest elevation.

4.9 WATER QUALITY IMPLICATIONS

Water quality conditions in the estuary are influenced by the beach state, therefore beach management can affect estuarine salmonid habitat conditions via water quality. The Biological Opinion seeks to enhance freshwater and brackish[4] water conditions, so that juvenile salmonids benefit from lagoon conditions, which lower salinity and form a greater extent of freshwater and brackish water habitat. Estuarine rearing habitat is also determined by temperature and dissolved

4 The Biological Opinion (2008) defines ‘brackish’ as salinity between ocean salt water and freshwater. Boughton et al. (2017) further refine the definition for salinity into 4 classes that include ‘hypotonic’ (< 10 ppt), ‘isotonic’ (10-15 ppt), ‘hypertonic’ (15-28 ppt), and ‘marine’ (> 28 ppt).

oxygen. As described in more detail by Section 3.1, Boughton et al. (2017) developed a rating scheme for all three of these water quality parameters as they relate to juvenile steelhead habitat. The remainder of this section describes the implications of beach state for these three key water quality parameters.

The current understanding of the relationships between beach state and water quality are:

- **Tidal conditions:** When the tidal inlet conveys ocean tidal flows into the estuary, water quality conditions are dominated by cold, salty marine water from the mouth to Sheephouse Creek. Between Sheephouse Creek to Freezeout Creek, the marine influence depends on the tide range (e.g. stronger ocean tides typically penetrate further upstream). Upstream of Freezeout Creek, warmer freshwater conditions tend to dominate. The salt/fresh water boundary shifts with the tides, particularly in the lower estuary. While salt water intrudes further upstream during incoming flood tide, during an outgoing ebb tide fresh water can propagate further downstream, particularly at the surface. Dissolved oxygen is typically sufficient for salmonid rearing habitat throughout most of the estuary. Overall, the depth and extent of fresh water, particularly downstream of Freezeout Creek, are typically much smaller with tidal conditions than during closed conditions.
- **Closed conditions:** When the tidal inlet closes, the fresh and salt water settle into layers, with less dense fresh water on top of more dense salt water. The bottom saline water layer accumulates through much of the lower estuary and also in the deep pools at Sheephouse Creek, Heron Rookery, Freezeout Creek, and as far upstream as Browns Pool near Austin Creek. Fresh water overlies this saline water in deeper areas and fills the entire water column in shallower areas. Because the bottom salt water layer is cut off from the atmosphere by the fresh water layer, the dissolved oxygen in the salt water layer is consumed by biologic activity in the first few weeks after closure until the lower layer becomes hypoxic (< 3 mg/L) or anoxic (0 mg/L), and inhospitable to salmon. The upper fresh water layer remains well oxygenated due to exchange with the atmosphere. Because the fresh water comes from the watershed and river, it is fairly warm, and with closed conditions, this warm water extends further downstream. Near the mouth, the trapped saltwater slowly seeps out to the ocean through the beach, such that the freshwater layer becomes deeper over time due to both a decline in the salt water layer and increasing water surface elevation.
- **Perched outlet channel conditions:** An outlet channel drains a perched lagoon and thus limits the water surface elevation and extent of the upper freshwater layer. In this situation, water levels in the lagoon might fluctuate slightly as waves and ocean tides affect the ability of the channel to drain the lagoon, but no ocean tides are actually entering the lagoon through the channel. The strength of the outflow is not likely sufficient to cause vertical mixing (Behrens, 2012), and vertical stratification with a fresh upper layer and salty bottom layer would remain. While outlet channel conditions have not been observed for more than several days at a time, the available data suggest that the loss of freshwater from the upper layer is more rapid than seepage losses of saltwater from the bottom layer. Otherwise, water quality during perched outlet channel conditions are similar to closed conditions.

These three states and three water quality parameters are thought to be most important for setting salmonid rearing habitat. Other water quality parameters, such as nutrients and phytoplankton, also affect rearing habitat, but less directly than the primary three parameters. Other external factors can also affect estuarine water quality, such as coastal fog and sea breezes (particularly for temperature), and riverine inflows from the watershed. Water quality conditions can also be different during transitions between the three beach states, that carries over to the start of the next state. For example, a longer period of tidal muting preceding closure may drain some of the freshwater from the upper layer of the estuary, sharpening the salt stratification at the beginning of closure. Or the abrupt outflows due to breaching may re-distribute some low-oxygen water parcels into areas that were well-oxygenated during closure. However, these transition times are generally short-lived.

4.10 FLOODING AND SEA LEVEL RISE

Managing the beach to enhance salmonid habitat while at the same time limiting the potential for flooding of low-lying properties along the inner shoreline is a current challenge given the dynamic conditions at Goat Rock State Beach. Although Sonoma Water has developed a successful tool for predicting near-term (~1 week) rise of water levels based on measured freshwater inflows at Hacienda Bridge, ocean wave conditions are harder to predict. Wave overwash events can also cause a significant rise in estuary water levels on their own and also prevent safe beach access for the equipment needed to construct an outlet channel. With an upward shift in ocean water levels due to future sea level rise, both the higher ocean tides and waves riding on these higher tides would make it harder to manage the estuary water level within the target range of 7-9 feet NGVD.

The potential geomorphic effects of sea level rise are discussed in detail in Section 5.4 of the Jetty Study. The beach elevation is expected to shift towards higher elevations at a rate that matches sea level rise, while also shifting toward land. The upward shift is expected because the same wave processes that form the beach would shift upward and landward with the higher tides.

Taken together, these changes to the beach are expected to cause several challenges to beach management:

- As the beach elevation shifts upward, water levels during periods of mouth closure will likely reach 7-9 feet NGVD29 sooner as higher sea levels would raise the baseline water surface level at the time of closure. This would compress the window of time available for planning, monitoring, and equipment mobilization between the date of closure and the date that water levels begin to flood properties.
- As the beach rises, its overall shape should remain similar, so the beach width in the range of 7-9 feet NGVD29 would increase, meaning a larger amount of excavation would be required for both types of beach management, artificial breaching and an outlet channel implementation.

Predictions for sea level rise in California have been updated several times over the past 10 years. The most recent guidance from the California Ocean Protection Council (OPC, 2018) is based on updated technical analysis from Griggs et al. (2017). Depending on the scenario, sea levels are projected to rise about one foot by 2050, and three to six feet by 2100.

4.11 ASSUMPTIONS AND LIMITATIONS

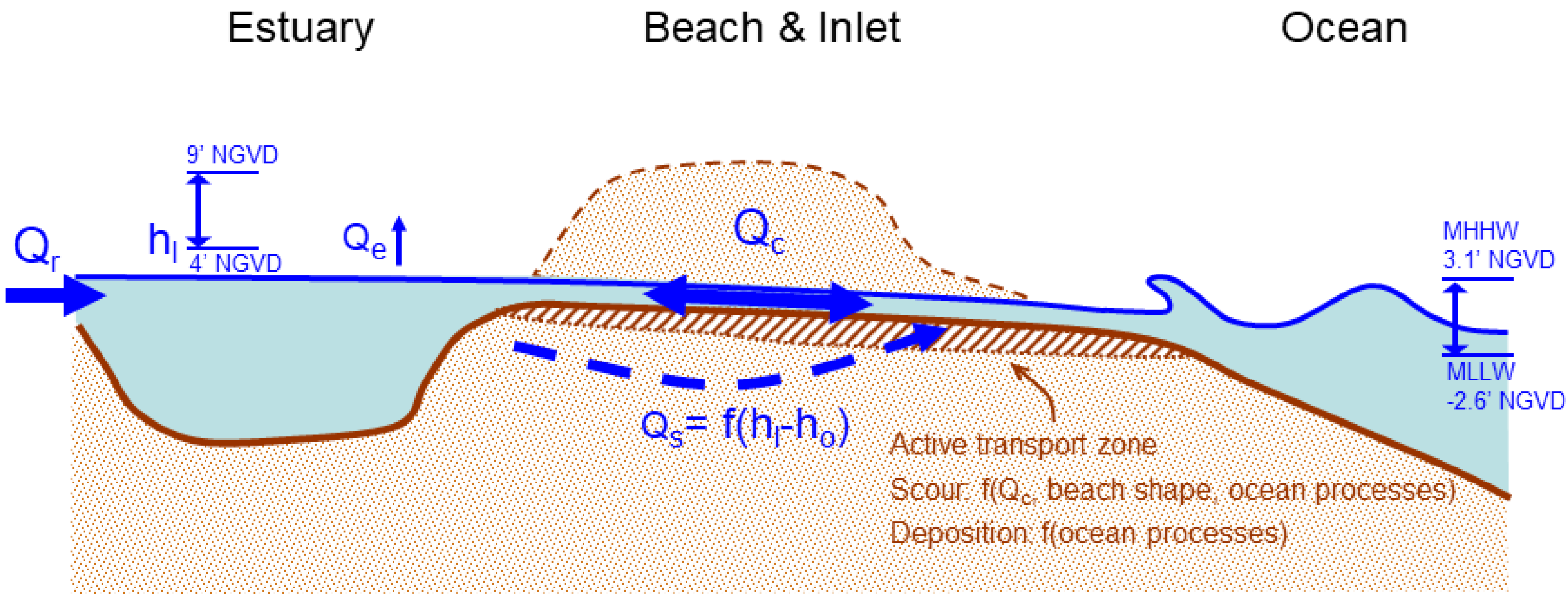
The assumptions made to develop the conceptual model are uncertain, and may not capture all relevant processes affecting the barrier beach and estuarine habitat. Although the conceptual model leaves out some processes which may slightly influence the beach and estuary, this reduction in scope prevents the conceptual model from becoming so complex that it becomes unwieldy. However, by making assumptions about the outlet channel explicit, they can be monitored, documented, discussed, and tested, all of which are necessary steps in the adaptive management process. The conceptual model and its assumptions will be tested and refined based on observations of beach and estuary response. The increased and refined understanding of the beach and estuary since implementation of the Biological Opinion began have been incorporated into this adaptive management plan. Future observations and analyses will undoubtable continue to inform management objectives and approaches.

The conceptual model is not a numerical hydrodynamic or sediment transport model but rather uses empirical observations and geomorphic interpretations to identify likely responses to key forcing parameters, given antecedent conditions and management actions. Therefore, its outputs are not quantitative, but rather qualitative. When quantitative models are used to analyze the estuary, such as described in Section 6, the quantitative predictions are assumed to be consistent with the conceptual model.

These beach processes occur at many natural tidal inlets and river mouths, but are considered problems at the Russian River mouth because modified forcing parameters have affected the timing and frequency such that salmonid species may be adversely affected (see the Biological Opinion), as well as conflicts with other man-made constraints. One of the key questions in this management plan is the degree to which the inherently dynamic system can be managed to enhance estuarine habitat conditions.

This conceptual model is based on existing literature, knowledge of similar estuaries, professional judgment, and ongoing discussion with Sonoma Water, NMFS, CDFW, and CSP. New data and experience from monitoring and managing the beach will be used adaptively to revise the conceptual model in subsequent management plans.

4.12 FIGURES



Parameters

u_c= f(channel slope, length, and width; Q_r; ocean water level)
(can be managed to greater or lesser degree)

u_{crit} is f(grain size)

Processes

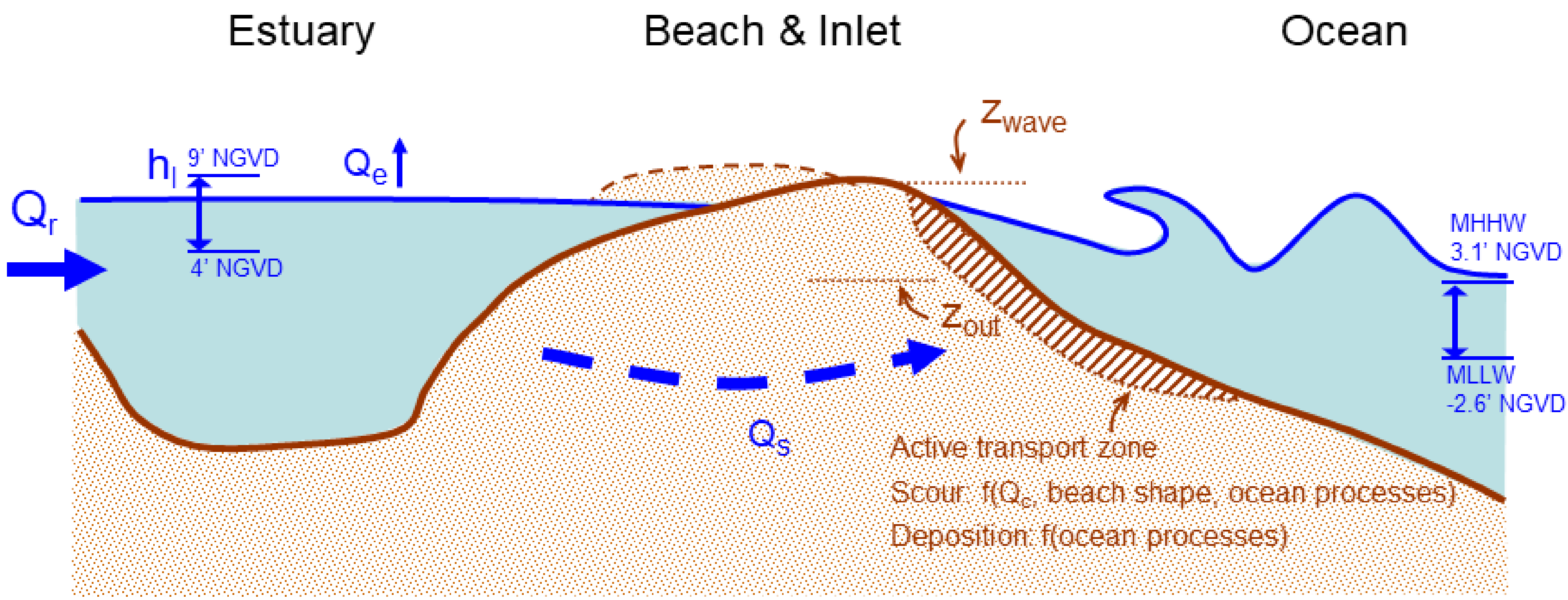
- $u_c > u_{crit}$; high velocities scour channel
- Q_s increases; high seepage creates groundwater piping and erosion
- sediment transport within outlet channel

figure **4-1**
Russian River Estuary Beach Management Plan

Conceptual Model – Open Tidal Inlet

ESA Ref# DW1958

ESA



Parameters

z_{out}=target channel bed elevation

z_{wave}=wave runup elevation; f(wave conditions, ocean water level, channel location)

Processes

- $z_{wave} \geq z_{out}$
- wave-induced sediment transport closes outlet channel
- $Q_c \rightarrow 0$
- h_l increasing

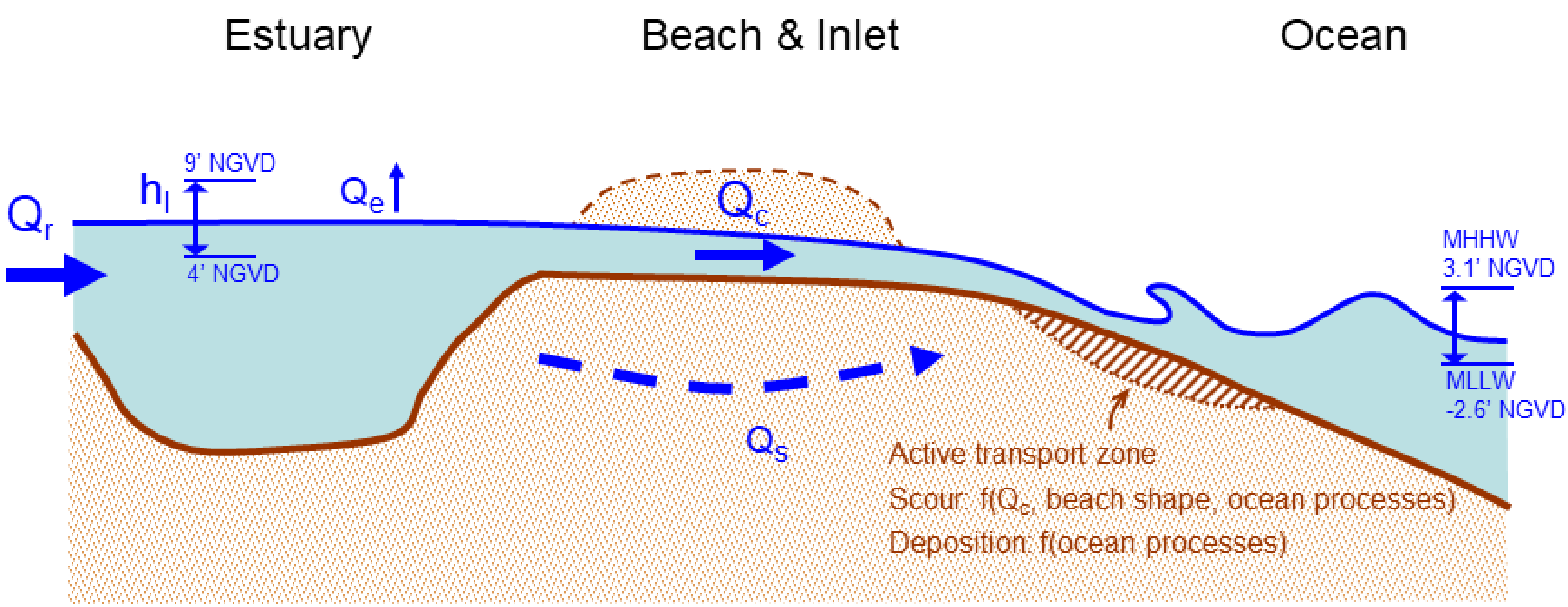
figure **4-2**

Russian River Estuary Beach Management Plan

Conceptual Model – Closed Lagoon

ESA Ref# DW1958

ESA



Parameters

h_l=lagoon water level
Q_r=river discharge
Q_c=outlet channel discharge
Q_s=seepage discharge
Q_e=evaporation from lagoon

Processes

- $Q_r = Q_c + Q_e + Q_s$ (averaged over days)
- No sediment transport within outlet channel
- Active sediment transport outside outlet channel

figure **4-3**
Russian River Estuary Beach Management Plan

Conceptual Model – Perched Lagoon with Outlet Channel

ESA Ref# DW1958

ESA

5. EMPIRICAL ASSESSMENT OF HISTORIC INLET CONDITIONS

The Russian River inlet is highly variable in form, position, and capacity for tidal conveyance. Analyses of field data and an extensive photographic record of daily conditions show that this variability is largely influenced by tides as well as seasonal changes in wave and river conditions (Rice, 1974; Behrens, 2008). Management actions also influence the timing and duration of closure events (Goodwin and Cuffe, 1994).

When the estuary is open to the ocean, the inlet can take one of the following forms:

- A river-dominated channel with minimal influence from tides and waves. This occurs during short-lived river flood events between December and April.
- A channel controlled by a mix of river inflows, tides, and wave action. This is the most common inlet state, with waves tending to deposit sand in the inlet and estuary-to-ocean flows due to tide and river being active in removing sand from the inlet. Estuary tidal range is a fraction of the ocean tidal range, ranging from zero to over 70%, varying in response to sediment infilling and scouring of the inlet channel. Here we give special attention to "marginally tidal inlets", where tidal conveyance is less than 10%.
- A one-way overflow channel with water draining from a perched estuary, i.e., the sand barrier is built across the mouth of the estuary, but the estuary water level is high enough to overflow. Waves have limited control over such an "overflow inlet", and tidal influence is nonexistent. River inflow rate controls estuary water level and overflow volume, which determines the susceptibility to breaching.

This section provides an overview of inlet states observed during the years 1999 to 2008, the time period for which the photographic record has been analyzed in detail. The analysis emphasizes the dates corresponding to the proposed management period of May 15 to October 15. The purpose of this assessment is to use existing data to identify relationships between forcing due to river, tides and waves and the response of the estuary mouth ("inlet") – and to explore the frequency of the latter two conditions described above.

5.1 FREQUENCY AND FATE OF RUSSIAN RIVER INLET STATES

The possible occurrence of an "overflow" channel at the mouth of the Russian River estuary was investigated by comparing water level records from the Jenner gage with tidal data from the NOAA Point Reyes station. The focus was to analyze events when the inlet was open for at least 24 hours with water levels remaining above tidal influence and slowly varying. Attention was also given to events when the inlet allowed minimal amounts of tidal interaction. Dates for which the inlet was at least partially open were disaggregated into a series of categories based on the ratio of the estuary tide range observed at the Jenner gage to ocean tide range (defined here as "tidal conveyance") – see Table 1. Estuary tide is driven by ocean tide, but estuary tide range is reduced either due to the elevation of the channel base that precludes complete draining of the estuary to low tide levels or due to the channel size being too small for enough water to be transported between estuary and ocean. The estuary-ocean tidal ratio is thus an indicator of mouth state, with smaller values representing an increasingly choked mouth (near to closure or overflow state).

Table 1 Frequency of observed inlet states from May 15 to October 15 for years 1999-2008.

Inlet state		**Number of days observed**	**Proportion of period**
Tidal conveyance[1]	0-5%	10	0.8%
	6-10%	4	0.3%
	10-29%	82	5.4%
	30-49%	315	20.9%
	50-69%	590	39.2%
	≥ 70%	142	9.4%
Full inlet closure		161	10.7%
Overflow channel, stable or decreasing water level(≥ 24 hours)		0	0.0%
Device error		199	13.2%

[1]Defined as the ratio of estuary tide range to ocean tide range.

The 161 days when the estuary was closed consisted of 26 separate closure events. Of these, 19 were artificially breached and the remaining 7 were self breaches. Although the low number of self-breach events prevents any statistically significant comparisons with river or wave data, it is worth noting that flows over 400 ft^3/s resulted in self breaches within 1-2 days of closure. Including all closures, there was a correlation between Hacienda flow and closure duration, with lower flows leading to longer closure periods.

During the years 1999-2008, there were no instances of overflow conditions during the proposed management period, but there were five relevant events that occurred just outside of the management period. All events had decreasing water levels, reflecting down-cutting of the barrier, although the rate of down-cutting was slow enough to prevent tidal interaction for at least 24 hours. Two of these events occurred during October, one in November, and two in May. Three of the events were associated with closure events and most lasted for less than 48 hours. An exception was a five-day event that occurred 6-11 May 2008. In this case, the inlet was breached artificially, and Sonoma Water immediately noted that the channel had become elongated, beginning near "Haystack Rock", nearly 450 feet north of the jetty, and terminating at the jetty. This is uncommon, as post-breach channels are almost always short and wide (Behrens, 2008). The sudden elongation of the channel is likely associated with onshore bar migration.

During tidal periods, tidal conveyance was less than 10% on only 14 days during the management period from 1999-2008. These states were generally a precursor to closure events – all dates for which tidal conveyance was below 10% resulted in closure and the muted tidal state typically lasted for only one or two days. They were most commonly observed during short periods when an artificial breach failed to keep the inlet open for more than 1 or 2 days, or during periods of low flow when the inlet was narrow and elongated. Note that there is a diminishing propensity for the inlet to be in a muted tidal state when it is close less than 30% of the full tide range. This indicates that being in between fully open or fully closed is not a condition supported by natural processes at this site.

5.2 WAVE AND RIVER CHARACTERISTICS

Wind waves and river outflow characteristics strongly influence the behavior of the inlet. These forcings exhibit seasonal patterns and other trends that correlate with different inlet states. Details of these relationships are presented below.

5.2.1 Seasonal patterns

Wave data were obtained from the CDIP Point Reyes buoy and a transformation matrix accounting for shoaling and refraction (e.g. http://cdip.ucsd.edu/) was used to transfer deepwater conditions to conditions at a location at 10-meter depth near the inlet. This method provides a first-order estimate of nearshore wave conditions that is necessary as there is a significant difference between deepwater/offshore waves and those nearshore. Wave energy is greatest in winter, declining through spring, to a minimum in July-August. However, late spring storms and/or early fall storms can occasionally produce waves exceeding 10 feet in the vicinity of the inlet during the management period. As discussed in Rice (1974) and Behrens et al. (2009), predominant swell waves from the northwest are often the cause of prolonged inlet migration or closure during late spring.

Data on river flow at Hacienda[5] show a rapid decline from a maximum at the beginning of the management period (mid-May) to a minimum in August (Table 2). Flows in July through September are low, between 80 and 225 ft^3/s for the years 1999 to 2008.

5.2.2 Conditions during different inlet states

Wave and flow conditions were compared with specific inlet states, as shown in Table 2.

Marginally tidal inlet: There is a relation between tidal conveyance and nearshore waves (H_s is significant wave height). Marginal tidal conveyance (< 10%) occurs during larger waves (H_s of 2.5 to 3.25 feet), consistent with the idea that these are transitory states associated with inlet closure and one needs waves big enough to overcome tidal (plus river) flows. These wave conditions may be lower during periods of weaker river flow. Further, if this marginally tidal mouth condition persisted, it could do so for any weaker wave conditions (which would not close the mouth).

Closed inlet: Estuary water level increase during closure events was analyzed to understand how close these conditions were to a steady-state overflow scenario. In all cases, water levels rose at rates of 0.1 ft/day or faster (Table 2). However, accounting for estuary area, the slower water level rise suggests that it may be possible to achieve a steady state with limited flow over the berm if river

[5] USGS gaging station located just downstream of Hacienda Bridge, station ID 11467000.

flows are of order 100 ft^3/s or weaker. Flows marginally over 100 ft^3/s may be possible, depending on the limit on overflow rate without eroding the sand barrier.

Overflow inlet: All of the five observed overflow events had flows higher than 100 ft^3/s, but only one persisted for more than a couple of days. Further, all of these events exhibited unusual conditions. The October 1999, November 1999 and first May 2008 event occurred during a sequence in which high waves began to induce closure, but a sudden increase in river flow prevented full closure and eroded the channel down to its original state. It appears that overflow conditions only occurred because the initial transition towards closure allowed estuary water levels to temporarily exceed high tide levels. The event in October 2006 occurred after a self breach of a four-day closure, so the lower flows observed in this case are expected. Finally, the most persistent event in May 2008 was associated with an unusually long channel, which is important in that frictional losses may have encouraged the prolonged high water elevation in the estuary. As noted above, this event was likely due to seasonal onshore bar migration.

Table 2 Comparison of average wave and average river conditions for various ranges of tidal conveyance and water level increase in the estuary. Overflow conditions are analyzed for five events observed outside of the proposed management period.

Inlet state		**Hacienda flow, ft^3/s**	**Nearshore H_s, ft**
Open inlet with given tidal conveyance:	<10%	323	3.2
	10-29%	261	2.5
	30-49%	219	2.1
	50-69%	276	2.0
	≥70%	328	1.8
Closed inlet; estuary stage rising at given rates:	0.1-0.29 ft/day	146	2.7
	0.3-0.49 ft/day	175	2.6
	0.5-0.7 ft/day	185	3.4
	≥0.7 ft/day	211	4.1
Overflow channel (outside management period)	Oct 28, 1999	291	15.7
	Nov 4-5, 1999	247	5.9
	Oct 26, 2006	155	2.2
	May 1-2, 2008	323	6.6
	May 6-11, 2008	283	1.3

5.2.3 Analysis of wave runup

The mouth of the estuary is typically closed by waves depositing sediment in the inlet channel during slack high tides, but waves can only do so if wave runup can reach the height of the inlet channel base. Thus, wave runup exceedance curves were generated for each of the management months to assess the likelihood of the (overflow) channel being closed by wave action. De-shoaled deepwater equivalent wave heights were combined with daily higher-high tide water levels to estimate runup height following Stockdon et al. (2006), and assuming a constant beach-face slope.

The height exceeded by 2% of the waves under given monthly wave conditions is shown in Figure 5-1. Runup is highest in October, with heights of 11ft being exceeded on 1 in 10 days. For May, June and September, runup exceeds 10ft on 1 in 10 days, and this drops to 9ft for July and August. This is consistent with the seasonal cycle of large swell events, due to winter storms in the north Pacific, which may occur in October, and occasional swell events due to storms in the tropical or south Pacific during summer. The locally generated waves due to northerly winds in summer are of shorter period and lower height. These data suggest that wave-induced closure of an overflow channel will be a greater concern at the beginning and end of the May-October management period.

5.3 CHANNEL PLANFORM GEOMETRY

Inlet morphological behavior has been studied by Behrens (2008) for the years 1999-2008 through an analysis of inlet width, length and position estimates derived from photographic records. Data collection methods and error estimates are described in Behrens et al (2009). Inlet planform geometry and closure risk are summarized for different mouth states (Table 3).

Table 3 Inlet planform geometry for overflow conditions and various ranges of tidal muting (May 15 to October 15, 1999-2006). Overflow conditions are analyzed despite the fact that they occurred outside of this timeframe.

Inlet state		Inlet width[1], ft	Inlet length[1], ft	Most common configuration	Closure risk[2]
Open inlet with given tidal conveyance:	<10%	25 ± 1.8	530 ± 37.1	≥2 channel bends	81.3%
	10-29%	51 ± 3.6	358 ± 25.1	1-2 channel bends	35.3%
	30-49%	71 ± 5.0	282 ± 19.7	1 channel bend	28.6%
	50-69%	86 ± 6.0	236 ± 16.5	1 channel bend	13.7%
	≥ 70%	92 ± 6.4	221 ± 15.5	Straight	3.5%
Overflow channel (outside management period)	Oct 28, 1999	60 ± 4.2	140 ± 9.8	Straight	--
	Nov 4-5, 1999	20 ± 1.4	360 ± 25.2	Deflected by jetty	--
	Oct 26, 2006	25 ± 1.8	110 ± 7.7	Straight	--
	May 1-2, 2008	65 ± 4.6	100 ± 7.0	Straight	--
	May 6-11, 2008	20 ± 1.4	480 ± 33.6	Deflected by jetty	--

[1] Ranges are based on error estimates from Behrens *et al* (2009).

[2] Defined as the number of observations that were followed by closure within two weeks, divided by the total number of observations.

The data for overflow channel geometry indicate that the limited number of overflow events exhibited a range of shapes. The geometry of the only persistent case (6-11 May 2008) suggests that frictional loss plays an important role in attenuating channel velocity and the resulting downcutting.

However, there is a tradeoff for the frictional losses associated with sinuous channels. For a marginally tidal inlet the channel is long and narrow, with a couple of bends – and there is a very high risk of closure. There is no apparent relation between inlet position (not shown in this table) and tidal conveyance. However, marginally tidal inlets and overflow inlets were observed only at the northern or southern extreme of the inlet's migration range. Inlet width and length are known to vary in concert with river flow during the wetter months of the year and with tidal range during the drier months (Behrens et al., 2009). In general, low-flow conditions (low tides or river flow) appear to encourage inlet elongation and narrowing. Inlet width, length, and the number of channel bends all influence the tidal signal by determining frictional losses in the channel.

5.4 NOTES ON OTHER ESTUARIES

Overflow inlets have been observed in numerous estuaries along the coasts of California, Oregon, Chile and South Africa (and probably other areas with comparable climate and topography) (personal communication, John Largier). These are unpublished observations. Specifically, an overflow inlet is typically observed to persist for 1 to 3 months each year at the mouth of Salmon Creek (10 miles south of the Russian River) and at the mouth of the Gualala River, discussed below. Further, small central coast estuaries exhibit overflow states during spring and summer, e.g., Scott Creek and Waddell Creek. Systems photographed along the Chilean, South African and Oregon coasts are of similar size in terms of river flow and lagoon area. The absence of observations of overflow conditions in larger estuaries, similar to the size of the Russian River, suggests that there is a limit to the flow energy that can be accommodated by flow over a sand barrier of finite width (and thus high slope).

5.4.1 Gualala River

The mouth of the Gualala River is located 31 miles northwest of Jenner. Both its tidal prism and annual river flow are significantly lower than those of the Russian River. Despite this, the sites have several similarities, most notably their similarly sized beaches bordered by headlands. During a typical year, the inlet is closed for the entire summer and is opened by the first major storm of the winter (ECORP, 2005). The inlet requires consistent rainfall to remain open, and it is common for closures to occur within several weeks after each major storm event. As rainfall decreases during the spring, the inlet undergoes repeated cycles involving a closure event, a period of gradual estuary stage increase leading to a natural breach, and finally, several days to several weeks of minimal tidal conveyance and/or overflow conditions culminating in a new closure event. These cycles appear to continue until evaporative and seepage losses counterbalance inflows into the estuary, preventing the stage increase required to cause a natural breach event.

5.4.2 Carmel River

California State Parks adaptively manages the beach berm which creates a lagoon at the mouth of the Carmel River (CA Dept. of Parks and Recreation, 2008). The goal of this management is similar to the goal stated in the Russian River Biological Opinion (NMFS, 2008): to enhance the freshwater salmonid rearing habitat during summer months. Sometime in April, May, or June, once the Carmel River inflows into the estuary drops below 20-25 ft^3/s, bulldozers are used to increase the height of the beach berm. This elevated berm blocks ocean tides and saline water from entering the estuary, thereby creating a perched lagoon. When forming the elevated beach berm, an outlet channel is also created so that if lagoon water levels exceed 10 feet NGVD, the outlet channel will drain water from the lagoon into the ocean. The outlet channel only conveys water if the inflows to the lagoon does not taper off from 25-20 ft^3/s to 10 ft^3/s as rapidly as expected. Once river inflows falls below approximately 10 ft^3/s, evaporation and seepage export enough water from the lagoon that lagoon water levels no longer increase. As compared to the intermittent Russian River closures, the Carmel River estuary closes every year for months, typically at least July through November.

The Carmel River's outlet channel is more dynamic, fluctuating between open, overflow, and closed during the wet season, approximately December through June. As such, this period, although not corresponding to the Russian River management season, may inform the understanding of the Russian River's outlet channel dynamics.

The Monterey Peninsula Water Management District collected and analyzed water levels, riverine flow rates, waves, inlet state, and salinity in the Carmel River estuary between 1991 and 2005 (James, 2005). In approximately half of winters, an elongated channel has formed to connect the Carmel estuary to the ocean. With an elongated channel, water level fluctuations in the estuary were more muted than water level fluctuations when the channel aligned more directly to the ocean. The more muted conditions typically lasted for several weeks or up to a month, and then increased river discharge, tide range, and/or wave overwash caused water level fluctuations to return to the more typical range of two-three feet. In December 2004, at the direction of NMFS, an elongated channel was mechanically excavated to run north along the beach. The northern inlet alignment persisted through the winter and muted tidal conditions persisted for most the winter with only brief periods of larger water level fluctuations. However, this elongated alignment raised considerable concerns about the potential for erosion to adversely affect roads and buildings, and has not been repeated as a management option.

The elongated channel and muted tides correlate with a slight decrease in Carmel estuary salinity (James, 2005). Compared to a straight channel, when salinity is typically less than about 0.6 ppt at the surface, the elongated channel coincides with slightly lower salinity of less than about 0.3 ppt. Salinity measurements were not made at the bottom of the estuary water column, where higher salinity is likely due to greater water density.

The applicability of the Carmel River estuary's winter-time channel condition to the management of the Russian River estuary outlet channel may be limited.
The Carmel River estuary has considerably smaller riverine discharge and estuary tidal prism, which combine to cause predominantly closed conditions. In contrast, the larger Russian River estuary is predominantly open, owing to its larger riverine discharge and tidal prism. Similar to the Carmel River estuary, management of the Russian River estuary faces a number of infrastructure and operational constraints that limits inlet re-alignment, such as flooding, beach access, and marine mammals. Due to bedrock embedded within the beach, the Carmel outlet channel resists downcutting and preserves higher estuary water levels. The Carmel's minimum observed water level is approximately 2.3 NGVD, only about 0.5 foot below oceanic MHHW. This suggests that the Carmel water levels are perched in large part due to the underlying geology. For comparison, the Russian River estuary's minimum observed water level is -1.6 ft NGVD, 4.5 ft below oceanic

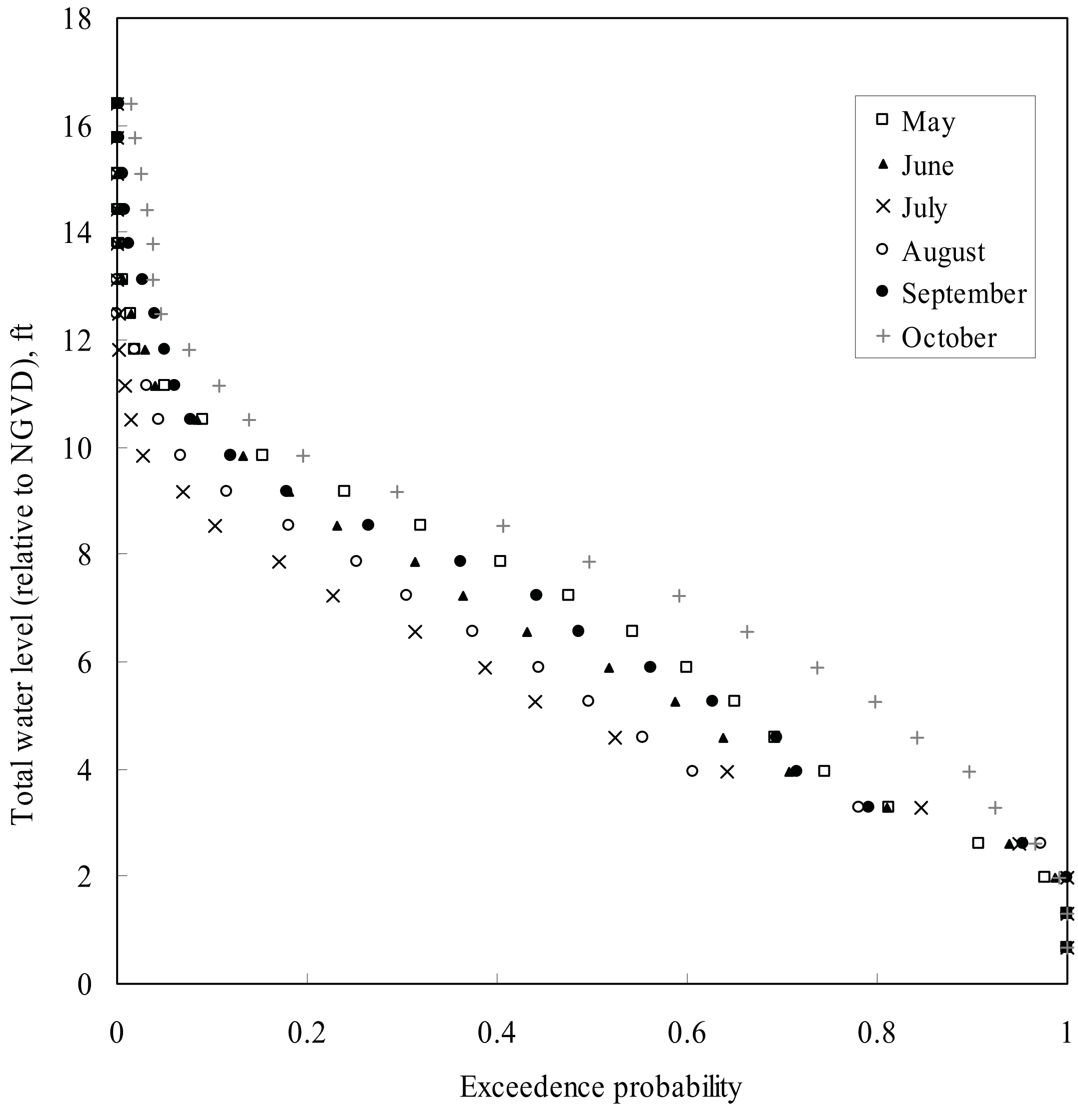
MHHW and only about one foot above oceanic MLLW. In addition to these elevation differences, muted tidal condition occur at the Carmel estuary during the winter, when high wave energy provides more sand transport into the channel, likely offsetting scour due to tidal and riverine discharge.

In summary, the Carmel Lagoon outlet channel differs from the proposed Russian River outlet channel with respect to several key features, as summarized in Table 4. Overall, the Russian River outlet channel is likely to be more difficult to manage for perched conditions than the Carmel River outlet channel because of its higher required conveyance, longer operational period, and lack of natural grade control.

Table 4 Comparison between Russian River and Carmel River outlet channel features

Outlet channel feature	Russian River	Carmel River
Conveyance capacity	50 ft^3/s	10 ft^3/s
Operational period	5 months (May-Oct)	1 month
Grade control	none	natural rock outcrops
Minimum observed water level	-1.6 ft NGVD	2.3 ft NGVD

5.5 FIGURES



Source: D. Behrens (unpublished). Wave data from CDIP Point Reyes buoy.
Note: Total water level calculated as sum of daily higher high tide and wave runup elevation. Wave runup calculated from Stockdon et al (2006) using estimated de-shoaled deepwater equivalent wave heights.

figure **5-1**
Russian River Beach Management Plan

Total Water Level Exceedance, May-Oct

ESA Ref#DW 1958

6. HYDRAULIC AND GEOMORPHIC ANALYSES

Ocean, river, and beach conditions interact in complex ways to determine estuarine water levels and habitat, as described in the conceptual model (Section 4) and the empirical assessment of the Russian River's inlet conditions (Section 5). To better characterized the hydraulic and geomorphic conditions of the inlet and estuary, the management plan analysis includes quantified representations of the key physical processes, linked into a numerical model. This section describes the development, validation, and application of this quantified conceptual model.

Prior hydraulic and geomorphic analysis, which addressed the Biological Opinion's request for "channel design criteria to minimize channel scour at the anticipated rate of Russian River discharge" can be found in Attachment A.

6.1 DEVELOPMENT OF THE QUANTIFIED CONCEPTUAL MODEL

ESA developed the quantified conceptual model (QCM) of the Russian River Estuary. At its core, the QCM is a water balance model, accounting for the different sources of inflows and outflows to the estuary. This water balance is coupled with a sand balance that characterized the dynamically-varying mouth conditions, accounting for the fact that the mouth's beach and inlet can have rapid morphologically shifts that affect the estuary's water level, volume, and flows.

The model dynamically simulates time series of inlet, beach, and estuary state based on external forcing from waves, tides, and riverine input. The QCM approach was originally developed for Crissy Field Lagoon in San Francisco Bay (Battalio et al. 2006) and has since been refined using approaches developed by ESA for over a dozen other coastal estuaries that form lagoons, including Pescadero Creek, Carmel River, San Dieguito Creek, and Devereux Slough. It benefits from lessons learned in similar approaches from Shuttleworth et al. (2005) in Australia and more recently from Rich and Keller (2013) for Carmel River. Peer-reviewed application of the QCM to the Russian River Estuary was published in Behrens et al. (2015). The model is based on two core concepts:

- Tracking the balance of all water flows entering and leaving the system
- The net erosion/sedimentation at the mouth results from a balance of erosive (fluvial and tidal) and constructive (wave) processes to shape the beach and inlet

6.1.1 Estuary Water Balance

The estuary water balance is illustrated in Figure 6-1 and can be expressed as:

$$\Delta V_{estuary} = (Q_{river} + Q_{mouth} + Q_{overwash} - Q_{seep} - Q_{evaporative} + Q_{error})\Delta t \qquad (1)$$

Where $\Delta V_{estuary}$ is the change in estuary volume, Δt is the time step, Q_{river} is the freshwater input to the system, Q_{mouth} is the mouth flow rate (may be positive or negative), $Q_{overwash}$ is the flow rate into the estuary of waves overtopping the beach crest, Q_{seep} is the seepage flow through the beach berm, $Q_{evaporative}$ represents losses from evapotranspiration, and Q_{error} is an error term. For each time step, the sum of all inflow and outflow terms is multiplied by the length of the time step to calculate the change in estuary volume, which is used in conjunction with the estuary's water level-storage relationship to update the estuary's change in water level.

River flows are input from the USGS Hacienda gage measurements. Wave overwash is estimated using the empirical method of Laudier et al. (2011) with a constant beach slope of ten percent, as derived from beach survey data. Evapotranspiration is estimated using data from BML, 10 miles away. Seepage losses are estimated with a D'Arcy approach (Bear, 1988) using Sonoma Water beach surveys to characterize beach width (Behrens et al. 2015). Tidal flows through the mouth are resolved using the solution to a one-dimensional momentum equation accounting for water surface slope and channel friction (described in further detail by Behrens et al.,2015).

6.1.2 River Mouth

The size and shape of the river mouth are influenced by the estimated inlet flows, via a set of empirical relations that include data from small inlets throughout the US Pacific and Atlantic coasts, and parts of Australia and New Zealand (Behrens et al. 2015). Inlet hydraulics are estimated with the Van de Kreeke (1967) model. Flow velocities through the channel are generated by the head difference between the estuary and ocean tides, and are slowed by channel friction, which scales with inlet length, the sediment type (e.g. coarse beach sand), and inversely with depth. Inlet shape and flow rate are interrelated, and flow velocity is used to assess the total erosion rate in the inlet bed for each time step. Deposition from waves is also assessed based on nearshore wave power and TWL. The deposition rate in the inlet is adjusted via an inlet trapping efficiency parameter (Rosati 1999), which is the main way the model is calibrated to match observed inlet closure events. Total erosion and deposition are summed with each time step to give a net erosion/deposition rate, causing the mouth thalweg in the model to either erode (i.e. during breach or flooding events) or aggrade (during mouth closure).

As the QCM advances in time, the inlet state ("closed" or "open") is determined based on the elevation of the mouth thalweg relative to the ocean and estuary water levels. When closed, mouth flow terms are zero, and the seepage and evaporative terms become the only pathways for flows to leave the estuary. Breaches are induced in the model if estuary water levels overtop the barrier beach elevation. When this happens, the model reintroduces a small channel on the beach, which either leads to non-breaching perched outlet channel conditions or a full tidal breach depending on hydraulic conditions (primarily driven by hydraulic head between the estuary and ocean water surface elevations). Figure 6-2 illustrates a flow chart for the model.

6.1.3 Beach Dynamics

The beach berm influences the estuary water levels by blocking runoff from leaving the lagoon when the mouth is closed, by moderating the rate that waves spill into the estuary, and by setting the potential flood level. Since the estuary water level cannot rise above the minimum beach crest elevation without spilling over the beach, this crest elevation provides a good surrogate for the peak estuary water level (Behrens et al. 2015).

In the QCM, the beach crest is modeled separately from the estuary and the estuary mouth. A representative beach width (cross-shore direction), length (alongshore direction) and beach slope are assumed based on the Sonoma Water monitoring surveys of the beach. The beach crest is modeled in this way because of its direct influence on estuarine hydrology. The beach crest in the QCM directly influences the hydrology in two ways: it sets the level at which a closed lagoon self-breaches, and it influences the amount of wave overwash that spills into the estuary.

Since the beach crest height varies along its length, we subdivide the beach into two groups: three "non-mouth" 800-foot segments (two segments south of the groin, and one north) and a variable-width "mouth" segment occupied by the river mouth. The crest height of the non-mouth sections of the beach is constant and is only used to estimate their contribution of the total wave overwash into the estuary. The crest height within the mouth segment is variable. This part of the beach where inlet closure occurs tends to be lower than the other segments as waves have had less time to build it. In the model it also contributes overwash into the estuary, but also sets the elevation for lagoon self-breaching after closure.

For existing conditions, within each non-mouth beach segment, a representative beach crest elevation is assumed based either LiDAR or Sonoma Water survey data. Within the river mouth segment of the beach, the beach crest is assumed to vary in height. When the river mouth is open (i.e. either perched, muted, or tidal inlet phases), the crest is taken to be the same as the inlet thalweg elevation and overwash is assumed to be negligible compared to the hydraulic flow through the mouth. When the mouth is closed, the beach crest is allowed to grow vertically, but only when the wave runup elevation exceeds the crest elevation. The beach deposition rate is taken to be proportional to the wave power, so long-period swell waves contribute more to the beach growth than shorter-period waves. This growth is capped at the 99th percentile of annual wave runup elevation, which is usually in the range of 12-13 feet NGVD. Prior comparisons of beach crest elevation and the highest percentiles of wave run elevation have found a good relationship between these two variables (Battalio et al. 2006).

Since the river mouth is breached by Sonoma Water when water surface elevations approach 9 feet NGVD, the QCM assumes breaches are induced whenever the lagoon water surface elevation threaten flooding, even if the beach crest is estimated to be higher. If waves close the mouth of the river but are then too weak to build the beach crest quickly, it is possible in the model for the lagoon to breach at lower elevations if lagoon water surface elevations overtake the crest height.

6.1.4 Migration

Inlet migration affects the length of the inlet channel in the QCM, which alters the likelihood for closure (longer channels are more frictional and have a higher likelihood of closing in the model). An inlet migration module in the QCM was developed based on comparison of inlet position (from the overlook camera and prior observations) against the alongshore vector of wave power (see Jetty Study, ESA PWA (2017), for details about wave power predictions). Cumulative migration distance was also compared to a measure of inlet length estimated from the BML camera (Attachment J). Migration rate per model time step is related to inlet width and the alongshore power vector with an empirical coefficient, which is intended to characterize the rate of sediment accumulation on one side of the inlet channel. Since artificial breaches and river floods influence the migration at the site, the migration module includes a number of rules:

- Assumes artificial breaches take place when the water surface elevation reaches 7.5 ft NGVD.
    - If the inlet breaches naturally below 7.5 ft NGVD, do not relocate the inlet to Haystack Rock.
    - During artificial breach events, assume the inlet is relocated to Haystack Rock.
- Assumes the inlet only migrates if the inlet flows are less than peak spring tide flows or river flood flows below ~10,000 cfs
- The inlet length resets to a minimum (100 ft) during breach events and floods above a threshold value (>40,000 cfs)

6.2 MODEL VALIDATION

The QCM was validated by simulating estuary water surface elevations from 1999 to 2014 and comparing the model predictions with water surface elevations measured by Sonoma Water at Jenner during that period. Sonoma Water records of closure events were also used to test the model predictions of the number of closure events and number of days closed. The water surface elevation measurement record is discontinuous because of occasional instrument malfunction and did not record levels below 0 feet NGVD, so water surface elevations are only compared qualitatively. Also, since the mouth rarely experienced perched outlet channel flow from 1999 to 2014, model representation of outlet channel conditions had little data to compare against.

The model compares well against the observations, especially with regard to capturing the seasonality of closure events. Often, the predicted estuary water surface elevations closely reflect the observations as well. This indicates that the QCM is a reasonable method for predicting the estuary water surface elevations.

Predicting the exact timing of closure and breach events was difficult, especially since some of the observed closure events ended in managed breaches and some ended in the lagoon self-breaching. In general, when several closure and breach events were observed to occur in succession, the model did not always match the correct timing of the events. This is an expected shortcoming of the model, given the complexity of the system, the relative simplicity of the approach, and the sensitivity of closure events to previous conditions. As an example, if the mouth self-breaches at 8 feet NGVD due to large riverine inflows to the lagoon, the subsequent breach event may scour a deep inlet thalweg, allowing the inlet to remain open for weeks or months afterward. In contrast, if the inlet breaches at a lower elevation (e.g. a managed breach at 7 feet NGVD) a few days before the rainfall event, scouring may be weaker, even with the subsequent river discharge to the estuary, potentially allowing the inlet to close again much sooner. This sensitivity is apparent throughout the data, and thus this model is only anticipated to represent the seasonality of closure events and water surface elevations, rather than the specific timing of all closures and breaches.

Figure 6-3 illustrates the modeled estuary water surface elevation from September 2008 through December 2009. River flow and wave power are also shown for context. This figure summarizes a number of expected estuary behaviors that the model successfully captured:

- Closures are most frequent in fall and spring, when wave power is higher than in summer.
- Closure events are brief when river flows are above 200 ft^3/s and mostly prevented for flows above 1,000 ft^3/s.
- Muted and perched mouth conditions are brief transitions between tidal inlet and mouth closure conditions.
- Water surface elevations during mouth closure cannot be explained only by river flows. Wave overwash can contribute significantly to estuary water surface elevation, especially within the first week of closure when the beach crest is not fully built up.

Although the QCM results shown in Figure 6-3 sometimes deviate from observations, a major advantage of this approach is apparent: these processes that the model reproduces would be hard to predict from river flow or waves alone, or from models that only take into account one or the other. Combing these processes, such as the QCM does, is a necessary approach to characterize this system.

Figure 6-4 provides another comparison of the modeled water surface elevation against observations, from July to December 2007. In this case, the model predicts a closure event in September that was not observed, and does not predict an observed closure event in early November. In spite of this timing discrepancy, the overall number of days closed is similar between the model and observations, and the timing of closure and breach events is otherwise relatively close.

Figure 6-5 shows monthly summary statistics of the QCM. The model predicts 59 days of closure per year from 1999-2014 compared with 54 observed days of closure. The average number of closure days per month (averaged from 1999-2014) closely follows observations, deviating at most by two days per month in January. The lower panel of Figure 6-5 summarizes the number of closure events. The model predicts nine closures per year, which is close to the eight observed per year. The model under-predicts the average number of events in October. This under-prediction may be due to closure events predicted by the model to begin in September and carry over into October, that are tallied as September, not October closures.

To assess the model predictions of tidal muting, the model predictions of tide range were compared with the observed tide range. Tide range was defined as the difference between a day's highest and lowest water level. The estuary tide range is muted relative to the ocean's average tide range of 5.8 ft, with the amount of muting depending on inlet states, river flow, waves, and the spring-neap tidal cycle. The daily tide range during observations made from 1999-2014 were collated into one-foot intervals and then tallied for their frequency, as shown in Table 5. Also shown in Table 5 are the tide range frequencies for the model predictions of estuary water levels.

The QCM predictions for closure frequency agree closely with observed water levels. When the inlet is open, tide ranges greater than 2 ft are considerably more frequent than tide ranges less than 2 ft. For instance, aggregating across columns in Table 5, the observed tide range was greater than 2 ft

62% of the time and less than 2 ft only 17% of the time. The predicted tidal range is biased somewhat higher than observations. The model predicts the tide range to greater than 2 ft for 73% of the time and below 2 ft 8% of the time. A review of the observed water level time series indicates that muted tide ranges less than 2 ft typically occur for only a few days at a time, either as the inlet transitions from open to closed or during the weakest neap tides. Some of the difference between observed and predicted tide range, particularly for tide ranges above 4 ft, is probably due to the elevation of the Jenner water level gage. When the estuary drops to its lowest water levels, the water level falls below the Jenner gauge. Hence, the observations do not fully record the lowest water levels, and therefore under-predict the tide range when it is largest.

Table 5. Observed and QCM predictions of estuary tide range frequency, as percentage of time in 1999 to 2014.

		Tide Range when Open					
Estuary Water Level	**Closed**	**0-1 ft**	**1-2 ft**	**2-3 ft**	**3-4 ft**	**4-5 ft**	**>5 ft**
Observed	21%	6%	11%	24%	28%	9%	1%
QCM Predictions	20%	4%	4%	13%	27%	22%	11%

Inlet migration results are also consistent between the model and observations. Figure 6-6 shows that the seasonal pattern of northward migration in winter and return migration in most years in spring or summer is generally reproduced by the model. With the addition of the migration sub-module, the QCM predictions of mouth closure improved most notably in spring. This seasonality is consistent with the lengthening of the inlet that often occurs during this season.

While the QCM includes key processes affecting the inlet and estuary water surface elevations and replicates many of the characteristics of the observed water surface elevations, the QCM does not include all of the system's processes. In particular, the complex dynamics of the surf zone, where breaking waves, inlet flows, and sand transport interact with one another and are locally modulated by the jetty, are not included in the QCM. Even the most detailed hydrodynamic, wave, and sediment transport models available would not fully resolve all processes and would require extensive computing resources to simulate just a few hours or days. The QCM does not model flow turbulence and its coupled role in sediment transport. Breaking waves, tidal currents, and river discharge all create turbulence around the jetty that affect the local erosion and deposition of sand, and hence the geomorphology of the inlet channel when it is adjacent to the jetty. Turbulence generated when waves and currents interact with the jetty may cause the channel to have a lower elevation and thereby reduce tidal muting and closures. There is no data to estimate how much deeper the channel might be due to its interaction with the jetty since the highly energetic turbulence through the channel make data collection difficult and dangerous.

Even with these limitations, the QCM was calibrated to match historic closure and breaching conditions, indicating that the model does capture the typical net effect of the hydrodynamic and wave forces and sediment transport on the channel's geomorphology. In addition, the model does account for wave energy decreasing at the jetty, so when channel is adjacent to the jetty, the model predicts less deposition than when the channel is not at the jetty. While this is not the same process as scour, it does result in a similar tendency for the model to predict a deeper channel when the channel is near the jetty.

6.3 MODEL APPLICATION

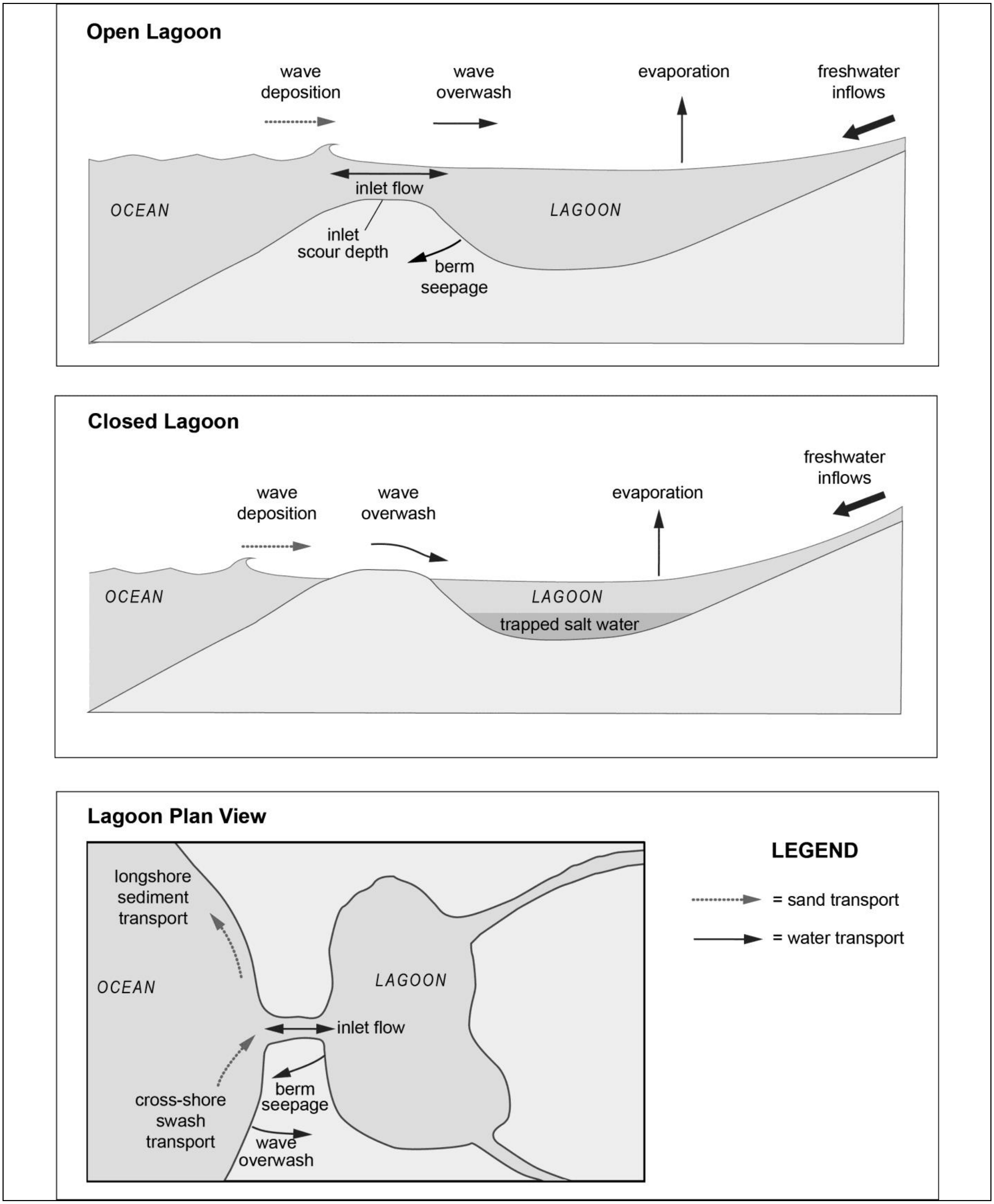
Once calibrated and validated, the QCM has been applied to several efforts to better understand the processes which affect estuarine water surface elevation and to assess potential changes to current conditions.

With the calibrated model demonstrating good agreement with observed estuarine water surface elevations, the QCM serves as an assessment platform for the relative importance of the key processes identified in the conceptual model (Section 4). In fact, the conceptual model and the QCM were developed iteratively, with processes first identified in the conceptual model incrementally added to the QCM. For example, earlier iterations of the QCM did not consider inlet migration. Since these earlier model iterations were still able to predict typical estuarine water surface elevations without considering this process, that suggests this process was not a primary factor in estuarine water surface elevation. The addition of this process improved model predictions most notably for inlet closures in the early part of the management period, suggesting a more important role for this process during this time window. In addition, the QCM has been used to communicate the understanding of inlet dynamics to estuary stakeholders, through an interactive workshop, and to the larger scientific community through a peer-review journal article, Behrens et al (2015).

The QCM was used to predict changes to inlet state in response to projected future ocean wave conditions associated with climate change (ESA, 2015). The model's ocean wave boundary conditions, which are inputs for predicting sand deposition and wave overwash, were adjusted to reflect the possible changes in wave magnitude and direction frequency (Argos Analytics, 2015). Overall, the potential effect of future wave conditions on the closure of the estuary's inlet appears relatively minor. This is primarily due to the relatively small changes in projected wave conditions during the management period as compared to existing conditions. For end-of-century wave conditions, predictions which only included higher southerly waves resulted in more frequent inlet closure. However, this increase was partially offset by the projected decrease in northerly wave energy, which tended to reduce closure. The modeling demonstrated that the timing of closures is important for their duration. Lower wave energy can lead to longer closures if closure occurs when inflows (and thus, potential for filling to breach levels) are lower.

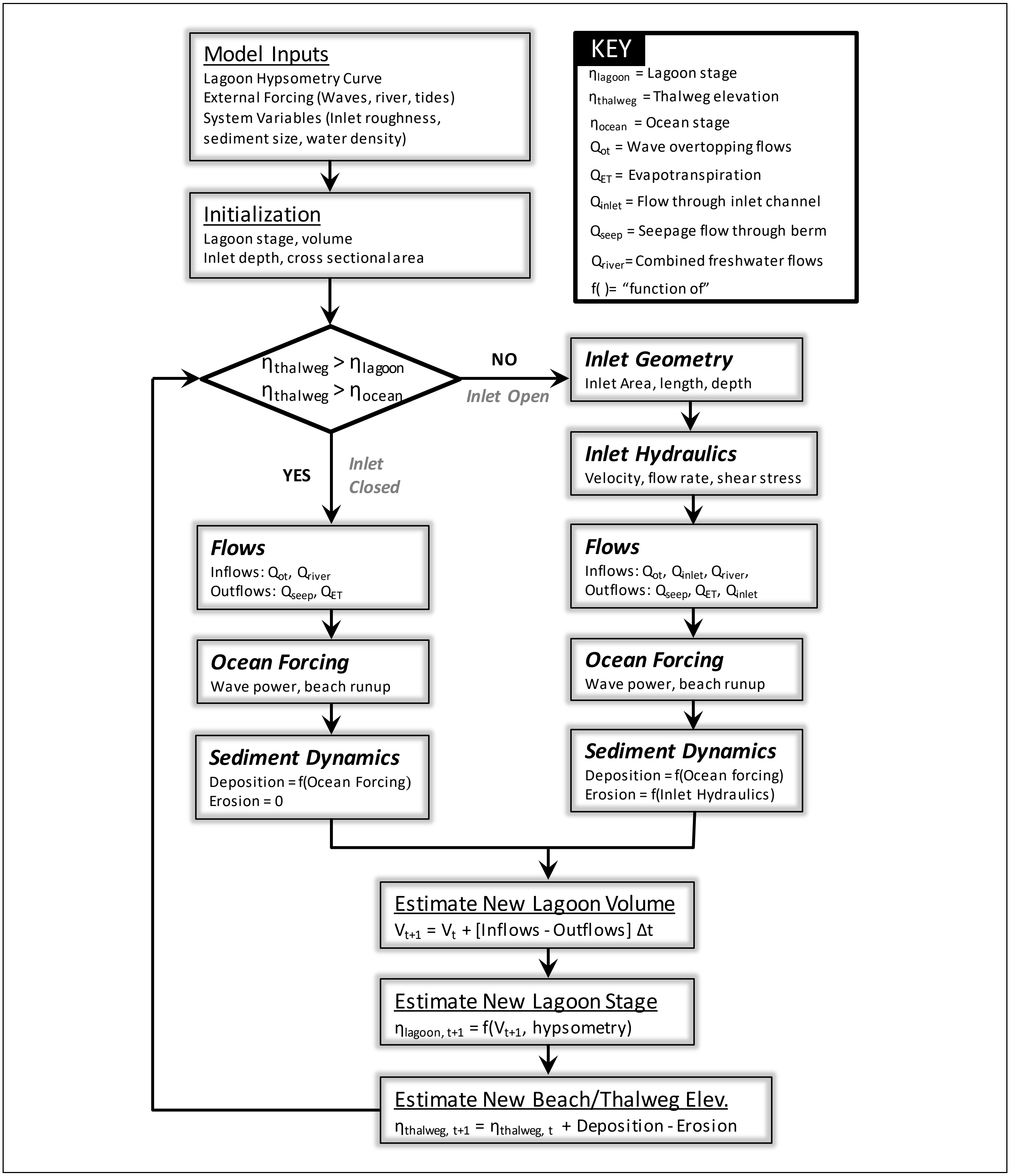
In partial fulfillment of the Biological Opinion's RPA, the QCM was also used as part of a feasibility study to investigate potential jetty impacts on beach permeability and lagoon formation. This study proposed and evaluated alternatives to the jetty at the mouth of the Russian River that might help achieve target water surface elevations in the estuary (ESA, 2017). The QCM's characterization of existing conditions was modified to represent the changes to seepage, beach crest lowering, and increased inlet migration range for each of four jetty removal alternatives. The predicted changes to the average number of days closed were relatively minor (four days or less) for three of the alternatives. While a larger change of 12 additional days closed was predicted for the fourth alternative, longer closures were only predicted to occur about once every three years. The model's predictions were part of a more comprehensive feasibility assessment of jetty removal, which also considered construction impacts, flood risk, biological resources, aesthetics, recreation, public access, and cost. When these other factors were considered along with the relatively minor predicted changes in water surface elevations, jetty removal was not recommended as a cost-effective way to enhance estuarine rearing habitat.

6.4 FIGURES



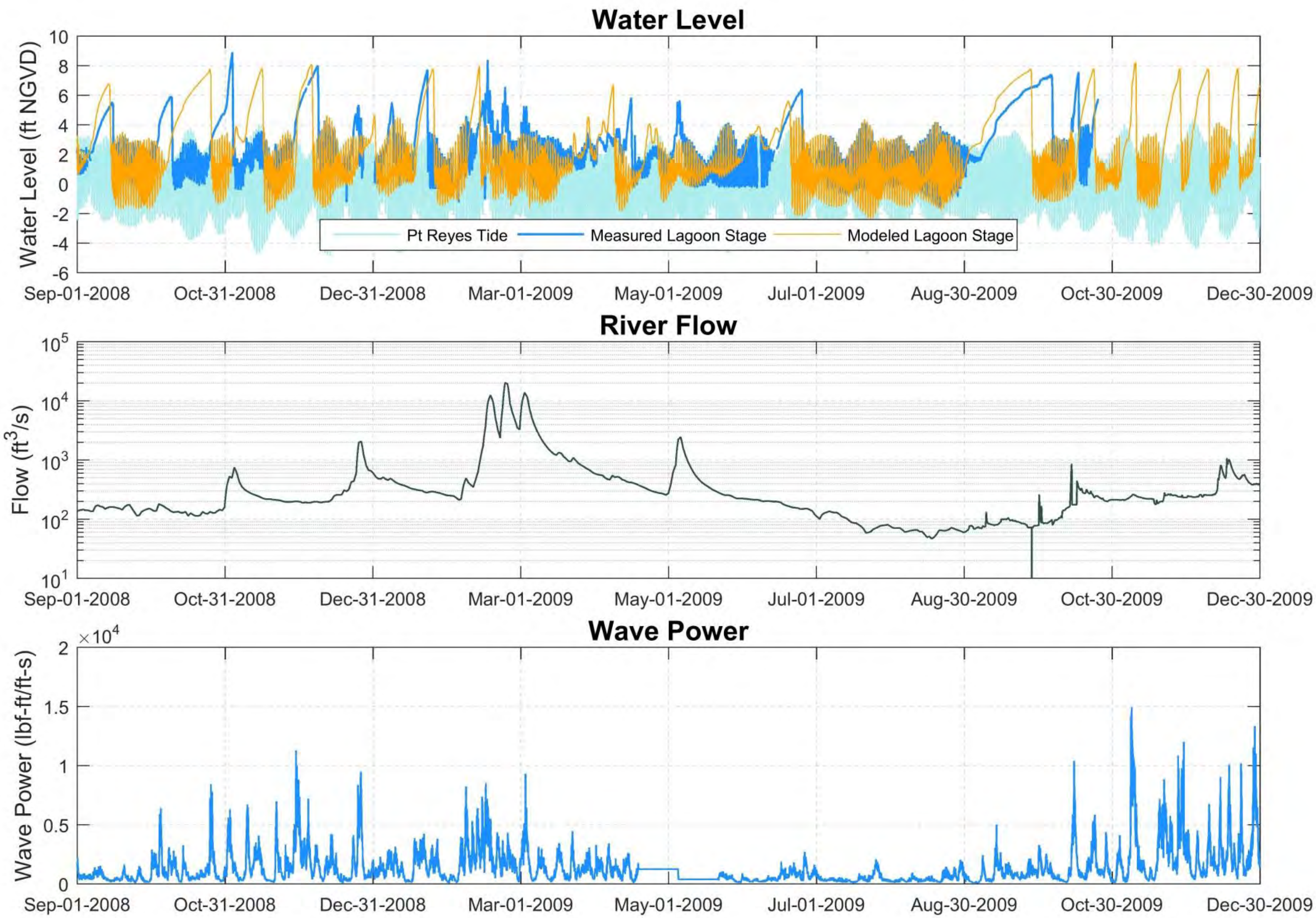
SOURCE: B. Evans illustration

Figure 6-1
Schematic of the dominant processes affecting lagoon hydrology.



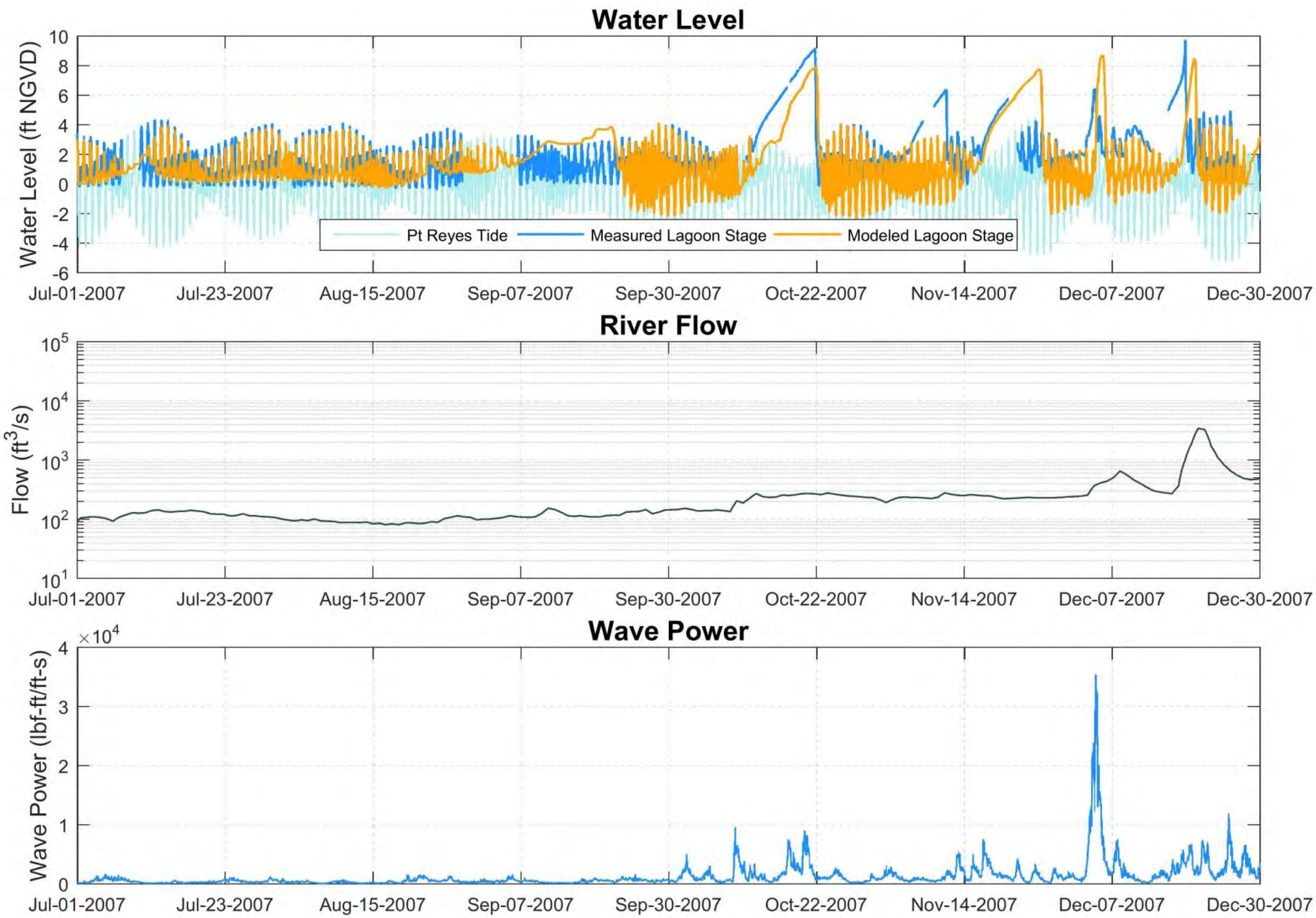
SOURCE: Behrens et al. 2015; modified from an earlier figure by Rich and Keller (2013)

Figure 6-2
Flow chart of the lagoon quantified conceptual model.



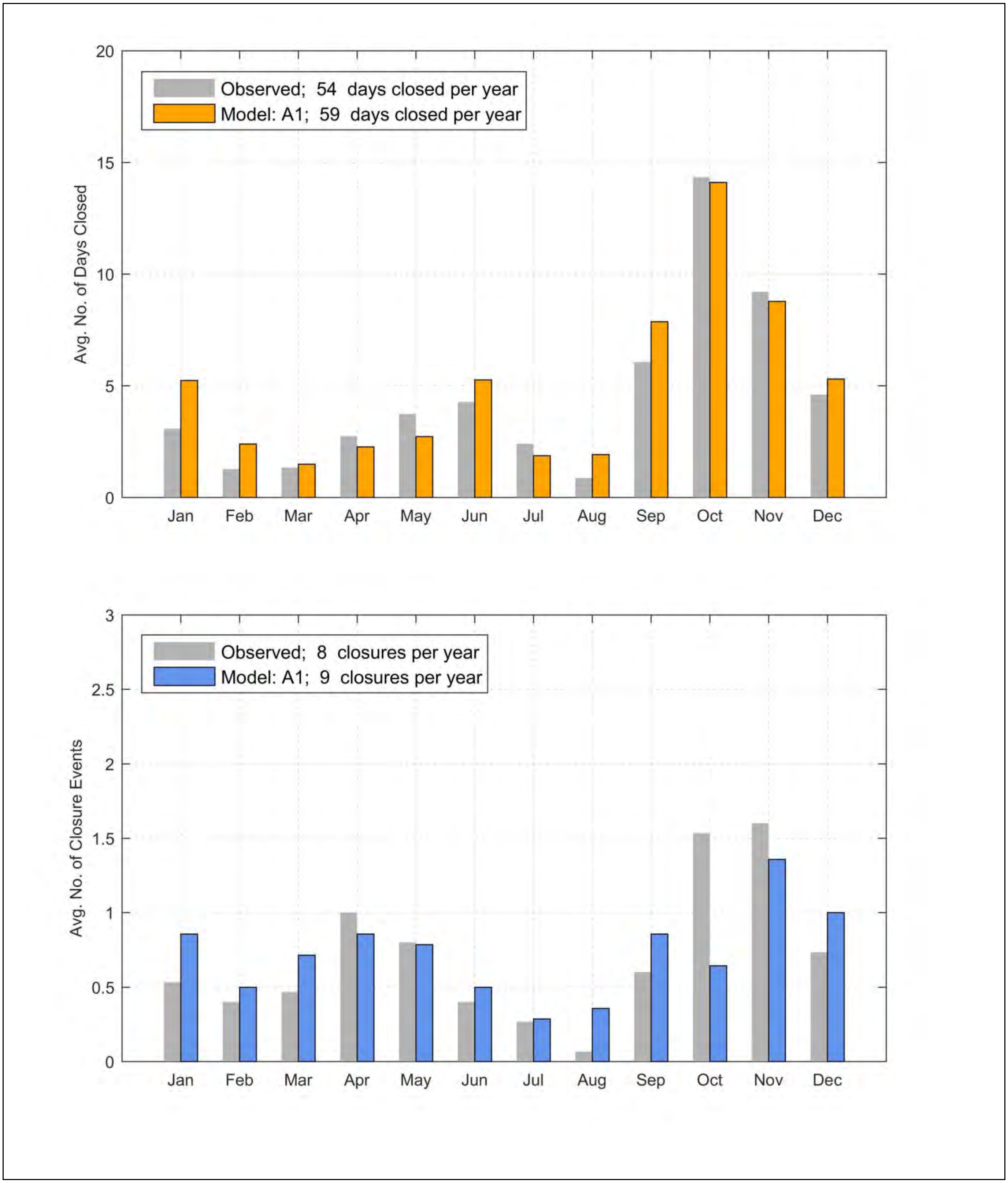
SOURCE: River flow from USGS Guerneville station, wave power from ESA SWAN model, tides provided by SCWA at Jenner, model water levels from ESA QCM model.

Figure 6-3
Test of QCM model accuracy in **(top)** predicting Russian River Estuary water levels, compared against **(middle)** river flow and **(bottom)** nearshore wave power for 2008-2009.



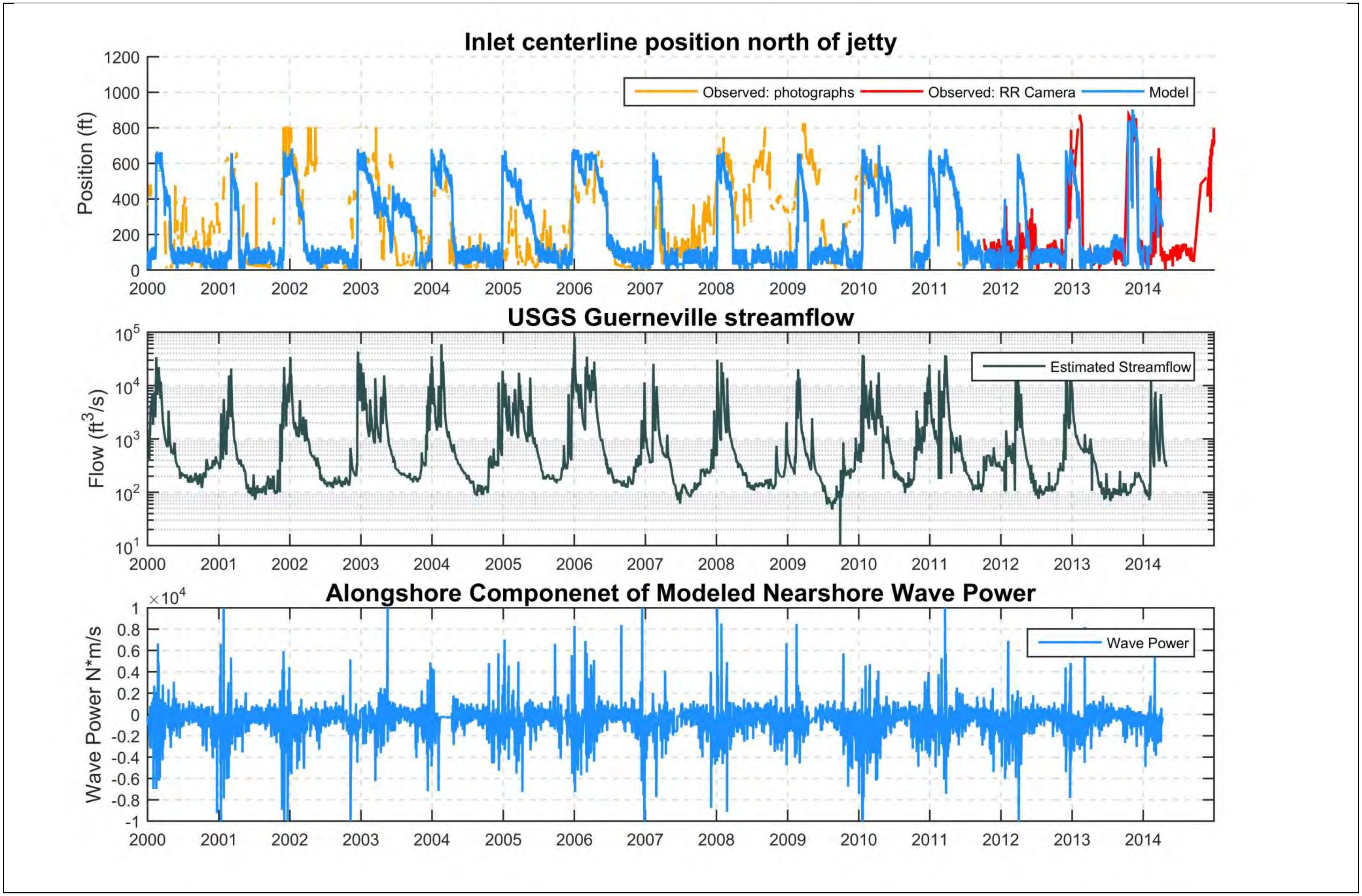
SOURCE: River flow from USGS Guerneville station, wave power from ESA SWAN model, tides provided by SCWA at Jenner, model water levels from ESA QCM model.

Figure 6-4
Test of QCM model accuracy in **(top)** predicting Russian River Estuary water levels, compared against **(middle)** river flow and **(bottom)** nearshore wave power for part of 2007.



SOURCE: ESA lagoon QCM model, SCWA closure data

Figure 6-5
Test of lagoon quantified conceptual model accuracy: comparison of **(top)** predicted number of days closed per month and **(bottom)** number of closure events.



SOURCE: River flow from USGS Guerneville station, wave power from ESA SWAN model, migration data provided by Behrens (2012).

Figure 6-6
Test of QCM migration model accuracy from 2000 to 2014, compared against **(middle)** freshwater runoff and **(bottom)** alongshore component of wave power vector.

7. PROPOSED BEACH MANAGEMENT FOR 2020

This section describes the 2020 recommended channel management practices related to the Biological Opinion requirements. Existing management practices for public safety, operator safety, operational responsibility, and other practices not related to meeting the Biological Opinion objectives are not discussed here. These existing practices are documented in the Standard Operational Procedures: Russian River Mouth Opening (SCWA, 2002).

The outlet channel management described in this section is based on the performance criteria, conceptual model and technical analysis described in the preceding sections, as well as extensive discussion between Sonoma Water, the resource management agencies, and ESA PWA. In addition, implementation efforts provided practical experience for adapting the plan. An account of the 2010 implementation is provided in Attachment E and an account of physical conditions is provided for 2011 (Attachment F), 2012 (Attachment G), 2013 (Attachment H), 2014 (Attachment I), 2015 (Attachment K), 2016 (Attachment L), 2017 (Attachment M), 2018 (Attachment N), and 2019 (Attachment O). A five-year review (Attachment J) compares the physical processes affecting the Estuary since implementation of the Biological Opinion's Estuary RPA (2010-2014) with the prior ten years (2000-2009). Some uncertainty remains about the exact outlet channel configuration that may best achieve the target performance criteria. This uncertainty arises from the dynamic natural setting for the outlet channel and from the unquantified tradeoffs between channel specifications which may benefit one performance criterion while impairing another criterion. For example, to reduce the likelihood of closure, it may be beneficial to locate the mouth of the channel further north where the coastline's aspect is more sheltered from waves from the north. However, extending the channel's length to the northern location may necessitate narrowing its width to keep excavation within currently-permitted volumes. A narrower channel increases the likelihood of scour-induced breaching. The relative importance of these factors is not known, precluding an exact determination of optimal channel configuration. In addition to these uncertainties, actual conditions at the time of closure, such as beach berm topography, may inform the selected configuration.

The assessment of the outlet channel conducted to date suggests two possible configuration options:

- a wide and short channel that seeks to minimize scour potential; or
- a narrow and long channel aligned to the north that seeks minimize closure potential.

The decision-making process for planning and implementing beach management is described in more detail in Section 7.2 and Attachment D below. The configuration that is selected at the time of closure will be documented to the resource management team in accordance with the communication protocol described in Section 9. Performance of implemented configurations will be monitored and documented to test the conceptual model which guides management and to suggest adaptive changes to future management actions, including some combination of these two configurations.

The strategy for outlet channel management is an adaptive and incremental approach. This strategy initially favored smaller, more frequent modifications over larger, less frequent, modification with less certain outcome. Once experience is gained from implementing the channel and observing its response, it may be possible to make larger changes during each incremental modification. One option, which was attempted in 2017, is an outlet channel excavated with its bed elevation above lagoon water level, to extend the length of closure and provide a 'release valve' as water levels approached flood stage. These larger changes will decrease the duration and frequency of management activity, thereby reducing the disturbance impact over time. Management practices will be incrementally modified over the course of the management period (May 15th to October 15th) in effort to improve performance in meeting the goals of the Biological Opinion.

The approach may be constrained by an excavation volume limit of 2,000 yd^3 and antecedent beach berm topography prior to implementation. This approach will be implemented to the extent feasible while still staying within the constraints of existing land use permits.

To provide context for the proposed management plan, the first section below describes previous breaching practices for the inlet. Subsequent sections describe the target channel initiation, location, dimensions and supporting operations details. A hypothetical implementation scenario for the outlet channel, based on actual beach berm and ocean conditions observed at the estuary from June 30 to July 6, 2009, is provided in Attachment B.

7.1 PREVIOUS BREACHING PRACTICES

Breaching has historically been performed in accordance with the *Russian River Estuary Study 1992-1993* (PWA, 1993) in effort to minimize flooding of low lying shoreline properties in the Estuary. The beach berm was artificially breached by Sonoma Water when the water surface elevation in the estuary is between 4.5 and 7.0 feet as read at the Jenner gage. Breaching was performed by creating a deep cut in the closed beach berm approximately 100 feet long by 25 feet wide and 6 feet deep by moving up to 1,000 yd^3 of sand. Based on experience and beach topography at the time of the breach, the planform alignment of the breach was selected to maximize the success of the breaches. Breaching activities were typically conducted on outgoing tides to maximize the elevation head difference between the estuary water surface and the ocean. After the last portion of the beach berm was removed, water would begin flowing out the channel at high velocities, scouring and enlarging the channel to widths of 50 to 100 feet. As the channel evolved and meandered, it reached lengths in excess of 400 ft. After breaching, the estuary would be subject to saline water inflow throughout incoming tides.

7.2 DECISION-MAKING PROCESS FOR BEACH MANAGEMENT

An overview of the beach management decision-making process is shown in Figure 7-1. Before the start of each lagoon management period, this process is reviewed and documented, as described in this plan. As described in Section 1, the previous year's lagoon management period is assessed at the start of each year and used as part to inform revisions of the beach management plan to draft the current year's plan by April 1. Throughout the year, Sonoma Water continuously monitors the estuary, as described next in Section 7.2.1. Then, when indicated, Sonoma Water plans and implements beach management actions to manage the estuary's water surface elevations and water quality. The decision-making process for the lagoon management period is described first, in Section

7.2.2, and then the modifications to this process for the non-lagoon management period are described in Section 7.2.3.

7.2.1 Estuary Monitoring

To inform the decision-making process, Sonoma Water uses both publicly available and collects data (Sonoma County Water Agency, 2016). Some of this data, such as estuary water levels, are collected continuously and are available in real-time via telemetry. Since this data is readily available, it is consulted throughout the decision-making process. Other data, such as fish monitoring, is only available after post-processing and compilation, so is available less frequently, and used for adaptive management of the decision-making process, e.g. the annual updates to the beach management plan.

Sonoma Water monitors the following data sets within the Russian River Estuary:

- **Hydrology and geomorphology** (year-round, at sub-hourly intervals)
    - Estuary water level at Jenner Visitor's Center and Highway 1 bridge (from USGS)
    - River discharge at Hacienda Bridge (from USGS)
    - Ocean tides and waves (from NOAA)
    - Inlet state, via autonomous camera and event-based staff visits
- **Beach topography** (year-round, at monthly and event-based intervals)
    - Monthly surveys, typically scheduled to coincide with neap tides, when inlet closures are more likely
    - Beach crest surveys, in response to closure events, when feasible
- **Water quality** (May-October, at sub-hourly & variable intervals)
    - Continuous sensors for water depth above sensor, temperature, salinity, dissolved oxygen, deployed at multiple stations along the Estuary
    - Weekly and event-based grab samples for nutrient and pathogen testing
- **Fish** (approximately May-October, at varying intervals)
    - Downstream migrant trapping of of juvenile salmonids
    - Beach seining, at multiple shoreline locations
- **Marine mammals** (year-round, at weekly and event-based intervals)
    - Weekly monitoring to establish baseline beach use
    - Event-based when Water Agency staff access the beach for surveying or beach management activities

7.2.2 Lagoon Beach Management

From May 15th through October 15th, Sonoma Water monitors and, when indicated, implements beach management actions to minimize flood risk and enhance estuarine salmonid rearing habitat. While habitat is the priority during this period, minimizing flood risk and preserving water quality remain parallel obligations which can override habitat management if warranted.

The beach is a dynamic setting which is continuously being re-shaped by the combination of ocean waves, ocean tides, and flow between the ocean and the estuary (Section 4). For the majority of the lagoon management period, tidal flows through the inlet scour enough sand to sustain the inlet in an open state. Intermittently, ocean waves deposit enough sand to fill in and close the inlet. A closure triggers Sonoma Water's planning and, if necessary, implementation, of beach management (Figure 7-1).

Once a closure occurs, the decision-making steps for beach management to facilitate lagoon conditions are as follows, as shown on Figure 7-2 and continuing on Figure 7-3:

A. **Initial Notification** – Sonoma Water notifies the Team by email about the closure and about relevant hydrologic and geomorphic conditions. The content of this notification email and a sample are provided in Attachment B. Also intensify hydrologic and geomorphic monitoring, by more frequent monitoring of ocean wave, tide, and riverine discharge data and forecasts, predicting the rate of the estuary's water level rise, and, to the extent feasible (given staff availability, safe beach access, and marine mammal presence), surveying beach crest elevations.

B. **Gather Information** – Sonoma Water gathers information about current conditions at the estuary, including both physical and habitat conditions. Using the estuary water surface elevation, riverine inflows data, and ocean wave forecasts, Sonoma Water performs a forecast of future water surface elevations.

C. **Schedule Next Steps –** Based on the elevation of the beach crest's low point and the water surface elevation forecast, Sonoma Water either decides to continue monitoring (i.e. iterate back to Step B) or to proceed to preparing a plan for beach management action.

D. **Plan Beach Management Action –** In collaboration with the Team, Sonoma Water prepares a draft plan for a beach management action. Team input is solicited by email and phone. Details regarding the selection of the action's type, timing, location, and dimensions are described in more detail in the following sections. In addition, Sonoma Water strives to include the Team in iterative plan review and refinement, ideally by hosting a field meeting overlooking the beach about one week before implementation, as Team schedules, available information, and estuary conditions allow.

After the plan for beach management activity is finalized, Sonoma Water begins the logistical process for implementation. The steps in this part of the process are shown in Figure 7-4. In the days just before implementation, Sonoma Water confirms beach access plans and conducts marine mammal monitoring, with particular attention to see if recently-born seal pups (neonates) are present and preclude beach access. Safe beach access is also closely monitored up to and during personnel and equipment presence on the beach. Conditions such as wave overwash, de-stabilizing seepage flows, or lack of a sufficiently flat and dry access route can make beach access unsafe. To the extent that other schedule constraints allow, the beach management is implemented during a rising tide, to reduce the potential for scour and breaching.

After a planned management activity, regardless of the outcome, Sonoma Water provides an email summary of the activity to the Team. This summary briefly describes the conditions during the activity, how the activity was carried out relative to the plan, and resulting changes to the estuary in the days after the activity.

A closure which starts in late September or early October may persist beyond the October 15th end of the habitat management. In this case, decision-making switches from lagoon-based to flood-minimization-based, which is described in the next section.

7.2.3 Artificial Breaching Beach Management

During the non-lagoon management period, October 15th to May 15th, Sonoma Water 's beach management activities are directed towards flood minimization. Sonoma Water artificially breaches the barrier beach following a natural closure when the water surface level in the Estuary is generally between 4.5 and 7.0 feet, in accordance with Heckel (1994).

The decision-making process for artificial breaching notification, monitoring, planning, implementing, and reporting are similar to those described above for the lagoon management period, with these differences:

- Closure-based beach crest surveys are not conducted.
- The decision-making time window is often shorter because higher riverine inflows and more frequent wave overtopping means estuary water surface elevation reaches flood stage more quickly. This reduces the typical post-closure decision-making period from weeks to days.
- Planning often does not include a field meeting at the estuary, limiting communication to email and phone.

The higher waves and lower beach heights can make it more difficult to safely access the beach north of Haystack Rock, so this location is infeasible more often.

7.3 INITIATION OF EXCAVATION

Initial channel excavation will be performed when the outlet channel first closes following May 15th, the beginning of the management period. Closure is often preceded by a lengthening and narrowing of the outlet channel, muting of the estuary tide range, and/or an increase in mean tide level within the estuary. The Agency will monitor the estuary for these conditions and initiate planning for a management action when they are observed.

Throughout the management period, Sonoma Water's permits with CSP and the California Coastal Commission dictate that management operations cannot occur on Friday, Saturday, Sunday or a holiday because these days coincide with high public use[6]. The incidental harassment authorization stipulates that management actions cannot occur for more than two consecutive days unless flooding is threatening. During the marine mammal pupping season (March 15th to June 30th), the initiation of Agency operations is further constrained. Outlet channel management activity must be delayed if a pup less than one week old is on the beach along site access pathways and there must be a week-long break between management actions. More details on timing restrictions are provided in Attachment C.

[6] Exceptions can be made in the event of emergency conditions. See Attachment C for more details.

Should the outlet channel close in the weeks immediately preceding the management period, Sonoma Water, in consultation with NMFS, CDFW, and CSP, may initiate excavation to increase the likelihood of entering the management period with the target channel configuration in place.

The constructed outlet channel may also close during the management season, such as following a large wave event. In such circumstances, it will be necessary to perform maintenance on the outlet channel, to re-connect the channel to the ocean before the lagoon water level rises too high above the new (higher) beach berm elevation.

7.4 CHANNEL LOCATION/PLANFORM ALIGNMENT

Two possible channel configurations within the extent of the existing alignment (Figure 1-1) may be pursued in 2020 since the location that may best achieve the performance criteria is not certain. Alternative channel alignments may be implemented to test the relationship of mouth location on channel stability.

7.4.1 Wide and short channel alignment

Preference for a wide and short outlet channel assumes that channel failure by scour-induced breaching (Section 4.4) is the controlling failure mode to avoid in selecting the channel's configuration. This assumption is based on the consequences of breaching, which returns the estuary to tidal habitat conditions that will persist until a large wave event occurs to renew the closure. Since these closure events are relatively infrequent during the management period (between 1999 and 2008, there were an average of 2.6 closures per management period), the next opportunity for creating freshwater habitat may be months away. In comparison, if the channel fails by closing, which may be more likely for the wide/short channel because of its mouth's location, another management action can be taken to re-open the outlet channel while preserving the freshwater condition of the lagoon. To reduce the possibility of scour-induced breaching, the hydraulic calculations and modeling in the channel configuration analysis indicates that the excavated channel should be as wide as possible. Under existing permits, the maximum width is 100 ft. The hydraulic modeling indicates that even a width of 100 ft is likely to scour; a narrower channel will further increase bed shear stress and the potential for scour. Once this width is selected, the channel length may need to be constrained to stay within the 2,000 yd^3 limit on excavation volume. The actual dimensions of the wide/short configuration will depend on the beach berm topography at the time of management action.

For a given lagoon water surface elevation, the wide/short configuration will have a higher average bed slope than the longer channel because of the channel's shorter length. The wide/short approach attempts to mitigate this by splitting the outlet channel into two reaches with varying steepness. Across the beach berm, a flat slope is recommended to reduce the contribution of bed slope to flow velocity, thereby minimizing the potential for scour. The entire drop in elevation between the lagoon water level and ocean water level is initially located at the end of the outlet channel, in the active transport zone. In the active transport zone, scour caused by the outlet channel flow accelerating down the beach face at low tides may be balanced by sediment deposition generated by wave action at high tide. As indicated by modeling (Attachment A), it is likely to be difficult to avoid scour even in the portion of the channel with a flat bed because the lagoon water level will set up to create the water surface slope necessary to convey the discharge that maintains constant lagoon water levels. So even if the bed slope is zero, the total energy slope (the combination of bed slope and water surface slope) is likely to generate scouring flow.

Failure by breaching may not be the controlling mechanism if the actual flows conveyed in the outlet channel are less than anticipated or if the channel develops an armored layer of larger particles. As discussed in Attachment A, direct observations of the flow that the outlet channel must convey are not available and have been inferred from upstream discharge observations and lagoon water levels during closure events. The anticipated outlet channel conveyance rates average 50 ft^3/s and range between 45-85 ft^3/s. If actual flow rates are less due to losses elsewhere (e.g. berm seepage), the outlet channel will be less likely to scour. For example, the sensitivity analysis scenario with reduced flow rates between 25-45 ft^3/s exhibited conditions less likely to scour (Attachment A). Channel armoring is the process by which the smaller sand particles are eroded, leaving behind larger particles that have a higher critical shear stress for erosion. Because of the uniformity of particle sizes observed on the beach berm (EDS, 2009a), armoring is thought to be unlikely within the range of target elevations for the outlet channel. Larger particles have been observed in the channel, but only when its elevation is lower and within the tidal regime.

The wide/short approach will be to construct the channel in the same general location and alignment as the preexisting channel (i.e., the location just prior to closure). When pursuing this approach, excavation will simply widen and connect the channel in place. As the channel migrates during the management season, the location of new excavation may follow this migration.

7.4.2 Narrow and long channel alignment

The narrow/long approach to channel design assumes that wave-induced closure (Section 4.3) is the controlling failure mode to avoid in selecting the channel's configuration. By excavating a longer channel that stretches to the northwest, the channel's mouth can be situated in an area that may be exposed to less wave energy. Because of its aspect, the area to the north is more sheltered from waves originating from the north. When large waves originate from the south, the channel will be oriented perpendicular to the incident wave direction, which may enhance the channel's capacity to transport sand that is washed into the channel's mouth by waves (Attachment D). Observations of lateral mouth migration in both directions (Behrens et al. 2009) suggest that waves from both north and south directions play a role in mouth dynamics. Additionally, the narrow/long alignment provides flexibility to locate the channel mouth at a location with a flatter beach face slope, which may reduce net scour (Attachment D). The narrow/long approach is supported by observations of outlet channels that form at some other California river mouths (Attachment D). However, many of these other river mouths drain smaller watersheds that have lower flow rates into the lagoon, and therefore are less likely to breach. Also, these lagoons may not be constrained by the risk of flooding to adjacent property. Without a flood risk, lagoon water levels can rise higher and possibly drive more seepage through the beach berm rather than through the outlet channel. Finally, a longer channel will reduce the average bed slope, which is hypothesized to reduce scour. However, as discussed for the wide/short channel, it is the total energy slope (the combination of bed slope and water surface slope), which drives flow through the channel. Hydraulic analysis indicates that even if there is no slope to the outlet channel (i.e. it is flat), the water level in the lagoon will increase to create the water surface slope required to maintain the outlet channel's discharge. For the anticipated discharge, the corresponding bed shear stress is predicted to cause scour (Attachment A).

The narrow/long approach will angle the channel to the northwest with an approximate aspect of 30-40 degrees with respect to the beach. This angled alignment tests possible advantages of site features such as areas of reduced wave energy and rocks imbedded in the beach.

7.5 TARGET CHANNEL DIMENSIONS

Prior to excavation the proposed outlet channel will be designed by Agency survey staff using computer-aided design (CAD) software. This design will then be used either to manually stake target channel dimensions or to automatically guide the excavation equipment via a GPS-based equipment controls. This operation protocol will ensure that the channel is excavated to the intended design.

7.5.1 Excavation Volume

The quantity of sand moved will depend on antecedent beach topography. To stay consistent with current permits, the excavated volume will not exceed 2,000 yd^3. Once either the wide/short or narrow/long planform alignment is selected, the limit on excavation volume will largely set channel dimensions. If a wide channel alignment is selected, the channel length will be limited so the total excavated volume remains below the limit. Similarly, if a long channel alignment is selected, the channel width will be limited so the total excavated volume remains below the limit. The actual dimensions at the time of implementation will depend on the beach berm topography at the time of implementation. Monthly surveys of the outlet channel, supplemented by spot checks at the time of management actions, will provide necessary information about beach berm topography.

Any sand excavated from the channel will be placed on the adjacent beach and graded to depths of approximately 1-2 ft higher than the existing grade. The placed sand will be distributed in such a way as to minimize changes to beach topography. If the time available for excavation is limited by uncontrollable factors such as tides, waves, seal use, or days when operations are forbidden, sand placed on the north side of the channel may be left in piles up to 3 ft high and not blended into the existing beach topography. The piles may need to remain un-graded on the north side because equipment access to this side is more difficult and may slow down operations. Once the outlet channel is in place, the north side is also less accessible, reducing the impact of any remaining sand piles on public use.

7.5.2 Bed Elevation

When excavating an outlet channel below the lagoon water level, the bed will be excavated 0.5 to 1 foot below the lagoon water level along its entire length, to achieve target channel depths (discussed below) upon initiation of flow. For this configuration, channel bed elevations are expected to be in the range of 3 to 7 ft NGVD, with corresponding lagoon water levels of 4 to 8 ft, using a typical flow depth of one foot. At the start of the management season, lagoon water levels and the channel bed may be on the lower of this elevation range, since the system will have recently transitioned from intertidal to closed and the beach berm may not yet have built up. As the management season progresses, sand is expected to move onto the beach berm, raising the viable bed elevation for the outlet channel. As the beach berm builds higher, it will support higher lagoon water levels while maintaining channel depth within the target range.

When a higher beach crest elevation has been established, another option is to excavate the outlet channel above the lagoon water level. In this configuration, the outlet channel serves as a 'release valve' that extends the length of closure until just before flood stage. The upper end of the bed elevation is governed by the flood stage elevation (9 ft NGVD) minus the anticipated water depth and a factor of safety to buffer against flooding. Therefore, the highest bed elevation is likely to be approximate 8.5 ft.

Frequent maintenance will likely be required early in the management season to maintain an open outlet channel as the beach berm elevation builds. Eventually, the outlet channel may be above the typical wave runup elevation, the elevation at which waves may induce channel closure, and close less frequently.

The bed elevation is a key determinant of lagoon water levels and influences the stability of the outlet channel. Higher bed elevations have the advantage of better meeting the Biological Opinion's performance criteria of higher lagoon water levels. Higher lagoon water levels would increase seepage through the beach berm, potentially reducing conveyance requirements and the possibility of scour in the outlet channel. A higher outlet channel is also less likely to be closed by waves. On the other hand, lower bed elevations reduce the potential energy, which may cause outlet channel scour, provide a greater buffer before flood stage, and may reduce the release of oxygen-depleting organic matter from inundated upstream marshes[7]. Developing a better feel the optimal bed elevation is one objective of the adaptive management plan.

The Phase 1 performance criteria are to develop an outlet channel that supports a stable, perched lagoon with water surface elevations at approximately 7 ft NGVD for several months (Section 3.2). Stable conditions imply that river inflows into the lagoon would be approximately the same as the sum of outflow through the outlet channel and seepage through the beach berm. Stable conditions also imply that net sand deposition or erosion does not impair the outlet channel's function. However, this goal may not be achievable in 2020 because additional constraints in place during this year call for modified performance criteria.

---

[7] Goodwin and Cuffe (1994) observed the release of anoxic water from upper Willow Creek into the Russian River Estuary after an artificial breach. Based on this observation, they recommended a preferred maximum water level of 7.0 ft NGVD.

The bed slope should be nearly flat within the outlet channel to minimize the likelihood of scouring the bed. This may be difficult to maintain. In particular, incision within the “flat” channel bottom may occur.

7.5.3 Depth

The target range of water depths, 0.5-2 ft, is constrained on the upper end by the maximum depth at which the channel is likely to be stable (not scour). Larger depths would be associated with a narrower channel. The lower end of the range is constrained by the width; shallower depths would require impractically large channel widths to provide sufficient cross-sectional area to convey flow. Shallower water depths represent a greater factor of safety with regard to preventing bed scour since bed friction retards flow speed more strongly for shallower depths. Prior to implementation the predicted rate of water elevation rise within the estuary will need to be considered to determine the bed elevation to achieve the flow depths desired at the completion of the channel excavation.

7.5.4 Width

The width of the channel is estimated to vary within 25-100 ft for consistency with the existing management permits. For the wide/short configuration, the channel bottom would be excavated to a width of 100 ft, the permitted maximum, to reduce the potential for scour. For the narrow/long configuration, the channel bottom width will be approximately 30 ft to achieve the desired channel length and slope while still staying within the 2,000 yd^3 excavation volume limit.

7.5.5 Length

The channel length is estimated to vary within 100-800 ft, consistent with historic channel lengths observed within the management period (Behrens, 2008). Length will be a function of the channel’s planform alignment while also balancing with other channel dimensions in order to keep excavation volumes less than 2,000 yd^3. The wide/short configuration would result in channel lengths between 100-400 ft while the narrow/long configuration would result in channel lengths approaching the maximum of 800 ft.

7.6 EXCAVATION TIMING RELATIVE TO THE TIDAL CYCLE

Under the proposed management plan, channel modifications will be initiated during low tide so that after several hours of work, the channel will be completed near high tide. As per existing practices, a temporary barrier will be left between the ocean and lagoon during excavation. When the last material is excavated, then the temporary barrier will be removed at or near high tide. This will minimize the difference in water levels between the estuary and ocean, reducing the potential for the re-connected channel to scour into a fully tidal inlet.

7.7 EXCAVATION FREQUENCY

Creating and maintaining the outlet channel will probably employ one or two pieces of heavy machinery (e.g. excavator or bulldozer) to move sand on the beach. At the start of the management period (late spring or early summer), when configuring the outlet channel for the first time that year, conditions may require operating machinery for up to two consecutive days (as allowed under the marine mammal incidental harassment permit). The precise number of excavations would depend on uncontrollable variables such as seasonal ocean wave conditions (e.g. wave heights and lengths), river inflows, and the success of previous excavations (e.g. the success of selected channel widths and meander patterns) in forming an outlet channel that effectively maintains lagoon water surface elevations. As technical staff and maintenance crews gain more experience with implementing the outlet channel and observing its response, maintenance during the remainder of the management season is anticipated to be less frequent.

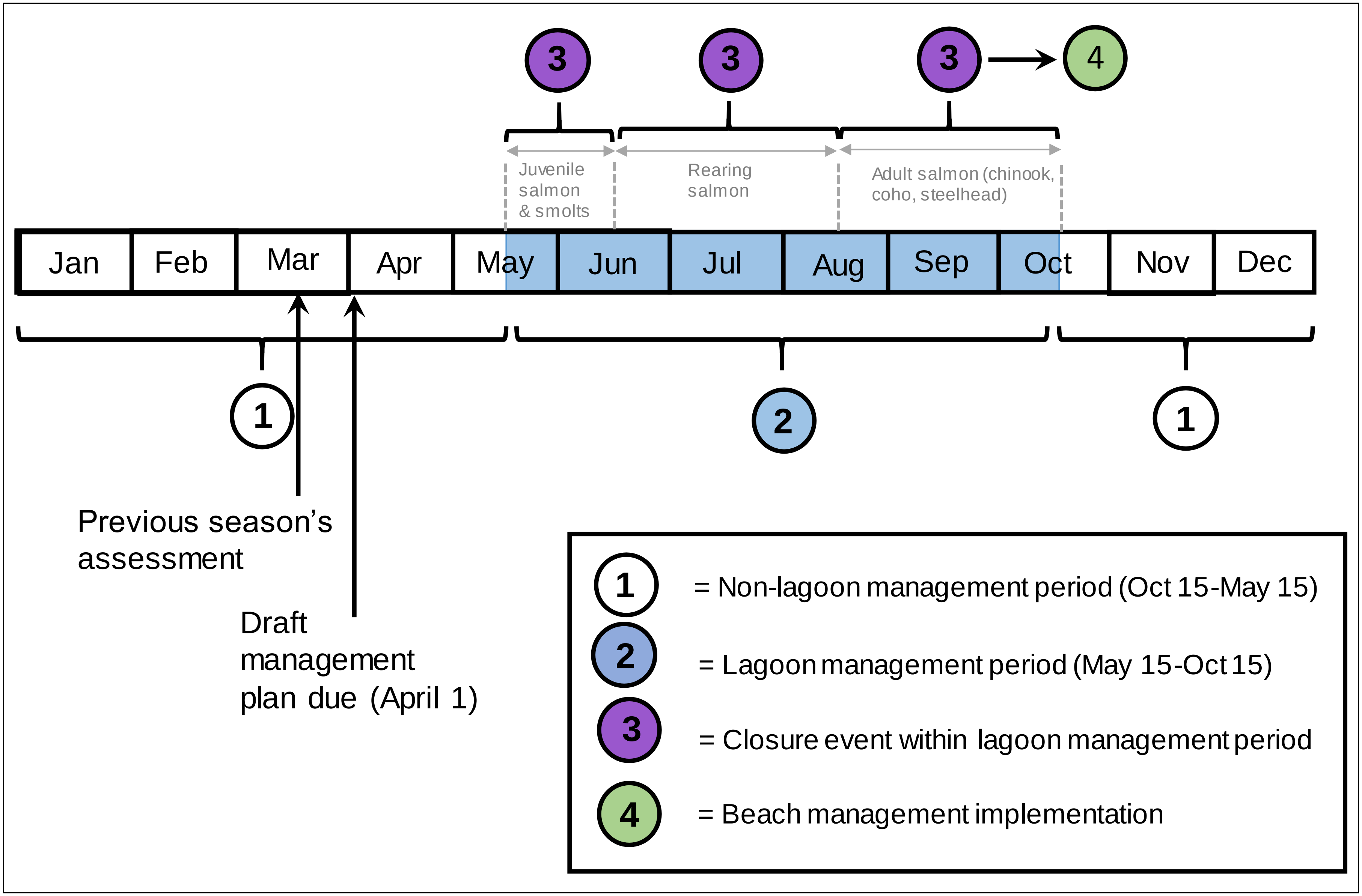
In consideration of the natural beach environment and public access, effort will be made to minimize the amount and frequency of mechanical intervention. Outlet channel management activities cannot last for more than two consecutive days. During the marine mammal pupping season (March 15th to June 30th), the duration and frequency of Agency operations is constrained by restrictions on incidental harassment. Seven days must pass between management events. More details on duration and frequency restrictions are provided in Attachment C.

7.8 UNCERTAINTY AND LIMITATIONS

The proposed operations are based on the analyses documented in this report, input from resource agency staff, and on our professional judgment. Uncertainties about the actual estuary inflow, berm seepage, and outlet channel performance remain. As described in Attachment A, the two methods for estimating estuary inflow, the water balance model and limited discharge measurements, predict disparate estuary inflows. Estuary inflows will fluctuate over the management period and may be greater than the modeled inflow. The seepage through the beach berm is based only on inferred, not observed, estimates of hydraulic conductivity. The outlet channel, particularly its downstream end, will be located in a highly dynamic environment that is influenced by changing river flow, tidal water levels and waves. Since the outlet channel will not include any hard structures, all of these sources of hydrologic forces can readily alter the channel's configuration, which may make it difficult to achieve and maintain the channel's successful function. Modifications of the proposed plan in response to actual conditions will be discussed with the resource agency management team and documented according to the communication protocol described in Section 9. Any modifications will be consistent with existing permit requirements.

Adaptive management once the channel is implemented will further enhance management practice. Actual feasibility with regards to the full range of dynamic conditions has not been determined. Risks associated with outlet channel failure have not been quantified. In addition to the channel's performance criteria, there are also water quality and ecological performance criteria for the perched lagoon. These additional criteria have not been evaluated as part of the outlet channel management plan.

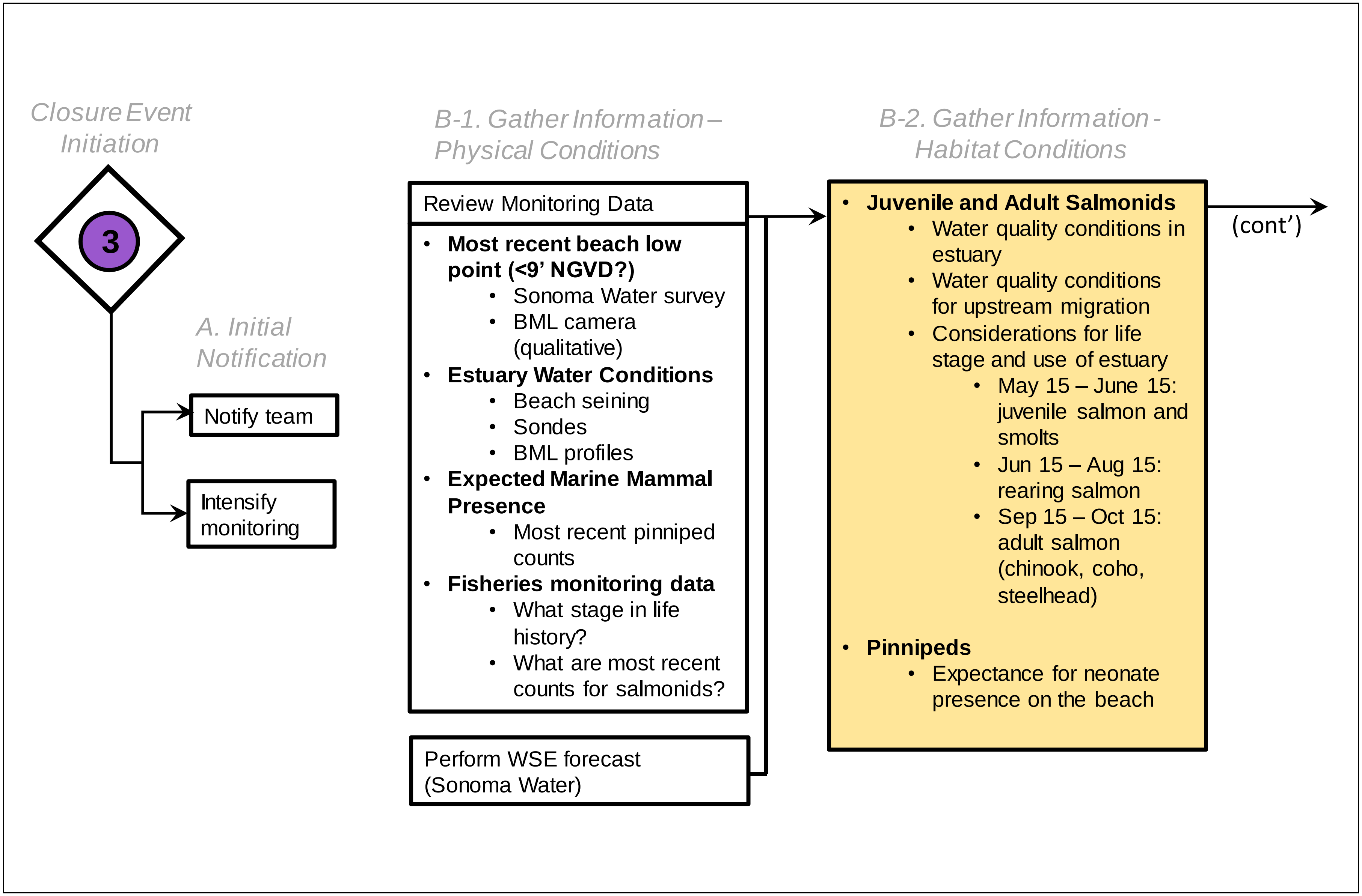
7.9 FIGURES



RREAMP . DW01958.08.001

Figure 7-1

Beach Management Decision-Making Process: Overview



RREAMP . DW01958.08.001

Figure 7-2

Beach Management: Closure Event Monitoring & Planning

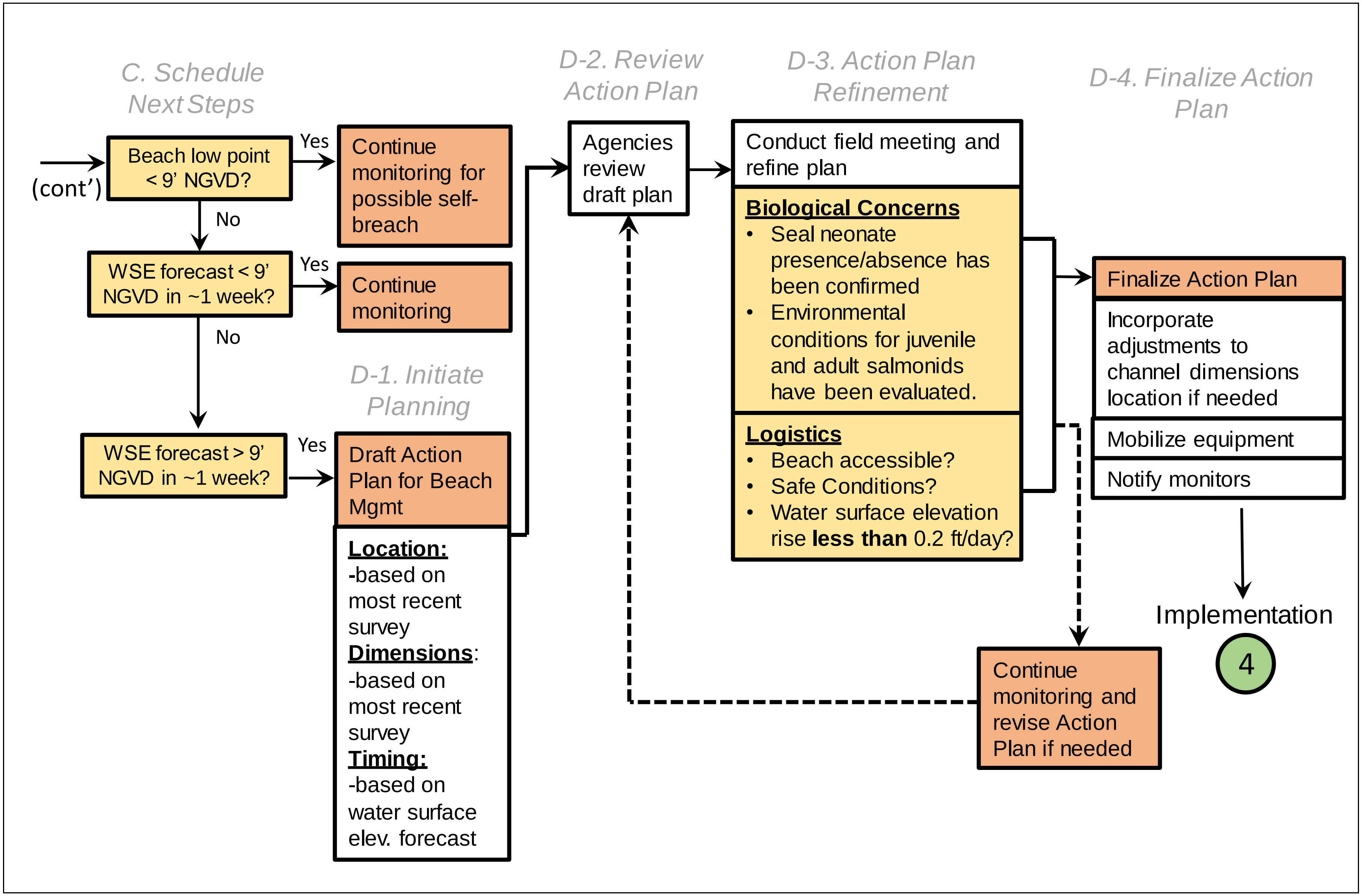


Figure 7-3
Beach Management: Closure Event Monitoring & Planning (cont'd)

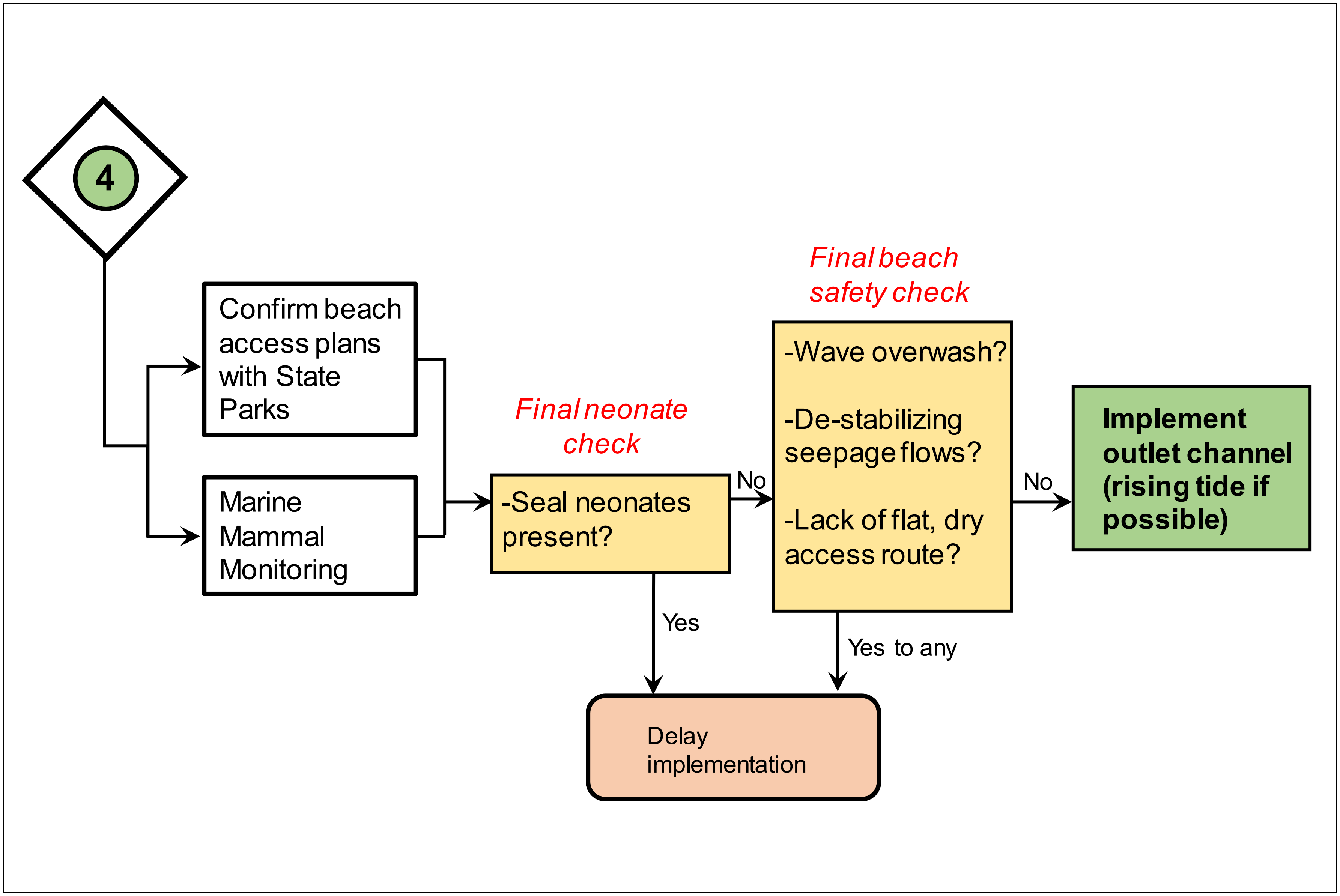


Figure 7-4

Beach Management: Implementation

8. OUTLET CHANENL MONITORING AND ADAPTIVE MANAGEMENT

Monitoring of the outlet channel should be implemented to facilitate an understanding of the channel's behavior and guide adaptive changes to this initial management plan. Adaptive management changes may be made over the course of the management season, in response to natural processes, outlet channel conditions, and/or outlet channel response. In addition, a more comprehensive review at the end of the management season will employ the monitoring data to recommend management revisions for the following year.

Because relatively few closure events occur per year and each one experiences different river and ocean conditions, a comprehensive monitoring plan is recommended to support adaptive management. The monitoring would quantify changes in the beach and channel elevation, lengths, and widths, as well as flow velocities and observations of the bed structure (to identify bed forms and depth-dependent grain size distribution indicative of armoring) in the channel. If feasible, the required monthly beach topography surveys should be scheduled just in advance of potential closure situations (neap tides, low discharge, and/or large wave events). Staff safety, staff availability, pinniped constraints, and/or rapidly changing physical conditions may preclude optimal scheduling of beach topographic surveys. Because monitoring requires human presence on beach, potentially disturbing the seal population, the monitoring frequency represents a balance between management of the outlet channel and minimizing disruption of wildlife.

A list of recommended monitoring tasks for 2020 is provided below in Table 6.

Table 6 Monitoring tasks associated with outlet channel management

Task	Description	Field Activities	Frequency
Recommended			
Operations log	Record of outlet channel management actions and ambient conditions.	Operations staff to generate written record of operations (excavation method, extent, and location) and ambient conditions (weather, ocean state, estuary water level)	Daily to monthly (Depends on operational activity)
Outlet channel location and state	An automated video or still camera station to capture the outlet channel's location and state.	Field staff to install and service a camera, power supply, and possibly communication system on hillside adjacent to estuary.	Hourly imaging (automated); Weekly servicing
Outlet channel discharge measurements	Collected within the outlet channel to verify the channel's conveyance.	Field staff to complete cross sectional flow velocity surveys using flow meter attached to a wading rod with electronic data logger.	Monthly
Outlet channel bed structure	Observe the bed for bed forms and depth-dependent grain size distribution indicative of armoring. Sediment sampler used.	Field staff to collect sediment sample from the surface of the channel bed.	Monthly
Outlet channel topography	Collect outlet channel elevation and width	Field staff to survey outlet channel features using a total station and prism mounted on a survey rod.	Monthly
Beach topography	Collect beach elevation	Field staff operating rod and staff on beach.	Monthly and supporting beach management actions
Estuary flow dynamics	Integrate cross sectional velocity data in estuary at various locations from mouth to Duncans Mills.	A boat with field staff, collecting cross sectional data from mouth to Duncans Mills.	Weekly

9. COMMUNICATION PROTOCOL

A communication protocol will provide guidance between Sonoma Water and identified points of contact representing key resource management groups in the estuary for the implementation of the Outlet Channel Management Plan during the management period (May 15 – October 15). This communication protocol will be reviewed prior to the beginning of each lagoon management season at the meeting to review and update the annual Adaptive Management Plan. Primary and alternative points of contact have been identified for each of the key resource management groups. These parties, which together are hereafter referred to as the "Team", include: Sonoma Water, NOAA National Marine Fisheries Service, California Department of Fish and Wildlife, and California State Parks. A list of contacts for these groups is shown in Table 7.

Table 7 Russian River Estuary Management Team

Contact	Level	Organization	Phone Number	E-mail
Jessica Martini Lamb	Primary	Sonoma Water	707-547-1903 (w) 707-322-8177 (m)	jessica.martini.lamb@scwa.ca.gov
Chris Delaney	Secondary	Sonoma Water	707-547-1946 (w) 707-975-5606 (m)	cdelaney@scwa.ca.gov
Gary Tourady	Primary	Agency Operator Sonoma Water	707-547-1065 (w) 707-975-6285 (m)	garywt@scwa.ca.gov
Jon Niehaus	Secondary	Agency Operator Sonoma Water	707-521-1845 (w) 707-975-3999 (m)	jon@scwa.ca.gov
Robert Coey	Primary	National Marine Fisheries Service, North Coast Branch	707-575-6090 (w)	Bob.Coey@noaa.gov
Josh Fuller	Secondary	National Marine Fisheries Service	707-575-6096 (w)	joshua.fuller@noaa.gov
Sara Azat	Tertiary	National Marine Fisheries Service	707-575-6067 (w)	sara.azat@noaa.gov
Kelly Prince	Front Desk	National Marine Fisheries Service	707-575-6050 (w)	kelly.prince@noaa.gov
Eric Larson	Primary	CA Dept. of Fish and Wildlife	707-576-2837 (w)	eric.larson@wildlife.ca.gov
Karen Weiss	Secondary	CA Dept. of Fish and Wildlife	707-428-2090 (w)	karen.weiss@wildlife.ca.gov
Ryan Watanabe	Tertiary	CA Dept. of Fish and Wildlife	707-576-2815 (m)	ryan.watanabe@wildlife.ca.gov
Brendan O'Neil	Primary	California State Parks	707-865-3129 (w)	BONEIL@parks.ca.gov
Damien Jones	Secondary	California State Parks	707-875-3907 (w)	Damien.jones@parks.ca.gov
Gil Falcone	Primary	North Coast Regional Water Quality Control Board	707-576-2653 (w)	Gil.Falcone@waterboards.ca.gov
Kaete King	Secondary	North Coast Regional Water Quality Control Board	707-576-2848 (w)	Kaete.King@waterboards.ca.gov

9.1 IMPLEMENTATION OF OUTLET CHANNEL MANAGEMENT ACTIVITIES

A minimum of one business day of notice shall be provided to the Team by Sonoma Water in advance of the excavation and maintenance of the outlet channel. Notice shall be submitted by e-mail (see Attachment B.1 for sample) with a general description of the proposed action to be pursued and will typically include:

- Proposed date and time of implementation;
- Design schematic of proposed channel which shall include:
  - Approximate antecedent beach berm height and width;
  - Proposed location and alignment of outlet channel;
  - Approximate outlet channel dimensions including bed elevation, channel depth, width, length, slope and aspect with respect to beach face
  - Predicted estuary water surface elevation at the time of implementation;
- Current river discharge at USGS Hacienda gage (website: http://waterdata.usgs.gov/nwis/uv?cb_00060=on&cb_00065=on&format=gif_stats&period=21&site_no=11467000)
- Predicted 24 hour precipitation as estimated by the NOAA National Weather Service for Bodega Bay (website: http://forecast.weather.gov/MapClick.php?CityName=Bodega+Bay&state=CA&site=MTR&textField1=38.3333&textField2=-123.047&e=0&FcstType=graphical;
- Predicted deep water swell height, period, and direction at San Francisco as estimated by CDIP (website: http://cdip.ucsd.edu/?nav=recent&sub=forecast&units=metric&tz=UTC&pub=public)
- Projected estuary water level
- Most recent beach crest elevation
- For maintenance actions a general description of maintenance to be performed;
- Presence of seal pups; and
- Equipment to be used for implementation.

NMFS and CDFW team members will also be contacted by phone, beginning with the primary contact and working through the designees in Table 7 until contact is made. Team members shall provide any comments or suggestions to the approach in writing within one business day of the proposed implementation time. If Agency does not receive any comments before this time and no responses to email and phone calls are received, it is assumed that there are no comments to the proposed action. Comments and recommendations will be recorded for consideration on that management action or future management actions, and Sonoma Water will do its best to respond to comments prior to implementation.

9.2 COMPLETION OF OUTLET CHANNEL MANAGEMENT ACTIVITIES

Within 36 hours of completion of outlet channel excavation or maintenance activities Sonoma Water shall provide the Team a summary of work performed. This summary will be submitted by e-mail and will typically include:

- Date, time and period of implementation;

- Estuary water surface elevation at the time of completion;
- River discharge at USGS Hacienda gage at time of completion
- Deep water swell at CDIP Pt. Reyes buoy at time of completion
- Approximate location of the centerline of the channel mouth in distance along beach berm north of the jetty;
- Approximate orientation of channel along the beach berm;
- Approximate dimensions and orientation of the excavated channel;
- Approximate water depth in the excavated channel;
- For maintenance actions, a general description of maintenance performed;
- Equipment used during implementation;
- Presence of seal pups; and
- Photos documenting work completed.

9.3 OVERRIDING CONDITIONS

Certain conditions such as declines in water quality or imminent flooding to properties and structures in the estuary could drastically change the course of management outlined in this plan and may force Sonoma Water to breach the estuary. The Agency shall stay in close contact with the Team on the development of any conditions that could affect the overall course of management. However, rapidly changing conditions may limit the notification lead time given to the Team in advance of management actions to alleviate flooding or water quality concerns.

9.3.1 Flooding

Based on past management experience in the estuary, Sonoma Water has found that if the estuary is in a closed condition, medium to large storm events can produce very rapid rises in estuary water levels. These storm events are frequently accompanied by large ocean swells which can close the estuary if outflows through the channel are not high enough to counteract the wave forces produced from the large swells. Management to avoid flooding is complicated by safety concerns; Sonoma Water is unable to operate equipment required for channel management activities if ocean swells are too large. In the past Sonoma Water has typically breached the estuary in anticipation of a large storm in order to prevent flooding.

The high water surface elevations pursued under this plan will diminish the storage capacity of the estuary to handle high inflows. Also, based on past management experience, Sonoma Water believes that the outlet channel as described in this plan will be especially susceptible to closure from large swell events. In an effort to avoid flooding of properties in the estuary during the outlet channel management period, Sonoma Water will consult with the Team regarding the possibility of breaching the estuary in anticipation of a large storm event.

9.3.2 Decline in Water Quality

Declines in water quality could have impacts to salmonids rearing in the estuary, other species which reside in the estuary and the public. Potential water quality concerns include, but are not limited to:

- Dissolved oxygen conditions becoming dangerously low to fish and other species;
- Elevated salinity levels in domestic water wells; and
- Elevated bacterial levels.

The Agency will stay in contact with the Team regarding water quality conditions during the management period. Should conditions get to the point that they are potentially dangerous to salmonids, other species, or the public, Sonoma Water shall consult with the Team on potentially changing the course of management. In cases of high bacterial levels, Sonoma Water will additionally consult with North Coast Regional Water Quality Control Board and the Sonoma County Department of Public Health on potential management actions.

Prior to management actions to alleviate water quality concerns, a coordination phone call with representatives of NMFS, CDFW, California State Parks, and North Coast Regional Water Quality Control Board will take place to review and discuss water quality data and conditions of concern to determine if a management action should occur (see Appendix C: Condition 1 of North Coast Regional Water Quality Control Board Section 401 Water Certification [1B04001WNSO]; Condition 6[c] of California Coastal Commission Coastal Development Permit [2-12-004]).

10. REFERENCES

Allen, J. and P. Komar. 2006. Climate controls on US West Coast erosion processes. Journal of Coastal Research 22(3): 511-529.

Argos Analytics. 2015. SCWA Russian River Estuary Pilot Report. May 28, 2015.

Aubrey, D.G. and Speer, P.E., 1984. Updrift migration of tidal inlets. Geology 92(5): 531-545.

Battalio B, Danmeier D, Williams P. 2006. Predicting Closure and Breaching Frequencies of Small Tidal Inlets – A Quantified Conceptual Model Proceedings of the 30th Conference on Coastal Engineering, San Diego, CA, USA.

Bear, J., 1988. Dynamics of Fluids in Porous Media, Dover Publications.

Behrens, D. 2008. Inlet closure and morphological behavior in a northern California estuary: the case of the Russian River. Masters Thesis. University of California, Davis. 160 pp.

Behrens, K. 2012. The Russian River estuary: inlet morphology, management, and estuarine scalar field response. University of California, Davis.

Behrens, D., Bombardelli, F., Largier, J. and E. Twohy. 2009. Characterization of time and spatial scales of a migrating rivermouth. Geophysical Research Letters. Vol. 36, L09402, doi:10.1029/2008GL037025.

Behrens, D., F. Bombardelli, J.Largier, and E. Twohy. 2013. Episodic closure of the tidal inlet at the mouth of the Russian River – a small bar-built estuary in California. Geomorphology 189 (2013): 66-80.

Behrens, D. and Largier, J. 2010. Preliminary study of Russian River Estuary: Circulation and Water Quality Monitoring - 2009 Data report. Prepared for the Sonoma County Water Agency.

Behrens, D., M. Brennan, and R. Battalio, 2015, A quantified conceptual model of inlet morphology and associated lagoon hydrology, Shore & Beach 83, 3, 33-42.

Boughton, D., J. Fuller, G. Horton, E. Larson, W. Matsubu, C. Simenstad. 2017. Spatial Structure of Water-Quality Impacts and Foraging Opportunities for Steelhead in the Russian River Estuary: An Energetics Perspective. NOAA-Technical Memorandum-NMFS-SWFSC-569.

Bray, D.I. 1979. Estimating average velocity in gravel-bed rivers. Journal Hydraul. Div., American Society of Engineers, 105 (HY9), pp. 1103-1122.

Bruschin, J. 1985. Discussion on Brownlie (1983): Flow depth in sand-bed channels. Journal of Hydraulic Engineering, ASCE, Vol. 111: pp. 736-739.

California Department of Parks and Recreation. 2008. Carmel River State Beach Lagoon Water Level Management Project – Initial Study, Mitigated Negative Declaration (Draft).

Dean, R. and Dalrymple, R. 2002. Coastal Processes: With Engineering Applications, 488 p. Cambridge University Press, New York.

de Graca, H. 1976. Study of the Ocean Beaches Adjoining the Russian River Mouth. Unpublished report, Department of Civil Engineering, University of California, Berkeley.

ECORP Consulting inc. and Kamman Hydrology & Engineering, Inc. 2005. Gualala Estuary and lower river enhancement plan: results of 2002 and 2003 physical and biological surveys. Prepared for Sotoyame Resource Conservation District and the California Coastal Conservancy. 270 pp.

EDS. 2009a. Unpublished grain size distribution data for the beach at the Russian River mouth. Conducted for Sonoma County Water Agency.

EDS. 2009b. Unpublished sidescan sonar bathymetry data and LiDAR topography data for the Russian River from the mouth to Duncan Mills. Conducted for Sonoma County Water Agency.

ESA. 2010. Russian River Estuary Management Project Draft Environmental Impact Report. Prepared for Sonoma County Water Agency.

ESA. 2015. Response of the Russian River Estuary's Inlet to Future Wave Conditions. Prepared for Sonoma County Water Agency.

ESA PWA. 2017. Feasibility of Alternatives to the Goat Rock State Beach Jetty for Managing Lagoon Water Surface Elevations. Prepared for Sonoma County Water Agency.

Fischenich, C. 2001. Stability thresholds for stream restoration materials. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29). U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Fuller, J. 2011. Extended Residency and Movement Behavior of Juvenile Steelhead (Oncorhynchus mykiss) in the Russian River Estuary, California. Masters Thesis. Humboldt State University.

Goodwin, P. and Cuffe, K., 1994. Russian River Estuary Study: hydrologic aspects of an estuary management plan. Project 1139. For Sonoma County Department of Planning. October.

Griggs, G, Árvai, J, Cayan, D, DeConto, R, Fox, J, Fricker, HA, Kopp, RE, Tebaldi, C, Whiteman, EA (California Ocean Protection Council Science Advisory Team Working Group). 2017.

Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Science Trust, April 2017.

Heckel, M. 1994. Russian River Estuary Study, 1992-1993. Prepared for Sonoma County Department of Planning and California State Coastal Conservancy

Kraus, N., Militello, A. and Todoroff, G. 2002. Barrier Breaching Processes and Barrier Spit Breach, Stone Lagoon, California. Shore and Beach, v. 70, n. 4. 21-28.

James, G. W. 2005. Surface Water Dynamics at the Carmel River Lagoon Water Years 1991 Through 2005. Monterey Peninsula Water Management District Technical Memorandum 05-01.

Jones, C., Brøker, I., Coulton, K., Gangai, J., Hatheway, D., Lowe, J., Noble, R., and Srinivas, R. 2005. Wave Runup and Overtopping - FEMA Coastal Flood Hazard Analysis and Mapping Guidelines Focused Study Report.

Julien, P.Y. 2002. River Mechanics. Cambridge: Cambridge University Press, UK.

Largier, J. and D. Behrens. 2010. Hydrography of the Russian River Estuary, Summer-Fall 2009, with Special Attention on a Five-Week Closure Event. Bodega Marine Lab, University of California, Davis. Prepared for Sonoma County Water Agency.

Lawrence Berkeley National Laboratory (LBNL). 2015. Geophysical Assessment of the Jenner Jetty and Beach Berm Seepage. Prepared for Sonoma County Water Agency.

Laudier, N.A., E.B. Thornton, and J. MacMahan. 2011. Measured and modeled wave overtopping on a natural beach. Coastal Engineering 58(9): 815-825.

Limerinos, J.T. 1970. Determination of the Manning coefficient for measured bed roughness in natural channels. Water Supply Paper 1898-B, U.S. Geological Survey, Washington, D.C.

National Marine Fisheries Service. 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed.

National Resources Conservation Service. 2007. Stream Restoration Design. Part 654 in the National Engineering Handbook.

Ocean Protection Council (OPC). 2018. State of California Sea-Level Rise Guidance, 2018 Update.

Pranzini, E. 2001. Updrift river mouth migration on cuspate deltas: two examples from the coast of Tuscany (Italy). Geomorphology Vol. 38, pp. 125–132.

Rice, M.P. 1974. Closure Conditions: Mouth of the Russian River. Shore and Beach, 42(1): 15-20.

Rich, A. and E.A. Keller, 2013. A hydrologic and geomorphic model of estuary breaching and closure. Geomorphology 191 (2013): 64-74.

Rosati, J.D., and N.C. Kraus 1999. "Coastal Engineering Technical Note CETN-IV-15." U.S. Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory, Vicksburg, MS.

Shuttleworth, B., A. Woidt, T. Paparella, S. Herbig, and D. Walker 2005. "The dynamic behaviour of a river-dominated tidal inlet, River Murray, Australia." Estuarine, Coastal and Shelf Science 64, 645-657.

Sonoma County Water Agency. 1999. Standard Operational Procedures: Russian River Mouth Opening.

Sonoma County Water Agency. 2000-2007. Unpublished water level data recorded at the Jenner Visitors Center.

Sonoma County Water Agency. 2013a. Construction, Monitoring, and Reporting Program for the Russian River Estuary Management Project. Prepared for the California Coastal Commission Coastal Development Permit. December 2013.

Sonoma County Water Agency. 2013b. Russian River Biological Opinion Status and Data Report Year 2012-2013. D.J. Manning and J. Martini-Lamb, editors. Sonoma County Water Agency, Santa Rosa, CA.

Sonoma County Water Agency. 2016. Russian River Biological Opinion: Status and Data Report, Year 2014-2015.

Soulsby, R. 1997. Dynamics of Marine Sands. Thomas Telford Ltd. London. 272 pp.

Smith, J. 1990. The effects of sandbar formation and inflows on aquatic habitat and fish utilization in Pescadero, San Gregorio, Waddell and Pomponio estuary/lagoon systems, 1985-1989, Report prepared for California Department of Parks and Recreation

Stockdon, H., Holman, R., Howd, P. and A. Sallenger. 2006. Empirical Parameterization of Setup, Swash, and Runup. Coastal Engineering 53(7): 573-588.

Strickler, A. 1923. Beitrage zur frage der geschwindigkeitsformel und der rauhigkeitszahlen fuer stroeme kanaele und gescholossene leitungen. Mitteilungen des eidgenossischen Amtes fuer Wasserwirtschaft 16. Bern, Switzerland. (in German).

USGS. 1984. Guide for selecting Manning's roughness coefficients for natural channels and flood plains. U.S. Geological Survey Water Supply Paper 2339.

Van de Kreeke, J., 1967. Water-level fluctuations and flow in tidal inlets. Journal of the Waterways and Harbors Division, American Society of Civil Engineers 4: 97–106.

11. LIST OF PREPARERS

This report was prepared by the following ESA staff:

Matt Brennan
Michelle Orr
Bob Battalio
Dane Behrens
Justin Vandever
Lindsey Sheehan
Alex Trahan

With Bodega Marine Laboratory, University of California at Davis:

John Largier
Dane Behrens (2009-2012)

ATTACHMENT A: CHANNEL CONFIGURATION ANALYSIS

As discussed in the conceptual model for target conditions (Section 4), an outlet channel would ideally meet two key constraints: convey sufficient discharge from the estuary to the ocean to preserve estuarine water surface elevations above ocean tides but below flood stage, and to preserve channel function by avoiding closure or breaching. Note that these two constraints can be in conflict since both conveyance capacity and the potential for breaching increase with flow rates but closure is more likely for lower flow rates. As requested in the Biological Opinion, the technical analyses described in this attachment inform the range of target channel conditions by quantifying the relationship between outlet channel dimensions, bed scour potential, and hydraulic conditions. The ocean-driven processes associated with closure, the wave runup elevation and planform alignment, are discussed in the main report's Section 5. Preventing breaching, a necessary condition for enhancing estuary rearing habitat and promoting brackish/freshwater habitat, is the focus of this attachment.

Since an outlet channel would be located within a bed of unconsolidated beach sand, a key management objective is creating a channel that can sustain its cross section geometry instead of scouring. Breaching can occur if the discharge through an outlet channel is sufficiently forceful to scour the channel bed. To reduce the possibility of scour, threshold design principles (NRCS, 2007) are used to examine channel configurations most likely to avoid scour while meeting the other constraints of the system.

Channel design using a threshold methodology consists of the following steps:

- *Estimate the critical shear stress threshold.* This is a function of the site's bed particle composition, which can be characterized by grain size.
- *Predict hydraulic conditions for the proposed channel.* Use engineering calculations of steady flow and a one-dimensional hydraulic model of time-varying flow to estimate the velocity and shear stress for a proposed set of channel geometry, flow, and bed roughness.
- *Compare threshold and predicted bed shear stress.* The estimates from the two previous steps are compared with a factor of safety to account for variations in hydraulic conditions about the mean and uncertainty in parameter estimation.
- *Sensitivity analysis and uncertainty.* Evaluate the sensitivity of threshold and predicted bed shear stress to input parameters as well as the factors contributing to overall uncertainty.

A.1 CRITICAL SHEAR STRESS

The critical shear stress is defined as the applied bed shear stress at which sediment motion occurs. The critical threshold represents a balance between the force exerted by the flow on the bed and the resisting gravitational force of individual sediment particles. Flows above the critical shear stress will transport sediment while flows below the critical shear stress will result in no motion. The critical shear stress is dependent on characteristics of the sediment such as sediment density and particle size.

Sediment samples at the Russian River mouth were collected in March 2009 to inform the assessment of critical shear stress within an outlet channel. Ten sediment samples taken along the proposed outlet channel alignment were analyzed to determine the characteristic grain size distribution. On average, 78% of the sediment had a grain diameter between 0.6-2.0 mm (coarse sand), 18% was greater than 2.0 mm (granular), and 4% was between 0.2-0.6 mm (medium sand) (EDS, 2009a). Visual observations of grain size by ESA PWA near the mouth indicated a typical diameter between 0.8-1.25 mm (coarse sand).

Based on this assessment of typical beach grain size, ESA PWA estimated the critical shear stress using methods outlined in Soulsby (1997) and Fischenich (2001). For the typical range of observed grain size from 0.8-1.25 mm, a critical shear stress of 0.4-0.7 Pa (0.008-0.015 lb/ft^2) was determined for sand particles in the vicinity of the proposed outlet channel (Worksheet A-1).

A.2 PREDICTED HYDRAULIC CONDITIONS

A.2.1.1 Steady mean flow conditions

ESA PWA conducted a preliminary assessment of outlet channel hydraulics under steady typical summer flow conditions as a screening tool to characterize the range of possible channel geometry parameters (bed elevation, channel slope, width, and length). Simple hydraulic equations for open channel flow were used to estimate the in-channel velocity and bed shear stress.

ESA PWA evaluated different combinations of river discharge, bed roughness, channel slope, and flow depth to evaluate channel performance. For a given discharge the hydraulic equations can be solved to determine the values of slope, width, and depth that satisfy the critical shear stress threshold for sediment motion. Once one of these three parameters is selected, the other two are fixed to meet a given shear stress threshold (NRCS, 2007). Multiple combinations of channel slope and width are capable of conveying the design flow at or below the critical shear stress threshold.

Figure A-1 shows an example slope-versus-width stability curve for outlet channel design. A stability curve is a tool used by designers to evaluate channel stability under a range of feasible slope-width combinations. Any combination of slope and width that falls on the stability curve will be stable for the prescribed discharge. Combinations of width and slope that plot above the stability curve will result in erosion and scour of the channel. Combinations of width and slope that plot on or below the stability curve will be stable (or depositional). For a given width, the depth of flow can be determined from the corresponding depth-width curve (Figure A-1). For example, a 100-ft wide channel discharging 70 ft^3/s will be stable for channel slopes less than approximately 0.000125 and will flow at a depth of approximately 11 inches. The stability curve shows that as slope increases, channel width must also increase to keep channel velocities below the critical threshold for transport. Channel width and depth are inversely related for points on the stability curve, resulting in either a narrow channel with relatively deep flow or a wide channel with relatively shallow flow.

A.2.1.2 Calculation of estuary inflows

ESA PWA developed and calibrated a water balance model based on observed lagoon water levels at Jenner, CA. The purpose of the water balance model is to estimate the reduction in river discharge that occurs over the 21 river miles between Guerneville, a USGS continuous discharge gaging station, and the mouth of the estuary. The losses in discharge are attributed primarily to seepage through the beach berm (Largier and Behrens, 2010), with diversions, interaction with the adjacent aquifer, and groundwater pumping as possible contributing factors. No direct observations of these loss terms is available. The reduction factor serves as the calibration variable for the water balance model. For all cases, predicted estuary water levels during closure periods do not match observations unless lagoon inflows are reduced relative to the Guerneville discharge.

Model Setup

During a closure event, the rate of water level increase is a direct function of the net flows into and out of the lagoon (Goodwin and Cuffe 1993):

$$\frac{\Delta V}{\Delta t} = A\frac{\Delta h}{\Delta t} = \alpha Q_R - Ai_{evap} - Q_s$$

where:

ΔV	=	lagoon inflow during closure (ft^3)
Δt	=	duration of closure (days)
A	=	surface area of the lagoon (ft^2)
Δh	=	change in water level in the lagoon (ft)
Q_R	=	river discharge at Guerneville (ft^3/day)
α	=	discharge reduction factor for groundwater losses
i_{evap}	=	rate of evaporation from the lagoon (ft/day)
Q_S	=	rate of seepage loss through the barrier beach (ft^3/day)

All terms in the water balance equation can be measured or approximated to allow calculation of α, the discharge reduction factor, for each closure event. The components and data sources of the water balance model are described below:

- Estuary water level and inlet state (Δh) – Jenner water level time series, (SCWA, 2000-2007). The inlet was assumed to be closed (no flow) during the calibration, based on periods when the estuary water levels were non-tidal and increasing estuary water levels.
- Guerneville discharge (Q_R) – USGS gaging station 11467000 (Russian River near Guerneville, CA at Hacienda Bridge) (http://waterdata.usgs.gov).
- Evaporation (i_{evap}) – estimated based on climatological evaporation rates for CIMIS evapo-transpiration reference Zone 1 (California coast) (*www.cimis.water.ca.gov*, Worksheet A-3, Figure A-2).
- Berm seepage (Q_S) – estimated using Darcy's Law based on water level difference between lagoon and ocean (Worksheet A-4).
- Lagoon stage-storage curve (A) – determined from 2009 sidescan survey and LiDAR digital elevation model (EDS 2009b).

The volume of water entering the closed lagoon as a result of waves overtopping the beach berm is not included in the water balance model. Two lines of reasoning provide the basis for this exclusion. First, wave conditions during the May through October management period are generally associated with beach berm building, not with extensive overtopping and berm erosion more prevalent during winter storm events. The wave runup analysis in Section 5.2.3 confirms that runup elevations sufficient to overtop the berm are infrequent. Second, the observed water levels used in the water balance model exhibited nearly constant rates of increase, typically over two days or more. Short periods of rapidly changing water levels indicative of overtopping were not used in the water balance analysis.

Model Calibration

The observed rate of water level increase ($\Delta h/\Delta t$) in the lagoon during 18 closure events was calculated from the Jenner gage data. Rates of water level increase ranged from 0.4 ft/day to 3 ft/day and averaged 1 ft/day. The required inflow ($\Delta V/\Delta t$) to yield the observed rates was calculated based on an assumed lagoon surface area (A) at closure of approximately 400 acres. From the observed average discharge at Guerneville (Q_R) over each closure period, a discharge reduction factor, α, was calculated for estuary inflow during each of the closure events. The percent reduction ranged from 10% to 53% and averaged 37% (Worksheet A-5). The largest reductions in discharge typically occurred in summer and were less in the spring and fall.

The reduction factors were averaged over each month from May-October to approximate a seasonal trend. The resulting calibration curve (Worksheet A-5) was used to reduce the anticipated Guerneville discharge in the unsteady hydraulic modeling discussed in Section A.2.3 to predict downstream flow rates into the lagoon based on upstream discharge measurements.

Comparison with Discharge Measurements

A limited set of USGS and Sonoma Water discharge measurements provides estimates of river flow at other locations besides the continuous discharge measurements at Guerneville. These discharge measurements, collected at four stations[1] in the 14 miles below Guerneville, typically fall within 10% of the Guerneville average daily discharge. For example, Behrens and Largier (2010) found that the longest record, collected by Sonoma Water in 2009 at Vacation Beach, agreed to within 10 ft^3/s of the discharge measurements made at the permanent USGS Guerneville gage. These relatively low losses suggest that the losses calculated to complete the estuary water balance occur downstream of these discharge measurements, in the lower 6 miles of the river. Since the results of the water balance are used to estimate estuary inflow in the unsteady hydraulic model (see Section A.2.3 below) and have a significant level of uncertainty, the estuary inflow values in the unsteady hydraulic model may not represent actual estuary inflow. Presently, the existing data are insufficient to fully characterize the losses between the discharge measurements and lagoon water levels. Higher rates of seepage through the beach berm are one possible explanation. Largier and Behrens (2010) estimate seepage rates to average 60 ft^3/s for all closure data. Their seepage estimates vary from approximately 30 ft^3/s when the estuary is closed and its water level exceeds the ocean water level by 2-3 ft to more than 70 ft^3/s when the water level difference exceeds 5 ft. Substantial uncertainty about the seepage rate, on the order of ±20 ft^3/s, remains; therefore monitoring to resolve this discrepancy is recommended in Section 7.7. The implications of alternative lagoon inflows are discussed in the model sensitivity analysis and outlet channel management sections of this report.

---

[1] Data available from USGS National Water Information System (http://waterdata.usgs.gov/nwis), Russian River station names (site number): Duncan Mills (11467210), Monte Rio (382757123003801), Vacation Beach (11467006), and Rio Nido (383012122574501).

A.2.2.3 Hydraulic modeling of unsteady mean flow conditions

Using the calibrated water balance model results described in Section A.2.2, ESA PWA developed a hydraulic model to evaluate the performance of an outlet channel for various hydrologic scenarios. This modeling is a refinement of the steady mean flow calculations described in Section A.2.1 because it quantifies estuary discharge, explicit channel geometry, and temporal changes in hydraulic parameters. Sources and sinks accounted for in the model include river discharge, groundwater losses, berm seepage, evaporation, and outlet channel discharge (described in more detail in Section A.2.2 and Figure A-2). Flow in an outlet channel is represented by one-dimensional channel hydraulics as a function of estuarine water levels, channel dimensions, channel slope, and bed roughness. Tidally-varying ocean water levels are included in the model, but since these water levels stay below the channel's bed elevation, they do not influence flow in the channel. Initial channel dimensions were based on the results of the preliminary analysis described in Section A.2.1. Model channel geometry was revised iteratively based on subsequent hydraulic analyses and discussions with Sonoma Water and NMFS. Channel geometry is fixed throughout the simulation, even though the channel may be subject to scour and its mouth lies in the active transport zone created by ocean waves (Section 4). This assumption has been made because currently available data and models cannot adequately characterize the active transport zone. The management implications of this assumption are discussed in Section 7. The model simulates estuary water levels and outlet channel flow for the period spanning proposed outlet channel operations, from May 15 to October 15.

Discharge Boundary Condition

ESA PWA analyzed historic discharge data at Guerneville to select a "typical" water year for the hydraulic model boundary condition. A time series of monthly discharge was obtained from USGS for the time period from 1970 to 2008 and compared to the median monthly discharge for the duration of record to select a typical water year. For each month, the difference between the month's discharge and the median monthly discharge was computed. The sum of the differences (for May-Oct only) was used to rank each year relative to median conditions. Based on this ranking, the 2000 water year was selected as the most typical year (Figure A-3).

The year 2000 discharge time series was used to generate a synthetic discharge time series to approximate anticipated reduced instream flow conditions. A measured time series is preferable to using the median daily discharge because it retains some of the short-term variability in the observed flow rates. A synthetic discharge time series for anticipated flow conditions was derived from the typical discharge time series by scaling the Guerneville discharge to an average summertime flow of 120 ft^3/s. This reduction to 67% of observed 2000 discharge is based on the anticipated reduced instream flow requirements (Section 3.1) versus historic instream flows. When flows are adjusted to average 120 ft^3/s from July to October, short-term variability ranges from about 85-150 ft^3/s. The resulting discharge time series at Guerneville is shown in Figure A-4a for the simulation period.

The anticipated discharge time series at Guerneville was further reduced using the calibration curve developed in Section A.2.2 to account for downstream losses between the gaging station and the lagoon. The resulting estuary inflow time series is shown in Figure A-4a. Anticipated inflows to the lagoon vary from approximately 45-90 ft^3/s and average approximately 55 ft^3/s during the summer months. Once seepage and evaporation losses are subtracted from the lagoon inflow, modeled baseline flows in an outlet channel are 45-85 ft^3/s and average 50 ft^3/s.

Model Setup

The configuration for the unsteady HEC-RAS hydraulic model is very similar to the water balance model described in Section A.2.2. The unsteady model includes the lagoon, outlet channel, and beach face, and simulations span the duration of the operational period, from May 15-October 15. An outlet channel was parameterized as a prismatic rectangular channel with a width of 100 ft and length of 300 ft. Bed roughness (Manning's n) was set to 0.02 (Worksheet A-2). The channel bed was set at 5 ft NGVD and transitions to a 1V:70H slope on the beach face. The actual beach face slope is believed to be closer to 1V:10H; however, a milder slope was required for model stability. Sensitivity runs with a steeper beach face slope indicated negligible influence on velocities in the upstream portion of an outlet channel. Time-varying seepage and evaporation losses from the lagoon were estimated from Darcy's Law and CIMIS climate statistics for coastal areas, as described in Section A.2.2. The time series of these losses used as model input are shown in Figure A-4b. Because these combined losses are less than 10% of the lagoon inflow, the modeled lagoon outflow through an outlet channel is similar to the lagoon inflow (Figure A-4a). A downstream water level boundary condition was prescribed for the ocean; however, since an outlet channel's bed elevation is above the limit of tidal influence (approximately 4.5 ft NGVD), there was no impact on outlet channel hydraulics.

Results

Model runs were conducted for the operational period from May 15-October 15 for the proposed outlet channel geometry described above. Time series of lagoon water level, channel velocity, and bed shear stress were extracted to evaluate channel performance. Bed shear stress and lagoon water level results for the hydraulic modeling are shown in Figure A-3a and Figure A-3b, respectively. The bed shear stress values shown in Figure A-3a are mean model predictions times 1.5 to account for transverse variations in bed shear stress not captured by the one-dimensional model (Fischenich, 2001).

The results for the proposed channel geometry and the anticipated reduced instream hydrology are shown as the "Baseline" curve. The expected range of critical shear stress (0.4-0.7 Pa) is shown in Figure A-3a for reference. After the initial higher flow period during the spring and early summer, both shear stress and lagoon water level are relatively constant throughout the summer and fall (July-October). Bed shear stresses fluctuate during this period, but are always above the critical shear stress, indicating likely sediment motion and scouring of an outlet channel. Lagoon water levels (Figure A-3b) are relatively constant around 5.6 ft NGVD, resulting in a typical flow depth of approximately 0.6 ft in the channel. Channel velocities average 1.1 ft/s and range between 1.0-1.3 ft/s.

A.2.3 SENSITIVITY ANALYSIS AND UNCERTAINTY

ESA PWA conducted sensitivity and uncertainty model runs for important variables and parameters to assess their impact on channel performance. The testing focused on conditions that may encourage a stable channel by reducing predicted bed shear stress below the critical shear stress. Parameters tested were reduced outlet channel flow and critical shear stress.

Reduced Outlet Channel Flow

Anticipated flows in an outlet channel are somewhat uncertain because the losses between upstream observed discharges and an outlet channel are not well characterized, as described in Section A.2.2. The baseline simulation presented in Section A.2.3 used a calibrated seasonally-varying coefficient to reduce flow rates into the lagoon. Once seepage and evaporation losses are subtracted from the lagoon inflow, modeled baseline flows in an outlet channel are 45-85 ft^3/s. To test channel performance under conditions with further flow reductions (due to higher losses, groundwater recharge, diversions, or berm seepage), a sensitivity run was conducted with outlet channel flows reduced to 25-45 ft^3/s, approximately 45% less than baseline conditions.

Critical Shear Stress

Uncertainty in the critical shear stress for beach sand at the Russian River mouth is primarily due to the fact that the beach is comprised of a distribution of particles of varying diameter (see Section A.1), as opposed to a uniform grain size. Grain size analyses indicate a narrow distribution of approximately 0.8-1.25 mm diameter sand, for which the critical shear stress ranges from 0.4-0.7 Pa. The critical shear stress for the typical grain size of 1 mm is 0.5 Pa.

Results

The results of the reduced outlet channel flow sensitivity model run are shown in Figure A-5a for bed shear stress and Figure A-5b for lagoon water level. The 45% reduction in outlet channel flow resulted in reduced bed shear stress and water level. Average water levels and channel depth decreased by approximately 0.1 ft relative to the baseline simulation. Average bed shear stress decreased by approximately 30% to an average value of 0.58 Pa for the summer months. The range of critical shear stress, 0.4-0.7 Pa, is shown in Figure A-5a as a blue band. While the predicted bed shear stress for baseline conditions almost always exceeds this range, the predicted bed shear stress for reduced outlet channel flow falls within the range of critical shear stress.

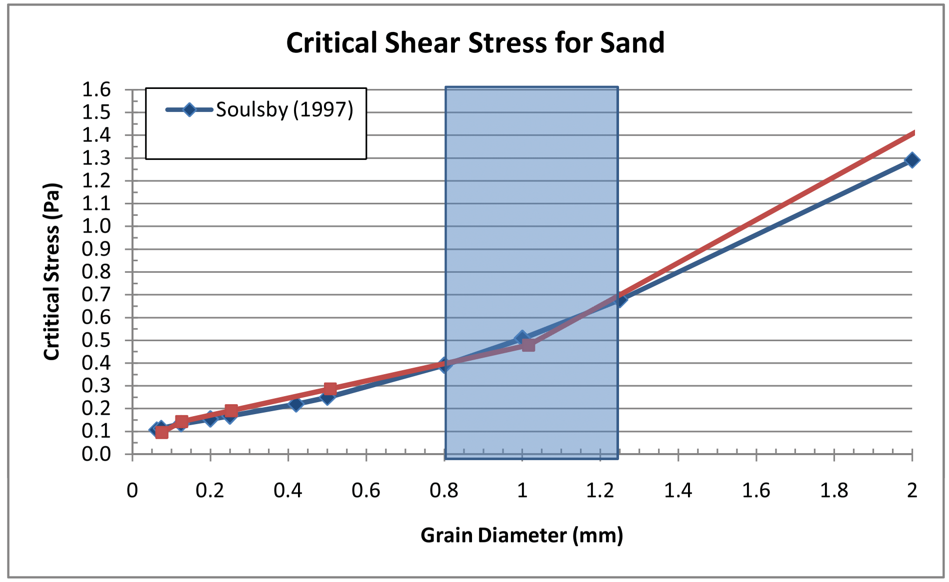
The results of the sensitivity simulations suggest that while the baseline conditions are likely to cause scour, variability in outlet channel flow and critical shear stress could result in a marginally stable channel. If necessary, a wider channel could be excavated (or could develop naturally) to reduce bed shear stress below the critical threshold. This model was not used to predict sediment transport and therefore the modeled channel geometry was held fixed. Under target conditions, active transport is expected at the channel mouth. In order for an outlet channel to persist, scour caused by an outlet channel flow accelerating down the beach face at low tides needs to be balanced by sediment deposition generated by wave action at high tides. However, if the active transport zone moves upstream into an outlet channel, such a channel is likely to breach and return to tidal conditions.

Worksheet A-1. Critical shear stress for incipient motion of sand particles

1958.01 Russian River Estuary Outlet Channel
J. Vandever (PWA)
4/1/2009

Variables		
p	1000	kg/m^3
g	9.81	m/s^2
s	2.65	(quartz)
v	1.0E-06	m^2/s

D (mm)	D*	Theta_crit	tau_crit (Pa)	Grain Size
0.0625	1.58	0.105	0.11	Very Fine Sand
0.074	1.87	0.094	0.11	
0.125	3.16	0.066	0.13	Fine Sand
0.20	5.06	0.048	0.15	
0.25	6.32	0.041	0.17	Medium Sand
0.42	10.62	0.032	0.22	
0.5	12.65	0.031	0.25	Coarse Sand
0.8	20.24	0.030	0.39	
1.0	25.30	0.031	0.51	Very Coarse Sand
1.25	31.62	0.033	0.68	
2.0	50.59	0.040	1.29	Granular



Notes: units Pa = N/m², assumes density of freshwater, quartz grained sand
Method based on Soulsby (1997) Dynamics of Marine Sand:

$$D_* = \left[\frac{g(s-1)}{\nu^2}\right]^{1/3} D$$

$$\theta_c = \frac{0.3}{1+1.2D_*} + 0.055\left[1-\exp\left(-0.020D_*\right)\right]$$

$$\tau_c = \rho(s-1)gd\theta_c$$

Note: does not account for gravitational effects on sloping bed

Worksheet A-2. Manning's n

1958.01 Russian River Estuary Outlet Channel
J. Vandever (PWA)
4/1/2009

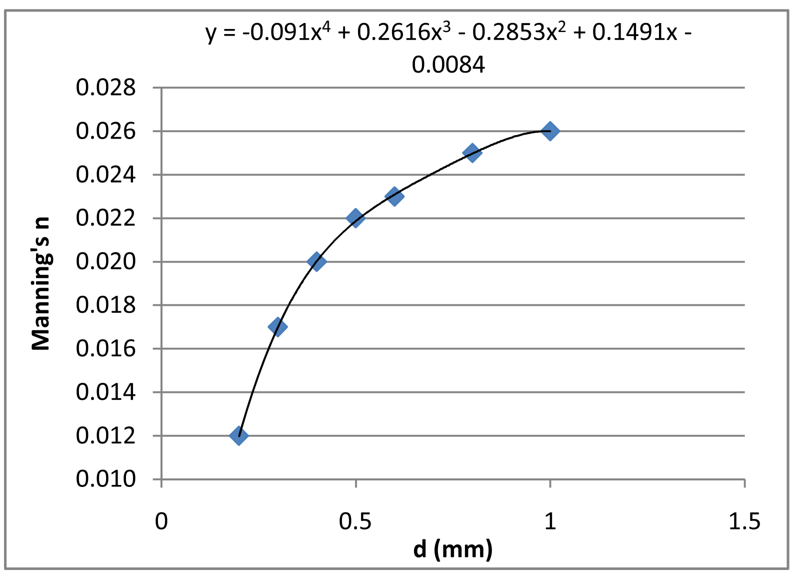
d_{50}	1	mm	0.003281	ft
D	0.84	ft		
Rh	0.83	ft		
S	0.00008	ft/ft		

Equation	n	Notes
Strickler (1923)*	0.018	*valid d range unknown
Limerinos (1970)*	0.021	
Bray (1979)*	0.017	
Bruschin (1985)*	0.018	
Julien (2002)*	0.024	
USGS (WSP2339)	0.026	for 0.2<d<1.0 mm
Average	**0.021**	
Average w/o USGS	**0.020**	

USGS

d (mm)	n
0.2	0.012
0.3	0.017
0.4	0.020
0.5	0.022
0.6	0.023
0.8	0.025
1.0	0.026
2.0	0.035

Polynomial fit to USGS data (d=2.0 mm not included):



A-3. Evaporation

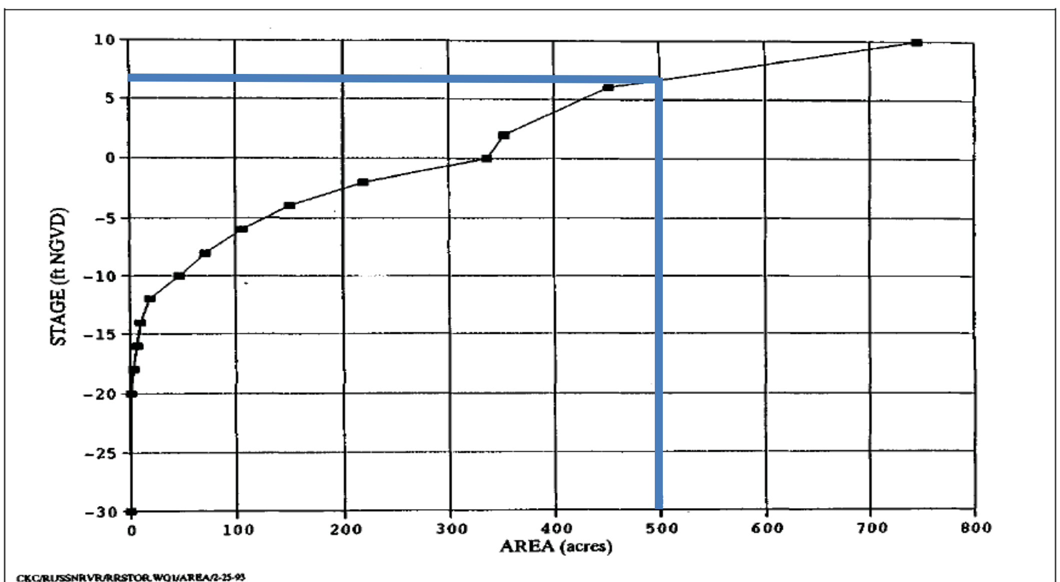
1958.01 Russian River Estuary Outlet Channel
J. Vandever (PWA)
15-Apr-09

CIMIS Reference Evapotranspiration (Eto) Zones
http://www.cimis.water.ca.gov/cimis/images/etomap.jpg

Russian River Estuary is located on California coast in Zone 1
(Coastal plains and heavy fog. Lowest Eto in California, characterized by dense fog)

	in/month	days	in/day	mm/day	cfs
Jan	0.93	31	0.03	0.76	0.6
Feb	1.40	28	0.05	1.27	1.1
Mar	2.48	31	0.08	2.03	1.7
Apr	3.30	30	0.11	2.79	2.3
May	4.03	31	0.13	3.30	2.7
Jun	4.50	30	0.15	3.81	3.2
Jul	4.65	31	0.15	3.81	3.2
Aug	4.03	31	0.13	3.30	2.7
Sep	3.30	30	0.11	2.79	2.3
Oct	2.48	31	0.08	2.03	1.7
Nov	1.20	30	0.04	1.02	0.8
Dec	0.62	31	0.02	0.51	0.4

RRE Surface Area	500	acres
	21,780,000	sq ft



Philip Williams & Associates, Ltd.
Consultants in Hydrology

Stage-Area Curve for Russian River Estuary - River Mouth to Monte Rio

Figure 5.6

Worksheet A-4. Berm Seepage and Hydraulic Conductivity

1958.01 Russian River Estuary Outlet Channel
J. Vandever (PWA)
16-Apr-09

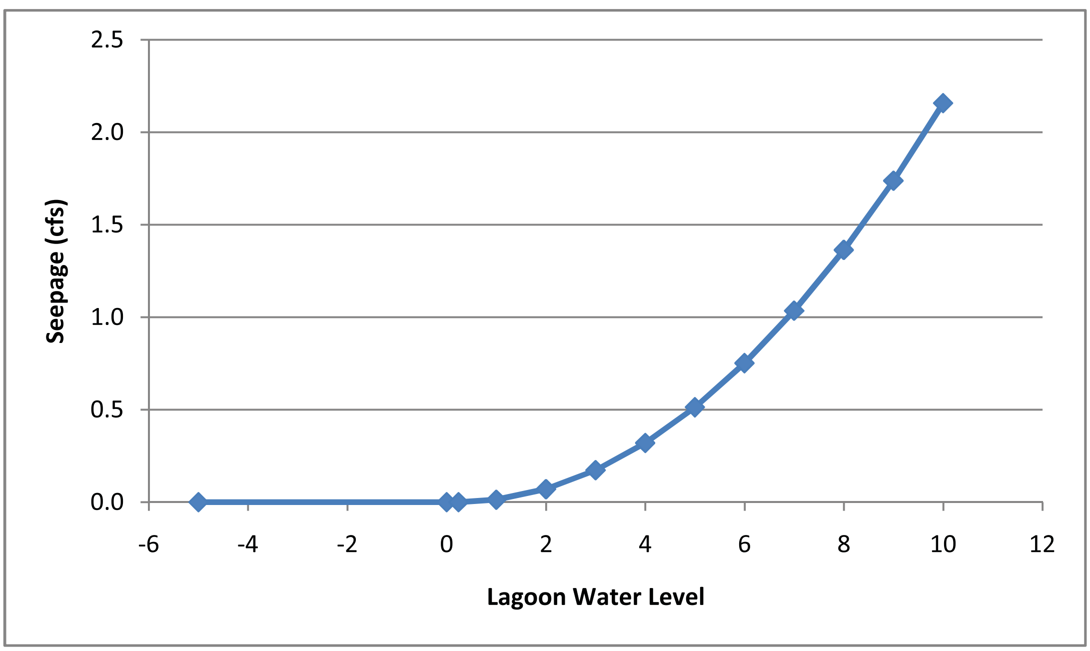
HEC-RAS Diversion Rating Curve

Lagoon WL (ft)	dh (ft)	q (cfs)	
-5	0	0.00	
0	0	0.00	
0.24	0	0.00	(MTL)
1	0.76	0.01	
2	1.76	0.07	
3	2.76	0.17	
4	3.76	0.32	
5	4.76	0.51	
6	5.76	0.75	
7	6.76	1.03	
8	7.76	1.36	
9	8.76	1.74	
10	9.76	2.16	(Flood Stage)
11	10.76	2.62	
12	11.76	3.13	

Darcy's Law

$$q = k\frac{\Delta h}{W}A = k\frac{\Delta h}{W}(\Delta h \cdot L)$$

W	250	ft
L	2500	ft
z_ocean	0.24	ft NGVD (MTL)
k	0.0023	ft/s



Worksheet A-4. Berm Seepage and Hydraulic Conductivity (con't)

1958.01 Russian River Estuary Outlet Channel
J. Vandever (PWA)
7-Apr-09

Bouwer, H. 1978. Groundwater Hydrology. McGraw-Hill, Inc. 480 p.

	Hydraulic Conductivity (m/day)		Hydraulic Conductivity (cm/s)		
	Low	High	Low	High	Mid
Fine Sand	1	5	0.001	0.006	0.003
Medium Sand	5	20	0.006	0.023	0.014
Coarse Sand	20	100	0.023	0.116	0.069
Gravel	100	1000	0.116	1.157	0.637
Sand and Gravel	5	100	0.006	0.116	0.061

Worksheet A-5. Mouth Closure Calibration

1958.01 Russian River Estuary Outlet Channel
J. Vandever (PWA)
17-Apr-09

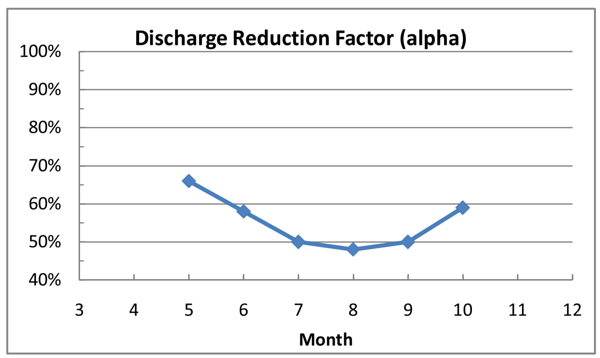
Russian River mouth closure calibrations - HEC-RAS model Years Examined: 2000, 2001, 2003, 2004, 2005, 2007
Accounts for losses between Hacienda Bridge (Guerneville, CA) and the lagoon and the interaction with the aquifer adjacent to the estuary.
No detailed information available for the aquifer groundwater elevations or extraction rates by wells. The loss term is a calibrated variable in the model.

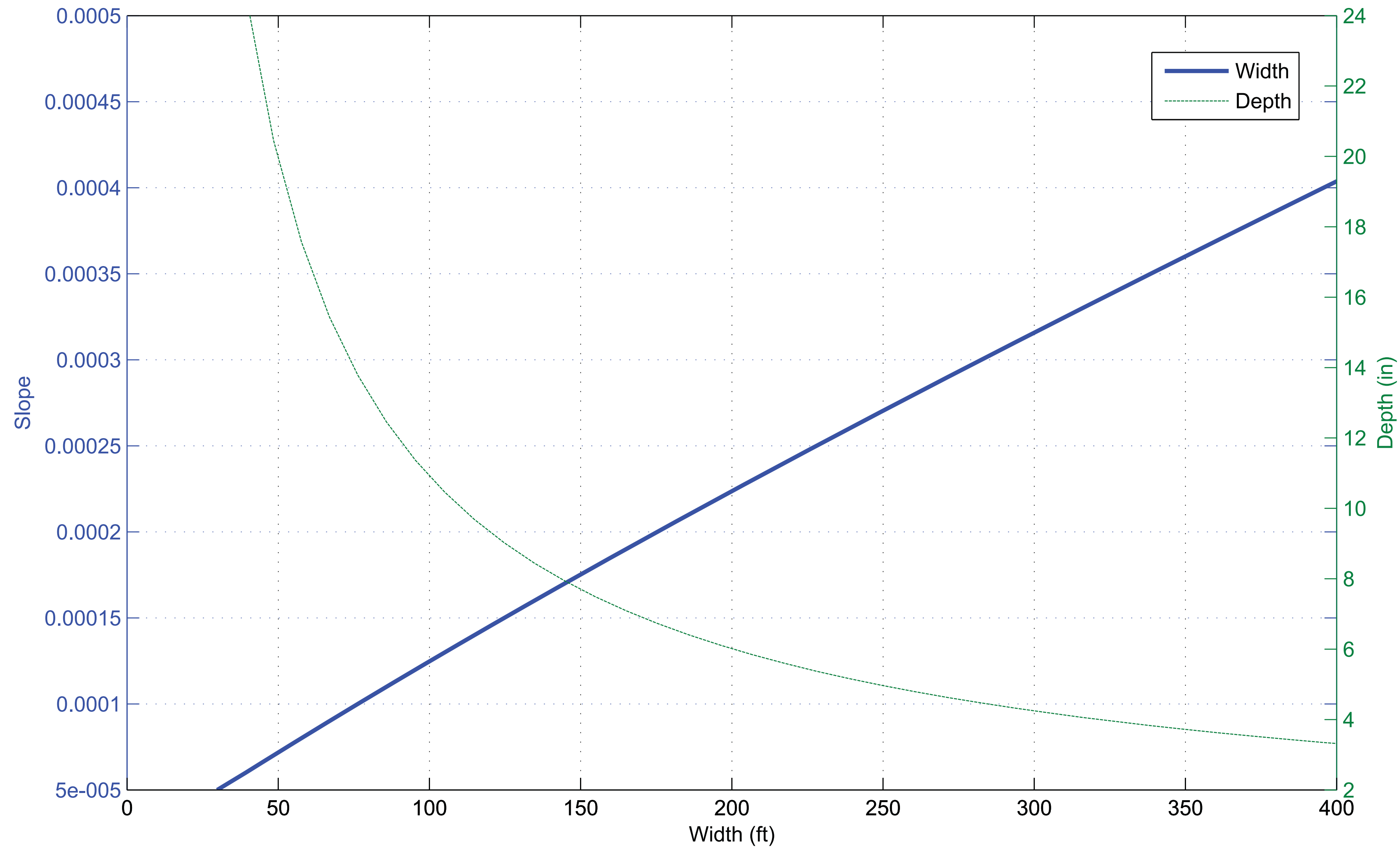
Lagoon Surface Area	400	ac
	17,424,000	sq ft
Evaporation and Seepage Losses	4	cfs

Calibration	Date		Water Level (ft NGVD)		dh	dt	dh/dt (ft/day)	dV/dt (cfs)	USGS Discharge (cfs)	% Reduction	alpha
Closure Event ID	Start	End	Start	End							
06May2000	5/6/2000 18:00	5/9/2000 6:00	3.10	8.40	5.30	2.50	2.12	432	580	26%	74%
24May2000	5/24/2000 8:00	5/25/2000 18:00	3.84	5.76	1.92	1.42	1.36	278	385	28%	72%
16June2000	6/16/2000 13:00	6/21/2000 6:00	4.79	6.90	2.11	4.71	0.45	94	200	53%	47%
25Aug2000	8/25/2000 0:00	9/5/2000 8:00	2.56	7.62	5.06	11.33	0.45	94	195	52%	48%
03Oct2000	10/3/2000 0:00	10/11/2000 12:00	2.85	6.53	3.68	8.50	0.43	91	140	35%	65%
15May2001	5/15/2001 23:00	5/21/2001 21:00	2.14	5.51	3.37	5.92	0.57	119	200	41%	59%
07Apr2007	4/7/2007 13:00	4/11/2007 0:00	1.17	7.68	6.51	3.46	1.88	384	480	20%	80%
13Apr2007	4/13/2007 21:30	4/17/2007 14:30	1.97	7.68	5.71	3.71	1.54	315	465	32%	68%
24Apr2007	4/24/2007 17:00	4/26/2007 14:00	1.51	7.57	6.06	1.88	3.23	656	725	10%	90%
13Oct2007	10/13/2007 2:30	10/22/2007 11:30	2.51	9.15	6.64	9.38	0.71	147	255	42%	58%
9June2003	6/9/2003 17:30	6/12/2003 1:00	2.77	6.47	3.70	2.31	1.60	322	475	32%	68%
9Oct2003	10/9/2003 23:11	10/14/2003 20:40	4.00	6.21	2.21	4.90	0.45	91	170	46%	54%
05Nov2004	11/5/2004 11:00	11/12/2004 4:00	2.40	8.93	6.53	6.71	0.97	196	300	35%	65%
26July2004	7/26/2004 15:41	8/5/2004 0:00	2.27	5.90	3.63	9.35	0.39	78	140	44%	56%
2May2004	5/2/2004 15:40	5/6/2004 19:35	3.44	8.39	4.95	4.16	1.19	240	420	43%	57%
16Apr2004	4/16/2004 9:09	4/18/2004 7:40	4.78	7.98	3.20	1.94	1.65	333	570	42%	58%
3Oct2005	10/3/2005 23:00	10/17/2005 6:30	2.40	8.30	5.90	13.31	0.44	89	170	47%	53%
17Sep2005	9/17/2005 2:00	9/21/2005 13:30	3.37	5.69	2.31	4.48	0.52	104	175	40%	60%

Note: Start and end times represent times used for water level calibration and do not correspond to exact timing of closures and breaches.

Month	Month	% Loss	N	HEC-RAS Multiplier
April	4	26%	4	
May	5	34%	4	66%
June	6	42%	2	58%
July	7	44%	1	50%
Aug	8	52%	1	48%
Sep	9	40%	1	50%
Oct	10	43%	4	59%
Nov	11	35%	1	
			18	





Source: Stability curve for local bed shear stress of 0.5 Pa, flowrate of 70 cfs, and Manning's roughness of 0.02.

Figure *A-1*

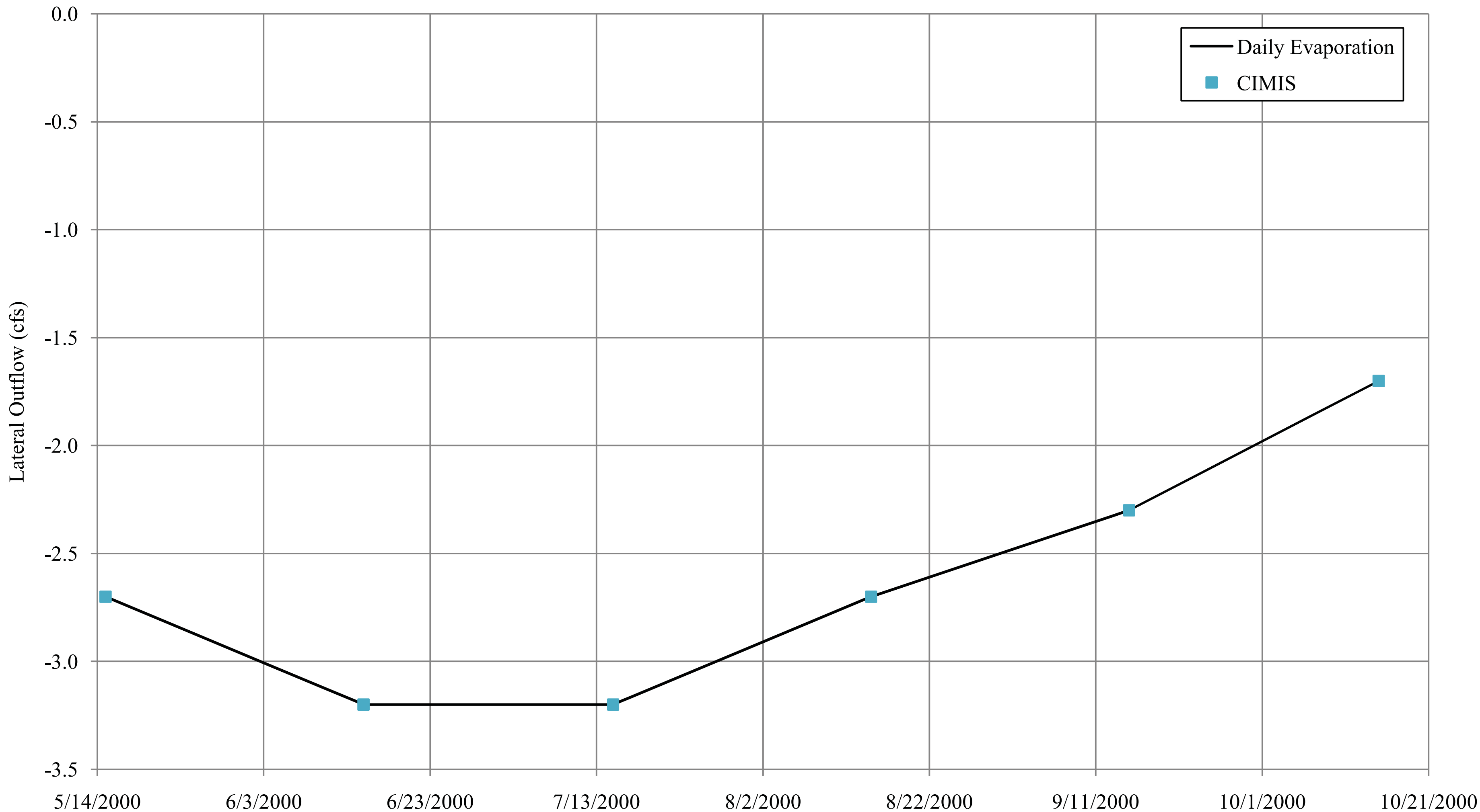
Russian River Estuary Outlet Channel Management Plan

Slope vs. Width Stability Plot

PWA Ref# 1958

PWA

j:\1958.01RREAMPOutletChannel\Task 4 Prelim geometry\matlab\solve_geometry.m



Notes: Daily evaporation rates for Russian River lagoon interpolated from CIMIS average monthly evapotranspiration statistics for Zone 1 (Coastal plains and heavy fog). Calculations assume lagoon surface area of 500 acres.

figure ***A-2***

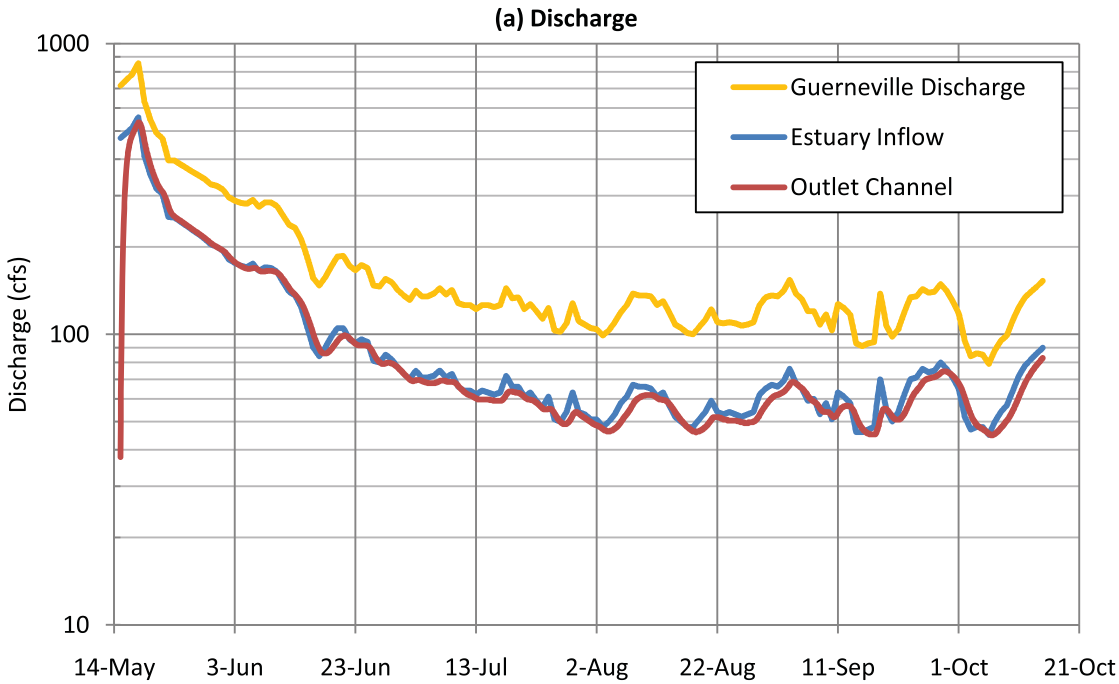
Russian River Estuary Outlet Channel Management Plan

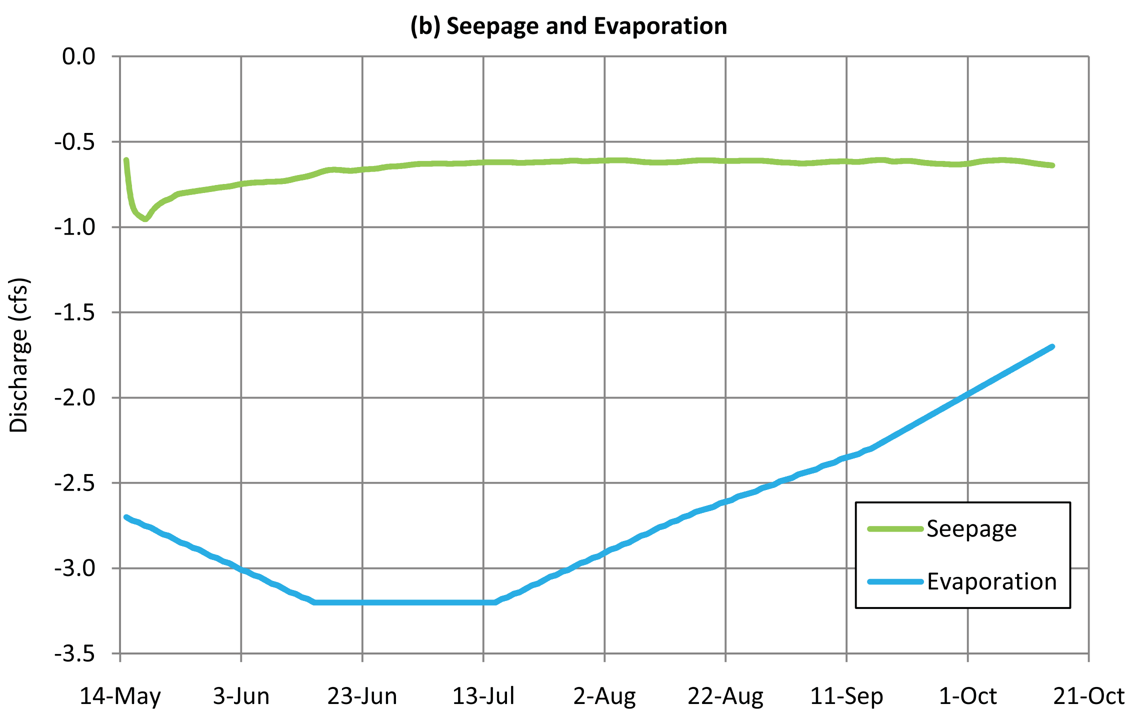
HEC-RAS model evaporation boundary condition

PWA Ref #: 1958.01

PWA

J:\1958.01RREAMPOutletChannel\Task 5 Hydrologic modeling\Data\Evaporation\1958.01_RRE_Evaporation_Worksheet.xls





Source: 2010 anticipated discharge at Guerneville and into lagoon calculated by scaling observed 2000 discharge at USGS gage #11467000 (Russian River near Guerneville, CA). Evaporation rates calculated from monthly climatological rates for CIMIS evapotranspiration zone 1 (California coast).

figure ***A-3***

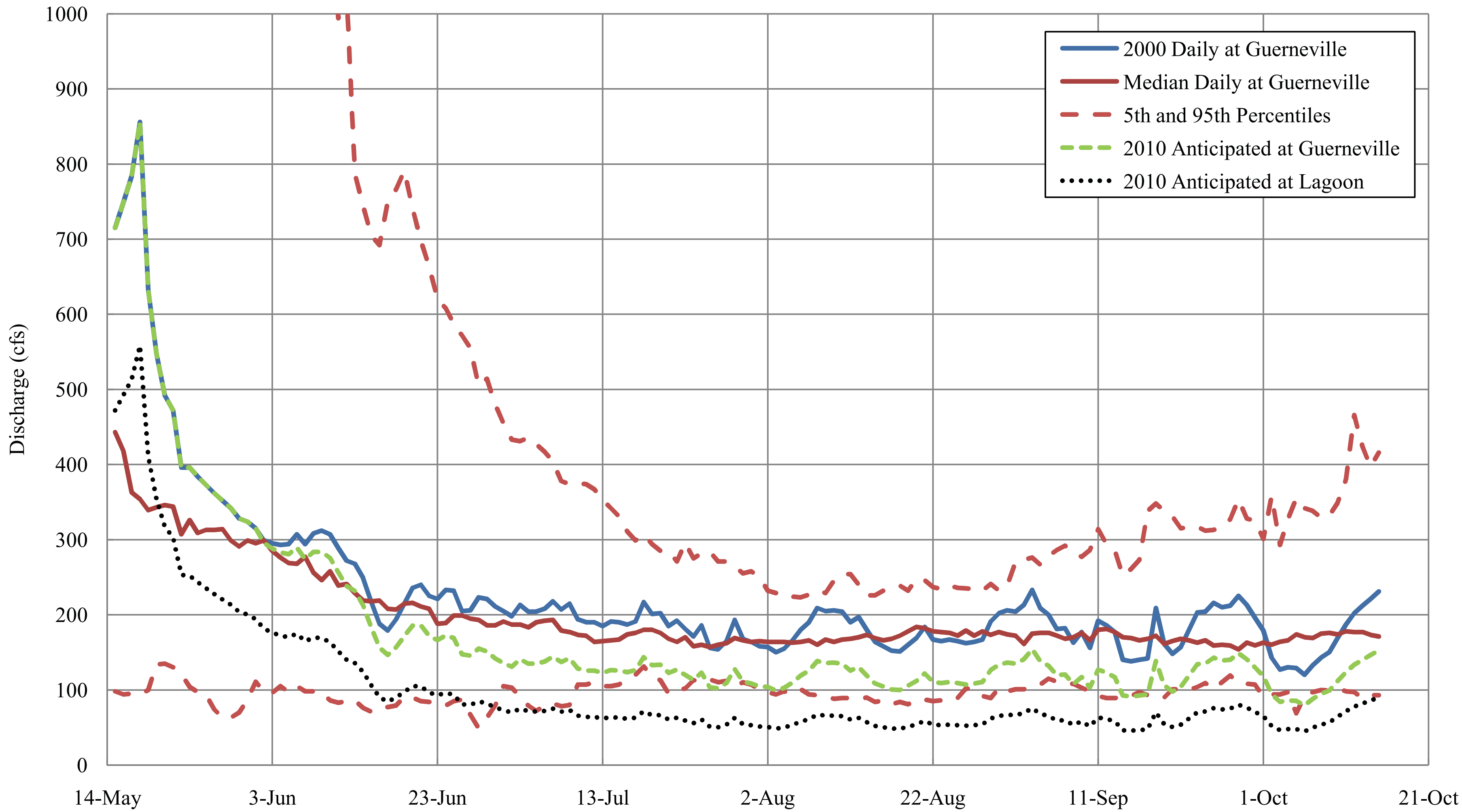
Russian River Estuary Outlet Channel Management Plan

Hydraulic Model Discharge - 2010 Anticipated Hydrology

PWA Ref#: 1958

PWA

58.01RREAMPOutletChannel\Task 5 Hydrologic modeling\HEC-RAS\Results\Figures\1958.01_2010_Rev_Anticipated_Operations.xls



Notes: Median daily discharge calculated from 1970-2008.
Source: USGS gage 11467000 (Russian River near Guerneville, CA). 2010 anticipated discharge at Guerneville calculated from 2000 discharge by scaling factor to obtain typical summertime flowrates of 120 cfs. 2010 anticipated lagoon inflow calculated based on calibrated seasonal losses from Guerneville to lagoon.

figure A-4

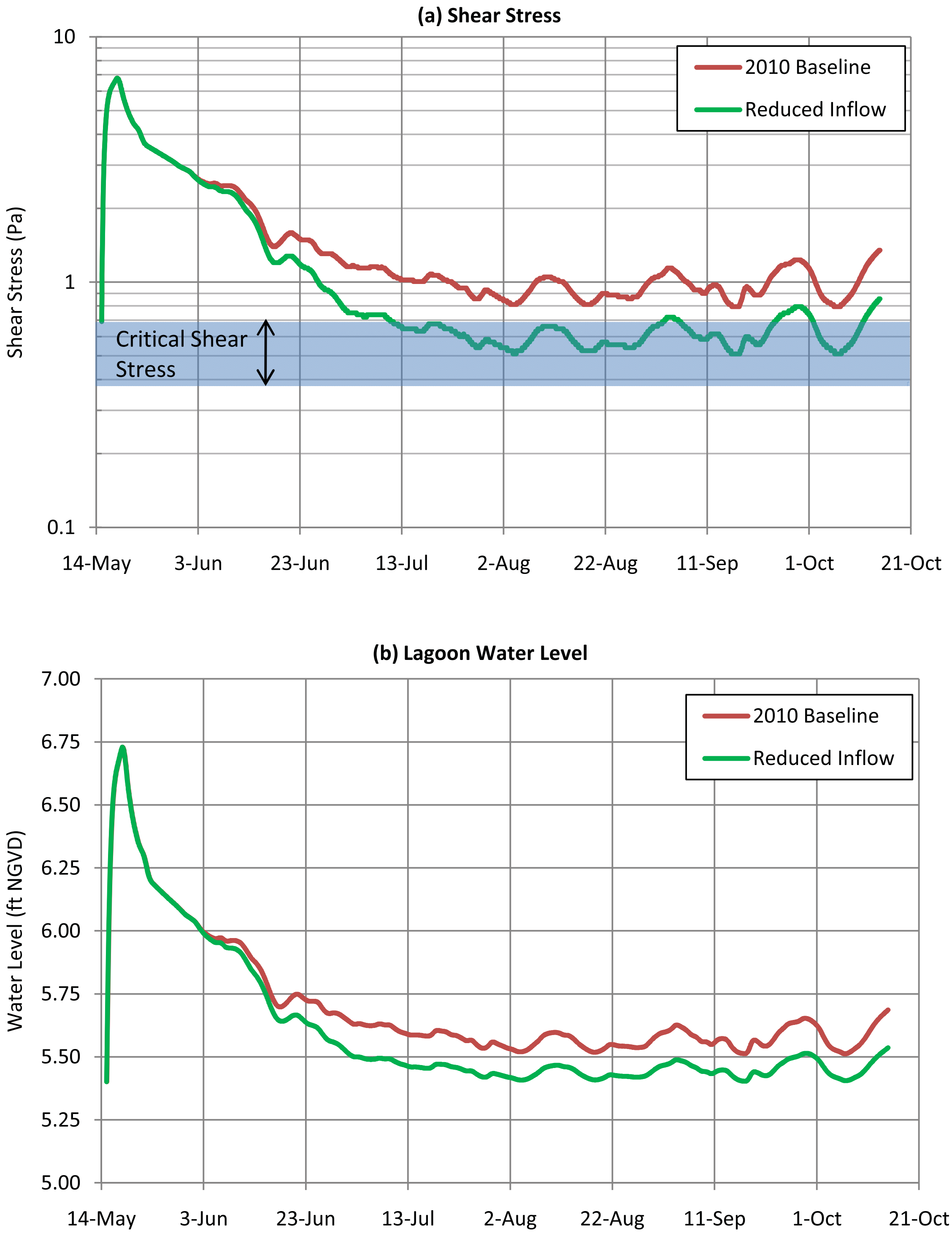
Russian River Estuary Outlet Channel Management Plan

Daily Russian River Discharge

PWA Ref #: 1958.01

PWA

J:\1958.01RREAMPOutletChannel\Task 5 Hydrologic modeling\Data\Streamflow\USGS_11467000_WaterYear_2000.xls



Notes: Baseline channel geometry: width=100 ft, length=300 ft, bed=5 ft NGVD, n = 0.02.
Source: HEC-RAS hydraulic model results for outlet channel.

figure ***A-5***

Russian River Estuary Outlet Channel Management Plan

Hydraulic Model Results - 2010 Anticipated Hydrology

PWA Ref#: 1958

PWA

1958.01_2010_Rev_Anticipated_Operations.xls

Attachment B. Hypothetical Implementation Scenario

The following hypothetical implementation scenario is presented to demonstrate how the outlet channel management plan may be implemented. The scenario is based on actual beach berm and ocean conditions observed at the estuary from June 30 to July 6, 2009.

This scenario is purely hypothetical and demonstrates how the adaptive management plan may be implemented based on historical conditions observed in 2009. Actual implementation of the plan may vary in terms of channel geometry, channel location and time required for implementation. The beach environment at the project site is highly dynamic so actual implementation of the plan will be evaluated on a case-by-case basis.

Wednesday, June 30th

Agency personnel have been tracking riverine and ocean conditions on a daily basis during the outlet channel management period. Several days ago, they identified a forecasted ocean swell event with the potential to close the estuary. When it arrives, this medium-sized (2-4 ft.) ocean swell, angled from the southwest, pushes sand into the tidal inlet cutting flow from the estuary to the ocean. Stage in the estuary at the time of closure is approximately 3.5 ft NGVD. Based on river discharge and the time of year, Agency personnel estimate that the estuary water level's rate of rise will be 0.5 ft/day.

Thursday, July 1st

Agency personnel visit the site to assess sandbar conditions. The outlet at the time of closure is just south of Haystack Rock, approximately 550 ft northwest of the jetty, with an alignment roughly perpendicular to the beach face. The preexisting channel slope is steep and would, therefore, be susceptible to scour and wave run-up. Agency decides that this is not the preferable alignment for the outlet channel. In effort to create a channel which has shallower gradient and less susceptible to ocean conditions, it is decided that the channel will be more ideally located to the north of Haystack Rock angled to the northwest. Agency staff collects measurements and limited survey data (e.g. elevation at low point of the berm) in the area to develop a design for the outlet channel.

[Note: If closure had occurred during the pupping season (March 15 – June 30), the site assessment would have included a survey for the presence of seal pups.]

Agency staff returns to their offices to develop a plan and design for the implementation of the outlet channel. Changes between the most recent monthly topographic data and current conditions are assessed using the time-lapse photography and today's survey data. If indicated, today's survey data and judgment may be used to revise the topographic data.

Stage in the estuary is now approximately 4.0 ft. NGVD. Observations from the Jenner gage are used to confirm the previously estimated rate of water surface rise of 0.5 ft/day. Based on current stage and this rate of water surface rise, implementation of the outlet channel is scheduled for Monday and Tuesday, July 5th and 6th so that stage in the estuary will be approximately 6.5 ft. NGVD after the outlet channel is completed.

A design is prepared using the best available topographic data. The outlet channel will be approximately 30 ft wide with 4:1 side slopes, 350 ft long to the mean high tide line, a channel bottom elevation at the inlet of approximately 6 ft NGVD, and a channel design flow depth at time implementation of approximately 0.5 ft. Channel will be aligned to the northwest with an approximate aspect of 35° with respect to the beach face. Estimated material to be excavated is approximated and confirmed to be less than 1,000 yd^3.

Agency staff prepares e-mail to management team to notify them of intention and schedule to construct the outlet channel, provide information regarding current conditions, and provide team with a design schematic according to the Communication Protocol procedure documented in Section 7.8.1 of the management plan. Please see Attachments B.1 and B.2 for an example of e-mail transmittal with attached design schematic. Agency biologists coordinate with Stewards of the Coast and Redwoods to schedule volunteers to assist with pre-, day of, and day after outlet channel creation pinniped monitoring.

Friday, July 2nd

Agency staff receives comments from management team on proposed approach. Time allowing, Agency responds, modifies the proposed approach as needed, and decides on the final approach.

Agency staff reviews rate of water surface rise in the lagoon to confirm that flooding is not expected before proposed management action.

Monday and Tuesday, July 5th and 6th

Agency maintenance crews arrive at the Goat Rock State Beach parking lot early in the morning to prepare for implementation. Agency biologist arrives to begin pinniped monitoring at least one hour prior to crews and coordinates with maintenance crew leader. Agency surveyors stake out designed channel and make corrections to alignment and channel geometry to account for potential changes in beach berm topography since last topographic survey. Outlet channel excavation is carried out according to Section 7.5 of the management plan and according to the plan submitted to the management team. Implementation is also conducted in accordance with the Agency's IHA for harbor seals, northern elephant seals and California sea lions which may be present at the site during excavation activities. Photos are taken to document all implementation activities, and following completion of the outlet channel Agency staff collects measurements of completed channel geometry, flow depth and location.

Wednesday, July 7th

Agency staff sends e-mail to management team to provide documentation of the completion of the outlet channel according to the Communication Protocol procedure documented in Section 7.8.2 of the management plan. Please see Attachment B.3 for an example of e-mail transmittal.

After implementation of the channel, the Agency will monitor performance of the outlet channel according to the monitoring program described in Section 7.7 of the management plan.

Attachment B.1: Sample Proposed Outlet Channel Implementation Email

Date: 7/1/10

Hello Outlet Channel Management Team -

The Russian River Estuary closed on 6/30/10. Sonoma Water plans to implement an outlet channel beginning at 7 am on July 5th and potentially extending to the afternoon of July 6th. Details of the proposed outlet channel are the following:

- Channel Width: 30 ft.
- Channel Length: 350 ft.
- Channel Bottom Elevation: 6 ft NGVD
- Design Flow Depth: 0.5 ft
- Location of Channel Inlet Centerline: 970 ft northwest of jetty
- Channel Alignment Aspect: 35 deg. with respect to beach face
- Estimated Estuary WSEL at Time of Completion: 6.5 ft
- Existing Beach Berm Crest Elevation: 10 ft NGVD
- Existing Beach Berm Width: 300 ft
- Excavation Equipment: 1 Excavator, 1 Bulldozer

Attached is a design drawing developed using the most recent topographical survey (6/30/10). Due to the highly dynamic nature of conditions at the site, actual topography at the time of implementation may vary. Implementation of the channel may differ from design in order to account for changed topography.

Current and predicted conditions at the site are the following:

- **River and Estuary:**
  - Russian River near Guerneville Flow (USGS 11467000): 120 cfs
  - Predicted 72 hour precipitation: 0 in.
- **Ocean:**
  - Approximate rate of estuary water surface rise: 0.5 ft/day
  - Current Swell Height and Direction: 5.8 ft @ 10 sec. @ 320 deg.
  - 7/5/10 Predicted Mean Swell Height and Direction: 2.5 ft @ 15 sec. @ 200 deg.

No seal pups were observed on the beach.

For updates on conditions please visit the following URL:

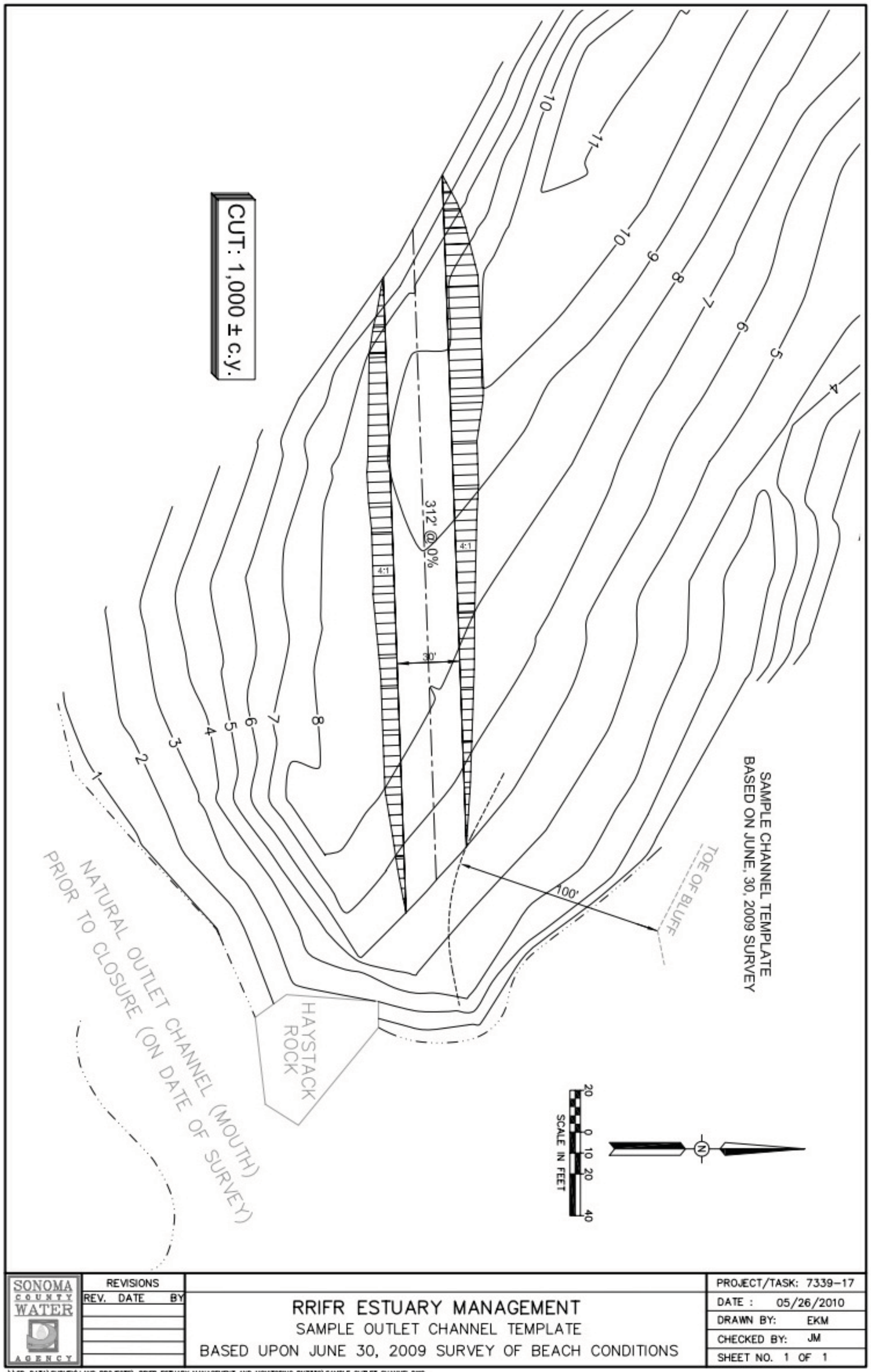
http://www.bml.ucdavis.edu/boon/russianriver

If you have any comments to the proposed implementation plan please provide comments no later than 7/2/10, 5 pm. Should you have any questions or concerns please contact me or Jessica Martini-Lamb at jessicam@scwa.ca.gov, 707-547-1903 (office), 707-322-8177 (mobile).

Sincerely,

Chris Delaney, P.E.
Agency Engineer
Sonoma Water
707-547-1946 (office)
707-975-5606 (mobile)

Attachment B.2: Sample Proposed Outlet Channel Design Schematic



\\SD-DATA\SURVEY\LAND PROJECTS\ RRIFR ESTUARY MANAGEMENT AND MONITORING PN7339\SAMPLE OUTLET CHANNEL.DWG

Attachment B.3: Sample Proposed Outlet Channel Implementation Email

Date: 7/8/10

Hello Outlet Channel Management Team -

The Russian River Estuary closed on 6/30/10. Sonoma Water implemented an outlet channel beginning at 7 am on July 5th and extending to the afternoon of July 6th. Details of the implemented outlet channel are the following:

- Channel Width: 30 ft.
- Channel Length: 350 ft.
- Channel Bottom Elevation: 6 ft NGVD
- Flow Depth: 0.7 ft
- Location of Channel Inlet Centerline: 970 ft northwest of jetty
- Channel Alignment Aspect: 35 deg. with respect to beach face
- Estuary WSEL at Time of Completion: 6.7 ft
- Existing Beach Berm Crest Elevation: 10.2 ft NGVD
- Existing Beach Berm Width: 300 ft
- Excavation Equipment: 1 Excavator, 1 Bulldozer

Attached are photographs of the beach before, during, and after the outlet channel implementation, as well as projected estuary water levels and beach crest elevation figures.

Current and predicted conditions at the site are the following:

- **River and Estuary:**
  - Russian River near Guerneville Flow (USGS 11467000): 115 cfs
  - Predicted 72 hour precipitation: 0 in.
- **Ocean:**
  - Current Swell Height and Direction: 2.7 ft @ 14 sec. @ 200 deg.
  - 7/10/10 Predicted Mean Swell Height and Direction: 2.4 ft @ 12 sec. @ 200 deg.

No seal pups were observed on the beach.

For updates on conditions please visit the following URL:

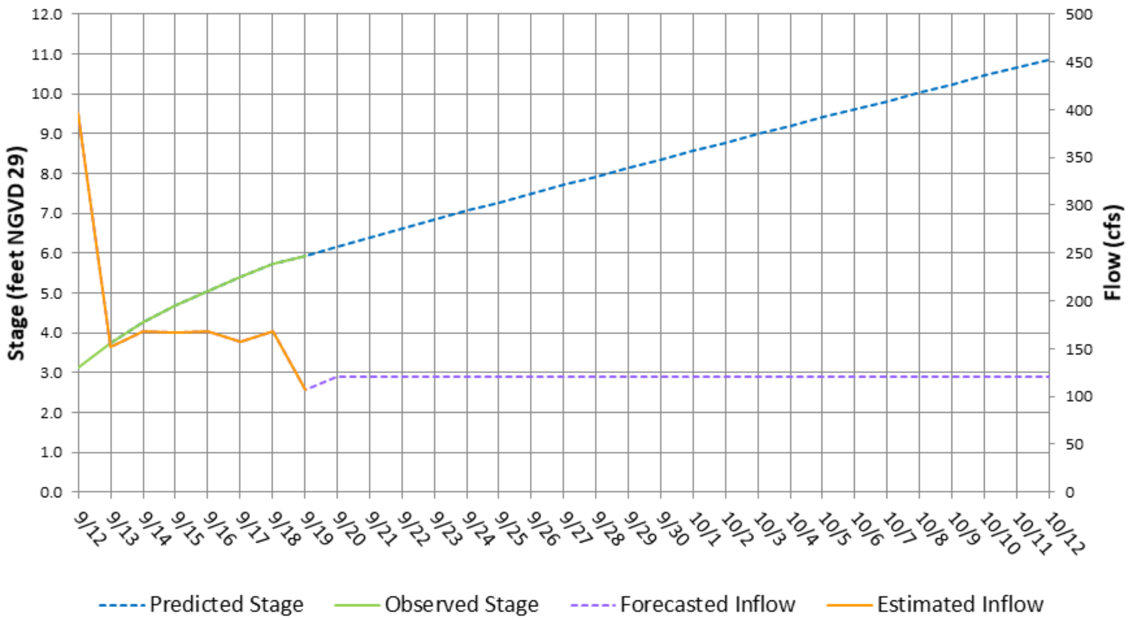
http://www.bml.ucdavis.edu/boon/russianriver

If you have any comments on the implemented channel, please provide comments no later than 7/12/10, 5 pm. Should you have any questions or concerns please contact me or Jessica Martini-Lamb at jessicam@scwa.ca.gov, 707-547-1903 (office), 707-322-8177 (mobile).

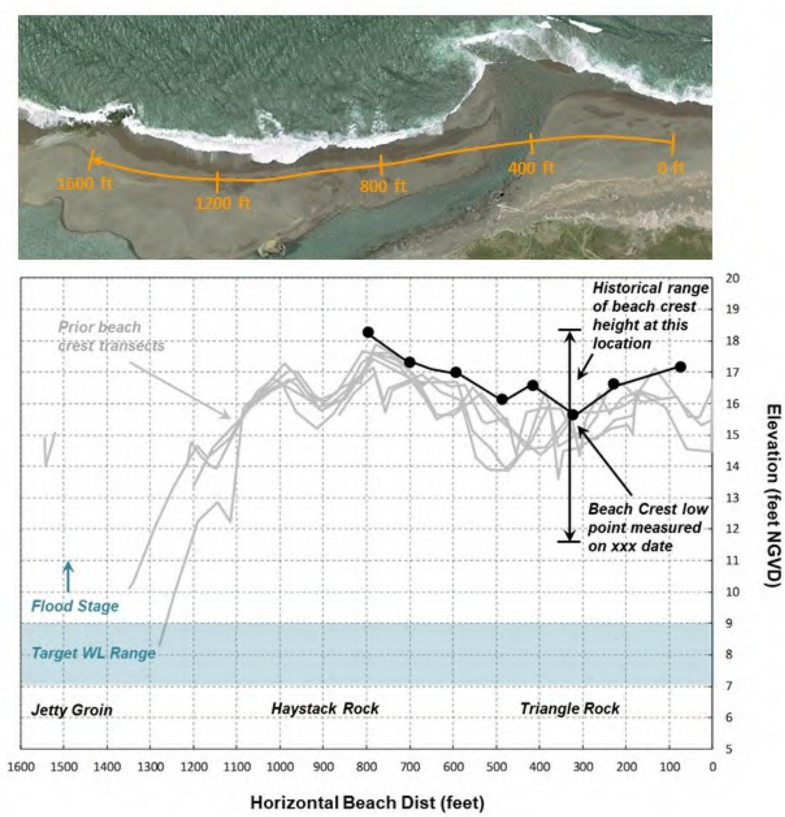
Sincerely,

Chris Delaney, P.E.
Agency Engineer
Sonoma Water
707-547-1946 (office)
707-975-5606 (mobile)

Estuary Water Level Projection (EXAMPLE)



Beach Crest Elevation Profile (EXAMPLE)



Attachment C. Summary of Land Use Permits

Russian River Estuary Management Project

(Updated January 22, 2020)

List of Valid Permits and Agreements for the Russian River Estuary Management Project

Page	Agency	Permit No.	Expiration
C-2	California Department of Fish and Wildlife	Lake and Streambed Alteration Agreement (1600-2010-0380-R3)	December 31, 2020
C-6	California Regional Water Quality Control Board, North Coast Region	Section 401 Water Certification (1B10122WNSO)	December 21, 2023
C-12	California Coastal Commission	Coastal Development Permit 2-12-004	August 15, 2016 (new CDP request in review; emergency CDP requested as needed)
C-21	US Army Corps of Engineers, San Francisco District	Section 404 & Section 10, Individual Permit (2004- 285610N)	December 31, 2023
C-22	California Environmental Quality Act		None
C-22	California State Lands Commission	General Lease, Public Agency Use (PRC 7918.9)	December 31, 2023
C-25	California Department of Parks and Recreation	Right of Entry Temporary Use Permit	November 5, 2019 (extension requested)
C-32	California Department of Parks and Recreation	Collections Permit	April 2, 2018
C-33	US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service	Letter of Authorization Incidental Harassment Authorization	April 20, 2022

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Department of Fish and Wildlife Lake and Streambed Alteration Agreement (III-1176-96) - November 6, 1996 Agreement Renewal – November 14, 2001 Agreement Extension – October 17, 2002 Agreement Renewal – November 13, 2003 Agreement Renewal – September 30, 2005 Agreement Extension – December 7, 2009 Agreement Amendment – December 13, 2009 Lake and Streambed Alteration Agreement (1600-2010-0380-R3) - September 8, 2011	**1. Administrative Measures** Permittee shall meet each administrative requirement described below. 1.1 Documentation at Project Site. Permittee shall make the Agreement, any extensions and amendments to the Agreement, and all related notification materials and California Environmental Quality Act (CEQA) documents, readily available at the project site at all times and shall be presented to DFG personnel, or personnel from another state, federal, or local agency upon request. 1.2 Providing Agreement to Persons at Project Site. Permittee shall provide copies of the Agreement and any extensions and amendments to the Agreement to all persons who will be working on the project at the project site on behalf of Permittee, including but not limited to contractors, subcontractors, inspectors, and monitors. 1.3 Notification of Conflicting Provisions. Permittee shall notify DFG if Permittee determines or learns that a provision in the Agreement might conflict with a provision imposed on the project by another local, state, or federal agency. In that event, DFG shall contact Permittee to resolve any conflict. 1.4 Project Site Entry. Permittee agrees that DFG personnel may enter the project site at any time to verify compliance with the Agreement. 1.5 Work Period Extension. If the Permittee needs more time to complete the authorized activity, the work period may be extended on a day-to-day basis by contacting the DFG representative found within the Contact Information section of this Agreement.	May 1: Adaptive Management Annual Report

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Department of Fish and Wildlife (continued) Agreement Extension - February 25, 2016 Expiration - December 31, 2020	1.6 To the extent that any provisions of this Agreement provide for activities that require the Permittee to traverse another owner's property, such provisions are agreed to with the understanding that the Permittee possesses the legal right to so traverse. In the absence of such right, any such provision is void. 1.7 If, in the opinion of the DFG, conditions arise, or change, in such a manner as to be considered deleterious to the stream or wildlife, operations shall cease until corrective measures approved by the DFG are taken. **2. Avoidance and Minimization Measures** To avoid or minimize adverse impacts to fish and wildlife resources identified above, Permittee shall implement each measure listed below. 2.1 In each year that this Agreement is in effect, the Permittee shall provide DFG with an annual lagoon outlet channel adaptive management plan by April 15. 2.2 No excavation of the lagoon outlet channel may occur until DFG has reviewed and approved the annual lagoon outlet channel adaptive management plan. DFG shall provide written comments or approval by May 15 of each year this agreement is in effect. 2.3 The project site has been identified as an area that is potentially inhabited by steelhead trout (Federal Threatened), chinook salmon (Federal Threatened), coho salmon (Federal and State Endangered) and green sturgeon (Federal Threatened). This agreement does not authorize the take, or incidental take of any State or Federal listed threatened or endangered listed species. The Permittee is required, as prescribed in the state or federal endangered species acts, to consult with the appropriate agency prior to commencement of the project. Any unauthorized take of such listed species may result in prosecution. 2.4 To avoid impacts on aquatic and terrestrial species within the immediate work area, prior to implementation of an outlet channel, a qualified biologist will conduct a preconstruction survey to ensure no special-status species are occupying the site. If special-status species are observed within the project site or immediate surroundings, these areas will be avoided until the animal(s) has (have) vacated the area, and/or the animal(s) have been relocated out of the project area by a qualified biologist, upon approval by the regulatory agencies. In addition, the site will be surveyed	

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Department of Fish and Wildlife (continued)	periodically during construction to ensure that no special-status species are being impacted by construction activities. 2.5 The project biologist will conduct a preconstruction training session for construction crew members. The training will include a discussion of sensitive biological resources within the project area and the potential presence of special-status species, special-status species' habitats, protection measures to ensure species are not impacted by project activities and project boundaries. 2.6 Any material, which could be hazardous to aquatic life and enters a stream or lake (i.e., a piece of equipment tipping-over in a stream and dumping oil, fuel or hydraulic fluid), shall be removed immediately and the DFG shall be notified within 24 hours. 2.7 Any hazardous or toxic materials that could be deleterious to aquatic life that could be washed into State waters or its tributaries shall be contained in water tight container or removed from the project site. 2.8 The Permittee/contractor shall not dump any litter or construction debris within the riparian/stream zone. All such debris and waste shall be picked up daily and disposed of at an appropriate site. 2.9 Refueling of construction equipment and vehicles may not occur within 300 feet of any water body, or anywhere that spilled fuel could drain to a water body. Tarps or a similar material shall be placed underneath the construction equipment and vehicles, when refueling, to capture incidental spillage of fuels. 2.10 Any equipment or vehicles driven and/or operated within or adjacent to the stream/lake shall be checked and maintained daily to prevent leaks of materials that if introduced to water could be deleterious to aquatic life, wildlife, or riparian habitat. 2.11 Any equipment or vehicles driven and/or operated within or adjacent to the stream/lake shall be cleaned of all external oil, grease, and materials that, if introduced to water, could be deleterious to aquatic life, wildlife or riparian habitat.	

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Department of Fish and Wildlife (continued)	**3. Reporting Measures** Permittee shall meet each reporting requirement described below. 3.1 The Permittee shall notify DFG a minimum of 24 hours in advance of implementing the outlet channel management plan during the lagoon management period (May 15 to October 15). All communications shall be made in the method prescribed within the communication protocol section of the DFG approved annual lagoon outlet channel adaptive management plan. 3.2 The Permittee shall submit an annual report detailing that year's outlet channel management activities. This report may be submitted as a section of the annual lagoon outlet channel adaptive management plan required by May 1 of each year this agreement is in effect.	

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Regional Water Quality Control Board, North Coast Region Section 401 Water Certification (1B04001WNSO) - May 6, 2004 Amendment Extension – October 14, 2009 Amendment Extension – January 20, 2011 Amendment Extension – January 5, 2012 Amendment Extension – December 11, 2012 Amendment Extension – December 16, 2013 Expiration - December 31, 2014 Section 401 Water Certification (WDID 1B10122WNSO) - May 14, 2014 Expiration – May 14, 2019	**All conditions of this order apply to the applicant (and all their employees) and all contractors (and their employees), sub-contractors (and their employees), and any other entity or agency that performs activities or work on the project as related to this water quality certification.** 1. If monitoring results identify potentially dangerous water quality conditions, the applicant will promptly consult with Regional Water Board staff in addition to staff from other agencies identified in the application, including the National Marine Fisheries Service, the California Department of Fish and Wildlife, and California State Parks, with the intent of examining possible resolution through management action. Potentially dangerous conditions may include, but are not limited to, high bacterial levels, the presence of cyanobacteria, or other conditions that could affect human health. 2. The mitigation measures detailed in the Environmental Impact Report (SCH 2010052024) are hereby incorporated by reference and are conditions of approval of this certification. Notwithstanding any more specific conditions in this certification, the applicant shall comply with all mitigation measures identified in the Environmental Impact Report that are within the Regional Water Board's jurisdiction. 3. The annual fee amount for this Clean Water Act Section 401 Water Quality Certification shall be in accordance with the current dredge and fill fee schedule, per Division 3, Chapter 9, Article 1, section 2200(a)(3) of title 23 of the California Code of Regulations, based on the maximum dredge amount of 49,000 cubic yards proposed for the first year, and each year following. This fee shall be submitted prior to authorization of that year's management period and shall be approved by amendment to this Order by signature of the Executive Officer. The fee payment shall indicate the WDID number, and which season it is for. If the entire proposed beach dredging work for that year is not completed during that management season, the fee for the remaining amount of beach dredging for that year shall be applicable to the remaining management season(s), until the remaining amount of the fee is exhausted. In the case the remaining amount of the fee is exhausted within the five year term of this Order, the appropriate fee amount shall be paid at that point to be based on the actual volume of beach dredging performed, and/or proposed to be performed. There shall be no fee refunded to the Applicant if at the expiration of this Order there is any unapplied fee. ~~4. A draft water quality monitoring plan was submitted on December 23, 2013, which includes datasonde deployment, nutrient/bacterial/algal sampling, and sediment chemistry and benthic community indices. Regional Water Board staff issued a letter to SCWA on April 1, 2014, detailing the Regional Water Board's requirements for a water quality monitoring plan. A final water quality monitoring and reporting plan (WQMRP) must be submitted to the Regional Water Board by July 15, 2014, for approval by the Executive Officer. The WQMRP must include the following:~~ ~~a. Datasonde deployment – Since the size of estuary pool will increase at times under the new estuary management, it is expected that there will be an increase in shallow over-bank habitat along the new shoreline. Diel water temperature, dissolved oxygen, and pH levels in these expanded littoral regions should be evaluated for impacts to the COLD beneficial use during target water surface elevations. Sampling will~~	March 31: Draft Annual Adaptive Management Plan

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Regional Water Quality Control Board, North Coast Region (continued) Amendment to Condition 4, Section 401 Water Certification (WDID 1B10122WNSO) – August 2, 2016 Amendment Extension – December 21, 2023	consist of vertical profiles in shallow water areas to characterize lagoon backwater areas. b. Stage measurements – The river reach near Monte Rio is expected to be affected by the backwater effects under the new estuary management. An additional water level measurement station should be placed in this river reach to evaluate when backwater effect on water quality conditions at stations sampled in the reach. c. Bacteria Sampling i. Duncans Mills and Bridgehaven stations should be replaced with public beach access locations at Patterson Point Preserve and Vacation Beach. ii. The monitoring plan should specify that the USEPA (2012) Beach Action Value for *E .coli* bacteria concentration (i.e., 235 MPN/100mL) will be used to determine if sampling should proceed the next day. iii. Water samples should be diluted when higher concentrations of bacteria are expected so that the results are not censored. iv. Assessment of the human-host *Bacteroides* bacteria levels should also be conducted to determine if the new estuary management increases a threat to public health from human sources. Quantifiable levels of human-host *Bacteroides* bacteria indicate recently deposited human waste. The assessment should be conducted at the public recreation beaches (i.e., Monte Rio, Patterson Point Preserve, and Vacation Beach) during the lagoon management period when the estuary is closed and the beaches are inundated. The Sonoma County Public Health Laboratory (as well as other labs) has the capability to quantify human-host *Bacteroides* bacteria that indicate recently deposited human waste. d. Algal sampling – Since the size of estuary pool will increase at times under the new estuary management, it is expected that there will be an increase in shallow over-bank habitat along the new shoreline. The larger areas of shallow habitat will provide additional habitat substrate for periphytic algal mats. The spatial extent of these algal mats and the resulting impact under the new estuary management should be evaluated. In addition, an evaluation of possible cyanobacteria within the periphytic algal mats should be conducted, and if found, the possibility of cyanotoxins should be evaluated. e. A Quality Assurance Project Plan (QAPP) needs to be submitted with the final WQMRP (i.e., EPA/240/B-01/003). Amendment to Condition 4 (August 2, 2016) In response to your request, this letter serves as an amendment to Condition 4 of the Certification, allowing a modification of the Estuary Plan described in the Certification as outlined below: 4. A draft water quality monitoring plan was submitted on December 23, 2013, which includes datasonde deployment, nutrient/bacterial/algal sampling, and sediment chemistry and benthic community indices. Regional Water Board staff issued a letter to SCWA on April 1, 2014, detailing the Regional Water Board's requirements for a water quality monitoring plan. A final water quality monitoring and reporting plan (WQMRP) was submitted to the Regional Water Board by July 15, 2014, for approval by the Executive Officer. The WQMRP was revised to incorporate monitoring requirements of the Temporary Urgent Change	

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Regional Water Quality Control Board, North Coast Region (continued)	Order issued by the State Water Resources Control Board. The Applicant shall implement the final approved *Water Quality Monitoring Plan for the Russian River Estuary Management Project,* submitted by SCWA on June 30, 2016, including the addition of *Appendices G and E.* I hereby issue an amendment to the project description in Condition 4 of the Certification for the Sonoma County Water Agency Russian River Estuary Management Project (WDID No. 1B10122WNSO), certifying that the remainder of the Water Quality Certification findings and conditions of the May 14, 2014, Order are still valid. 5. This certification action is subject to modification or revocation upon administrative or judicial review, including review and amendment pursuant to Water Code section 13330 and title 23, California Code of Regulations, section 3867. 6. This certification action is not intended and shall not be construed to apply to any discharge from any activity involving a hydroelectric facility requiring a Federal Energy Regulatory Commission (FERC) license or an amendment to a FERC license unless the pertinent certification application was filed pursuant to title 23, California Code of Regulations, section 3855, subdivision (b) and the application specifically identified that a FERC license or amendment to a FERC license for a hydroelectric facility was being sought. 7. The validity of this certification is conditioned upon total payment of any fee required under title 23, California Code of Regulations, section 3833, and owed by the applicant. 8. Regional Water Board staff shall be notified in writing at least five working days, when conditions allow, prior to the commencement of ground disturbing activities, or as soon as possible prior to or upon initiating ground disturbing activities, with details regarding the construction schedule, in order to allow staff to be present onsite during construction, and to answer any public inquiries that may arise regarding the project. 9. No debris, soil, silt, sand, bar, slash, sawdust, cement or concrete washings, oil or petroleum products, or other organic or earthen material from any construction or associated activity of whatever nature, other than that authorized by this Order, shall be allowed to enter into or be placed where it may be washed by rainfall into waters of the state. When operations are completed, any excess material or debris shall be removed from the work area. 10. All activities and best management practices (BMPs) shall be implemented according to the submitted application and the conditions in this certification. BMPs for erosion, sediment, and turbidity control shall be implemented and in place at commencement of, during, and after any ground clearing activities or any other project activities that could result in erosion or sediment discharges to surface water.	

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Regional Water Quality Control Board, North Coast Region (continued)	11. In accordance with state and federal laws and regulations, the applicant is liable and responsible for the proper disposal for project-generated waste. When handling, transporting, and disposing of project-generated waste, the applicant and their contractors shall comply with all applicable state and federal laws and regulations. When disposing of project-generated waste offsite, the applicant and its contractors shall: a. Make appropriate arrangements to dispose of the material, including, but not limited to, property owner agreements, permits, licenses, and environmental clearances; b. Obtain satisfactory evidence that the work in 11.a has been completed; and c. Obtain a dated, signed manifest from the disposal site owner, or authorized representative, that identifies the type and quantity of disposed waste. 12. The applicant shall prioritize the use of wildlife-friendly, biodegradable (not photo- degradable) erosion control products wherever feasible. The applicant shall not use or allow the use of erosion control products that contain synthetic materials within waters of the United States or waters of the state at any time. The applicant shall not use or allow the use of erosion control products that contain synthetic netting for permanent erosion control (i.e. erosion control materials to be left in place for two years or more after the completion date of the project). If the applicant finds that erosion control netting or products have entrapped or harmed wildlife, personnel shall remove the netting or product and replace it with wildlife-friendly biodegradable products. The applicant shall request approval from the Regional Water Board if an exception from this requirement is needed for a specific location. 13. Disturbance or removal of existing vegetation shall not exceed the minimum necessary to complete the project. 14. If, at any time, an unauthorized discharge to surface water (including wetlands, lakes, rivers, or streams) occurs, or any water quality problem arises, the associated project activities shall cease immediately until adequate BMPs are implemented including stopping work. The Regional Water Board shall be notified promptly and in no case more than 24 hours after the unauthorized discharge or water quality problem arises. 15. Fueling, lubrication, maintenance, storage, and staging of vehicles and equipment shall not result in a discharge or threatened discharge to any waters of the state including dry portions of the shoreline. At no time shall the applicant or its contractors allow use of any vehicle or equipment that leaks any substance that may impact water quality. 16. Prior to implementing any change to the project that may have a significant or material effect on the findings, conclusions, or conditions of this Order, the applicant shall obtain the written approval of the Regional Water Board executive officer. If the Regional Water Board is not notified of a significant alteration to the project, it will be considered a violation of this Order, and the applicant may be subject to Regional Water Board enforcement actions.	

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Regional Water Quality Control Board, North Coast Region (continued)	17. The Regional Water Board may add to or modify the conditions of this Order, as appropriate, to implement any new or revised water quality standards and implementation plans adopted and approved pursuant to the Porter-Cologne Water Quality Control Act or section 303 of the Clean Water Act. 18. The applicant shall provide Regional Water Board staff access to the project site to document compliance with this certification. 19. In the event of any violation or threatened violation of the conditions of this Order, the violation or threatened violation shall be subject to any remedies, penalties, process or sanctions as provided for under applicable state or federal law. For the purposes of section 401 (d) of the Clean Water Act, the applicability of any state law authorizing remedies, penalties, process or sanctions for the violation or threatened violation constitutes a limitation necessary to assure compliance with the water quality standards and other pertinent requirements incorporated into this Order. In response to a suspected violation of any condition of this certification, the State Water Board may require the holder of any federal permit or license subject to this Order to furnish, under penalty of perjury, any technical or monitoring reports the State Water Board deems appropriate, provided that the burden, including costs, of the reports shall bear a reasonable relationship to the need for the reports and the benefits to be obtained from the reports. In response to any violation of the conditions of this Order, the Regional Water Board may add to or modify the conditions of this Order as appropriate to ensure compliance. 20. The applicant shall provide a copy of this Order and State Water Board Order 2003- 0017-DWQ to any contractor(s), subcontractor(s), and utility company(ies) conducting work on the project, and shall require that copies remain in their possession at the work site. The applicant shall be responsible for ensuring that all work conducted by its contractor(s), subcontractor(s), and utility companies is performed in accordance with the information provided by the applicant to the Regional Water Board. 21. In the event of any change in control of ownership of land presently owned or controlled by the Applicant, the Applicant shall notify the successor-in-interest of the existence of this Order by letter and shall forward a copy of the letter to the Regional Water Board at the above address. To discharge dredged or fill material under this Order, the successor-in-interest must send to the Regional Water Board Executive Officer a written request for transfer of the Order. The request must contain the requesting entity's full legal name, the state of incorporation if a corporation, and the address and telephone number of the person(s) responsible for contact with the Regional Water Board. The request must also describe any changes to the Project proposed by the successor- in-interest or confirm that the successor-in-interest intends to implement the Project as described in this Order. Except as may be modified by any preceding conditions, all certification actions are contingent on: a) the discharge being limited to and all proposed mitigation	

Agency / Permit / Expiration	Special Conditions	Report Due Date
	being completed in strict compliance with the Applicant's Project description, and b) compliance with all applicable requirements of the Water Quality Control Plan for the North Coast Region (Basin Plan). 22. Except as may be modified by any preceding conditions, all certification actions are contingent on a) the discharge being limited to and all proposed mitigation being completed in strict compliance with the applicant's project description, and b) compliance with all applicable requirements of the Water Quality Control Plan for the North Coast Region (Basin Plan). 23. The authorization of this certification for any dredge and fill activities expires on May 14, 2019. Conditions and monitoring requirements outlined in this Order are not subject to the expiration date outlined above, and remain in full effect and are enforceable.	

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Coastal Commission Coastal Development Permit (CDP 2-01-033) – May 15, 2002 Amend. Extension (2-01-033-1A) – June 14, 2010 Monthly Extensions (January - June 2011) Emergency CDP (2-12-002-G) –January 9, 2012 New CDP Application Submitted – January 23, 2012 Application deemed complete – July 9, 2012 Emergency CDP (2-13-005-G) –February 21, 2013 Emergency CDP (2-13-005-G) –February 21, 2013 Emergency CDP (G-2-13-0221) –October 15, 2013 CDP (2-12-004) February 26, 2014	**<u>SPECIAL CONDITIONS:</u>** This permit is granted subject to the following special conditions: 1. **Approved Project.** Subject to these standard and special conditions (including modifications to the project, mitigation measures, and/or the project plans required by them), this CDP authorizes implementation of the Russian River Estuary Management Project and related jetty study, including: 1) a new program that would implement a lagoon outlet channel during the lagoon management season, from May 15th to October 15th, 2) sand bar breaching from October 16th to May 14th and as necessary from May 15th to October 15th to minimize flooding, and 3) a geotechnical evaluation of a relic jetty at the river mouth, all as more specifically described in the proposed project materials (see Appendices A and B and Exhibits 2, 3, and 7). 2. **Construction Plan.** PRIOR TO ISSUANCE OF THE COASTAL DEVELOPMENT PERMIT, the Permittee shall submit two copies of a Construction Plan (the Plan) to the Executive Director for review and written approval. The Plan shall, at a minimum, include the following: a. **Construction Areas.** The Construction Plan shall identify the specific location of all construction areas, all staging areas, and all construction access corridors in site plan view. All such areas within which construction activities and/or staging are to take place shall be	August 15: Annual Report for CDP (2-12-004)

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Coastal Commission (continued) CDP Extension Request (2-12-004) April 15, 2016 3-yr Extension approved - June 15, 2016 Expiration-August 15, 2019 New CDP Requested – June 6, 2019 Emergency CDP – November 26, 2019 (issued but not used) Emergency CDP (G-2-20-0002) – January 6, 2020	minimized to the maximum extent feasible in order to have the least impact on public access and adjacent biological resources as well as to maintain best management practices (BMPs) to protect coastal dune and marine resources on-site and in the surrounding area, including by using offsite areas for staging and storing construction equipment and materials, as feasible. In addition, all construction areas shall avoid sensitive dune plant species, including Tidestrom's lupine, as required in subsection (c), below. The placement of the piezometers shall occur no closer than fifty feet from the sensitive dune plant habitat (as outlined in Exhibit 3 – Jetty Study Location, Detail, and Photos). Construction (including but not limited to construction activities, and materials and/or equipment storage) is prohibited outside of the defined construction, staging, and storage areas. **b. Construction Methods and Timing.** The plan shall specify the construction methods to be used, including all methods to be used to keep the construction areas separated from sensitive coastal dune and marine resources and public recreational use areas (including using unobtrusive fencing (or equivalent measures) to delineate construction areas). All work shall take place during daylight hours and all lighting of the beach, river, and dune habitat is prohibited. **c. Dune Plants Avoidance.** The plan shall include methods to avoid impacts to sensitive dune plant species, including Tidestrom's lupine. All sensitive species shall be avoided during construction, including through locating the defined construction areas required in subsection (a) away from such species (as generally depicted on Exhibit 3 – Jetty Study Location, Detail, and Photos). Furthermore, the sensitive dune plant habitat shall be fenced off during the two weeks wherein the instruments are being placed and the seismic work is occurring. For the duration of the project, markers identifying the boundaries of the sensitive dune plant habitat shall remain in place. A monitor shall be on site during instrument placement, testing, and removal to ensure that project activities occur within the defined construction, staging, and storage areas and outside of the sensitive dune plant habitat. **d. Best Management Practices.** The plan shall clearly identify all BMPs to be implemented during construction and their location. Contractors shall ensure that work crews are carefully briefed on the importance of observing the appropriate precautions and reporting and cleanup of accidental spills. Construction contracts shall contain appropriate penalty provisions, sufficient to offset the cost of retrieving or cleaning up improperly contained foreign materials. **e. Construction and Instrument Noise Level Restrictions.** Noise generated by any instrument driving or hammer strike activities shall be minimized to the maximum extent practicable. Underwater noise shall not exceed an accumulated 187 dB SEL as measured 10 meters from the source. At no time shall peak dB SEL rise above 206 at 10 meters from the source. Furthermore, the Applicants shall limit activities at the site that involve the use of heavy equipment to between local sunrise to local sunset. **f. Construction Site Documents.** The plan shall provide that copies of the signed CDP and the approved Construction Plan be maintained in a conspicuous location at the construction job site	

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Coastal Commission (continued)	at all times, and that such copies are available for public review on request. All persons involved with the construction shall be briefed on the content and meaning of the coastal development permit and the approved Construction Plan, and the public review requirements applicable to them, prior to commencement of construction. g. **Construction Coordinator.** The plan shall provide that a construction coordinator be designated to be contacted during construction should questions arise regarding the construction (in case of both regular inquiries and emergencies), and that their contact information (i.e., address, phone numbers, etc.) including, at a minimum, a telephone number that will be made available 24 hours a day for the duration of construction, is conspicuously posted at the job site where such contact information is readily visible from public viewing areas, along with indication that the construction coordinator should be contacted in the case of questions regarding the construction (in case of both regular inquiries and emergencies). The construction coordinator shall record the name, phone number, and nature of all complaints received regarding the construction, and shall investigate complaints and take remedial action, if necessary, within 24 hours of receipt of the complaint or inquiry. In addition, all construction personnel shall be trained in proper material handling, cleanup, and disposal procedures. h. **Notification.** The Permittee shall notify planning staff of the Coastal Commission's North Central Coast District Office at least three working days in advance of commencement of construction, and immediately upon completion of construction. i. **Property Owner Consent.** The plan shall be submitted with evidence indicating that the owners of any properties on which construction activities are to take place, including properties to be crossed in accessing the site, consent to such use of their properties. Minor adjustments to the above construction requirements may be allowed by the Executive Director in the approved Construction Plan if such adjustments: (1) are deemed reasonable and necessary; and (2) do not adversely impact coastal resources. All requirements above and all requirements of the approved Construction Plan shall be enforceable components of this CDP. The Permittee shall undertake construction in accordance with the approved Construction Plan. 3. **Mitigation Monitoring Plan.** The project shall be conducted in compliance with the requirements of the Mitigation Monitoring Plan, dated August 17, 2011 (see Appendix B), except where the terms and conditions of this CDP require actions more protective of coastal resources. 4. **Marin e Mammal Avoidance and Monitoring.** To the maximum extent feasible, all work shall avoid the river mouth area where seal haul out is typically located (see Exhibit 4 – Pinniped Haul Outs). In addition, all work shall be conducted consistent with the NMFS and NOAA-approved seal haul out plan described in the Incidental Harassment Authorization (April 2013) (IHA) and any updates to this IHA. Project activities shall comply with all mitigation, monitoring and reporting requirements contained in the IHA, including the following requirements as outlined in the IHA:	

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Coastal Commission (continued)	**a. Avoid Sudden Flushes.** Permittee crews shall cautiously approach the haul-out ahead of heavy equipment to minimize the potential for sudden flushes, which may result in a stampede. Crews on foot shall make an effort to be seen by seals from a distance, if possible, rather than appearing suddenly at the top of the sand bar, again preventing sudden flushes. Boats operating near river haul-outs during monitoring shall be kept within posted speed limits and driven as far from the haul-outs as safely possible to minimize flushing seals. **b. Avoid Haul-Out.** Permittee crews shall avoid walking or driving equipment through the seal haul-out. Physical and biological monitoring at the haul-out location shall not be occur if a pup less than one-week old is present at the monitoring site or on a path to the site. **c. Monitoring From Bluff.** During breaching events, all monitoring shall be conducted from the overlook on the bluff along Highway 1 adjacent to the haul-out in order to minimize potential for harassment. **d. Disturbance Recovery.** The Permittee shall maintain a one-week no-work period between water level management events (unless flooding is an immediate threat) to allow for an adequate disturbance recovery period. During the no-work period, equipment must be removed from the beach. **e. Equipment BMPs.** All equipment shall be driven slowly on the beach and care shall be taken to minimize the number of shutdowns and start-ups when equipment is on the beach. All work shall be completed as efficiently as possible, with the smallest amount of heavy equipment possible, to minimize disturbance of seals at the haul-out. **f. Haul-out Maintained.** The Permittee shall conduct seal counts at the Jenner seal haul-out and at nearby coastal and river haul-outs in accordance with methods described in the Russian River Management Activities Pinniped Monitoring Plan (Pinniped Monitoring Plan), dated September 9, 2009, or as updated by requirements of NMFS under the Marine Mammal Protection Act (MMPA). If monitoring during the lagoon management period indicates decreases in overall use at the Jenner haul-out are correlated with increases in use at the three closest haul-outs, then the Permittee shall consult with the Executive Director, NMFS and CDFW to modify the Estuary Management Plan activities such that the haul-out site is maintained. Proposed alterations to the approved Estuary Management Plan shall be reported to the Executive Director. No alterations to the approved Estuary Management Plan shall occur without an approved amendment to this CDP, unless the Executive Director determines that no amendment is legally required. **5. Public Acc ess Management Plan.** PRIOR TO ISSUANCE OF THE COASTAL DEVELOPMENT PERMIT, the Permittee shall submit two copies of a public access management plan (Public Access Plan) to the Executive Director for review and approval. The Public Access Plan shall clearly describe the manner in which public access at the project site is to be protected, with the objective of avoiding any adverse impacts to public access at Goat Rock, Sonoma Coast State Beach. The Public Access Plan shall be consistent with all other terms and conditions of this CDP, and shall at a minimum include the following:	

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Coastal Commission (continued)	**a. No Disruption of Public Access.** Development under this CDP that blocks access to the beach at the project site shall be prohibited. Temporary signs shall warn the public of construction while construction activities are underway. Signs shall direct the public to safe access routes during construction activities. Signs shall not discourage public access. Signs shall notify beach users of channel conditions, potential for safety hazards from beach erosion or hydrologic action, and emergency contact information. Signs shall be posted and maintained at key locations, such as the parking lot at Goat Rock State Beach Parking lot, the unofficial beach access trail located on the north side of the beach off Highway 1, and 100 feet on either side of the outlet channel. **b. Peak Public Access Times Avoided.** Project activities shall occur Monday through Thursday only, to avoid impacts to park visitors during peak visitation times (Friday through Sunday). All requirements above and all requirements of the approved Public Access Plan shall be enforceable components of this CDP. The Permittee shall undertake development in accordance with the approved Public Access Plan, which shall govern all general public access to the site pursuant to this CDP. **6. Monitoring Plan.** PRIOR TO ISSUANCE OF THE COASTAL DEVELOPMENT PERMIT, the Permittee shall submit two copies of a Flood Analysis, Habitat and Water Quality Monitoring Plan (Monitoring Plan) to the Executive Director for review and approval. The Flood Analysis portion of the Monitoring Plan shall identify avoidance and mitigation measures as detailed in Special Condition 6(a). The Habitat Monitoring portion of the Monitoring Plan shall cover all approved project activities, and shall evaluate project effectiveness and alternatives as detailed in Special Condition 6(b). The Water Quality Monitoring portion of the Monitoring Plan shall direct management actions in response to water quality conditions and as detailed in Special Condition 6(c). The primary objective of the Monitoring Plan shall be to ensure that approved project activities protect and enhance project area habitats while also protecting development from flooding and enhancing water quality, and shall be measured against a clearly defined project baseline, which shall be provided in the Monitoring Plan. The Monitoring Plan shall be based upon an adaptation framework where lessons learned from approved project activities and monitoring are applied through adaptive changes designed to better achieve the primary objective over the course of this authorization. The Monitoring Plan shall include all monitoring components of the BO and the FEIR for the project, and shall include, at minimum, the following: **a. Flood Analysis.** The Permittee shall continue to coordinate with NMFS and work with property owners affected by flooding to identify measures that would, if necessary, substantially minimize or avoid any damages to existing structures that would occur as a result of increasing water elevations in the lagoon pursuant to the approved project. As appropriate and indicated in the BO, the Permittee shall continue to survey properties within the estuary's maximum water elevation in greater detail to more accurately and precisely determine the elevation of the structures potentially at risk; this information shall be kept on record by the Permittee and a copy shall be provided to each of the property owners. A detailed account of individual properties and development of these properties for each foot of estuary water surface elevations shall be	

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Coastal Commission (continued)	provided. The range of options available to protect affected developments, other than breaching or controlling water levels in the estuary, including relocating, elevating, or reinforcing structures, shall be provided. At a minimum, and evaluation of the effects of flood levels at 4.5, 7, and 9 feet shall be so evaluated. b. **Habitat Monitoring.** Monitoring shall be conducted consistent with the BO to provide information on (1) the ways in which the project results in benefits to juvenile steelhead and/or adverse impacts to other salmonids, (2) whether a controlled outlet program can achieve optimal lagoon elevations, and (3) whether habitat improvements would result if no breaching occurred, water levels were allowed to be higher than current management, a larger estuary was formed, and low-lying development within the historic estuary footprint were flooded. A geotechnical study shall be conducted prior to December 31, 2014 to contribute to a determination as to what modifications to/removal of the jetty infrastructure would optimize seepage through the sand barrier and allow estuary levels to rise to a maximum elevation without the sand bar manipulation. An evaluation of the need for additional monitoring wells and frequency of water level data needed to adequately characterize seepage through the sand bar and jetty shall be conducted at the commencement of the geotechnical work so that reliable information is assured to be included in the study. c. **Water Quality Monitoring.** The water quality monitoring data collected for the 2008 BO, the Temporary Urgency Change Petition's surface water sampling program, and the Stipulated Judgment's sediment sampling requirement shall be integrated under the direction of an independent water quality professional. These data collection programs shall be linked and coordinated so that they provide a cohesive and useful data set that can be used to evaluate the low velocity lagoon outlet channel and whether or not it is successful in sustaining raised water elevations and improved water quality conditions in the estuary. At a minimum, the Plan shall specify the water quality analyses, sampling locations, sampling frequency, quality control and data reporting that will be used to assess water quality impacts of implementing the Russian River Estuary Management Program Adaptive Management Plan. In addition, the Water Quality Monitoring Plan shall include sampling for the following constituents, at a minimum, temperature, salinity, pH, nutrients, chlorophyll, and bacteria indicators used to assess human health impacts consistent with the most up-to date methods and standards required by the North Coast Regional Water Quality Control Board (NCRWQCB). Monitoring shall occur weekly during the Lagoon Management Period at the locations that are currently included in the Russian River Water Quality Summary for the Sonoma County Water Agency 2012 Temporary Urgency Change. Finally, the Plan shall include a contingency to increase sampling frequency to daily if the bacteria indicators exceed the operative standards required by the NCRWQCB and monitoring shall continue daily until measurements are below the operative standards. If the operative standards are exceeded, the Permittee will immediately inform the NCRWQCB and Sonoma County Public Health and seek direction on whether warning signs should be posted at the affected beaches regarding a potential health threat and consult with NCRWQCB and Sonoma County Public Health to determine if mechanical breaching is a recommended action to reduce the threat to public health.	

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Coastal Commission (continued)	d. **Monitoring Reports.** The Monitoring Plan shall provide for submission of annual reports of monitoring results to the Executive Director for review and approval for as long as activities are authorized by this CDP, with the first annual monitoring report due on August 15, 2014, and subsequent reports due on August 15th of each year thereafter. Each monitoring report shall be cumulative and shall summarize all previous results. Each report shall clearly document conditions in the project area related to project implementation, including in narrative (with supporting monitoring data) and through photographs taken from the same fixed points in the same directions each year, all commencing from the project baseline. Each report shall include a performance evaluation section where information and results from the monitoring program are used to evaluate the effect of project implementation with respect to flooding, habitat, and water quality impacts, both beneficial and detrimental. To allow for an adaptive approach, each report shall also include a recommendations section to address changes that may be necessary in light of monitoring results and/or other information, including with respect to more current data and/or species information related to the habitat areas in question, if any. Actions necessary to implement the recommendations shall be implemented within 30 days of Executive Director approval of each Monitoring Report, unless the Executive Director identifies a different time frame for implementation. Minor adjustments to the above monitoring requirements may be allowed by the Executive Director in the approved Monitoring Plan if such adjustments: (1) are deemed reasonable and necessary; and (2) do not adversely impact coastal resources. All requirements above and all requirements of the approved Monitoring Plan shall be enforceable components of this CDP. The Permittee shall undertake development in accordance with the approved Monitoring Plan. 7. **Assumption of Risk.** By acceptance of this CDP, the Permittee acknowledges and agrees, on behalf of itself and all successors and assigns: a. **Coastal Hazards.** That the site is subject to coastal hazards including but not limited to episodic and long-term shoreline retreat and coastal erosion, high seas, ocean waves, storms, tsunami, tidal scour, coastal flooding, and the interaction of same; b. **Assume Risks.** To assume the risks to the Permittee and the property that is the subject of this permit of injury and damage from the above-identified coastal hazards in connection with this permitted development; c. **Waive Liability.** To unconditionally waive any claim of damage or liability against the Commission, its officers, agents, and employees for injury or damage from the above-identified hazards; d. **Indemnification.** To indemnify and hold harmless the Coastal Commission, its officers, agents, and employees with respect to the Commission's approval of the project against any and all liability, claims, demands, damages, costs (including costs and fees incurred in defense of such	

Sonoma Water

Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Coastal Commission (continued)	claims), expenses, and amounts paid in settlement arising from any injury or damage due to the above-identified coastal hazards. 8. **Sand Bar Breaching L imitation**. Except under conditions requiring immediate action to prevent or mitigate loss or damage to life, health, property, or essential public services, the sand bar breaching activities authorized by the CDP shall not be initiated on or within 36 hours prior to any weekend or State holiday. 9. **CD P Term**. Development authorized by this CDP is valid for three (3) years from the date of Commission approval (until August 15, 2016). One request for an additional three-year period of development authorization may be accepted, reviewed and approved by the Executive Director for a maximum total of six (6) years of development authorization, provided the request would not alter the project description and/or require modifications of conditions due to new information or other changed circumstances. The request for an additional three-year period of development authorization shall be made at least 120 days prior to August 15, 2016. If the request for an additional three-year authorization period would alter the project description and/or require modifications of conditions due to new information or other changed circumstances, an amendment to this CDP shall be necessary to authorize development beyond August 15, 2016. If the Permittee submits a request/application to continue estuary management (including breaching and other activities intended to control water elevations) beyond August 15, 2016, such request/application shall be accompanied by a project alternatives analysis that, at minimum, provides a survey of potential flooding risks to properties within the estuary up to a water elevation of 14 feet, or the maximum water elevation known to occur, whichever is higher, to precisely determine the elevation of the structures potentially at risk. In addition, the analysis shall include an evaluation of the range of options available to protect against identified flooding risks, other than breaching or controlling water levels in the estuary, including relocating, elevating, or reinforcing structures. Such analysis shall also include an evaluation of the range of options available to modify or remove the jetty to reduce or eliminate the need for breaching. 10. **Other Agency Approval**. PRIOR TO ISSUANCE OF THE COASTAL DEVELOPMENT PERMIT, the Permittee shall submit to the Executive Director written evidence that all necessary permits, permissions, approvals, and/or authorizations for the approved project have been granted by Sonoma County, the North Coast Regional Water Quality Control Board, California State Lands Commission, California Department of Parks and Recreation, California Department of Fish and Wildlife, National Marine Fisheries Service, U.S. Army Corps of Engineers, and the U.S. Fish and Wildlife Service or that no such permits or approvals are necessary. Any changes to the approved project required by these agencies shall be reported to the Executive Director. No changes to the approved project shall occur without a Commission amendment to this CDP unless the Executive Director determines that no amendment is necessary. 11. **Liability for Costs and Attorneys' Fees.** By acceptance of this CDP, the Applicant/Permittee agrees to reimburse the Coastal Commission in full for all Coastal Commission costs and attorneys'	

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Coastal Commission (continued)	fees (including (1) those charged by the Office of the Attorney General, and (2) any court costs and attorneys' fees that the Coastal Commission may be required by a court to pay) that the Coastal Commission incurs in connection with the defense of any action brought by a party other than the Applicant/Permittee against the Coastal Commission, its officers, employees, agents, successors and assigns challenging the approval or issuance of this CDP. The Coastal Commission retains complete authority to conduct and direct the defense of any such action against the Coastal Commission.	

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
US Army Corps of Engineers, San Francisco District Section 404 & Section 10, Individual Permit (285610N) - July 22, 2005 Permit Modification - October 5, 2009 Time Extension January 5, 2011 Time Extension December 8, 2011 Time Extension December 10, 2012 Time Extension December 10, 2013 Section 404 & Section 10, Individual Permit (2004- 285610N) – April 1, 2014 Expiration - December 31, 2023	SPECIAL CONDITIONS: 12. To remain exempt from the prohibitions of Section 9 of the Endangered Species Act, the non-discretionary Terms and Conditions for incidental take of federally-listed Species shall be fully implemented as stipulated in the Biological Opinion entitled, *"Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Conh·ol and Water Conservation Improvement District in the Russian River Watershed,"* also known as the Russian River Biological Opinion, (NMFS File No. 151422SWR2000SRl50) dated September 24, 2008. Project authorization under this permit is conditional upon compliance with the mandatory terms and conditions associated with incidental take. Failure to comply with the terms and conditions for incidental take, where a take of a federally-listed species occurs, would constitute an unauthorized take and non-compliance with the authorization for your project. The NMFS is, however, the authoritative federal agency for determining compliance with the incidental take statement and for initiating appropriate enforcement actions or penalties under the Endangered Species Act. 13. SCWA shall provide USACE a copy of the approved Estuary Monitoring Plan and all subsequent Annual Monitoring Reports required by the Biological Opinion. 14. Unless otherwise approved, authorized discharges of dredged material on the sandbar below the high tide line shall consist only of the native sand excavated from the pilot channel. 15. SCWA shall provide USACE a Breaching Activities Report by 31 March for each year of the ten-year permit authorization period. Each Breaching Activities Report shall present a tabulation of the breaching events that occurred during the preceding year, including the approximate estuary closure date, the approximate number of estuary closure days occurring before the breach event, the breaching event date, and the recorded estuary water level of the breaching event date. 5. The current Coastal Development Permit (CDP 2-12-004) issued by the California Coastal Commission expires on 15 August 2016. The current Section 401 water quality certification (WDID No. IB04001WNSO) issued by the Regional Water Quality Control Board expires on 31 December 2015. SCWA shall obtain requisite time extensions for the Coastal Development Permit and water quality certification prior to the commencement of any work to be performed during the remainder of the ten-year Department of the Army permit authorization period. SCWA shall provide USACE a copy of all requisite time extensions to ensure continuing project conformance with State coastal zone and water quality standards.	March 31: Annual Breaching Report

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Environmental Quality Act Environmental Impact Report (EIR) Notice of Preparation – May 10, 2010 Notice of Completion – December 15, 2010 Notice of Determination – August 16, 2011	See EIR for Mitigation Measures.	None
California State Lands Commission General Lease, Public Agency Use (PRC 7918.1 R 08103) – June 29, 2004 Lagoon Outlet Channel Authorization – October 13, 2009 (Expiration - December 31, 2010) Monthly Extensions - January 1 to December 31, 2011 General Lease, Public Agency Use (PRC 7918.9) – January 1, 2012	**SECTION 2** **SPECIAL PROVISIONS** **BEFORE THE EXECUTION OF THIS LEASE, ITS PROVISIONS ARE AMENDED, REVISED OR SUPPLEMENTED AS FOLLOWS:** 1. Lessee agrees to be bound by and fully carry out, implement, and comply with all mitigation measures and reporting obligations identified as Lessee's, or Responsible Party's responsibility as set forth in the Mitigation Monitoring Program (MMP) attached hereto as Exhibit C and by this reference made a part of this Lease, or as modified by Lessor as permitted by law. 2. Lessee acknowledges that the land described in Exhibit A of this Lease is subject to the Public Trust and is presently available to members of the public for recreation, waterborne commerce, navigation, fisheries, open space, or other recognized Public Trust uses and that Lessee's proposed construction activities and use of the Lease Premises shall not interfere or limit the Public Trust rights of the public. At least 24 hours prior to and during the breaching activities, Lessee will contact the California Department of Parks and Recreation lifeguards and post signs and barriers to minimize potential hazards to the public. 3. Prior to the start of the initial freshwater lagoon construction on the Lease Premises, Lessee shall submit to Lessor copies of all permits and authorizations from agencies having jurisdiction over the construction of the authorized activities on the Lease Premises. Lessee shall maintain all regulatory permits and authorization required during the term of the lease.	No Date: Annual Water Quality Data Summary Reports; Annual Report for Russian River Estuary Management Activities Monitoring Plan

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California State Lands Commission (continued) Renewed General Lease, Public Agency Use (PRC 7918.9) – March 23, 2015 Expiration – December 31, 2023	4. All breaching activities shall be carried out in accordance with all applicable safety regulations, permits, and conditions of all other agencies. 5. During the term of the lease, Lessee shall provide Lessor with an annual report on frequency and timing of outlet channel construction and maintenance and breaching occurrences completed each calendar year, including number of days of closure of Goat Rock State Beach. The report should include narrative descriptions and evaluations of outlet channel and breaching events, including any adaptive management changes implemented. 6. Lessee shall submit to Lessor copies of the following: a. Adaptive estuarine water level and barrier beach management plans (as described in 2.1.1 of the Russian River Biological Opinion) after approval by the National Marine Fisheries (NMFS), the California Department of Fish and Wildlife, and the U.S. Army Corps of Engineers. b. Annual water quality data summary reports (as described in 2.2, Monitoring Estuarine Water Quality: Reporting and Review, of the Biological Opinion). c. Annual report, as specified in the "Russian River Estuary Management Activities Pinniped Monitoring Plan" and distributed to NMFS, the California Department of Parks and Recreation, and the Stewards of the Coasts and Redwoods, on pinnipeds' reaction to the proposed activities authorized in this Lease. 7. All personal property, tools, or equipment taken onto or placed upon the Lease Premises shall remain the property of the Lessee or its contractors. Such personal property shall be promptly removed by the Lessee, at its sole risk and expense upon the completion of the project. Lessor does not accept any responsibility for any damage, including damages to any personal property, including any equipment, tools, or machinery on the Lease Premises	

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California State Lands Commission (continued)	8. No refueling, repairs, or maintenance of vehicles or equipment will take place on the Lease Premises. 9. Lessee shall maintain a logbook on all work vessels during work within the Lease Premises utilized in operations conducted under this Lease to keep track of all debris created by objects of any kind that may fall into the water. The logbook should include the type of debris, date, time and location to facilitate identification and location of debris for recovery and site clearance verification. All debris shall be promptly removed from the Lease Premises. 10. Any equipment to be used on the Lease Premises is limited to that which is directly required to perform the authorized use and does not include any equipment that may cause damage to the Lease Premises. 11. Lessee acknowledges and agrees: a. The site may be subject to hazards from natural geophysical phenomena including, but not limited to waves, storm waves, tsunamis, earthquakes, flooding and erosion. b. To assume the risks to the Lessee and to the property that is the subject of any Coastal Development Permit (CDP) that is issued to Lessee for development on the leased property, of injury and damage from such hazards in connection with the permitted development and use. c. To unconditionally waive any claim or damage or liability against the State of California, its agencies, officers, agents, and employees for injury or damage from such hazards. d. To indemnify, hold harmless and, at the option of Lessor, defend the State of California, its agencies, officers, agents, and employees, against and for any and all liability, claims, demands, damages, injuries, or costs of any kind and from any cause (including costs and fees incurred in defense of such claims), expenses, and amounts paid in settlement arising from any alleged or actual injury, damage or claim due to site hazards or connected in any way with respect to the approval of any CDP that is issued to Lessee involving this property or issuance of this Lease, any new lease, renewal, amendment, or assignment by Lessor. 12. Lessor shall have the right to enter upon the property at reasonable times in order to monitor Lessee's compliance with and otherwise enforce the terms of the Lease. 13. Paragraph 10, Surety Bond, contained within Section 3 is hereby deleted from this Lease.	

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Department of Parks and Recreation Temporary Use Permit – December 30, 2003 Permit Extension – September 14, 2009 Permit Extension – December 28, 2009 Expiration – June 30, 2010 Temporary Use Permit – May 15, 2011 Time Extension – February 20, 2013 Time Extension – December 18, 2013 Time Extension – February 2, 2015 Time Extension – April 29, 2016 Time Extension – June 1, 2016 Time Extension – September 15, 2016 Time Extension – July 11,	1. Project Description: By this Permit, the State hereby grants to the Permittee permission to enter onto those lands depicted Error! Bookmark not defined. and/or described on Exhibit "B" (the Property), attached hereto and herein incorporated by this reference, solely for the purpose of Error! Bookmark not defined, the limits of which are described in the Environmental Document. 2. Permit Subject to Laws and Regulatory Agency Permits: This Permit is expressly conditioned upon Permittee's obtaining any and all regulatory permits or approvals required by the relevant regulatory agencies for the Project and Permittee's use of the Property, and upon Permittee's compliance with all applicable municipal, state and federal laws, rules and regulations, including all State Park regulations. Permittee shall, at Permittee's sole cost and expense, comply with the Project Description, and requirements and mitigations contained in the Environmental Document. Prior to commencement of any work, Permittee shall obtain all such legally required permits or approvals and submit to the State full and complete copies of all permits and approvals, including documentation related to or referenced in such permits and approvals, along with the corresponding agency contact and telephone numbers, and related California Environmental Quality Act (CEQA) and/or National Environmental Policy Act (NEPA) documentation as applicable. 3. Term of Permit: This Permit shall only be for the period beginning on November 5, 2018, and ending on November 5 2019, or as may be reasonably extended by written mutual agreement of the Parties. 4. Consideration: Permittee agrees to pay State the sum of one thousand nine hundred and no/100 Dollars ($) as consideration for the rights granted by this Permit. Payment has been received. 5. Permit Subject to Existing Claims: This Permit is subject to existing contracts, permits, licenses, encumbrances and claims which may affect the Property. 6. Waiver of Claims and Indemnity: Permittee waives all claims against State, its officers, agents and/or employees, for loss, injury, death or damage caused by, arising out of, or in any way connected with the condition or use of the Property, the issuance, exercise, use or implementation of this Permit, and/or the rights herein granted. Permittee further agrees to protect, save, hold harmless, indemnify and defend State, its officers, agents and/or employees from any and all loss, damage, claims, demands, costs and liability which may be suffered or incurred by State, its officers, agents and/or employees from any cause whatsoever, arising out of, or in any way connected with this Permit, exercise by Permittee of the rights herein granted, Permittee's use of the Property and/or the Project for which this Permit is granted, except those arising out of the sole active negligence or willful misconduct of State. Permittee will further cause such indemnification and waiver of claims in favor of State to be inserted in each contract that Permittee executes for the provision of services in connection with the Project for which this Permit is granted. 7. Contractors: Permittee shall incorporate the terms, conditions and requirements contained herein when contracting out all or any portion of the work permitted hereunder. Permittee shall be responsible for ensuring contractor/subcontractor compliance with the terms and conditions contained herein. Failure of Permittee's contractors to abide by State's terms and conditions shall constitute default by Permittee (see Paragraph 20) allowing State to terminate this Permit and seek all legal remedies. 8. Insurance Requirements: As a condition of this Permit and in connection with Permittee's indemnification and	No Reporting Required for TUP

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
2017 Expiration – September 30, 2017 Temporary Use Permit – November 5, 2018 Expiration – November 5, 2019 Temporary Use Permit extension request – January 22, 2020	waiver of claims contained herein, Permittee shall maintain, and cause its contractors to maintain, a policy or policies of insurance as follows: General Provisions Applying to All Policies A. Coverage Term – Coverage needs to be in force for the complete term of the contract. If insurance expires during the term of the contract, a new certificate must be received by the State at least ten (10) days prior to the expiration of this insurance. Any new insurance must still comply with the original terms of the contract. B. Policy Cancellation or Termination & Notice of Non-Renewal – Contractor is responsible to notify the State within five business days before the effective date of any cancellation, non-renewal, or material change that affects required insurance coverage. In the event Contractor fails to keep in effect at all times the specified insurance coverage, the State may, in addition to any other remedies it may have, terminate this Contract upon the occurrence of such event, subject to the provisions of this Contract. C. Deductible – Contractor is responsible for any deductible or self-insured retention contained within their insurance program. D. Primary Clause – Any required insurance contained in this contract shall be primary, and not excess or contributory, to any other insurance carried by the State. E. Insurance Carrier Required Rating – All insurance companies must carry a rating acceptable to the Office of Risk and Insurance Management. If the Contractor is self-insured for a portion or all of its insurance, review of financial information including a letter of credit may be required. F. Endorsements – Any required endorsements requested by the State must be physically attached to all requested certificates of insurance and not substituted by referring to such coverage on the certificate of insurance. G. Inadequate Insurance – Inadequate or lack of insurance does not negate the contractor obligations under the contract. H. Satisfying an SIR - All insurance required by this contract must allow the State to pay and/or act as the contractor's agent in satisfying any self-insured retention (SIR). The choice to pay and/or act as the contractor's agent in satisfying any SIR is at the State's discretion. I. Available Coverages/Limits - All coverage and limits available to the contractor shall also be available and applicable to the State. J. Subcontractors - In the case of Contractor utilization of subcontractors to complete the contracted scope of work, contractor shall include all subcontractors as insured's under Contractor and insurance or supply evidence of insurance to The State equal to policies, coverages and limits required of Contractor. 9. Reservation of Rights: State reserves the right to use the Property in any manner, provided such use does not unreasonably interfere with Permittee's rights herein. 10. Access Limits and Conditions: Access to the Property shall be limited to the access designated by State and is illustrated in Figure 2 of Exhibit "A" and as described below. The barrier beach would be accessed from the paved parking lot at Goat Rock State Beach, located at the end of Goat Rock Road off of Highway 1. Equipment would be off-loaded in the parking lot and driven north onto the beach via an	

Agency / Permit / Expiration	Special Conditions	Report Due Date
	existing access point within the parking lot. Additional detail is provided in the attached Russian River Estuary Management Activities. 11. Notice of Work: Any required notices to State shall be sent to the State authorities in charge of Error! Bookmark not defined. State Park named below. At least Error! Bookmark not defined. forty-eight (48) hours prior to any entry upon the Property for any of the purposes hereinabove set forth, Permittee shall provide the State contact[s] named below with written notice of Permittee's intent to enter the Property. Permittee shall also notify the State contact[s] listed below in writing at least Error! Bookmark not defined. forty-eight (48) hours prior to any change in the Project schedule or cessation or completion of work. Should State personnel need to contact Permittee, State shall notify Permittee's contact person listed below: STATE: Contact: Bill Maslach Address: 12301 North Highway 1 Mendocino, CA 95460 Telephone: 707.937.5805 Email: bill.maslach@parks.ca.gov 12. Limits of Work: In no event shall this Permit authorize work in excess or contrary to the terms and conditions of any regulatory agency permit or approval. Under no circumstances, whether or not authorized by any regulatory agency, other permit or any person or entity other than State, shall work exceed that which is authorized by this Permit. 13. Public Safety: Permittee shall erect orange plastic temporary construction fencing and appropriate signage prior to commencement of work to prevent public access to the construction zone. Permittee shall remove such fencing within two (2) days after the completion of work. Permittee shall take, and shall cause its contractors or subcontractors to take, any and all necessary and reasonable steps to protect the public from harm in connection with the Project or implementation of this Permit. 14. Compliance with Project Requirements, Monitoring and Mitigation Measures (if applicable): Resource monitoring and mitigation measures identified within the Russian River Estuary Management Project Final Environmental Impact Report, NMFS Biological Opinion, DFG Lake and Streambed Alteration Agreement, Regional Water Quality Control Board Section 401 Water Certification, California Coastal Commission Coastal Development Permit, US Army Corps of Engineers Section 404 and Section 10 Permit, and State Lands Commission General Lease shall be completed in accordance with and to the satisfaction of the District Superintendent or designee. Permittee's activities conducted under this Permit shall comply with all State and Federal environmental laws, including, but not limited to, the Endangered Species Act, CEQA, and Section 5024 of the Public Resources Code. Any of Permittee's archaeological consultants working within the boundaries of the Property shall submit a DPR 412A permit application to the District cultural resource specialist for approval prior to commencing any archaeological or cultural investigations of the Property. Permittee shall immediately advise State's contact person if any new site conditions are found during the course of permitted work. State will advise Permittee if any new historical resources	

Agency / Permit / Expiration	Special Conditions	Report Due Date
	(including archaeological sites), special status species, threatened/endangered species protocols, or other resource issues are identified within the Project site. Permittee shall abide by District Superintendent or designee's instructions to protect the resource(s) during the permitted work or risk revocation of the Permit. Permittee shall make all excavation activities on the Property available to the State archaeologist for observation and monitoring. During excavation, the State archaeological monitor may observe and report to the State on all excavation activities. State archaeological monitor shall be empowered to stop any construction activities as necessary to protect significant cultural resources from being disturbed. In the event that previously unknown cultural resources, including, but not limited to, dark soil containing shell, bone, flaked stone, groundstone, or deposits of historic trash are encountered during Project construction by anyone, work will be suspended at that specific location, and the Permittee's work will be redirected to other tasks, until a State archaeologist or professionally qualified designee has evaluated the find and implemented appropriate treatment measures and disposition of artifacts, as appropriate, in compliance with all applicable laws and department resource directives. If human remains are discovered during the Project, work will be immediately suspended at that specific location and the District Superintendent or designee shall be notified by Permittee. The specific protocol, guidelines and channels of communication outlined by the California Native American Heritage Commission (NAHC), and/or contained in Health and Safety Code Section 7050.5 and Public Resources Code Sections 5097.9 et seq., will be followed. Those statutes will guide the potential Native American involvement in the event of discovery of human remains. If resource monitoring is required to be performed by State staff, the Permittee shall provide a written work schedule to the State at least 48 hours in advance of the work. Permittee shall provide reasonable advance notice of and invite the District Superintendent or designee to any preconstruction meetings with the prime contractor or subcontractors. 15. Restoration of Property: Permittee shall complete the restoration, repair, and revegetation of the Property in consultation with, and to the satisfaction of, the State Environmental Scientist within one (1) year after completion of the Project or the expiration or termination of this Permit, whichever comes first. This obligation shall survive the expiration or termination of this Permit. 16. Performance Bond: If required by State in order to ensure that Permittee performs and completes its obligations in accordance with the terms of the Permit, Permittee shall obtain a Performance Bond in the amount of from a surety duly licensed in the State of California. Permittee shall provide State with a copy of such insurance bond. 17. Right to Halt Work: The State reserves the right to halt work and demand mitigation measures at any time, with or without prior notice to Permittee, in the event the State determines that any provision contained herein has been violated, or in the event that cessation of work is necessary to prevent, avoid, mitigate or remediate any threat to the health and safety of the public or state park personnel, or to the natural or cultural resources of the state park. 18. Use Restrictions: The use of the Property by Permittee, including its guests, invitees, employees, contractors and agents, shall be restricted to the daytime hours between sunrise and sunset on a day-by-day basis, unless otherwise approved in advance in writing by State. No person shall use or occupy the Property overnight. Activities on the Property shall be conducted only in a manner which will not interfere with the orderly operation of the	

Agency / Permit / Expiration	Special Conditions	Report Due Date
	state park. Permittee shall not engage in any disorderly conduct and shall not maintain, possess, store or allow any contraband on the Property. Contraband includes, but is not limited to: any illegal alcoholic beverages, drugs, firearms, explosives and weapons. Roads and trails where motorized vehicles are normally prohibited may be used for vehicle access by Permittee, its employees, agents or contractors for patrol, maintenance or repair purposes only, and only to the extent specified by State, and shall be otherwise subject to all other conditions and/or restrictions of this Permit and any applicable laws, state park regulations and state park policies. Permittee shall not use or allow the Property to be used, either in whole or in part, for any purpose other than as set forth in this Permit, without the prior written consent of the State. 19. State's Right to Enter: At all times during the term of this Permit and any extension thereof, there shall be and is hereby expressly reserved to State and to any of its agencies, contractors, agents, employees, representatives, invitees or licensees, the right at any and all times, and any and all places, to temporarily enter upon said Property to survey, inspect, or perform any other lawful State purposes. Permittee shall not interfere with State's right to enter. 20. Protection of Property: Permittee shall protect the Property, including all improvements and all natural and cultural features thereon, at all times at Permittee's sole cost and expense, and Permittee shall strictly adhere to the following restrictions: (a) Permittee shall not place or dump garbage, trash or refuse anywhere upon or within the Property, except in self-contained trash receptacles that are maintained to State's satisfaction by Permittee. (b) Permittee shall not commit or create, or suffer to be committed or created, any waste, hazardous condition or nuisance in, on, under, above or adjacent to the Property. (c) Permittee shall not cut, prune or remove any vegetation upon the Property, except as identified in the Project description and herein permitted or subsequently approved in writing by the District Superintendent. (d) Permittee shall not disturb, move or remove any rocks or boulders upon the Property, except as identified in the Project description and herein permitted or subsequently approved in writing by the District Superintendent. (e) Permittee shall not grade or regrade, or alter in any way, the ground surface of the Property, except as herein permitted, or subsequently approved in writing by the District Superintendent. (f) Permittee shall not bait, poison, trap, hunt, pursue, catch, kill or engage in any other activity which results in the taking, maiming or injury of wildlife upon the Property, except as identified in the Project description and herein permitted or subsequently approved in writing by the District Superintendent. (g) Permittee shall not use, create, store, possess or dispose of hazardous substances (as defined in the California Hazardous Substances Act) on the Property except as herein permitted, or subsequently approved in writing by the District Superintendent. (h) Permittee shall exercise due diligence to protect the Property against damage or destruction by fire, vandalism and any other causes. 21. Default: In the event of a default or breach by Permittee of any of the terms or conditions set forth in this Permit, State may at any time thereafter, without limiting State in the exercise of any right of remedy at law or in equity	

Agency / Permit / Expiration	Special Conditions	Report Due Date
	which State may have by reason of such default or breach: (a) Maintain this Permit in full force and effect and recover the consideration, if any, and other monetary charges as they become due, without terminating Permittee's right to use of the Property, regardless of whether Permittee has abandoned the Property; or (b) Immediately terminate this Permit upon giving written notice to Permittee, whereupon Permittee shall immediately surrender possession of the Property to State and remove all of Permittee's equipment and other personal property from the Property. In such event, State shall be entitled to recover from Permittee all damages incurred or suffered by State by reason of Permittee's default, including, but not limited to, the following: (i) any amount necessary to compensate State for all the detriment proximately caused by Permittee's failure to perform its obligations under this Permit, including, but not limited to, compensation for the cost of restoration, repair and revegetation of the Property, which shall be done at State's sole discretion and compensation for the detriment which in the ordinary course of events would be likely to result from the default; plus (ii) at State's election, such other amounts in addition to or in lieu of the foregoing as may be permitted from time to time by applicable law. State's Right to Cure Permittee's Default: At any time after Permittee is in default or in material breach of this Permit, State may, but shall not be required to, cure such default or breach at Permittee's cost. If State at any time, by reason of such default or breach, pays any sum or does any act that requires the payment of any sum, the sum paid by State shall be due immediately from Permittee to State at the time the sum is paid. The sum due from Permittee to State shall bear the maximum interest allowed by California law from the date the sum was paid by State until the date on which Permittee reimburses State. Revocation of Permit: The State shall have the absolute right to revoke this Permit for any reason upon ten (10) days written notice to Permittee. Written notice to Permittee may be accomplished by electronic or facsimile transmission, and the notice period set forth in this paragraph shall begin on the date of the electronic or facsimile transmission, or, if sent by mail, on the cf ate of delivery. If Permittee is in breach of the Permit or owes money to the State pursuant to this Permit, any prepaid monies paid by Permittee to State shall be held and applied by the State as an offset toward damages and/or amounts owed. Nothing stated herein shall limit the State's exercise of its legal and equitable remedies. Recovery of Legal Fees: In any action brought to enforce or interpret any provisions of this Permit or to restrain the breach of any agreement contained herein, or for the recovery of possession of the Property, or to protect any rights given to the State against Permittee, and in any actions or proceedings under Title 11 of the United States Code, if the State shall prevail in such action on trial or appeal, the Permittee shall pay to the State such amount in attorney's fees in said action as the court shall determine to be reasonable, which shall be fixed by the court as part of the costs of said action. Voluntary Execution and Independence of Counsel: By their respective signatures below, each Party hereto affirms that they have read and understood this Permit and have received independent counsel and advice from their attorneys with respect to the advisability of executing this Permit. Reliance on Investigations: Permittee declares that it has made such investigation of the facts pertaining to this Permit,	

Agency / Permit / Expiration	Special Conditions	Report Due Date
	the Property and all the matters pertaining thereto as it deems necessary, and on ttiat basis accepts the terms and conditions contained in this Permit. Permittee acknowledges that State has made, and makes, no representations or warranties as to the condition of the Property, and Permittee expressly agrees to accept the Property in its as-is condition for use as herein permitted. Entire Agreement: The Parties further declare and represent that no inducement, promise or agreement not herein expressed has been made to them and this Permit contains the entire agreement of the Parties, and that the terms of this agreement are contractual and not a mere recital. Warranty of Authority: The undersigned represents that they have the authority to, and do, bind the person or entity on whose behalf and for whom they are signing this Permit and the attendant documents provided for herein, and this Permit and said additional documents are, accordingly, binding on said person or entity. Assignment: This Permit shall not be assigned, mortgaged, hypothecated, or transferred by Permittee, whether voluntarily or involuntarily or by operation of law, nor shall Permittee let, sublet or grant any license or permit with respect to the use and occupancy of the Property or any portion thereof, without the prior written consent of State.	

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
California Department of Parks and Recreation (continued) Collections Permit – September 1, 2012 Collections Permit renewal – February 26, 2014 Collections Permit renewal – April 2, 2015 Collections Permit renewal – October 4, 2017 Expiration – April 2, 2018	PERMIT CONDITIONS: CONTACT UNIT PEACE OFFICER/RANGER PRIOR TO MAKING COLLECTIONS: 707/875-3483	No Reporting Required for Collectors Permit

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service Incidental Harassment Authorization (IHA) - April 21, 2011 IHA (renewal) - April 21, 2012 IHA (renewal) - April 21, 2013 IHA (renewal) - April 21, 2014 IHA (renewal) - April 21, 2015 IHA (renewal) - April 21, 2016 IHA (renewal) - April 21, 2017 Letter of Authorization - April 21, 2017 Expiration – April 20, 2022	UNITED STATES DEPARTMENT OF COMMERCE National Oceanic and Atmospheric Administration NATIONAL MARINE FISHERIES SERVICE Silver Spring, MD 20910 LETTER OF AUTHORIZATION The Sonoma County Water Agency (SCWA) is hereby authorized under section 101(a)(5)(A) of the Marine Mammal Protection Act (MMPA; 16 U.S.C. 1371(a)(5)(A)) to take marine mammals incidental to estuary management activities in Sonoma County, California, subject to the provisions of the MMPA and the Regulations Governing Taking of Marine Mammals Incidental to Russian River Estuary Management Activities (50 CFR Part 217, Subpart A) (Regulations). 1. This Letter of Authorization (LOA) is valid from April 21, 2017, through April 20, 2022. 2. This LOA is valid only for take incidental to the specified estuary management activities in Sonoma County, California, and described in the preamble to the Regulations. 3. <u>General Conditions</u> (a) A copy of this LOA must be in the possession of SCWA, its designees, and work crew personnel operating under the authority of this LOA. (b) SCWA is hereby authorized to incidentally take, by Level B harassment only, 4,692 harbor seals (*Phoca vitulina richardii*), 34 California sea lions (*Zalophus californianus californianus*), and 34 northern elephant seals (*Mirounga angustirostris*). These numbers represent the annual take authorization for five years. (c) Taking of these species that exceeds the numbers and/or intensity indicated in 3(b) or any taking of any other species of marine mammal is prohibited and may result in the modification, suspension, or revocation of this LOA. (d) If SCWA observes a pup that may be abandoned, it shall contact the National Marine Fisheries Service (NMFS) West Coast Regional Stranding Coordinator immediately (562-980-3230; Justin.Viezbicke@noaa.gov) and also report the incident to NMFS Office of Protected Resources (301-427-8425; Benjamin.Laws@noaa.gov) within 48 hours. Observers shall not approach or move the pup. 4. <u>Mitigation Measures</u> The holder of this Authorization is required to implement the following mitigation measures: (a) SCWA crews shall cautiously approach the haul-out ahead of heavy equipment. Printed on Recycled Paper season. (b) SCWA staff shall avoid walking or driving equipment through the seal haul-out. (c) Crews on foot shall make an effort to be seen by seals from a distance, if possible, rather than	April 1, annually: Marine Mammal Monitoring Results Report

Agency / Permit / Expiration	Special Conditions	Report Due Date
	(b) SCWA staff shall avoid walking or driving equipment through the seal haul-out. (c) Crews on foot shall make an effort to be seen by seals from a distance. (d) During breaching events, all monitoring shall be conducted from the overlook on the bluff along Highway 1 adjacent to the haul-out. (e) A water level management event may not occur for more than two consecutive days unless flooding threats cannot be controlled. (f) Equipment shall be driven slowly on the beach and care will be taken to minimize the number of shut-downs and start-ups when the equipment is on the beach. (g) All work shall be completed as efficiently as possible, with the smallest amount of heavy equipment possible. (h) Boats operating near river haul-outs during monitoring shall be kept within posted speed limits and driven as far from the haul-outs as safely possible. (i) SCWA shall implement the following mitigation measures during pupping season (March 15-June 30): (i) SCWA shall maintain a one week no-work period between water level management events (unless flooding is an immediate threat). During the no-work period, equipment must be removed from the beach. (ii) If a pup less than one week old is on the beach where heavy machinery will be used or on the path used to access the work location, the management action shall be delayed until the pup has left the site or the latest day possible to prevent flooding while still maintaining suitable fish rearing habitat. In the event that a pup remains present on the beach in the presence of flood risk, SCWA shall consult with NMFS and CDFW to determine the appropriate course of action. SCWA shall coordinate with the locally established seal monitoring program (Stewards of the Coast and Redwoods) to determine if pups less than one week old are on the beach prior to a breaching event. (iii) Physical and biological monitoring shall not be conducted if a pup less than one week old is present at the monitoring site or on a path to the site. 5. Monitoring The holder of this Authorization is required to conduct baseline monitoring and shall conduct additional monitoring as required during estuary management activities. 2	

Agency / Permit / Expiration	Special Conditions	Report Due Date
	Monitoring and reporting shall be conducted in accordance with the approved Pinniped Monitoring Plan. (a) Baseline monitoring shall be conducted each week, with two events per month occurring in the morning and two per month in the afternoon. These censuses shall continue for four hours, weather permitting; the census days shall be chosen to ensure that monitoring encompasses a low and high tide each in the morning and afternoon. All seals hauled out on the beach shall be counted every 30 minutes from the overlook on the bluff along Highway 1 adjacent to the haul-out using high-powered spotting scopes. Observers shall indicate where groups of seals are hauled out on the sandbar and provide a total count for each group. If possible, adults and pups shall be counted separately. (b) Peripheral coastal haul-outs shall be visited concurrently with baseline monitoring in the event that a lagoon outlet channel is implemented and maintained for a prolonged period of over 21 days. (c) During estuary management events, monitoring shall occur on all days that activity is occurring using the same protocols as described for baseline monitoring, with the difference that monitoring shall begin at least one hour prior to the crew and equipment accessing the beach work area and continue through the duration of the event, until at least one hour after the crew and equipment leave the beach. In addition, a one-day pre-event survey of the area shall be made within one to three days of the event and a one-day post-event survey shall be made after the event, weather permitting. (d) For all monitoring, the following information shall be recorded in 30-minute intervals: i. Pinniped counts by species; ii. Behavior; iii. Time, source and duration of any disturbance, with takes incidental to SCWA actions recorded only for responses involving movement away from the disturbance or responses of greater intensity (e.g., not for alerts); iv. Estimated distances between source of disturbance and pinnipeds; v. Weather conditions (e.g., temperature, percent cloud cover, and wind speed); and vi. Tide levels and estuary water surface elevation. 6. Reporting 3	

Sonoma Water
Summary of Special Conditions of Permits for Russian River Estuary Management Activities

Agency / Permit / Expiration	Special Conditions	Report Due Date
	The holder of this Authorization is required to: (a) Submit an annual summary report on all activities and marine mammal monitoring results to the Office of Protected Resources, NMFS. This report must be submitted within 90 days following the end of each calendar year. SCWA shall provide a final report within 30 days following resolution of comments on the draft report. The report must contain the following information: i. The number of seals taken, by species and age class (if possible); ii. Behavior prior to and during water level management events; iii. Start and end time of activity; iv. Estimated distances between source and seals when disturbance occurs; v. Weather conditions (e.g., temperature, wind, etc.); vi. Haul-out reoccupation time of any seals based on post-activity monitoring; vii. Tide levels and estuary water surface elevation; viii. Seal census from bi-monthly and nearby haul-out monitoring; and ix. Specific conclusions that may be drawn from the data in relation to the four questions of interest in SCWA's Pinniped Monitoring Plan, if possible. (b) Submit a comprehensive summary report to NMFS in conjunction with any future submitted request for incidental take authorization. (c) Reporting injured or dead marine mammals: i. In the unanticipated event that the specified activity clearly causes the take of a marine mammal in a prohibited manner, SCWA shall immediately cease the specified activities and report the incident to the Office of Protected Resources, NMFS, and the West Coast Regional Stranding Coordinator, NMFS. The report must include the following information: A. Time and date of the incident; B. Description of the incident; C. Environmental conditions; 4	

Agency / Permit / Expiration	Special Conditions	Report Due Date
	D. Description of all marine mammal observations in the 24 hours preceding the incident; E. Species identification or description of the animal(s) involved; F. Fate of the animal(s); and G. Photographs or video footage of the animal(s). Activities shall not resume until NMFS is able to review the circumstances of the prohibited take. NMFS will work with SCWA to determine what measures are necessary to minimize the likelihood of further prohibited take and ensure MMPA compliance. SCWA may not resume their activities until notified by NMFS. ii. In the event that SCWA discovers an injured or dead marine mammal and determines that the cause of the injury or death is unknown and the death is relatively recent (e.g., in less than a moderate state of decomposition), SCWA shall immediately report the incident to the Office of Protected Resources, NMFS, and the West Coast Regional Stranding Coordinator, NMFS. The report must include the same information identified in 6(c)(i) of this LOA. Activities may continue while NMFS reviews the circumstances of the incident. NMFS will work with SCWA to determine whether additional mitigation measures or modifications to the activities are appropriate. iii. In the event that SCWA discovers an injured or dead marine mammal and determines that the injury or death is not associated with or related to the specified activities (e.g., previously wounded animal, carcass with moderate to advanced decomposition, or scavenger damage), SCWA shall report the incident to the Office of Protected Resources, NMFS, and the West Coast Regional Stranding Coordinator, NMFS, within 24 hours of the discovery. SCWA shall provide photographs or video footage or other documentation of the stranded animal sighting to NMFS. iv. Pursuant to sections 6(c)(ii-iii), SCWA may use discretion in determining what injuries (i.e., nature and severity) are appropriate for reporting. At minimum, SCWA must report those injuries considered to be serious (i.e., will likely result in death) or that are likely caused by human interaction (e.g., entanglement, gunshot). Also pursuant to sections 6(c)(ii-iii), SCWA may use discretion in determining the appropriate vantage point for obtaining photographs of injured/dead marine mammals. 5	

Agency / Permit / Expiration	Special Conditions	Report Due Date
	7. Validity of this Authorization is contingent upon compliance with all applicable statutes and permits, including NMFS's 2008 Biological Opinion for water management in the Russian River watershed. This Authorization may be modified, suspended or withdrawn if the holder fails to abide by the conditions prescribed herein, or if NMFS determines that the authorized taking is having a more than a negligible impact on the species or stock of affected marine mammals. [signature] Donna S. Wieting Director, Office of Protected Resources, National Marine Fisheries Service. APR 19 2017 Date 6	

Attachment D. Russian River Barrier Beach and Estuary Water Surface Level Adaptive Management in Concert with Physical Processes

(from National Marine Fisheries Service)

Russian River Barrier Beach and Estuary Water Surface Level Adaptive Management in Concert with Physical Processes

John McKeon, National Marine Fisheries Service

To comply with NMFS' BO for adaptive management of the RR estuary, i.e., to manage the beach with the goal of conserving beach sand to allow formation of a stable low-flow season elevated outlet-channel and creating a brackish /freshwater lagoon with marine influence minimized, the Sonoma County Water Agency (SCWA) will need to balance multiple natural physical processes when carrying out flood control activities. The two primary processes to balance are: wave and longshore transport of sand into the channel, dependent on wave direction, height and steepness; and outlet channel river-flow scour determined by slope, depth and roughness. The amount of sand transported by either force is dependent on sand supply. As the channel is likely to be of sand only, the vertical elevation-controls of the outlet channel will be the sum of sand transport out of the channel at low tide by the river outflow, versus transport of sand into the channel on the incoming high tide by wave action and longshore current. As the tide lowers and rises, one of these two physical forces will predominate. Balancing the two transport mechanism rates over a 24 hr tidal cycle will be key to maintaining an over-all stable vertical outlet channel elevation and stable estuary water levels minimally influenced by tidal fluctuation. The wave-face between the low tide line and the top of the wave-face crest (height determined by wave height at high tide) will be the key area of scour and accretion during the cycle.

Calculation of scour in open flume channels is a well studied subject, with critical shear stress of when sediments are mobilized on the channel bottom a function of grain size, water velocity and depth. Velocity is determined by roughness and slope. Channel dimension, slope and roughness can be calculated for predicted flow ranges to minimize sheer stress, bed mobilization, scour, and incision of the channel. However, slope across the wave face will be determined by the beach profile where the river outflow meets the ocean. This is the likely point at which channel headcutting would begin, resulting in significant lowering of the outlet channel elevation and estuary water surface elevation (WSE). Because SCWA cannot influence the slope of the wave face beach profile, strategies to minimize scour potential are limited to: 1) choose a river channel outlet location across the wave face where the beach profile has the least slope between the low tide line and wave-face crest height, and 2) minimize depth with increased channel width across the crest of the wave face. This will both limit scour on the outgoing tide, and increase wave transport of sand into the mouth with a greater length of wave break pushing sand into the channel on high tides. Also, to limit propagation of any headcutting precipitated at low tide, the velocity in the channel above the wave face can be decreased with increased roughness and length, or the depth (and scour potential) decreased by increasing the outlet channel width. The beach size and configuration at the time of closure, and the jetty, will constrain, and in part determine, these three channel characteristics.

However, if flood threats and subsequent breaching actions are to be avoided, minimization of scour in the channel and across the wave face needs to be balanced against the ability of channel outflow to remove the predictable transport of sand into the channel by wave and longshore transport, both of which significantly increase during a beach building event and result in a channel closure event.

Transport of sand by waves on to a beach (and into the outlet channel) occurs when wave height compared to wave length reaches a critical point, which is called critical steepness, expressed as Critical H/L. JW Johnson determined critical steepness in the laboratory as = 0.03; waves with a lower H/L value moved sand offshore, those with a higher value moved sand onshore[2]. Wave length is directly proportional to wave period. Using the acceleration rate of gravity, 32/ft/sec/sec= g; and pi for rough approximation of wave form as sinusoidal, L = g/2pi* T^2 or $5.12T^2$ (*e.g.,* 13 ft waves, 9 second period; 9 squared*5.12= 414.72; 13/414.72= 0.0314, steep enough to accrete, or 9 ft waves, 7 second period; 7 squared*5.12= 250.88; 9/250.88= 0.0359).

Because of the coastal aspect of the RR beach and the presence of headlands to the north and south, wave direction is important in determining the height of waves which reach the beach. Wave direction and size also determine the strength of the longshore current, and thus the rate of channel infilling on an incoming tide. The larger the waves, and greater the angle of wave incidence away from perpendicular to the beach, the stronger the longshore current and amount of sand transport.

The incidence of the outlet channel to the wave-face crest will be critical in limiting channel infilling by wave action during a beach building event. When a beach building/closure event is occurring, at high tide waves will be delivering and depositing sand up and over the wave face crest into the mouth of the channel at a rate much greater than the ability of the relatively low flow of the channel to transport sand in opposition to the direction of wave transport. However, a channel behind the wave-face crest and close to perpendicular to the wave direction will be more capable of transporting the sand washed into it by wave action, as flow from the wave will be entrained in the flow of the outlet channel, with the added flow increasing the transport power of the outlet channel. Thus, by orienting the outlet channel near to perpendicular to wave run-up direction, the out-flow channel will be better at limiting or preventing accretion of sand in the channel mouth by successive waves than if the channel is parallel to the wave run-up direction. Strategies for minimizing accretion of sand in the lagoon outlet channel mouth during a beach building event, and limiting likelihood of outlet channel closure events will be: 1) choose a river channel outlet location where the beach profile has the least slope between the low tide line and wave-face crest height, as less slope will mean a greater distance for waves to expend their energy before topping the wave crest, and/or the lower wave-face crest would signify an area of reduced wave size and transport capacity; 2) align the channel from the lagoon outlet, and behind the wave-face crest, to be as near to perpendicular as possible to wave run-up direction in order to minimize sand accretion at the channel mouth during high tide.; 3) insure there is sufficient slope from the lagoon WSE to the point the channel crosses the wave-face crest sufficient to maintain flow across the wave-face crest when waves push the crest above the high tide line (~ 3.3 ft NGVD with a 6 foot high tide). This means planning for the outlet channel invert to be above the lowest point of the wave-face crest height.

---

[2] Willard Bascom. 1980. *Waves and Beaches.* Anchor Books Edition. ISBN: 0-385-14844-5

Channel Planform and Slope

In addition to the above described means to balance scour and accretion in the channel mouth and across the wave face, the channel planform will be dictated by beach topography. The entire beach topography above the tide lines is determined by waves and longshore current that will continue to sculpt the beach once the outlet channel has been established. To avoid repetitive heavy equipment excursions on to the beach to reform the outlet channel, the beach topography should dictate both the channel planform and slope of the outlet channel. To determine the most natural channel planform and slope, *i.e.*, the planform location and slope that will most likely be maintained by wave and tidal action subsequent to formation of an outlet channel by SCWA, a detailed topographic survey of the beach will need to be prepared post lagoon-closure, and prior to beach and estuary WSE management actions.

Natural Analogues

When waves reach critical steepness and sand accretion occurs on the beach, the underwater sand bar just outside the wave break is moved onshore with the incoming tide. The beach increases in both width and height, which results in a lengthening of the outlet channel as it has a greater width of beach to cross, and behind the wave-face crest, flows longitudinally along the beach to the lowest point of the crest. The increased length of the channel results in more resiliency to scour and incision during low tide and allows for stabilized lagoon WSE, with tidal influence becoming muted. Lacking subsequent beach building events, the channels may scour back down below the high tide level within weeks, reintroducing tidal influence to the lagoon WSE. However, with continued or subsequent beach building events, the channel continues to elevate and lengthen, and with river inflows declining in spring/summer, the channel loses its ability to incise, and a closed of perched lagoon WSE eventually results.

A short duration event of critically steep waves and beach building occurred along the California Coast the week of May 27th to June 3, 2010. Attached are photos of these river mouth beaches and the channels that resulted from that short duration beach building event. A WSE stage monitor in the Carmel lagoon recorded the effect on lagoon WSE, in which subsequent to the event and the lengthening of the channel, the WSE of the lagoon was maintained above the high tide level and tidal influence became muted. Photos included are of Carmel, San Lorenzo, Scott, Waddell, Pamponio and Navarro river beaches. A plot of the Carmel lagoon WSE for June 2010 can be viewed at http://www.mpwmd.dst.ca.us/wrd/lagoon/webplots/2010/2010webplots.htm

CARMEL, 6/9/2010

San Lorenzo, 6/10/2010

Scott Creek, 6/10/2010

Waddell, 6/10/2010

Pamponio, 6/10/2010

Navarro, 6/6/2010

Navarro, 6/6/2010

Navarro, 6/6/2010 (high tide-/Lagoon WSE ~ 6-7 feet NGVD estimated)

Navarro, 6/6/2010

Attachment E. Implementation of the 2010 Outlet Channel Adaptive Management Plan

At the direction of NMFS, Sonoma County Water Agency (the Agency) has been tasked with creating an outlet channel intended to improve salmonid habitat in the Russian River Estuary while maintaining the current level of flood protection for properties adjacent to the estuary (NMFS, 2008). The adaptive management plan, described in the main body of this report, was developed by the Agency with assistance from ESA PWA and the resource agency management team in 2009 and revised in 2010. Because of permit constraints, the Agency was only able to implement the plan beginning in 2010. This attachment documents the management actions in response to inlet closures that occurred during the 2010 lagoon management period.

During the management period, May 15th to October 15th, Agency staff regularly monitored current and forecast estuary water levels, inlet state, river discharge, tides, and wave conditions to anticipate inlet closure. For the first month and a half, river discharge was somewhat larger than historic daily median conditions due to a wetter-than-average spring, but then receded to nearly replicate historic median flow rates. Average monthly wave energy in 2010 was similar to historic averages for most of the management period and higher for June and October. Two periods of inlet closure occurred (Figure 1), leading the Agency to begin planning for management action to create an outlet channel, in accordance with the plan's communication protocol:

- Starting in late June 2010, physical conditions at the mouth of the Russian River Estuary naturally established an outlet channel that persisted for a week before wave action completely closed the lagoon. In response to this closure, the Agency attempted to create an outlet channel for the first time. This management action briefly re-established outlet channel conditions, but within a half day, wave action re-closed the outlet channel. Before the next scheduled management action could take place, the lagoon breached, returning the estuary to tidal conditions.
- The estuary closed twice more in the management period, during the third week of September and again at the start of October. Although action to create an outlet channel was initially considered after the September closure, an extended period of large waves limited beach access due to safety concerns. As a result, water levels continued to rise, heightening flood risk. Therefore, in consultation with the resource agency management team, the Agency decided to implement full breaching. Two attempts were required for each closure before the lagoon was successfully breached.

The next section of this attachment reviews the process for leading up to and during the July outlet channel implementation. In the following section, the September and October closures are assessed. Although the September and October closures did not result in creation of an outlet channel, the planning process and physical processes are relevant to adaptive management. The last section summarizes lessons learned from the 2010 management period to consider in subsequent years.

JUNE-JULY 2010 OUTLET CHANNEL EVOLUTION

In the second half of June, an outlet channel and perched lagoon were naturally established at the mouth of the Russian River. For about one week, this channel conveyed enough water to the ocean to sustain 4.5 to 5 ft NGVD water levels in the lagoon. Once waves closed the outlet channel and lagoon water levels began to rise, the Agency implemented a management action to create an outlet channel. In the face of strong waves, this outlet quickly closed. Several days later, the lagoon was breached and tidal conditions returned until September. Details of this channel evolution are provided below.

NATURALLY ESTABLISHED OUTLET CHANNEL

Outlet channel conditions (defined as a nearly steady lagoon water levels above ocean water levels and maintained by uni-directional outflow in a channel passing through the beach berm) naturally established over a week-long period in late June. The physical conditions associated with this evolution are described below.

Water level

Water levels in the lagoon, as observed at the Jenner gage, exhibited a muted tide range, indicative of partial closure, starting on June 20th as shown in Figure 2a. The tide range gradually decreased from about 1.5 ft until tidal variations ceased early on the morning of June 27th. Lagoon water levels then increased over the next day to just over 4 ft NGVD. Water levels were then fairly constant at about 4 ft NGVD for three days. On June 30th, the water levels started to decline, probably due to the drop in upstream riverine discharge as compared to higher outlet channel discharge. Water levels declined to a minimum of 3 ft NGVD before the channel closed on July 4th.

Ocean waves and tides

Significant wave height at CDIP's Point Reyes buoy increased above 2 m starting on June 24th as shown in Figure 2b. About the time that tidal influence disappeared from lagoon water levels on June 27th, the significant wave height exceeded 3 m and stayed above 3 m until July 1st. Peak wave period during this time period was approximately 8 seconds and the peak direction was from the northwest. Figure 3 illustrates the wave direction, period, and magnitude from June 16th through July 14th. Astronomic tides were declining from peak spring levels, with the higher high water on June 27th of just over 3 ft NGVD as shown in Figure 2c.

Riverine discharge

Riverine discharge in late June was higher than to median conditions because of late season precipitation and full reservoirs. Figure 2d illustrates how flow dropped rapidly from 325 ft^3/s on June 27th to 225 ft^3/s on June 30th. Flow then continued to drop more slowly at a rate of less than 5 ft^3/s per day for the next two weeks.

Planform alignment

At the time of closure, the channel exited the northwest corner of the lagoon and ran along the foot of the bluff, landward of the berm crest, for approximately 550 ft. The channel then crossed the berm and exiting to the ocean. This alignment was similar to the alignment observed during 1998, an El Nino year (personal communication, C. Delaney). Several days before the closure, the channel was observed further south than its alignment along the bluff once the outlet channel established. Unfortunately, the Agency's automated camera did not collect pictures between June 23-29 due to a power failure, precluding a more detailed analysis of the channel's planform evolution in the days preceding the establishment of the outlet channel.

Beach and channel topography

The beach berm north of the outlet channel and the downstream end of the channel was surveyed by Agency staff on July 1st (Figure 4). The presence of seals on the beach to the south of the channel prevented additional survey data from being collected. On both sides of the channel's mouth, sand had deposited such the intertidal beach protruded approximately 50 feet into the ocean as compared to the beach alignment further south (Figure 4 and Figure 5a). Just north of the outlet channel, the beach face that had been covered by wave runup during the previous high tide extended up to 8 ft NGVD. Then the beach profile stepped up to a bench with elevations above 10 ft NGVD. South of the channel, the berm crest elevation was estimated to approximately 7 ft NGVD, but was not measured directly. The outlet channel was approximately 60 ft wide, with its bed elevation at 0-1 ft NGVD for last one hundred feet before it entered the ocean. The channel flowed around numerous large boulders along much of its length. These boulders may have served as natural grade control inhibiting erosion.

Channel discharge

On June 30th, the Agency collected water depths and point velocities in the outlet channel, which was approximately 60 ft wide. Water in the outlet channel flowed at depths up to 2.7 ft and velocities of at least 5.4 ft^2/s. These velocities are in excess of permissible scour criteria for beach sands, but not sufficient to scour the larger boulders found in the outlet channel (Fischenich, 2001). Integrated water depth and point velocity measurements yielded an estimate the channel's discharge of 297 ft^3/s (SCWA unpublished observations). As shown in Figure 2d, this discharge magnitude was observed upstream at Guerneville approximately two days earlier and was larger than the concurrent Guerneville discharge. This is consistent with the dropping water levels in the lagoon (Figure 2a) and tributary inflows downstream of Guerneville.

WAVE-INDUCED OUTLET CHANNEL CLOSURE

After the week of sustained outlet channel conditions, the wave energy briefly relaxed on July 2nd, and then returned to significant wave heights from the northwest exceeding 3.5 m starting on July 3rd (Figure 2b). This increase in wave height was accompanied by an increase in northwest swell wave period to approximately 10 seconds. This increase in wave energy provided enough landward sand transport to close the outlet channel. Riverine discharge had recently declined, reducing the channel's ability to clear sand and remain open. This closure occurred during a neap tide, when higher high water levels just barely exceeded 2 ft NGVD.

Changes to the wave climate continued for the next several days, with the peak direction shifting to the south and the wave period lengthening to nearly 14 seconds (Figure 3). Significant wave height dropped to less than 1.5 m. This long-period, low-steepness swell is likely to have built the beach berm with onshore sand transport. This likely onshore transport changed the beach topography changed in two ways. The protruding sand deposits at the channel's mouth noticeably diminished in size between July 4th and July 5th, and were essentially gone by July 6th. In addition, the onshore transport probably built the berm crest elevation from the estimated berm crest elevation of 7 ft NGVD on July 1st (C. Delaney) and July 4th (J. Largier) to an elevation of 8.5 ft NGVD as surveyed on July 8th.

Once the outlet channel closed, lagoon water levels began to rise at a rate of approximately 0.5 ft/day. The channel closure and rising water levels initiated the Agency's outlet channel management plan.

MANAGEMENT ACTION

Management action to create an outlet channel was scheduled for July 8th in consultation with the resource management team. The action was scheduled for July 8th because it was a Thursday, the last day that action could be taken before the State Parks permit restrictions on Friday-Sunday operations went into effect. Given the observed rate of lagoon water level rise of 0.5 ft/day, waiting until the following Monday was deemed to be too risky in terms of flood hazard and channel scour. To provide operational flexibility in response to site conditions, two different management options were proposed during planning. Figure 4 shows the alignment of these options, both 30 ft wide, as laid on the topographic surface collected on July 1st. This schematic design was used to discuss management plans with the resource agencies, to estimate volumes of excavated material, and to guide operations staff. Option A, the preferred option, followed the northwest alignment of the natural outlet channel prior closure. In the event that beach surveys indicated a low point in the berm further south or if access to the Option A location was restricted by waves, Option B was proposed just north of Haystack Rock.

Based an assessment of site conditions early on the morning of July 8th, Option A was selected for implementation. Excavation began at approximately 7am on July 8th with a bulldozer and backhoe excavator. The lagoon water level at the time work began was 5.9 ft NGVD.

The excavated portion of the managed channel followed the alignment of the southern half of the naturally established outlet channel, as shown in Figure 5b. This alignment allowed the excavation equipment to avoid rocks embedded in the berm. The backhoe removed sand from the landward portion of the berm, adjacent to a large rock. The bulldozer pushed sand towards the ocean to form the lower portion of the channel. A small berm was preserved between the two pieces of equipment to prevent lagoon outflow before the channel was complete. After approximately two hours of work, wave runup associated with the rising tide started to enter the channel's mouth. Therefore, the middle berm was removed with the excavator at approximately 9:30am, completing the channel.

At the time of completion, the outlet channel was approximately 30 ft wide and had an invert of approximately 4.5 ft NGVD. Water flowed in the channel at a depth of approximately 0.5 ft. Flow was typically uniformly seaward in the upstream portion of the newly excavated channel. However, in the downstream portion, wave runup periodically overwhelmed the outflow, causing the flow to switch direction to landward. The transition between the existing channel and the newly excavated portion created a hydraulic control across which water transitioned from subcritical to supercritical, thereby explaining the channel's lower water level as compared to the lagoon. Bed erosion was observed starting from this transition region and into the new portion.

During the period when the outlet channel was open, water levels in the lagoon continued to increase at a similar rate to the rate before the management action. This constant rate of water level increase indicates that flow in the outlet channel was relatively small compared to riverine inflow to the lagoon.

OUTLET CHANNEL CLOSURE

As ocean tides increased water levels throughout July 8th, the wave runup from the south swell advanced up and over the beach face, as evidenced by the absence of equipment tracks on the beach in July 9th photographs. By the evening of July 8th, this advancing wave runup transported enough sand into the outlet channel that the channel once again closed. Higher high water on the evening of July 8th was above 3 ft NGVD, as tidal conditions were building towards large spring tides.

After reviewing lagoon and beach conditions on July 9th, the Agency scheduled follow-up management for Monday, July 12th, the first day which they were allowed to operate on the beach under their State Parks permit.

BREACHING TO TIDAL CONDITIONS

Lagoon water levels continued to rise at a rate of approximately 0.5 ft/day in the days following closure. On the evening of July 11th, the lagoon breached in the vicinity of Haystack Rock. The lagoon water level at the time of the breach was 7 ft NGVD, which is approximately 1.5 ft below the berm crest elevation surveyed on July 8th. This difference suggests that the breach may have been caused by seepage through the berm. Just before the breach, the water's edge extending towards the breach site, indicating that breach occurred at the low point in the beach berm's crest elevation.

Because the estuary returned to tidal conditions on July 11th, the management action planned for July 12th was cancelled. Tidal conditions persisted in the estuary until September.

SEPTEMBER-OCTOBER 2010 CLOSURES AND MANAGEMENT

In the end of August, coincident with neap tides and increased wave heights, the estuary water levels became muted, diminishing to a tide range of less than one foot (Figure 6a). Shortly afterwards, starting on September 4th, wave energy increased considerably from the northwest (Figure 7b) to sustained wave heights exceeding 3 m and peaking above 4 m (Figure 6b). This combination of muted tides followed by large waves, would seem to have been ideal conditions to prompt closure. However, the inlet stayed open throughout this high wave period. Several factors probably contributed to the inlet's persistent opening. Although large in height, the waves' period was relatively short (below 12 seconds) and from the northwest. Because of the beach faces the southwest, it may be partially sheltered from waves out of the northwest. The tides were transitioning from neap to spring, so the increasing tidal prism would have contributed to scouring the inlet's channel. Wave overtopping also may have contributed to maintaining inlet by adding water to the estuary that then flowed out the inlet, scouring the channel.

After the muted tides in early September, full tide range returned to the lagoon, probably assisted by the arrival of larger spring tides. Around September 18th, during the month's second neap tide, another wave event was observed with significant wave height less than 2 m, nearly half the magnitude of the early September event (Figure 6b). However, the wave period was longer, 16-18 seconds instead of 8-10 seconds, and waves were from the south instead of the northwest. These conditions closed the estuary on September 21st.

After the inlet closed on September 21st, planning to establish an outlet channel began. Based on the most recent beach topography, the projected rate of lagoon water level increase, tides, and wave forecasts, September 28th, was selected for an attempt at creating an outlet channel. Two options for the channel were proposed, one extending to the northwest from the edge of the lagoon, and one just south of Haystack Rock where the inlet had been just before closure. Lagoon water levels were above 6 ft NGVD by the 28th, as anticipated, in part due to wave overwash. Although water levels were rising, runup from large waves made beach access unsafe and operations were postponed to September 29th. Unsafe wave conditions persisted on the 29th, again preventing beach access. Since wave forecasts predicted only a brief lull on the next day before large waves returned and weekend access restrictions loomed, the Agency, in consultation with the resource agency management team, decided on the evening of Wednesday, September 29th, to switch from attempting to create an outlet channel to attempting a full breach.

Wave and tide conditions on the morning of September 30th allowed for beach access and a full breach was implemented. However, waves carried on the rising tide re-closed the inlet that afternoon and lagoon water levels continued to rise. A second attempt at breaching the afternoon of the 30th was cancelled because of unsafe wave conditions on the beach. Because of the impending flood risk (9 ft water levels were projected by Sunday, October 3rd), the Agency sought and received permission from State Parks to access the beach Friday, October 1st. The breach on October 1st was successful, helped by extensive scour coinciding with tides dropping to lower low water during the night. Estuary water levels dropped to 1 ft NGVD on October 2nd.

After a brief lull, wave conditions once again intensified and the inlet closed again on October 4th. Although still within the management period, the proximity to the end of the management season, as well as continuing forecasts for high waves, led the Agency to propose and receive permission from the resource agency management team for a full breach. Breaching was attempted on October 11th, when lagoon water levels had exceeded 7 ft NGVD. This attempt failed as waves pushed sand into the breach before it could enlarge and lower lagoon water levels. A second breach attempt was made on the afternoon of October 12th, successfully creating a sustained breach that lowered estuary water levels to tidal conditions. A third closure occurred on October 21st and self breached on October 24th, partly in response to high river discharge. Although this third event was outside the outlet channel management period, it was indicative of the extended period of large waves during September and October 2010.

LESSONS LEARNED AND RECOMMENDATIONS

Based on observations of the estuary, associated physical processes, and the July 8th outlet channel management action, we note the following lessons about implementing the outlet channel management plan.

CONCEPTUAL MODEL

- All four closures discussed above occurred coincident with noticeable wave energy associated with periods greater than 12 seconds. In fact, a long period, but relatively low wave height (less than 2m) event closed the inlet in the third week of September even though a larger wave height, but shorter period wave event two weeks earlier did not close the inlet. In all but one case, the long period waves which caused closure originated from the south or west.
- When wave runup started to progress into the outlet channel and force operations to end, it was decided to favor a deeper outlet channel over a wider outlet channel. Channel depth was sought to facilitate more discharge from the lagoon to counter incoming waves. We recommend continuing to observe channel/ocean dynamics in subsequent outlet channels to inform tradeoff decisions of this nature.

FEASIBILITY

- In hindsight, a better opportunity for establishing an outlet channel in July may have been July 10th or the morning of July 11th, when the long-period south swell had subsided but before the breach occurred. However, based on available information (wave forecasts and no knowledge of the breach) the management action was enacted earlier, on July 8th, because the following days were Friday through Sunday when State Parks restricts beach access. Future outlet channel management opportunities are likely to face similarly constrained time windows: too soon after closure, the wave conditions which caused closure may prevent safe beach access and lagoon water levels will be less than the BO targets; too late after closure and water levels may cause flooding or overtopping the beach berm. In addition to the State Parks weekend access constraints, operations are constrained by IHA rules, particularly before June 15th when pupping season ends.

- If the rocks embedded in the beach are essential for stabilizing against failure by scour, then the elevation of the rocks will largely determine the outlet channel bed elevation and lagoon water level. During the naturally established outlet channel which occurred from June 27th through July 3rd, the channel's bed elevation just before the beach face was 0-1 ft NGVD (July 1st Agency survey) and the lagoon water level was between 4.5 and 5 ft NGVD. Under these conditions, the outlet channel was able to convey approximately 300 ft^3/s.
- If an outlet channel had been in place at the start of the September-October large wave period, it quite likely would have closed since waves frequently overtopped the beach berm and even some full breaches were quickly closed. If the lagoon water level was close to or at the BO target 7 ft NGVD when the closure occurred and beach access was limited by wave conditions for multiple days, e.g. the five day period from September 26th to September 30th, the lagoon would likely have reached flood stage.
- Management actions attempting full breaching, which aim to convert the inlet between two of its stable modes (breached and closed) and which are informed by decades of management experience, still fail quite regularly. For example, in 2010, two of four breach attempts were unsuccessful and historically, one out of every three attempts have been unsuccessful (Behrens et al., in prep). We anticipate that the failure rate of efforts to create an outlet channel, a less common and less stable transitional state, to be at least as frequent, if not more frequent, than the failure rate for full breaches.

COMMUNICATION

- Continue the practice of developing and communicating a backup plan for the outlet channel management action in the event that surf conditions were unsafe at the preferred channel location. Communicating this backup plan ahead of time allowed time for discussion among the resource management team, reducing the potential for last minute disagreement if this option had to be enacted.
- Agency, NMFS, and ESA PWA staff consulted as to the specifics of the outlet channel implementation immediately before and during the excavation. This discussion was necessary because of uncertainty about the actual beach topography, the excavation progress relative to the tides, and the overall development of outlet channel strategy for this initial implementation. It enabled real-time adaptation to on-site constraints. For instance, the excavation's location was shifted slightly south of the prior channel's location to avoid large rocks known to be hidden within the berm. After following this alignment beyond the rocks, the excavation was guided northward so that the mouth of the outlet channel would be as close as possible to the prior location.
- After each management action, we suggest asking State Parks staff if operations had gone in accordance with their expectations with regard to parking lot use, public safety, sand placement, etc.

STAFFING

- The Agency's engineer on site had broad knowledge of the project objectives and operational constraints, enabling him to engage in discussion with the other on-site personnel (particularly the NMFS representative), observe physical conditions, and make real-time decisions about the outlet channel configuration. This presence and decision-making authority was essential since the management action was only defined ahead of time as a strategy, not construction-grade drawings.
- Develop capacity of other Agency staff to manage outlet channel operation so availability of informed decision-makers does not hinder management operations.
- Although equipment operators were new to the site, they adeptly executed outlet channel design as directed by Agency staff. Encourage the contractor to provide staff familiar with the project whenever possible.

EQUIPMENT AND OPERATIONS

- The backhoe excavator was more adept at operations adjacent to rock, the bulldozer was faster for areas with open sand. Particularly if operations occur over two days, consider choice of equipment. For example, on the first day, choose two bulldozers for speed in excavating a larger channel and replace one bulldozer with an excavator on the second day for more precise operations.
- Tides, daylight, and permits all restrict the time available for operations. To maximize time available for implementing management actions, consider the following procedures:
    - When possible, have key resource management team members discuss the operations plan ahead of time, ideally on-site the day before, or by phone if on-site is not practical.
    - Clarify staging procedure between equipment operators and engineering staff to reduce waiting
    - Consider the use of lights to enable equipment to operate under low-light conditions.
- Because rocks limit the outlet channel's alignment; having survey staff on-hand to stake locations of rocks covered by the sand was useful. Agency surveys should continue to monitor rock locations during monthly surveys.
- Equipment operators demonstrated good coordination between the pieces of equipment, with neither piece idle for an extended period. The two pieces smoothly switched the two primary tasks of channel excavation and feathering excavated material onto the beach face.
- Sand cleared from the outlet channel was left as a temporary berm at the mouth of the outlet channel to impede wave runup into the outlet channel. This berm was re-shaped just before finishing to open the outlet channel while still providing some protection from south swell.

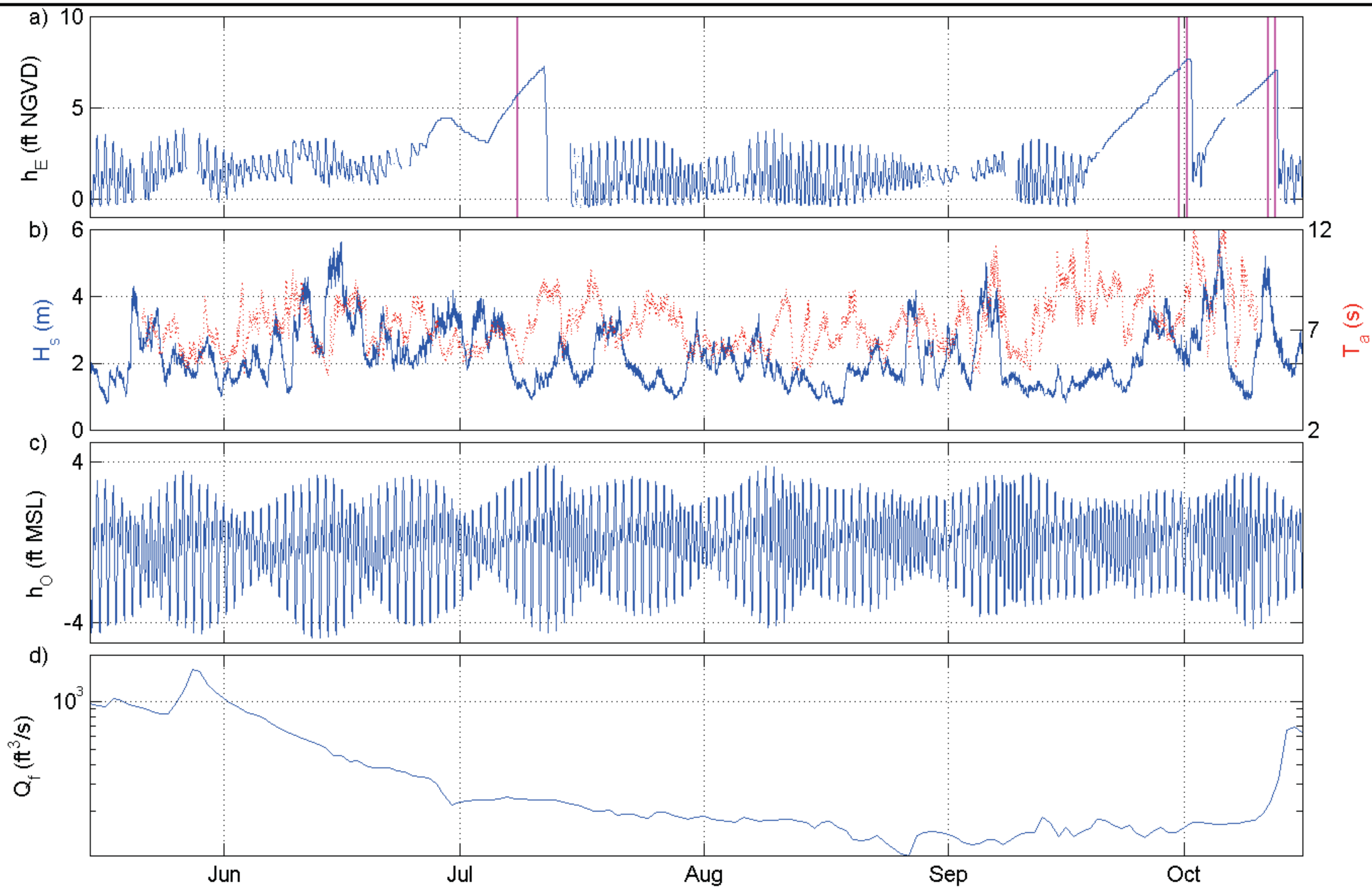
MONITORING

- Because the IHA limits the days available to place people on the beach to collect data, use the full two days allotted for outlet channel creation to collect additional data. For instance, consider having the survey team return at 12-hr intervals to take photographs and survey channel bathymetry and discharge.
- Consider an alternate automated camera placement to capture the northern portion of the beach.

REFERENCES

Behrens, D.K., F. A. Bombardelli, J. L. Largier, and E. Twohy. in preparation. Natural and human influences on tidal inlet closure in small bar-built estuaries

Fischenich, C. 2001. Stability thresholds for stream restoration materials. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29). U.S. Army Engineer Research and Development Center, Vicksburg, MS.



Sources:

a) h_E=estuary water level (SCWA); pink bar = mmgt action

b) H_s=sig. wave height; T_a=avg. wave period (CDIP, Pt. Reyes, #029)

c) h_O=ocean water level (NOAA, Pt. Reyes #9415020)

d) Q_f=river discharge (USGS, Guerneville #11467000)

Figure 1

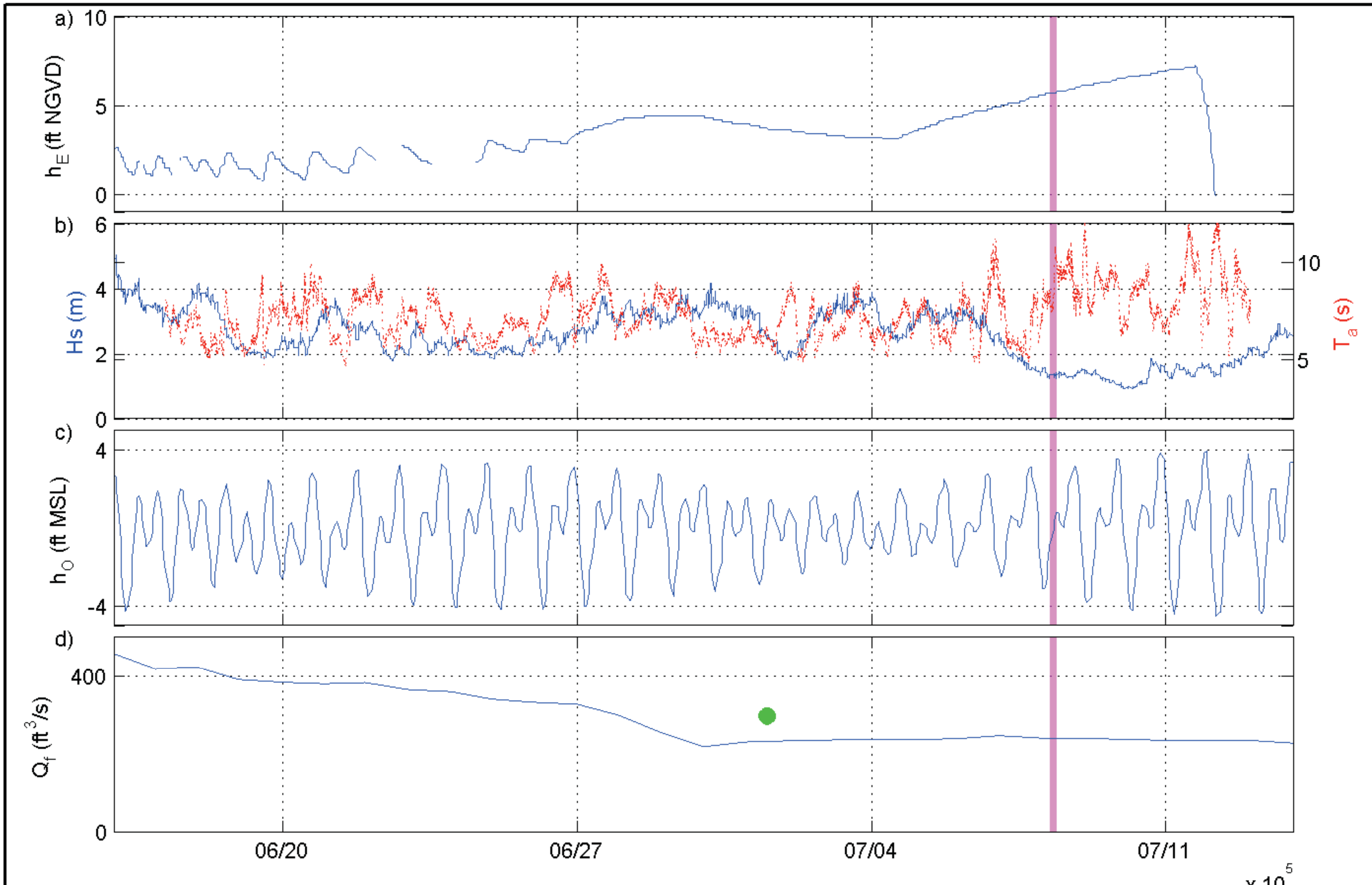
Russian River Estuary Outlet Channel Management Plan

Estuary and Ocean Conditions, May 15 - October 15 2010

PWA Ref# 1958.01

ESA PWA

K:\projects\1958.01RREAMPOutletChannel\Task 8 Year 1 eval & 2011 plan\Year 1 eval memo\mfiles\plot_rre.m



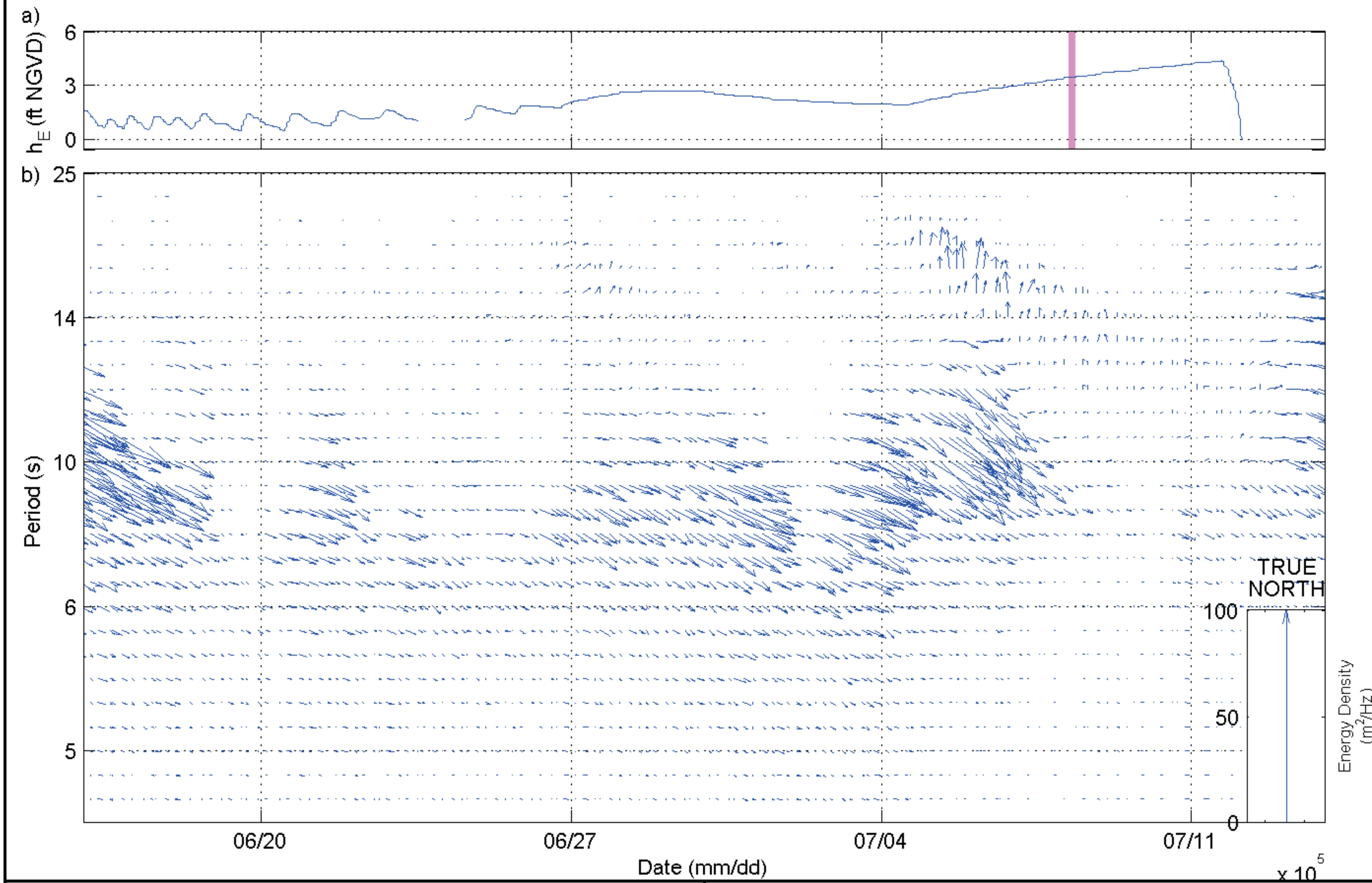
Sources:
a) h_E=estuary water level (SCWA); pink bar = mngt action
b) H_s=sig. wave height; T_a =avg. wave period (CDIP, Pt. Reyes, #029)
c) h_O=ocean water level (NOAA, Pt. Reyes #9415020)
d) Q_f=river discharge (USGS, Guerneville #11467000)

Figure 2
Russian River Estuary Outlet Channel Management Plan

Estuary and Ocean Conditions, June - July 2010

PWA Ref# 1958.01

K:\projects\1958.01RREAMPOutletChannel\Task 8 Year 1 eval & 2011 plan\Year 1 eval memo\mfiles\pwa_fig.m



Sources:
a) h_E=estuary water level (SCWA); pink bar = mmgt action
b) Wave magnitude and direction (CDIP, Pt. Reyes, #029)

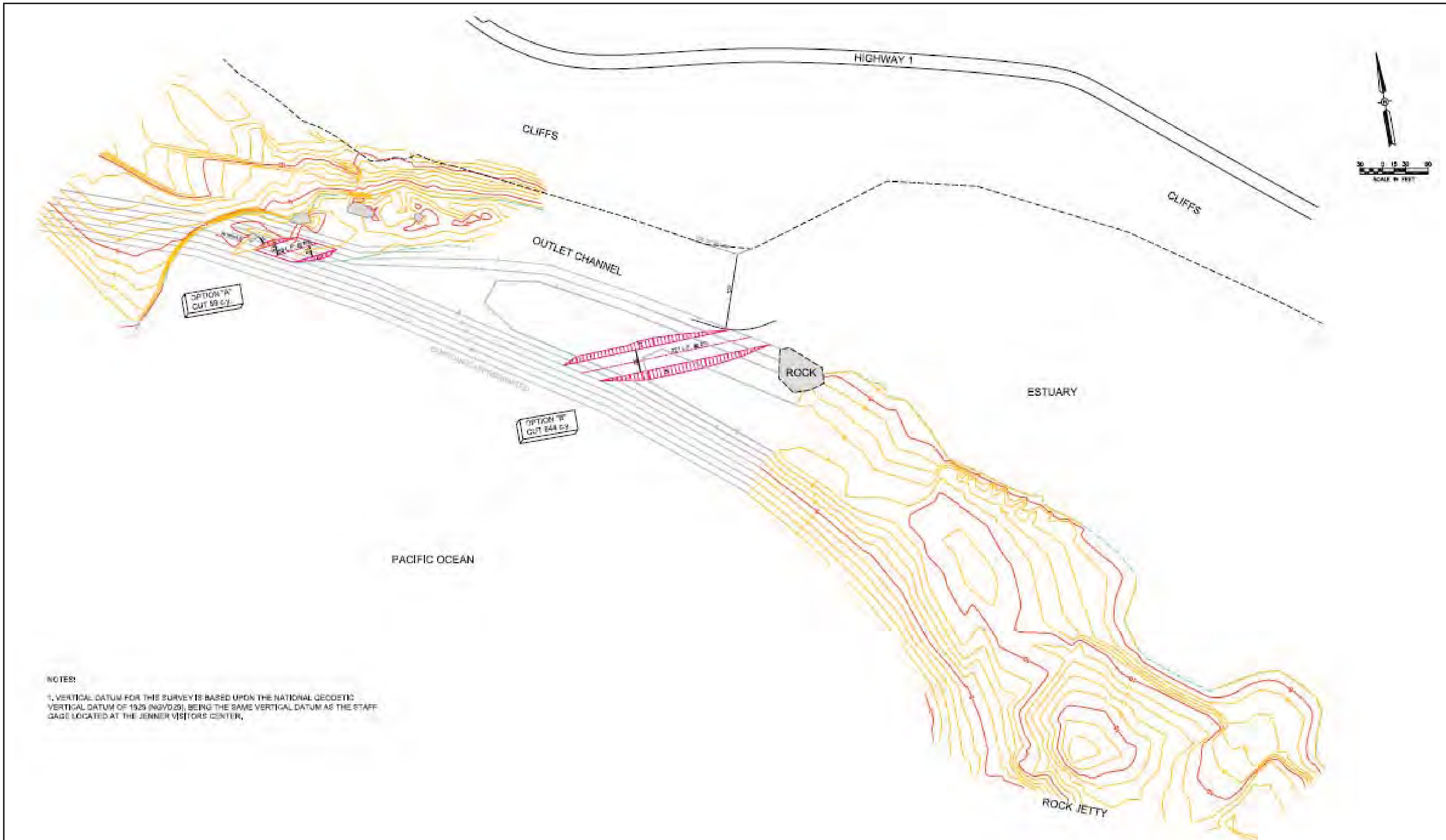
Figure 3
Russian River Estuary Outlet Channel Management Plan

Estuary Water Level and Wave Energy/Direction Spectrum
JUNE-JULY 2010

PWA Ref# 1958.01

ESA PWA

K:\projects\1958.01RREAMPOutletChannel\Task 8 Year 1 eval & 2011 plan\Year 1 eval memo\mfiles\featherfigure.m



Source: SCWA

figure **4**

Russian River Outlet Channel Adaptive Management Plan

Beach Topography and Management Options, June 2010

PWA Ref# 1958.01

ESA PWA

K:\projects\1958.01RREAMPOutletChannel\Task 8 Year 1 eval & 2011 plan\Year 1 eval memo\figs\FigX BeachTopoJune.doc

a)

b)

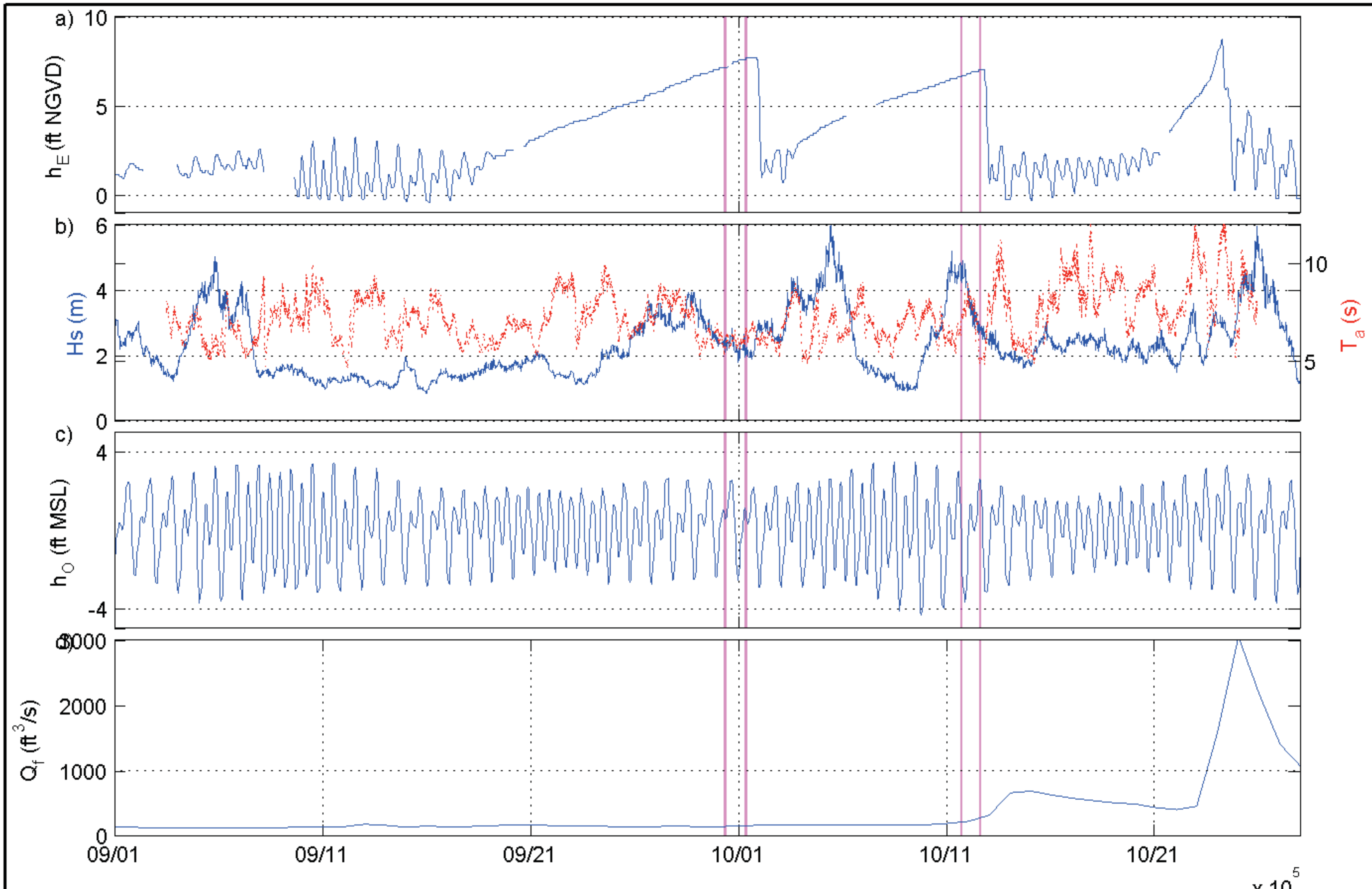
Source: C. Delaney, SCWA

figure 5
Russian River Outlet Channel Adaptive Management Plan

Natural and Managed Outlet Channels

PWA Ref# 1958.01

ESA PWA



Sources:
a) h_E=estuary water level (SCWA); pink bar = mmgt action
b) H_s=sig. wave height; T_a =avg. wave period (CDIP, Pt. Reyes, #029)
c) h_O=ocean water level (NOAA, Pt. Reyes #9415020)
d) Q_f=river discharge (USGS, Guerneville #11467000)

Figure 6

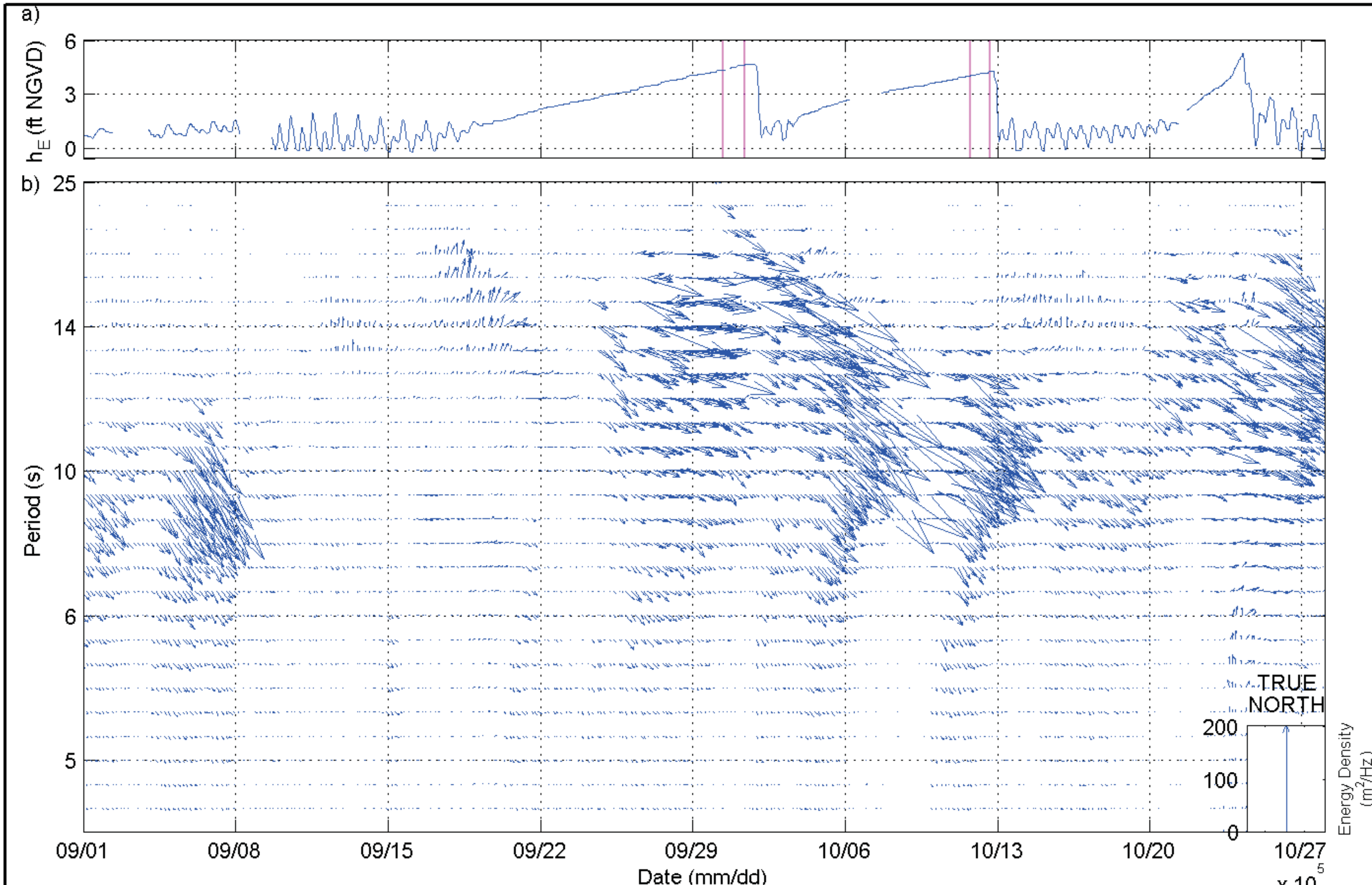
Russian River Estuary Outlet Channel Management Plan

Estuary and Ocean Conditions, September - October 2010

PWA Ref# 1958.01

ESA PWA

K:\projects\1958.01RREAMPOutletChannel\Task 8 Year 1 eval & 2011 plan\Year 1 eval memo\mfiles\plot_rre.m



Sources:
a) h_E=estuary water level (SCWA); pink bar = mmgt action
b) Wave magnitude and direction (CDIP, Pt. Reyes, #029)

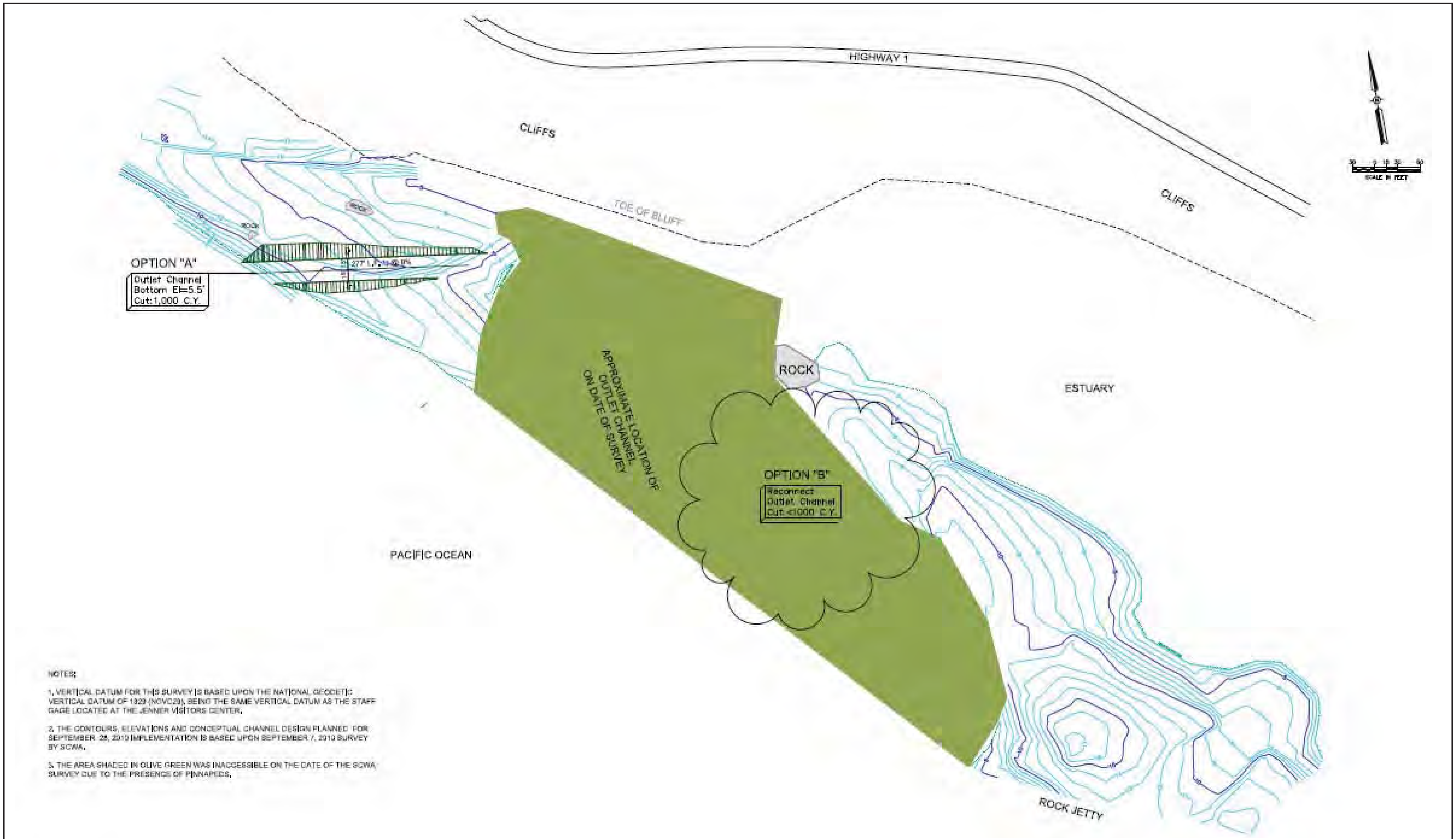
Figure 7
Russian River Estuary Outlet Channel Management Plan

Estuary Water Level and Wave Energy/Direction Spectrum
September-October 2010

PWA Ref# 1958.01

ESA PWA

K:\projects\1958.01RREAMPOutletChannel\Task 8 Year 1 eval & 2011 plan\Year 1 eval memo\mfiles\featherfigure.m



Source: SCWA

figure 8

Russian River Outlet Channel Adaptive Management Plan

Beach Topography and Management Options, September 2010

PWA Ref# 1958.01

ESA PWA

K:\projects\1958.01RREAMPOutletChannel\Task 8 Year 1 eval & 2011 plan\Year 1 eval memo\figs\FigX BeachTopoSept.doc

Attachment F. Physical Processes During the 2011 Management Period

As required by the Russian River Biological Opinion, Sonoma County Water Agency (Water Agency) has been tasked with managing a summer lagoon intended to improve salmonid habitat in the Russian River Estuary by creating an outlet channel while maintaining the current level of flood protection for properties adjacent to the estuary (NMFS, 2008). The adaptive management plan, described in the main body of this report, was developed by the Water Agency with assistance from ESA PWA and the resource agency management team in 2009 and revised in 2010 and 2011. Because of permit constraints, the Water Agency was only able to implement the plan beginning in 2010. The revised plan was in effect for 2011, but no opportunities for management action occurred during the management period.

During the 2011 management period, May 15th to October 15th, Water Agency staff regularly monitored current and forecasted estuary water levels, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. High river discharge in the first two months of the management period followed by the typical low wave energy conditions during the summer contributed to the inlet staying open for the first four months of the management period. Starting in late September, the inlet went through a succession of perched lagoon conditions and self breaches, during which the Water Agency closely monitored estuary conditions and considered management options. The perched episodes were short-lived, lasting no more than a week, and included a small outlet channel flowing along and sometimes through gaps in the jetty. The perched episodes ended when lagoon water levels increased, overtopped the beach berm, and scoured a new tidal channel. Since the perched lagoon episodes did not evolve to the point that management action was warranted, the Water Agency did not take any management actions to encourage formation of an outlet channel.

Even though no management actions were implemented to inform the adaptive management process, the physical conditions and inlet response during the management period are reviewed in this attachment to contribute to site understanding and to inform future management actions.

METHODOLOGY

This review of the 2011 outlet channel management period examined water levels, ocean wave conditions, ocean water levels, riverine discharge, beach topography, as well as inlet size and location. The sources for these parameters are listed in Table 1. These data were supplemented with personal observations and discussion with staff from the Water Agency, NMFS, DFG, and the Bodega Marine Laboratory.

Table 1. Data Sources

Parameter	Source
Estuary water level (h_E)	Water Agency Jenner gage*
Wave height (H_s), period (T_a), and direction	CDIP Point Reyes buoy #029
Ocean water level (h_O)	NOAA Point Reyes #9415020
Russian River discharge (Q_f)	USGS Guerneville #11467000
Beach topography, ft NGVD	Water Agency monthly surveys
Inlet size and location	Water Agency and Bodega Marine Laboratory autonomous cameras

*Gage failed near the end of July, and was replaced by early September.

INLET STABILITY PARAMETER AND CLOSURE RISK PROBABILITY

In addition to considering individual parameters, researchers at the Bodega Marine Laboratory have developed a combined parameter to evaluate the stability of the inlet's state, with the aim of predicting closure risk. (Note that the inlet stability parameter does not differentiate between full closure and the perched conditions with a small outlet channel that formed in fall 2010. When discussing this parameter, both states are referred to as a 'closure'.) The inlet stability parameter presented by Behrens et al. (in publication) quantifies the risk of inlet closure based on a sediment balance in the inlet. It considers the daily balance between wave-driven sediment import to the inlet and sediment export driven by tidal fluctuations. The former is estimated from wave measurements and the latter is estimated from tide gage data within the estuary and a stage-storage relation derived from the available bathymetry. Using daily-average values of the stability parameter within the period 1999-2008, Behrens et al. (in publication) showed that high-percentile values of the parameter are closely linked to the risk of the inlet closing within five days. As the percentile of the stability parameter increases, the risk of inlet closure within five days increases exponentially, from risks of roughly five percent when the parameter is at the 50th percentile to a risk of 80 percent when it is measured at the 99th percentile.

FALL PERCHED EPISODES AND SELF BREACHES

Time series of estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 1 for the entire management period. Prior to September, no inlet closures occurred, so lagoon water levels fluctuated in concert with ocean tides (Figure 1a). As shown in Figure 1d, discharge remained high for the first two months of the management period as a result of a wet spring, including precipitation in the start of June. River discharge did not drop below 400 ft^3/s until after June 15th and below 200 ft^3/s until after July 15th. This elevated discharge probably reduced the likelihood of inlet closure during the first two months of the management season even though some sizeable wave events occurred during these months (Figure 1b). In late July and particularly in August, wave energy was at the annual minimum, so tidal exchange was sufficient to maintain an open inlet. As typically occurs on the California coast, wave energy increased starting in September, which eventually caused the estuary to perch six times, starting in late September and into November.

All six inlet perched lagoon episodes in fall 2011 lasted a week or less, ending when the estuary water levels reached 4-5 ft NGVD, overtopped the beach berm, and scoured a new tidal channel. Conditions during the perched lagoon episodes (September 22-29, October 3-8, October 10-14, November 3-8, November 10-12, and November 17-20) are shown in Figure 2. Although the management period ends on October 15th, conditions up through the end of November were reviewed since they were consistent with the inlet behavior that started in late September. Six instances of perched lagoon conditions are slightly higher than the average number of closures, 4.6, in September through November (ESA, 2011). However, a series of repeated perched episodes and self breaching is not common; since 1996, this pattern has only been observed only one other time, in 2006.

Consistent with the existing conceptual model described in Section 4 of the Management Plan, perched lagoon conditions typically occurred when both wave energy increased and tidal exchange decreased. All perched episodes occurred when the mean wave period was greater than 10 seconds and five perched episodes occurred when significant wave heights were greater than 12 ft. The October 10th episode coincided with wave heights of only 8 ft, but since these waves had long, 16-second periods and originated from the southwest, they still conveyed significant wave energy to the beach. Five of the 2011 episodes occurred during neap tides when the tide range was reduced to less than 5 ft (Figure 2c). When the tide range is less, tidal scour in the inlet is also less, making the inlet more susceptible to infill with sand. Only the November 10-12 episode occurred when the oceanic tide range was greater than 6 ft. All but the first episode occurred with riverine discharge elevated above 250 ft^3/s and the three November episodes occurred when riverine discharge was approximately 400 ft^3/s.

PERCHED LAGOON AND NATURAL BREACH DYNAMICS

As an example of a perched lagoon-breach cycle, Figure 3 shows a sequence of photos of the inlet before, during, and after the October 3-8 episode. As was the case for almost all of the management period, the inlet was located next to the jetty. Shortly before the episode, on September 30 (Figure 3a), the inlet had narrowed in width to approximately 30 feet.

The estuarine water level became muted starting on October 3 with the arrival of some larger, longer-period waves (Figure 2a and b). By October 5, a tidal signal was absent from the estuary and water levels began to rise. The inlet transformed into a small outlet channel running immediately adjacent to and among the rocks at the toe of the jetty (Figure 3b; Figure 4a). The outlet channel was narrow, with a width of approximately ten feet. When the channel reached the portion of the jetty which had been damaged, the channel turned south and flowed through the gap in the jetty (Figure 4b).

The jetty and rocks which had been a part of the jetty may have stabilized the outlet channel, both in sheltering the outlet channel from waves and by providing bank and bed stabilization that minimized channel scour. Sheltering by the jetty probably reduced berm build-up at the inlet's location, leaving a low point in the beach berm that was the site for subsequent overtopping and self breaching. This small outlet channel, present from the start of the episode, contrasts with other historic closures that were more extensive. For these extensive closures, almost the entire inlet was filled with sand, with only a small indentation on the backside of the berm providing any indication of the inlet's prior location, and no outlet channel was present. All the 2011 episodes were less extensive, which left the beach berm more susceptible to self breaching.

Self breaching probably occurred when the estuary water level had risen sufficiently high that it overtopped the beach berm in the vicinity of the outlet channel. This overtopping increased the flow rate through the outlet channel and, in spite of any bank stabilization provided by the jetty and associated rocks, the increased flow rate scoured sand from the channel bed and banks. The enlarged channel was then sufficiently deep to allow tides and salt water to return to the estuary. Shortly after self breaching, the tidal channel was approximately 50 feet wide (Figure 3c), wider than it had been in the days preceding the episode. This channel enlargement is consistent with the self breaching mechanism as the higher flow, induced by the elevated estuary water levels during episode, scoured the channel.

CLOSURE RISK PROBABILITY

The 5-day closure risk probability, a derivative of the inlet stability parameter described above, was hindcast for 2011 according to the method described in Behrens et al. (in publication). This hindcast provides an indication of the utility of the stability parameter as a prediction tool for monitoring inlet conditions and planning management action. This parameter integrates wave and ocean forcing conditions, as well as estuary water levels, to provide greater predictive skill than just waves or ocean tides on their own. The stability parameter combines these factors, and the corresponding five-day closure risk time series exceeded 50 percent before each 2011 event (Figure 2a). Some 2011 episodes occurred quickly, transitioning from fully tidal to perched lagoon within a day, so the risk time series did not provide much forewarning in these cases. However the risk was elevated more than two days before the episodes on September 22, November 3, and November 17.

TOPOGRAPHIC CHANGE

The Water Agency has conducted monthly surveys of Goat Rock State Beach that cover a region starting from the jetty and extending approximately 1,500 feet to the north. Typically, the surveys do not include bathymetry within the inlet because flow conditions in the inlet prevent safe access. Also, the survey extent is often limited by the Water Agency's compliance with its marine mammal incidental harassment authorization, which prohibits the survey crew from disturbing the marine mammals hauled out on the beach. Water Agency survey staff collected spot elevations using RTK-GPS and then assembled these elevations into a set of contour lines at 1 ft intervals. The survey elevations are reported in the NGVD29 vertical datum, the working datum for estuary monitoring and management.

To characterize beach berm topographic conditions, ESA PWA assessed data from the Water Agency's 2010 (July to September) and 2011 (May to October) surveys. The locations of five transects selected for analysis are shown in Figure 5. The locations include two transects backed by cliff (Figure 6 and Figure 7), two transects which extend into the estuary (Figure 8 and Figure 9), and a transect just north of the jetty (Figure 10).

This review focuses on the 2011 surveys when the surveys captured a clearer picture of beach evolution. However, the 2010 surveys are included in the transect plots for context. In general the crest elevations in 2010 were lower than 2011. The cause of the lower crest elevations is not known, but may the result of inter-annual variations in wave energy and littoral sediment supply. In addition, the inlet exhibited greater variation in its location in 2010, extending far to the north in July before moving south later by August. As the inlet opened and closed or changed location, it resulted in large changes in beach topography. For example, at Transect 4, the inlet's closure in early July 2010 is readily apparent as substantial increase in the berm's size between the 7/1/2010 and 7/8/2010 transect (Figure 6). The inlet's migration south is evident at Transect 3 (Figure 7) when the crest elevation drops from its 7/8/2010 profile to less than 4 ft NGVD on 8/3/2010. The inlet migration and gaps in the survey data yield little information for evaluating crest elevation evolution at most transects. However, there is sufficient data at Transect 4 to show a trend of increasing crest elevation during summer 2010.

The crest elevations of Transects 2, 3, and 4 steadily increased over the 2011 management period. This trend is consistent with seasonal patterns on many California beaches. After some initial increase from May to June, when wave energy was at the annual minimum in July and August, transect changes were minimal. Then berm building accelerated in the fall with the concurrent increase in wave energy (Figure 1), as indicated by the change between the August 15th survey and the September 19th survey. The largest change occurred between the September and October surveys, the period that also experienced the largest wave energy. Over the course of the management period, the crest moved landward at Transect 3 and Transect 4, with the exception of the October survey, when the crest moved seaward at Transect 3. This landward movement is opposite to the typical crest movement at other California beaches (Weigel, 1992) and may be indicative of additional processes affecting these transects, such as supply-limited alongshore transport. At Transects 1 and 2, the crest moved seaward as it built upwards, consistent with typical summer-time response.

Transect 0, which is located just north of and parallel to the jetty, had noticeably different elevations and evolution than the other transects. Compared to the other transects, crest elevations were highest at this transect for both 2010 and 2011. In addition, Transect 0 did not evolve during the management periods, as was observed at the other transects. The only significant change occurred during the winter between the 2010 and 2011 management periods. These two characteristics, the higher crest and lack of management period variability, suggest that the jetty shelters this portion of the beach from small to moderate waves that occur during the management period. Only the larger waves associated with winter storms may be sufficient to re-shape the beach berm near the jetty.

The changes to the beach berm at Transect 1 were intermediate between the monthly changes that occurred to the north (Transects 2-4) and the negligible change in berm elevation adjacent to the jetty (Transect 0). Crest elevations at Transect 1 only increased between the September and October survey, the portion of the management period with the strongest wave energy. This suggests that the jetty may alter wave conditions over some distance from its location: Transect 1 is approximately 200 ft north of the jetty and outside of the area occupied by the inlet during most of the 2011 management period.

LESSONS LEARNED AND RECOMMENDATIONS

Based on observations of the estuary, associated physical processes, and the Water Agency's planning for outlet channel management, we note the following lessons about implementing the outlet channel management plan.

CONCEPTUAL MODEL

- Elevated discharge in the late spring and early summer (greater than 400 ft^3/s until June 15th; greater than 200 ft^3/s until July 15th) reduced the likelihood for inlet closure at that time. However, multiple perched lagoon episodes occurred in the fall when riverine discharged exceeded 250 ft^3/s. This is consistent with Behrens et al. (in publication) that although discharge affects probability of closure, the threshold that prevents closure is likely in excess of 2,000 ft^3/s. A likely contributing factor to the fall perched episodes was the higher wave energy.
- The inlet moved south early in the management period, reaching the jetty in late May or early June, and remained there throughout the 2011 management period and the following winter. This inlet alignment is not common, but has been observed in past years (Behrens et al., 2009).
- During the management period, steady growth of the beach berm was observed north of the jetty, consistent with typical beach berm building that occurs during the summer. However, the rate of berm growth appeared to decrease approximately 200 ft north of the jetty and was negligible immediately adjacent to the jetty.
- Although autumn wave events were large enough to create perched lagoon conditions, the beach berm remained at low elevations, approximately 5 ft NGVD. The inlet then self breached when rising estuary water levels overtopped the berm at this low point and scoured a new tidal channel.

OUTLET CHANNEL FEASIBILITY

- The jetty may shelter the inlet, making closure less likely and also limiting berm growth, which then maintains a low point for self breaching. When the lagoon self breaches, management actions cannot be implemented.
- Even if the inlet being near the jetty hinders formation of sustained lagoon and outlet channel conditions, management opportunities for re-locating the outlet channel are limited and constrained. At a minimum, creating an outlet channel further north from the jetty requires a full natural closure, absence of a low point in the beach berm near the jetty, and equipment access to the area north of the jetty.
- A small outlet channel formed during the fall perched lagoon episodes. However, it did not convey enough discharge to prevent lagoon water levels from rising at 0.8 ft/day.

- The outlet channel that formed during the perched lagoon episodes flowed along the jetty and among the disaggregated rock at the damaged end of the jetty. This rock from the jetty may have provided channel stabilization for the outlet channel, increasing the channel's resilience to scour.
- Once outlet channel discharge increased due to rising lagoon water levels, the discharge scoured a new channel, breaching the estuary to the tides. This behavior highlights the susceptibility of a sand bed outlet channel to scour, limiting conveyance capacity.
- The mere occurrence of a perched lagoon is not sufficient to provide an opportunity for outlet channel management; other factors may not permit management action. This point is highlighted by both the 2011 self breachings and the early fall closures in 2010, when continuing ocean swell precluded outlet channel management action. Over the first two years of effort to implement the outlet channel adaptive management plan, only one closure (July 2010), has been suited for outlet channel management action.

OPERATIONS

- When equipment operators visited the beach to plan a possible management action, they noted that the channel had incised a steep bank in the berm adjacent to the jetty (Figure 11), which would have made equipment access to any areas north of the jetty infeasible.

COMMUNICATIONS

- Although the perched lagoon episodes did not evolve to the point that management action was warranted, the Water Agency began planning management actions as soon as the episodes occurred. Planning included heightened observations of inlet conditions by Water Agency staff, email updates to inform the resource management group, and pre-implementation meetings at the project site to refine plans for management action.

MONITORING

- The Water Agency's upgrades to monitoring the estuary (water levels and photographs available in real-time via the Internet) enhance both management planning and the ability to observe inlet processes.

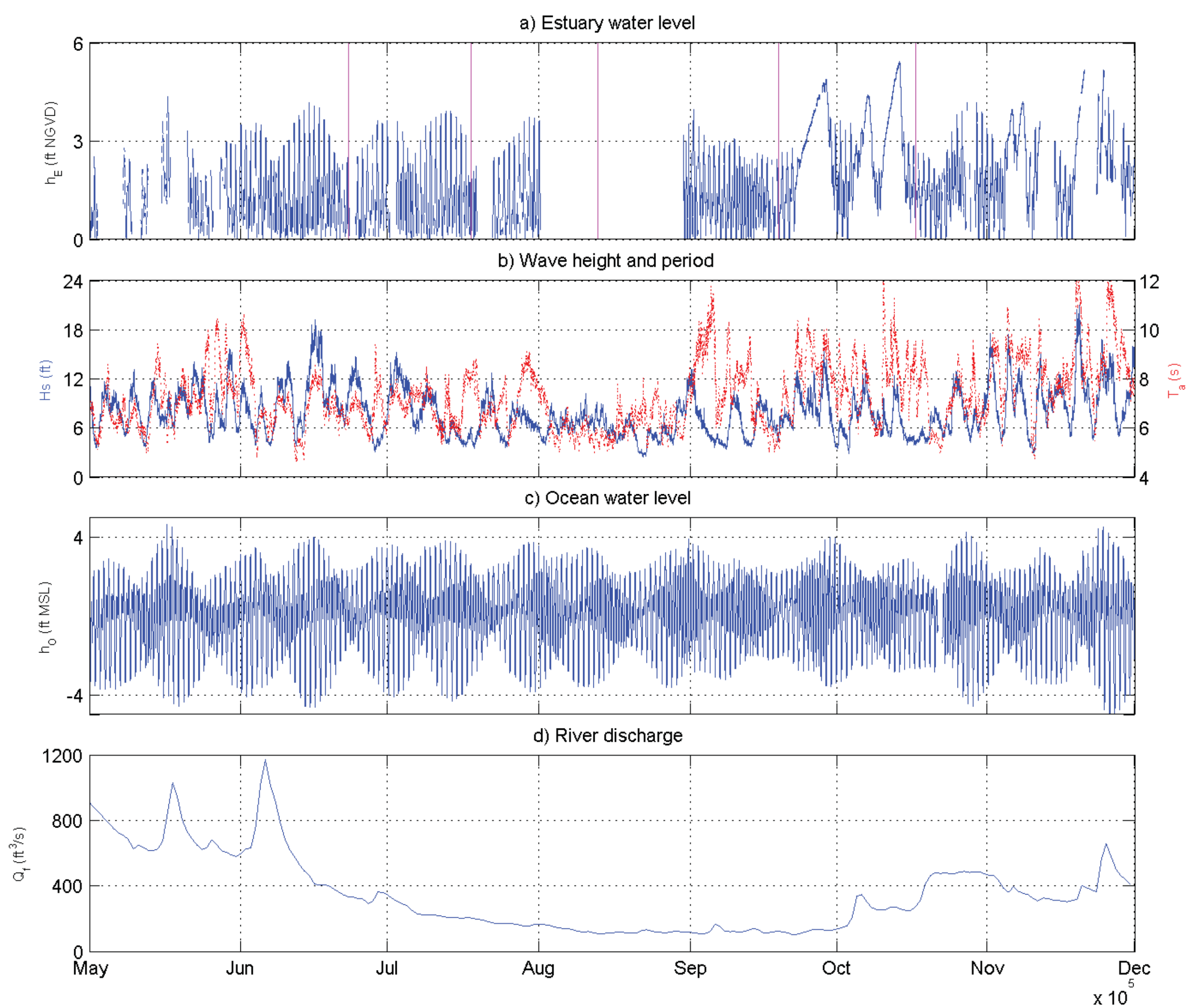
REFERENCES

Behrens, D., Bombardelli, F., Largier, J. and E. Twohy. 2009. Characterization of time and spatial scales of a migrating rivermouth. Geophysical Research Letters. Vol. 36, L09402, doi:10.1029/2008GL037025.

Behrens, D., Bombardelli, F., Largier, J. and Twohy, E. In publication. Episodic closure of the tidal inlet at the mouth of the Russian River – a small bar-built estuary in California. Geomorphology.

ESA. 2011. Russian River Estuary Management Project Environmental Impact Report. Prepared for Sonoma County Water Agency.

Weigel, R. 1992. Oceanographical Engineering.



SOURCE:

a) h_E=estuary water level (SCWA); pink bar = beach survey

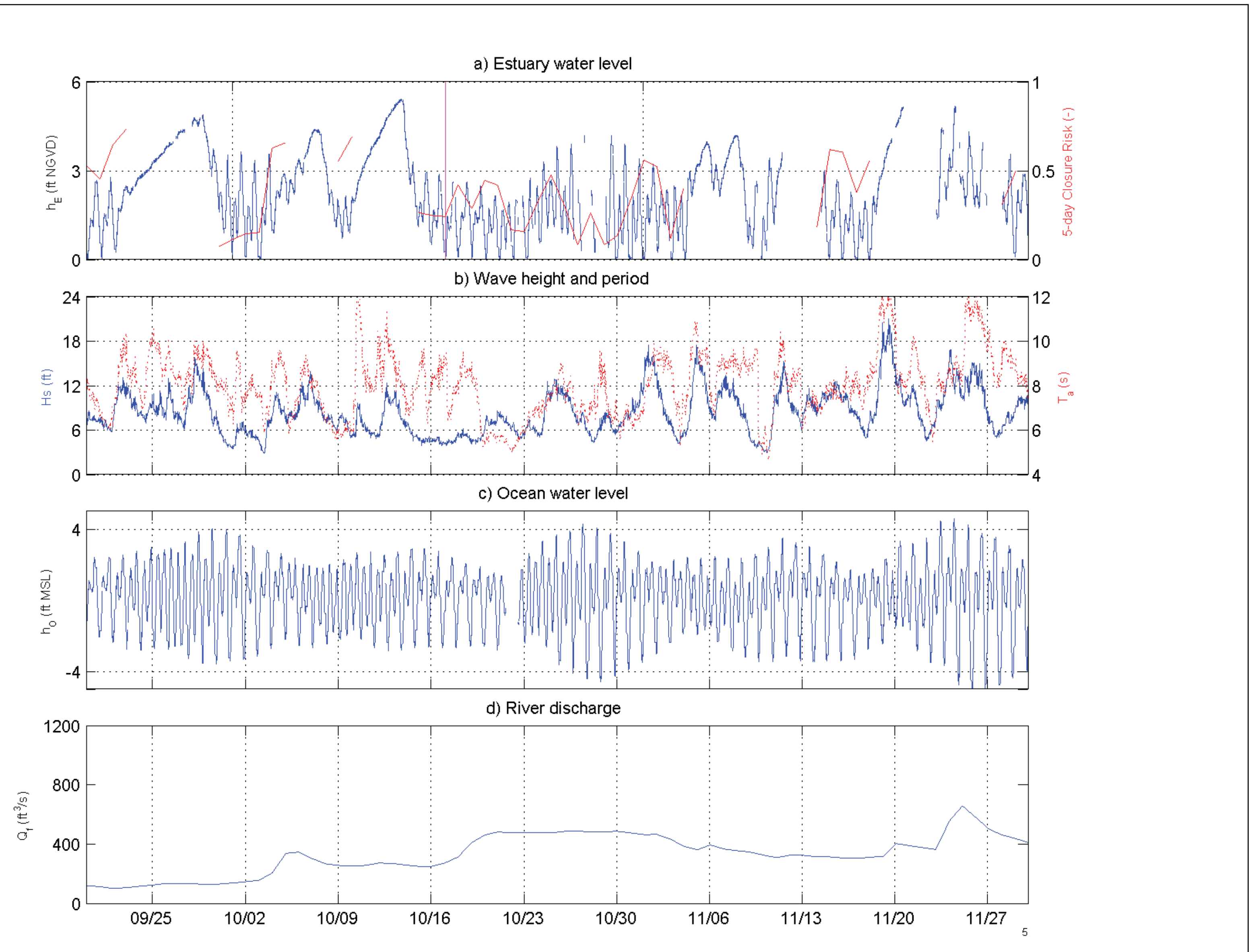
b) H_s=sig. wave height; T_a=avg. wave period (CDIP, Pt. Reyes, #029)

c) h_O=ocean water level (NOAA, Pt. Reyes #9415020)

d) Q_f=river discharge (USGS, Guerneville #11467000)

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 1
Estuary, Ocean, and River Conditions
May - November 2011



SOURCE:

a) h_E=estuary water level (SCWA); pink bar = beach survey

b) H_s=sig. wave height; T_a=avg. wave period (CDIP, Pt. Reyes, #029)

c) h_O=ocean water level (NOAA, Pt. Reyes #9415020)

d) Q_f=river discharge (USGS, Guerneville #11467000)

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 2

Estuary, Ocean, and River Conditions
September - November 2011

a)

b)

c)

SOURCE: Bodega Marine Lab

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 3

Inlet State, September 30, October 6, and October 9, 2011

a) b)

SOURCE: Sonoma County Water Agency

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 4

Outlet Channel Along and Through Jetty, September 26, 2011

Source: Sonoma County Water Agency survey data

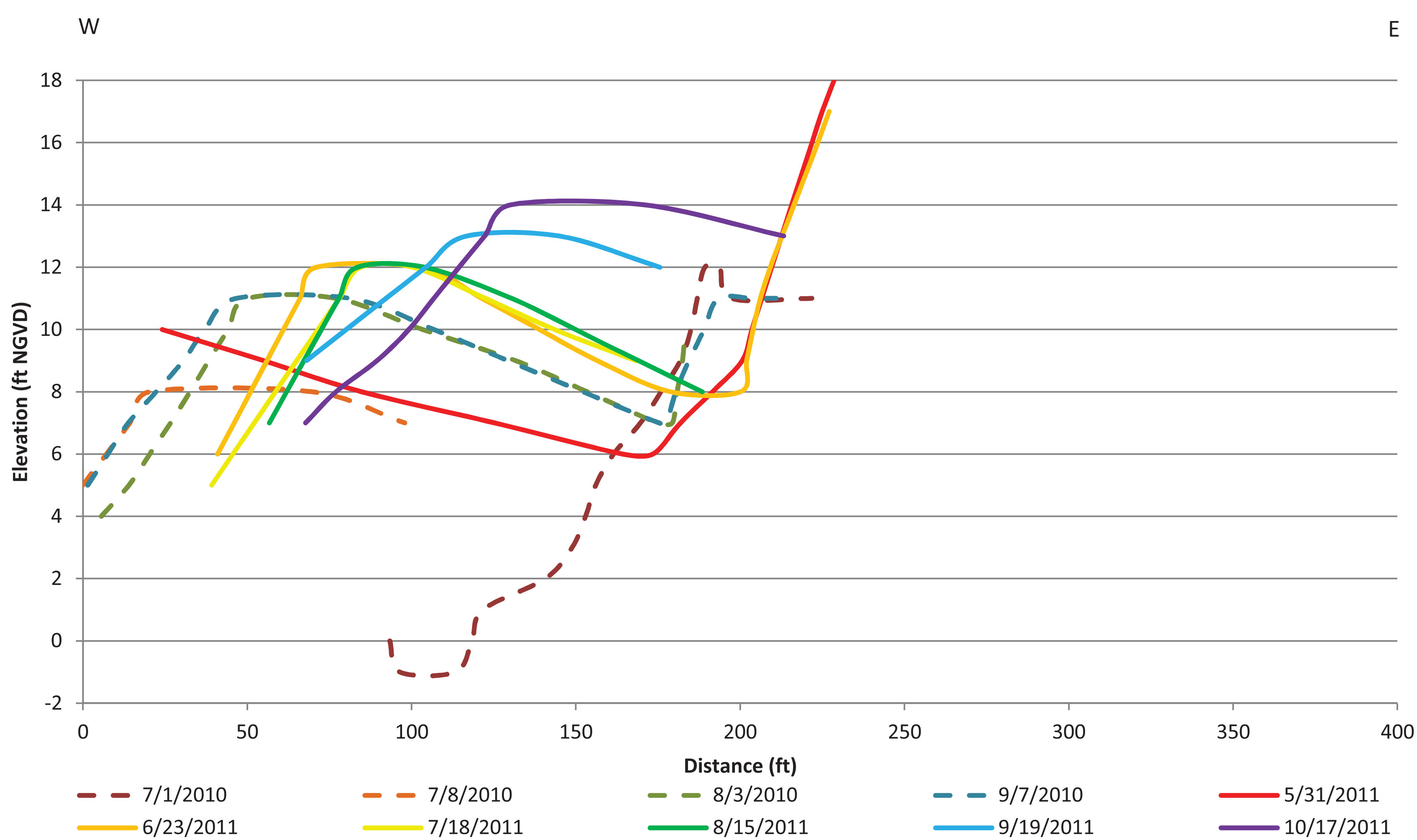
N

figure 5
Russian River Outlet
Channel Management Plan

Beach Topography Transect Locations

ESA PWA Ref# - DW01958

Beach_topo.mxd



Source: Sonoma County Water Agency survey data

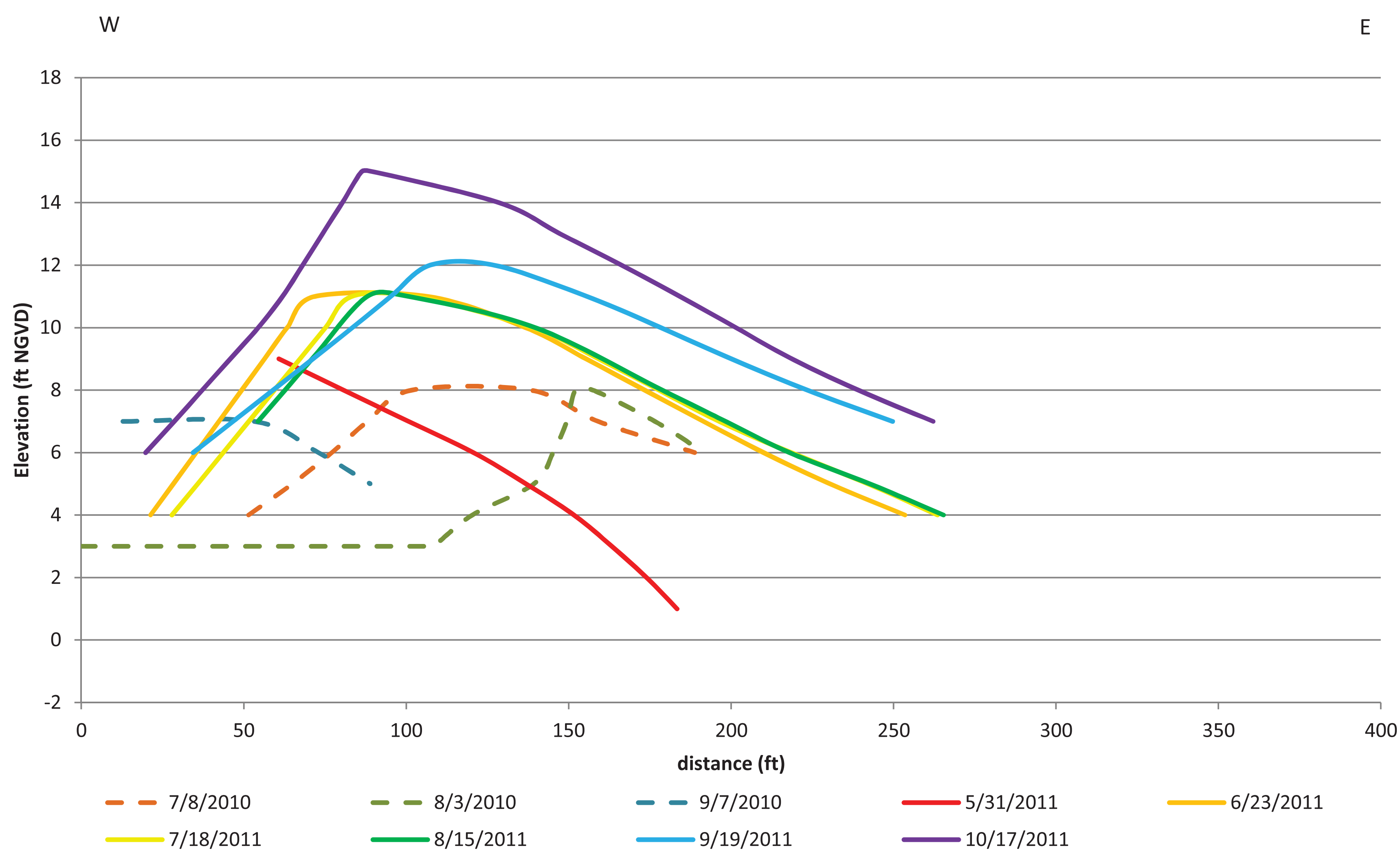
figure **6**

Russian River Outlet Channel Management Plan

Beach Transect 4

ESA PWA Ref #: DW01958

Bathy_transects.xlsx / Transect4



Source: Sonoma County Water Agency survey data

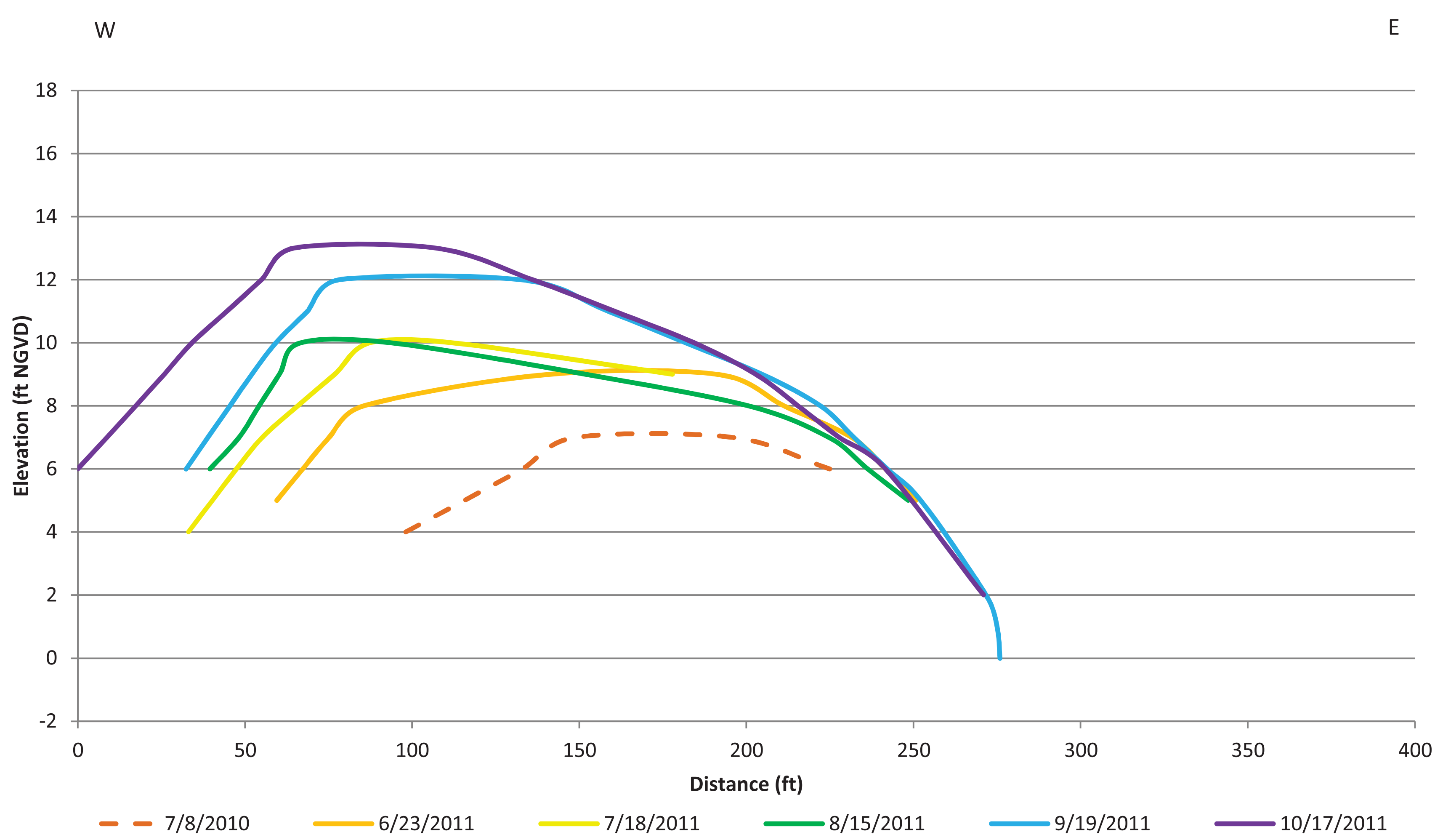
figure 7

Russian River Outlet Channel Management Plan

Beach Transect 3

ESA PWA Ref #: DW01958

Bathy_transects.xlsx / Transect3



Source: Sonoma County Water Agency survey data

figure **8**

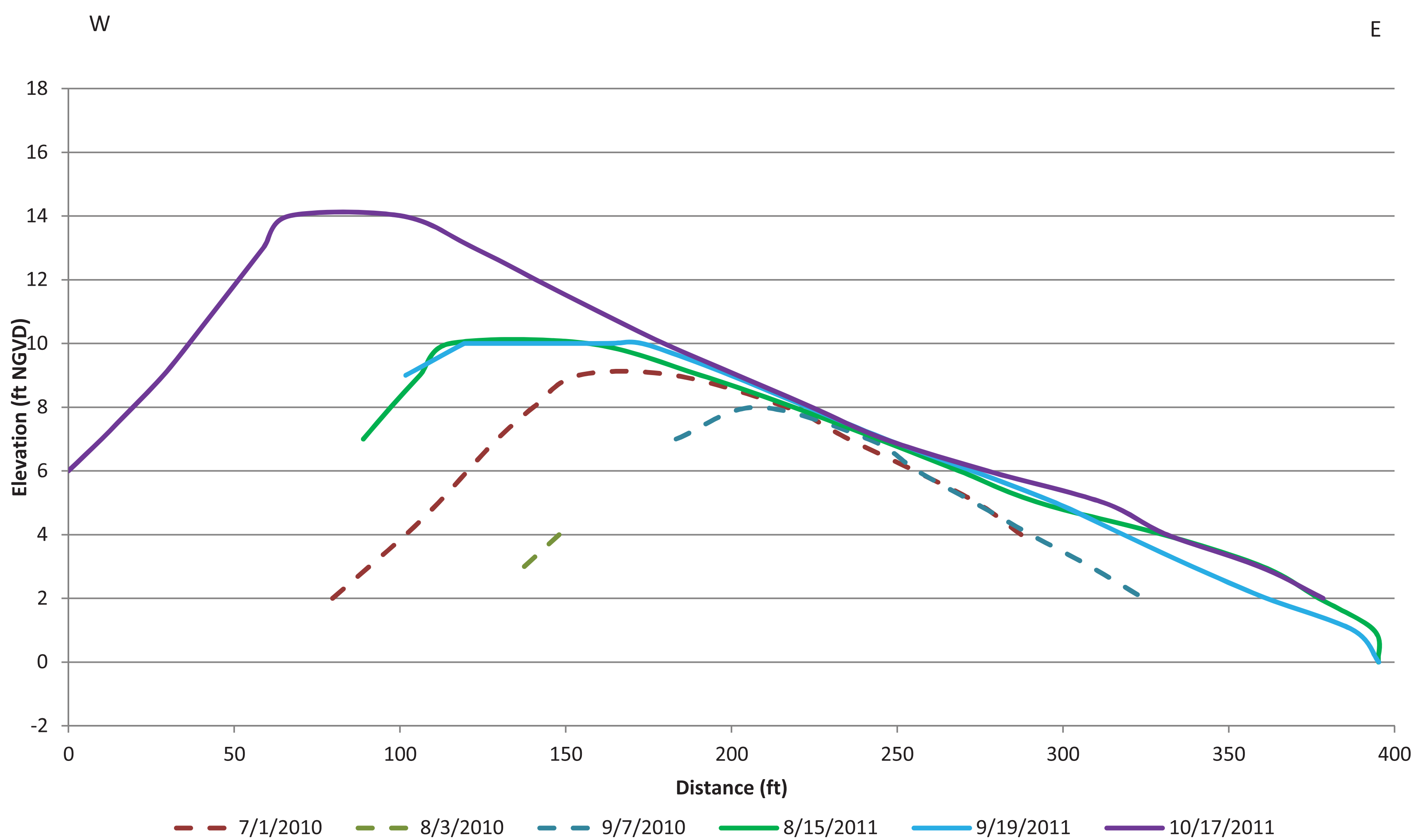
Russian River Outlet Channel Management Plan

Beach Transect 2

ESA PWA Ref #: DW01958

ESA PWA

Bathy_transects.xlsx / Transect2



Source: Sonoma County Water Agency survey data

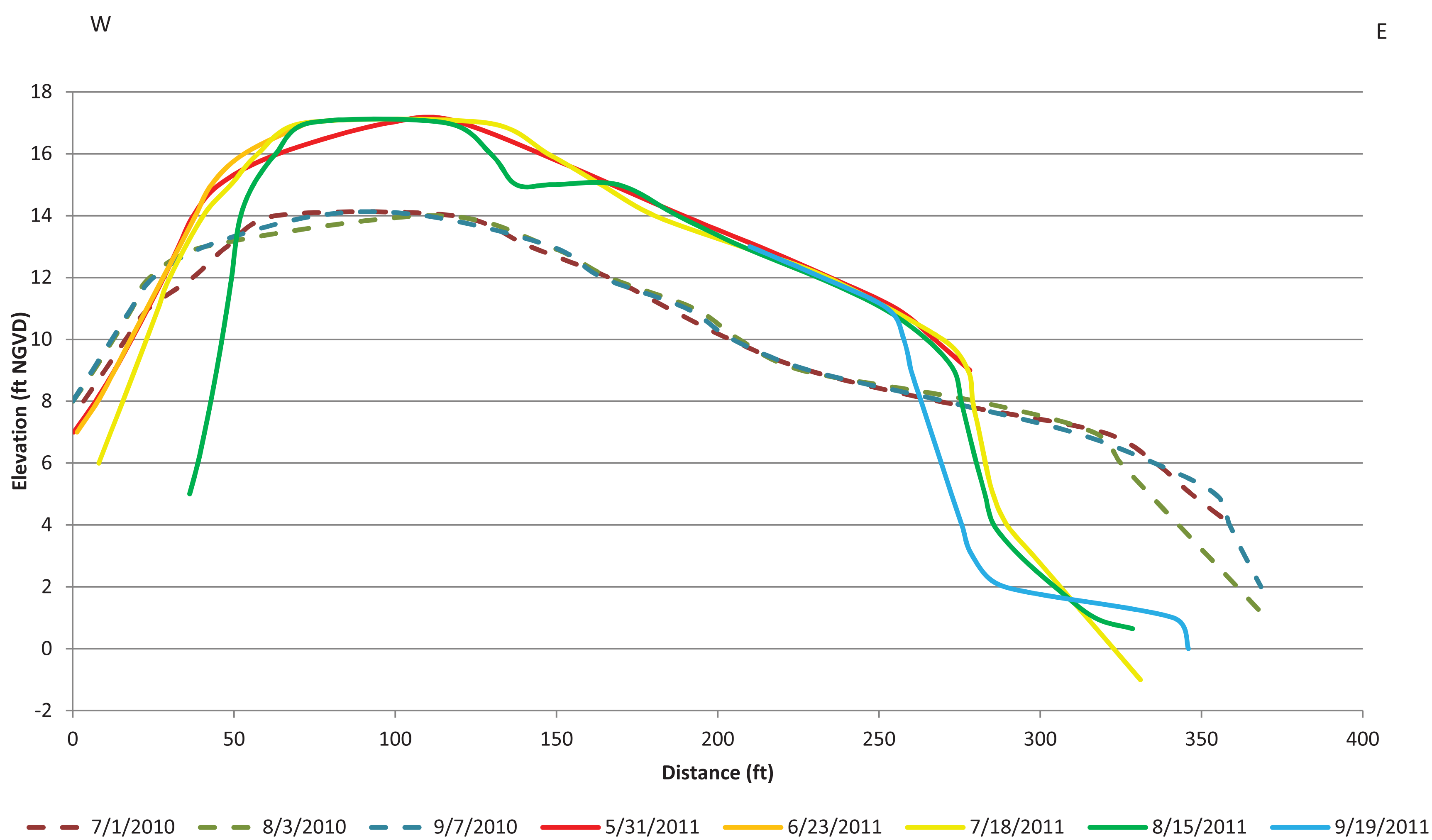
figure **9**

Russian River Outlet Channel Management Plan

Beach Transect 1

ESA PWA Ref #: DW01958

Bathy_transects.xlsx / Transect1



Source: Sonoma County Water Agency survey data

figure **10**

Russian River Outlet Channel Management Plan

Beach Transect 0

ESA PWA Ref #: DW01958

Bathy_transects.xlsx / Transect0

SOURCE: Sonoma County Water Agency

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 11

Steep Berm Limiting Beach Access, September 26, 2011

Attachment G. Physical Processes During the 2012 Management Period

As required by the Russian River Biological Opinion, Sonoma County Water Agency (Water Agency) has been tasked with managing a summer lagoon intended to improve salmonid habitat in the Russian River Estuary by creating an outlet channel while maintaining the current level of flood protection for properties adjacent to the estuary (NMFS, 2008). The adaptive management plan, described in the main body of this report, was developed by the Water Agency with assistance from ESA PWA and the resource agency management team in 2009 and revised annually in 2010-2013. Because of permit constraints, the Water Agency was only able to implement the plan beginning in 2010. The revised plan was in effect for 2012, but no opportunities for management action occurred during the management period.

During the 2012 management period, May 15th to October 15th, Water Agency staff regularly monitored current and forecasted estuary water levels, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. Although the inlet experienced several closures, none resulted in water levels above 5.5 ft NGVD prior to self-breaching. For much of June and July, the inlet was either closed or only allowing heavily muted tides (tide range < 1 ft), but the lagoon water surface never surpassed 5 ft NGVD. During this time, each closure ended when lagoon water levels increased, overtopped the beach berm, and scoured a new tidal channel. Since these episodes did not evolve to the point that management action was warranted, the Water Agency did not take any management actions to encourage formation of an outlet channel. For the remainder of July, all of August, and the first half of September, the estuary was fully tidal. Then the inlet closed twice between September 20th and October 10th. Both closures were short-lived, lasting less than one week, and again the inlet self-breached, precluding any Water Agency management action. The highest lagoon water level of the 2012 management period, 5.25 ft NGVD, occurred at the end of the October closure.

Even though no management actions were implemented to inform the adaptive management process, the physical conditions and inlet response during the management period are reviewed in this attachment to contribute to site understanding and to inform future management actions.

METHODOLOGY

This review of the 2012 outlet channel management period examined water levels, ocean wave conditions, ocean water levels, riverine discharge, beach topography, as well as inlet size and location. The sources for these parameters are listed in Table 1. These data were supplemented with personal observations and discussion with staff from the Water Agency, NMFS, DFG, and the Bodega Marine Laboratory.

Table 1. Data Sources

Parameter	Source
Estuary water level (h_E)	Water Agency Jenner gage*
Wave height (H_s), period (T_a), and direction	CDIP Point Reyes buoy #029
Ocean water level (h_O)	NOAA Point Reyes #9415020
Russian River discharge (Q_f)	USGS Guerneville #11467000
Beach topography, ft NGVD	Water Agency monthly surveys
Inlet size and location	Water Agency and Bodega Marine Laboratory autonomous cameras

*Data transmission failure due to cellular network issues occurred for several 1-5 day periods throughout the management period.

INLET STABILITY PARAMETER AND CLOSURE RISK PROBABILITY

In addition to considering individual parameters, researchers at the Bodega Marine Laboratory have developed a combined parameter to evaluate the stability of the inlet's state, with the aim of predicting closure risk (Behrens et al., 2013). (Note that the inlet stability parameter does not differentiate between full closure and the perched conditions with a small outlet channel. When discussing this parameter, both states are referred to as a 'closure' in that tides are prevented from propagating into the estuary.) The inlet stability parameter presented by Behrens et al. (2013) quantifies the risk of inlet closure based on a sediment balance in the inlet. It considers the daily balance between wave-driven sediment import to the inlet and sediment export driven by tidal fluctuations. The wave-driven import is assessed using nearshore wave estimates derived from a transformation matrix and offshore buoy data (ESA PWA 2012) and the latter is estimated from tide gage data within the estuary and a stage-storage relation derived from the available bathymetry. Using daily-average values of the stability parameter within the period 1999-2008, Behrens et al. (2013) showed that high-percentile values of the parameter are closely linked to the risk of the inlet closing within five days. As the percentile of the stability parameter increases, the risk of inlet closure within five days increases exponentially, from risks of roughly five percent when the parameter is at the 50th percentile to a risk of 80 percent when it is measured at the 99th percentile.

SUMMER AND FALL CLOSURES AND SELF-BREACHES

Time series of estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 1 for the entire management period. The lagoon water level time series (Figure 1a) summarizes the observed muted conditions in early summer and short-lived closure events that occurred at the end of the management period. As shown in Figure 1d, discharge remained high for the first two months of the management period. River discharge did not drop below 200 ft^3/s until after June 10th, at which time the estuary had already begun its muted tidal phase, leading up to four short-lived closures. This elevated discharge probably reduced the likelihood of inlet closure during the first 30-40 days of the management period (Figure 1d), despite the occurrence of energetic wave conditions in May (Figure 1b). Wave energy reached a minimum in August and early September, but was weaker throughout the 2012 management period than in 2011. The hourly significant wave height was less than 8 ft for the majority of this period.

The conditions leading to inlet closure were consistent with the existing conceptual model described in Section 4 of the Management Plan. All closure events coincided with either moderately high waves ($H_s > 6$ ft) having periods greater than 10 s, or with neap oceanic tide ranges of less than approximately 5 ft. Moderately high waves coincided with the closure events in June, July, September and October. The first closure observed in June and both July closures coincided with neap tide conditions, although long-period swells occurred prior to the former of the two. Closure events that occurred in June and July are examined in more detail in Figure 2, while Figure 3 summarizes conditions that occurred later in September-November.

All closure events occurred with the inlet located adjacent to the jetty. This positioning may have prevented perched conditions from arising by shielding this area of the beach from the wave-driven sediment deposition that caused closure, preventing the beach from accreting to a sufficient height to allow the desired outlet channel elevations from being attained. The low point in the beach berm that was subsequently overtopped and self-breached also persisted immediately adjacent to the jetty.

PERCHED LAGOON AND SELF-BREACH DYNAMICS

During the June and July closures (Figure 2), as well as the late September closure (Figure 3), the lagoon water level only increased at approximately 0.3 ft/day. This slower increase probably occurred because a small outlet channel that flowed over the beach berm and through a gap in the jetty partially balanced inflowing river discharge.

As an example of one of the several inlet closure events that resulted in self-breaching prior to target outlet channel elevations, Figure 4 shows a sequence of photos of the inlet before, during, and after an episode from October 8-15. As was the case for all of the management period, the inlet was located next to the jetty. Prior to closure, the inlet had allowed only muted tides, resulting from a partial breach on October 2nd that did not restore full tidal action. Neap oceanic tides compounded this, and 7-ft high nearshore waves having a dominant period above 20 seconds closed the inlet on October 8th (Figure 3b,c).

After the onset of closure, the estuary water levels began to rise. For the first two days of closure, the water level increased at approximately 0.5 ft/day from 3 to 4 ft NGVD, but this decreased to less than 0.3 ft/day afterwards (lagoon stage above 4 ft NGVD). Waves deposited sediment adjacent to the gap in the jetty structure, blocking outflows from the lagoon that had occurred in prior closures (Figure 4b). This partially-formed barrier berm was overtopped when the lagoon reached approximately 5.25 ft on October 15th (Figure 4c). The outlet channel was narrow, with a width of less than ten feet. This overtopping event coincided with a spring phase of the oceanic tides, which generated a large head difference between the estuary and ocean waters. This head difference presumably contributed to channel flow velocities exceeding the threshold for scouring the beach sand, since the spring lower-low tide on October 16th resulted in the small channel eroding the barrier and creating a new inlet (Figure 4d). After the initial breach, the increased flow rate scoured sand from the channel bed and banks, and the channel increased to more than 20 feet in width (Figure 4d).

The jetty and rocks which had been a part of the jetty appeared to have a significant influence on the geomorphic evolution of the channel. At times, the jetty elements may have stabilized the outlet channel, both in sheltering the outlet channel from waves and by providing bank and bed stabilization that minimized channel scour. Wave sheltering by the jetty probably reduced berm build-up at the inlet's location, leaving a low point in the beach berm that was the site for subsequent overtopping and self-breaching. Of the six closure events that occurred within the management period, all experienced a similar breaching pattern, self-scouring a tidal inlet before estuary water levels reached 5.5 ft NGVD. This was also true of the two closure events which occurred in November, following the management period (Figure 3). At times, the outlet channel flowed through notch in the jetty (Figure 5), such that the rocks probably provided stabilization that prevented bed scour. The jetty also halted lateral scour to the south. However, once lateral scour is halted, the channel may then maintain its cross-sectional area by scouring downward where it runs parallel to the jetty.

CLOSURE RISK PROBABILITY

The 5-day closure risk probability, a derivative of the inlet stability parameter described above, was hindcast for 2012 according to the method described in Behrens et al. (2013). This hindcast provides an indication of the utility of the stability parameter as a prediction tool for monitoring inlet conditions and planning management action. This parameter integrates wave and ocean forcing conditions, as well as estuary water levels, to provide greater predictive skill than just waves or ocean tides on their own. The stability parameter combines these factors, and the corresponding five-day closure risk time series exceeded 50 percent before each 2012 event (Figure 1e, Figure 2e, and Figure 3e). The closure event initiated on July 1st occurred quickly, transitioning from fully tidal to fully closed within a day, so the risk time series did not provide much forewarning in this case. This was also true of two closure events occurring outside of the management period, in November 2012. However, for all other events observed from June to November, the predicted probability of closure exceeded 50% 2-5 days in advance of each closure. There were no instances during the management period when the predicted probability of closure exceeded 50% and a closure did not occur within 5 days.

TOPOGRAPHIC CHANGE

The Water Agency has conducted monthly surveys of Goat Rock State Beach that cover a region starting from the jetty and extending approximately 1,500 feet to the north. Typically, the surveys do not include bathymetry within the inlet because flow conditions in the inlet prevent safe access. Also, the survey extent can be limited by the Water Agency's compliance with its marine mammal incidental harassment authorization, which sets guidelines for the survey crew's disturbance to marine mammals hauled out on the beach. Water Agency survey staff collected spot elevations using RTK-GPS and then assembled these elevations into a set of contour lines at

1 ft intervals. The survey elevations are reported in the NGVD29 vertical datum, the working datum for estuary monitoring and management.

To characterize beach berm topographic conditions, ESA PWA assessed data from the Water Agency's 2010 (July to September), 2011 (May to October), and 2012 (May to October) surveys. Surveys from November 2011 to May 2012 were also compared, to assess winter-time changes of beach shape. Survey transects from the 2011 analysis were reused (Figure 6), and include two transects backed by cliff (Figure 7 and Figure 8), one transect which extends into the estuary (Figure 9), and two transects just north of the jetty (Figure 10).

This review focuses on the 2012 surveys, although the 2010 and 2011 surveys are included for context. Compared with both 2010 and 2011, the 2012 topographic data indicate that the beach berm was less variable in shape than in previous years. This is especially true of the northern two transects (Figures 7 and 8), and to a lesser extent at Transect 2 (Figure 9). Because of inlet and seal haulout locations, topographic data were not collected in the vicinity of Transect 1 in 2012, so this is not included in the analysis. Adjacent to the jetty groin, Transect 0 showed little monthly change in topography, but extensive inter-annual variability.

During the management period in 2012, the beach berm along transects 2, 3, and 4 showed little variability, changing by less than two feet. The profile along Transect 2 (Figure 9) showed a slight aggradation trend over the course of the management period, but at Transects 3 and 4, the change in shape fluctuated only slightly (Figures 7 and 8). In contrast, between May 2011 and October 2011, the beach berm at these transects built in size by more than 6 feet. The difference in monthly variability at the northern transects between the 2011 and 2012 management periods can likely be tied to the difference in the extent of inlet migration. In 2011, the inlet migrated north of Haystack Rock during the winter, and returned to the jetty in late spring or early summer. This migration resulted in a lower beach profile at all transects. Over the course of the management period, the beach gradually built up to a typical summer profile. Even during the peak winter and spring flows of 2012, the inlet never migrated north of Haystack Rock, leaving a largely-intact beach berm north of Haystack Rock and a lower terrace between Haystack Rock and the jetty groin. Since these northern transects started at a much higher elevation at the start of the management period, the vertical growth of the beach profiles at these locations were several feet less than during the previous year in the same locations.

Transect 0, which is located just north of and parallel to the jetty, had noticeably different elevations and evolution than the other transects during the 2012 management period. Compared to the other transects, crest elevations were highest at this transect for both 2010 and 2011. This was not the case in 2012, when the northernmost two transects were the highest. The crest elevation at Transect 0 did not evolve during the management periods in 2010 and 2011, but was observed to erode between August and October in 2012. Images from the BML stationary camera indicate that this was the result of the inlet shifting from a sinuous alignment (resulting from southward migration) to a straight alignment running nearly parallel to the jetty. The only significant changes occurred during the winter between each of the management periods. The lack of management period variability of this region suggests that the jetty shelters this portion of the beach from small to moderate waves that occur during the management period. Only the larger waves associated with winter storms may be sufficient to re-shape the beach berm near the jetty.

Water Agency surveys taken during the months preceding the 2012 management period (November 2011 to April 2012, Figure 11) show more variability in beach berm height and width than was observed for the 2012 management period (Figure 9). The highest beach crests observed during the 12-month period from November 2011 to October 2012 occurred in November and December 2011, peaking between 14 and 15 ft NAVD88 at Transect 2 (Figure 11). This is consistent with the combination of high-energy, long-period swell waves and generally low fluvial flows during the late fall. By the February 2012 survey, erosion significantly reduced the beach crest elevation. This erosion is likely due to fluvial flows through the inlet at Transect 2. Farther north, at Transect 3, there was less influence from the inlet, and there appeared to be less erosion during winter 2011-12 (Figure 12). The berm crest was highest in late spring (March and May profiles) and in November 2012, peaking between 16 and 17 ft NAVD88. The difference between the evolution of Transects 2 and 3 may be a result of the inlet's lack of migration in 2012, or possibly a difference in the amount of wave exposure between locations.

Water Agency surveys were also used to assess the beach width at Transect 3. We focus on Transect 3, because the influence of the inlet caused the beach to be consistently lower at other transects, sometimes as low as the intertidal zone, where survey data were not consistently collected. The Transect 3 beach width was as the horizontal distance between a particular elevation on the ocean and estuary sides of the beach face, respectively. From November 2011 to June 2012, the beach width at the 12 ft NAVD88 elevation varied from 110 to 145 feet, showing signs of both narrowing and widening during the winter and spring (Figure 13). From June to August 2012, the beach width grew steadily from about 110 ft to 145 ft and appeared to remain at this width though November 2012. At an elevation of 14 ft NAVD88, the width followed the same pattern, but had larger fluctuations, varying from roughly 30 to 110 ft and grew steadily from June 2012 onward. These observations underscore the typical pattern of beach building in summer, but also indicate that waves in winter can build the beach between destructive events.

LESSONS LEARNED AND RECOMMENDATIONS

Based on observations of the estuary, associated physical processes, and the Water Agency's planning for outlet channel management, we note the following lessons about implementing the outlet channel management plan.

CONCEPTUAL MODEL

- Elevated discharge in the late spring (greater than 200 ft^3/s until June 10^{th}) may have reduced the likelihood for inlet closure in May, although the wave climate at this time was also significantly weaker than during the previous year.
- Several short-lived closure events occurred, but waves never built up the minimum crest height (the limiting height for closure) beyond 5.5 ft NGVD, and all events ended with

self-breaches below this elevation. This prevented management actions from being taken during the 2012 season.

- The inlet never migrated north of Haystack Rock during peak winter floods, and returned to the jetty in early spring, much earlier than in most years. This inlet alignment is not common, but has been observed in past years (Behrens et al., 2009).
- During the management period, most of the beach north of Haystack Rock underwent little topographic change. A transect adjacent to Haystack Rock aggraded slightly, consistent with typical beach berm building that occurs during the summer. Adjacent to the jetty, the berm did not aggrade, but rather remained largely unchanged for most of the season and then later eroded between August and October as a result of a shift in the inlet alignment.
- The wave climate remained weak throughout much of the summer and fall, which may have stunted the growth of the beach crest in the vicinity of the jetty (the location of the inlet throughout the 2012 season), preventing lagoon water levels from reaching levels conducive of the planned outlet channel.
- When an outlet channel is present, oceanic tide conditions can encourage scouring and formation of a new tidal inlet. During the spring phase of the tide, the lower-low tide creates a large head difference between the lagoon and ocean, likely increasing the flow velocity in the channel.

OUTLET CHANNEL FEASIBILITY

- The jetty may shelter the inlet, making closure less likely and also limiting berm growth, which then maintains a low point for self-breaching. When the inlet is in a fully or muted tidal condition, options for management become considerably more difficult to implement.
- An outlet channel that was intermittently observed during the 2012 closures conveyed a portion of the inflowing river discharge, slowing the rise in lagoon water levels to approximately 0.3 ft/day. This channel flowed through a gap in the jetty, whose large rocks likely provided some degree of channel stabilization against scour. However, this condition changed with lagoon levels, as described below.
- Once outlet channel discharge increased due to rising lagoon water levels or low oceanic tides, the discharge scoured a new channel, breaching the estuary to the tides. This behavior highlights the susceptibility of a sand bed outlet channel to scour, limiting conveyance capacity.
- Even if the inlet being near the jetty hinders formation of sustained lagoon and outlet channel conditions, management opportunities for re-locating the outlet channel are limited and constrained. At a minimum, creating an outlet channel further north from the jetty requires a full natural closure, absence of a low point in the beach berm near the jetty, and equipment access to the area north of the jetty.
- Over the first three years of effort to implement the outlet channel adaptive management plan, only one closure (July 2010), has been suited for outlet channel management action.

COMMUNICATIONS

- Although the perched lagoon episodes did not evolve to the point that management action was warranted, the Water Agency began planning management actions as soon as the episodes occurred. Planning included heightened observations of inlet conditions by Water Agency staff, email updates to inform the resource management group, and pre-implementation meetings at the project site to refine plans for management action.

MONITORING

- The Agency's month survey methods should be modified to collect specified contours, such as the beach berm ridge line, wetted edge (beach side), and water edge (estuary side).

REFERENCES

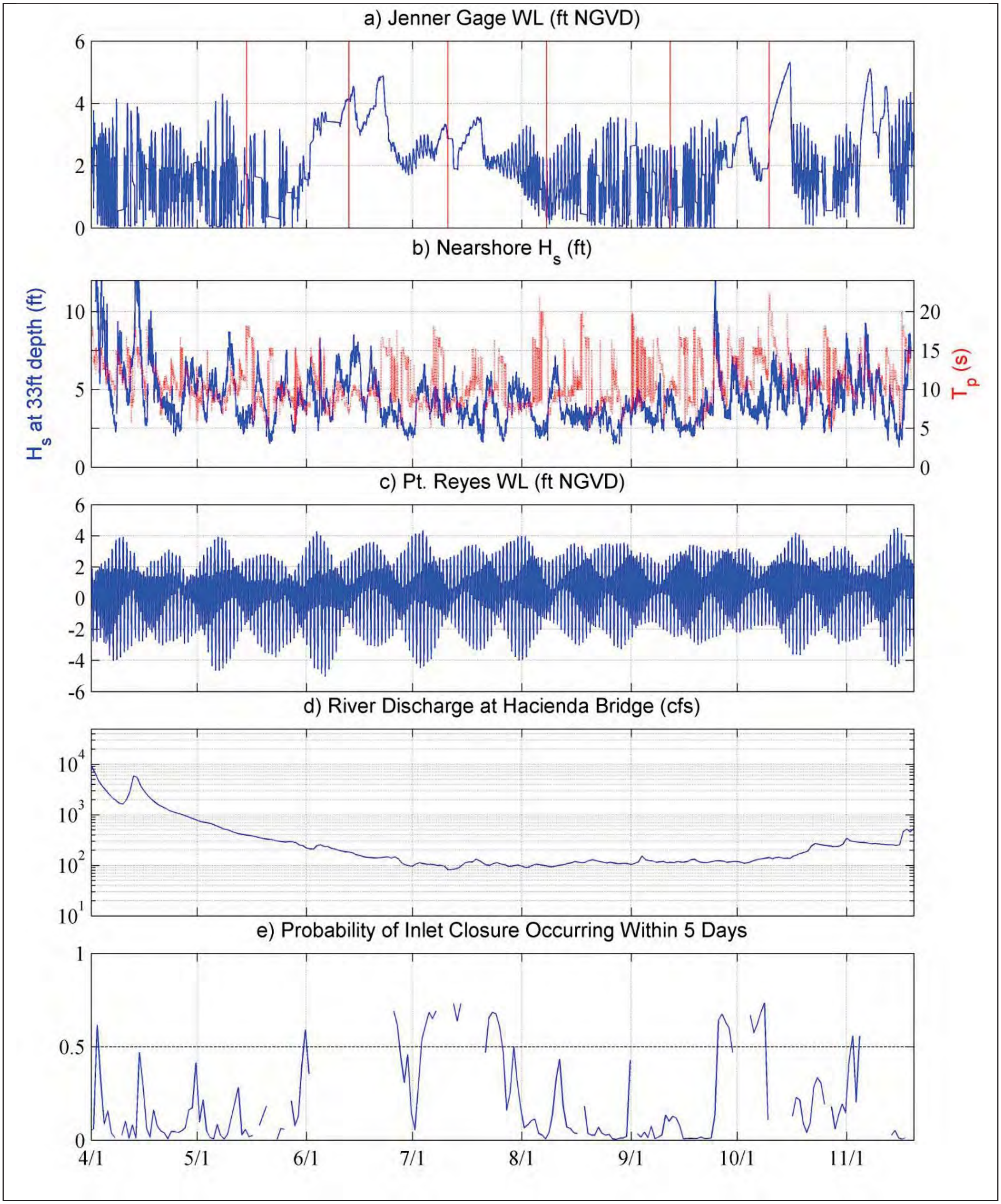
Behrens, D., Bombardelli, F., Largier, J. and E. Twohy. 2009. Characterization of time and spatial scales of a migrating rivermouth. Geophysical Research Letters. Vol. 36, L09402, doi:10.1029/2008GL037025.

Behrens, D., Bombardelli, F., Largier, J. and Twohy, E. 2013. Episodic closure of the tidal inlet at the mouth of the Russian River – a small bar-built estuary in California. Geomorphology.

ESA PWA. 2012. Feasibility of alternatives to the goat rock state beach jetty for managing lagoon water surface elevations: draft existing conditions report. Submitted to Sonoma County Water Agency.

National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed.

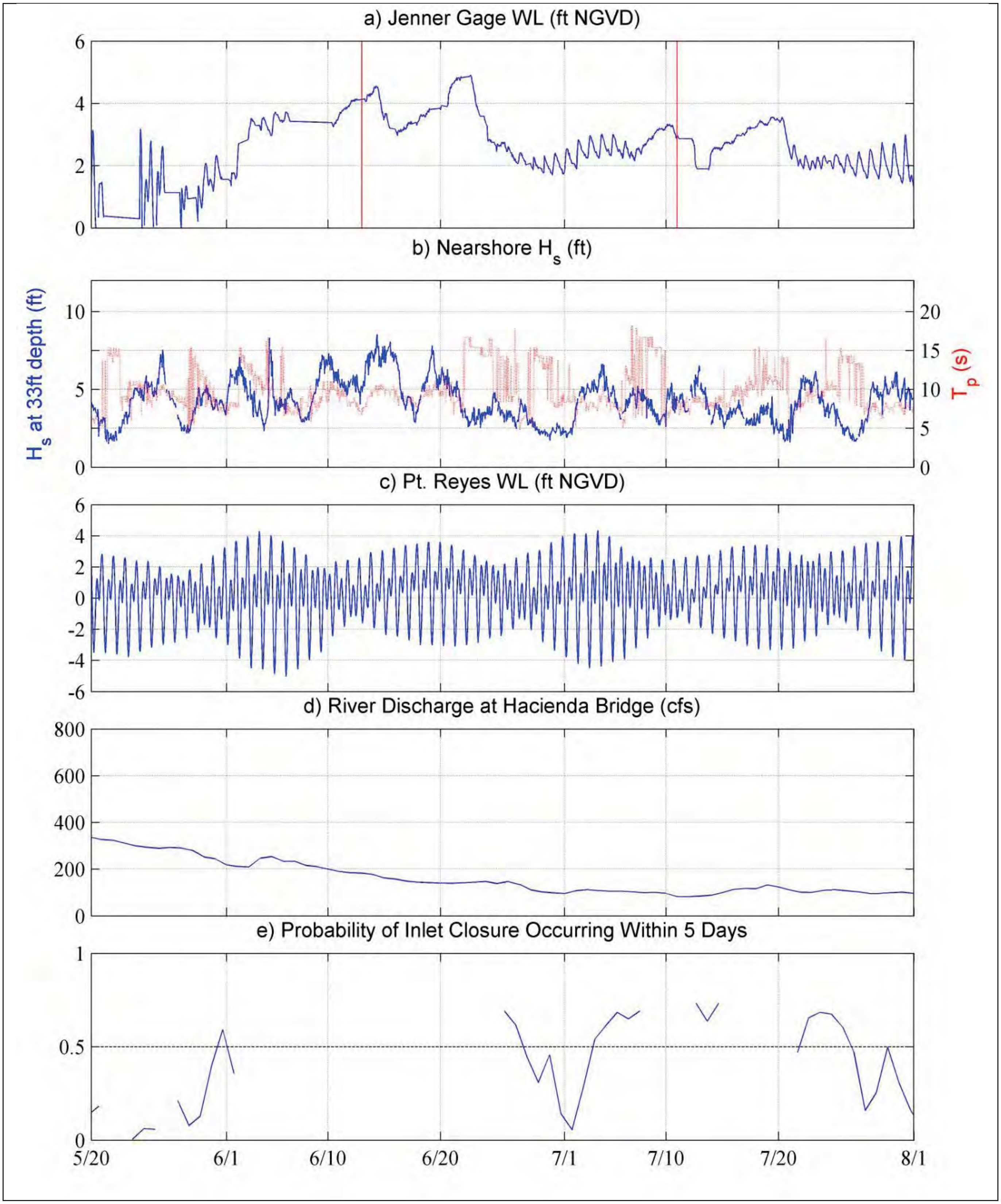
Weigel, R. 1992. Oceanographical Engineering.



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

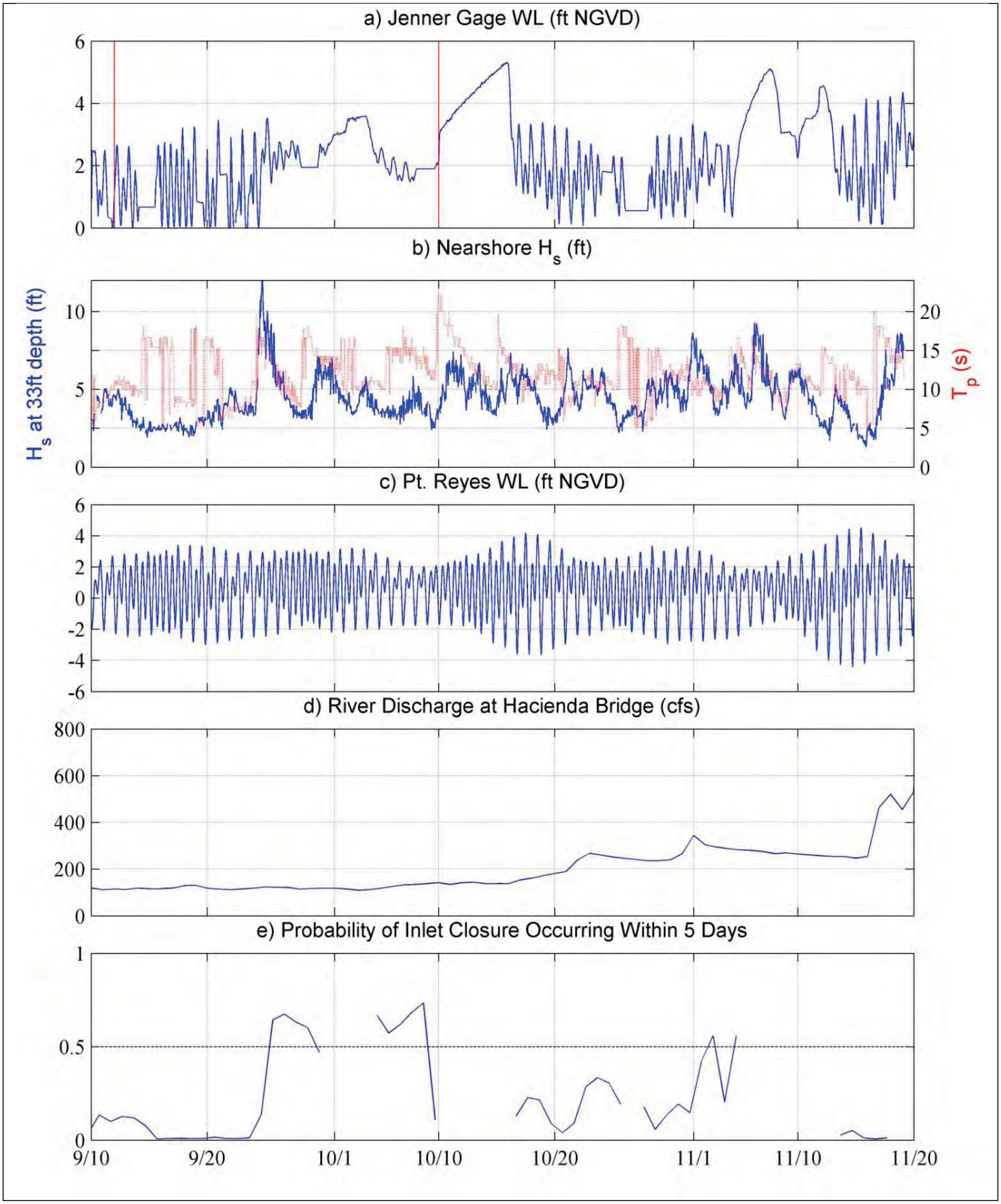
Figure 1
Estuary, Ocean, and River Conditions Compared with Closure Probability: September – November 2012



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; T_p=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

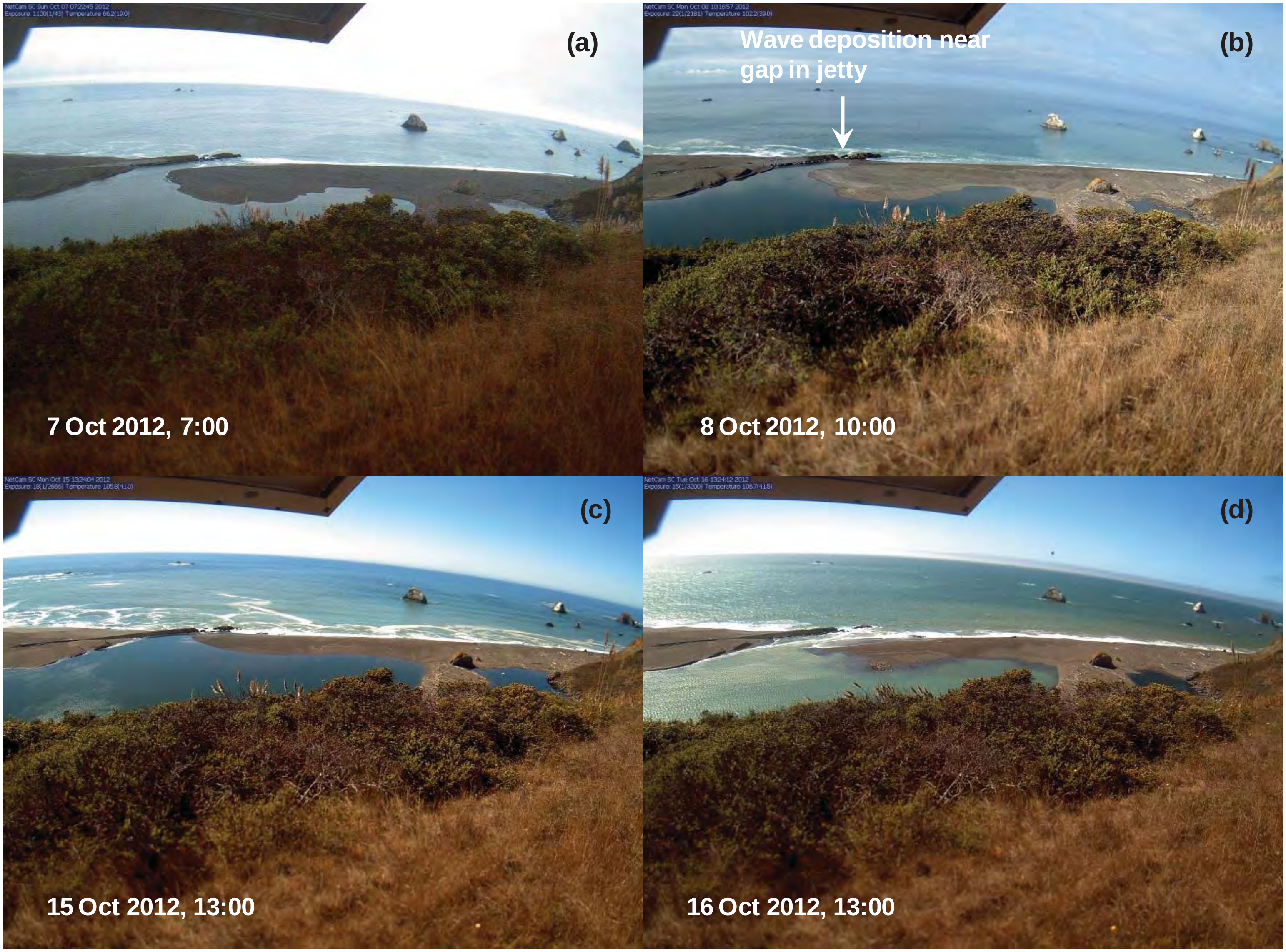
Figure 2
Estuary, Ocean, and River Conditions Compared with Closure Probability: May 20 – August 1, 2012



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; T_p=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 3
Estuary, Ocean, and River Conditions Compared with Closure Probability: September 10 – November 20, 2012



SOURCE: Russian River stationary observation camera (BML)

Figure 4
Inlet Closure and Self-Breach in October 2012

Source: Sonoma County Water Agency

figure 5
Project Name

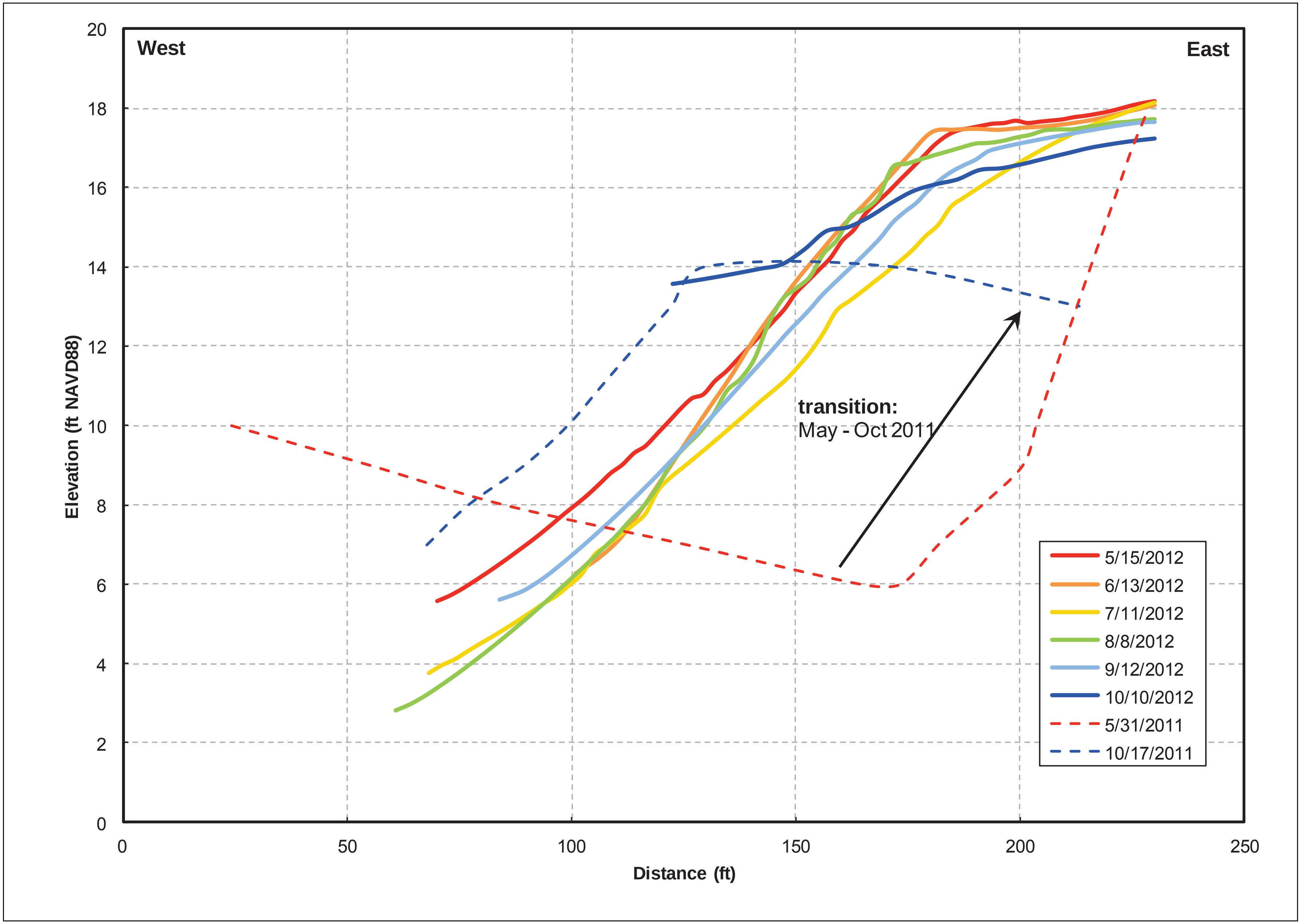
Outlet Channel Flow Through Jetty Notch

ESA PWA Ref# DW01958.02

SOURCE: image from USDA NAIP

Russian River Estuary Outlet Channel Management Plan . DW01958

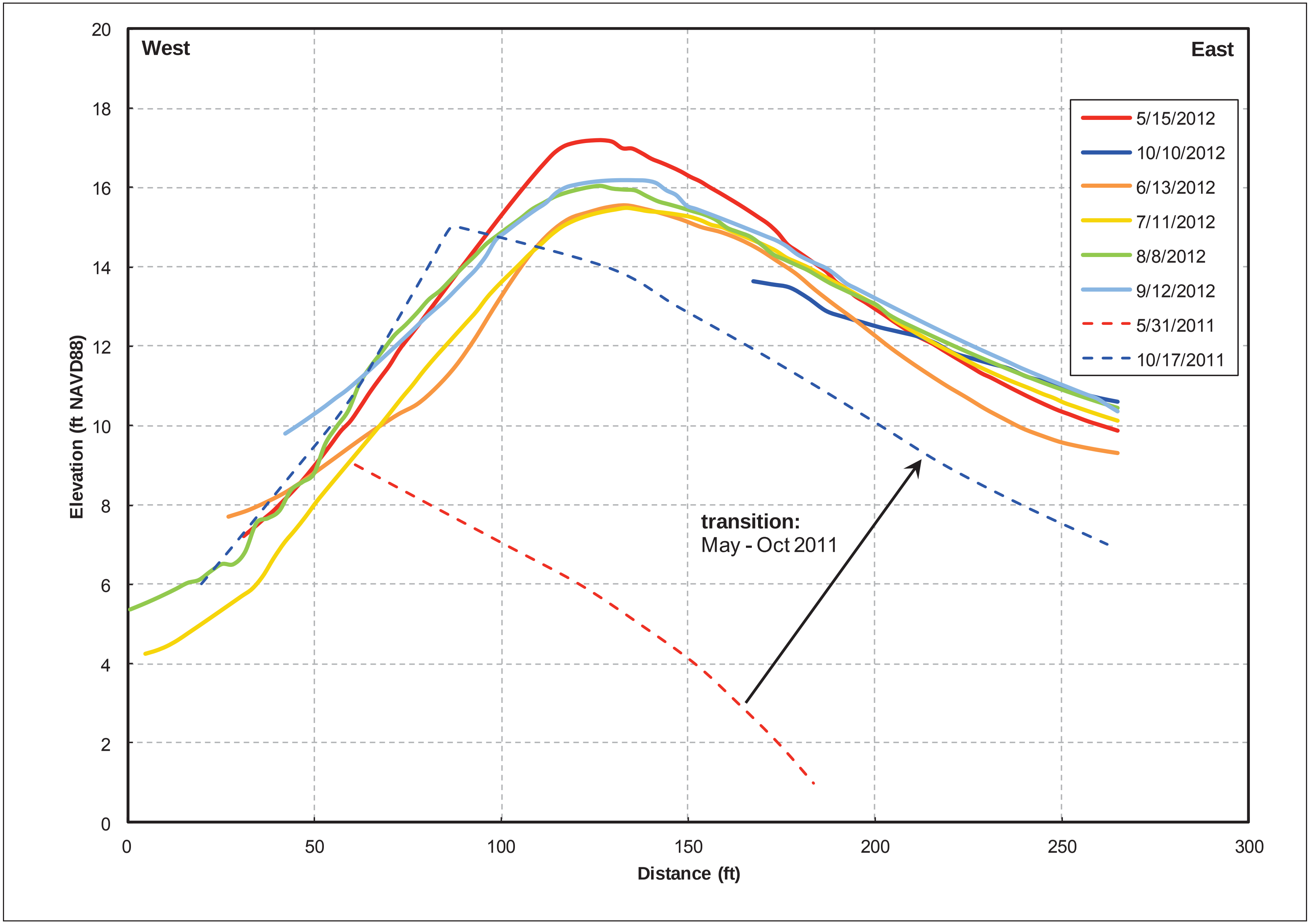
Figure 6
Beach Transect Locations



SOURCE: SCWA survey data

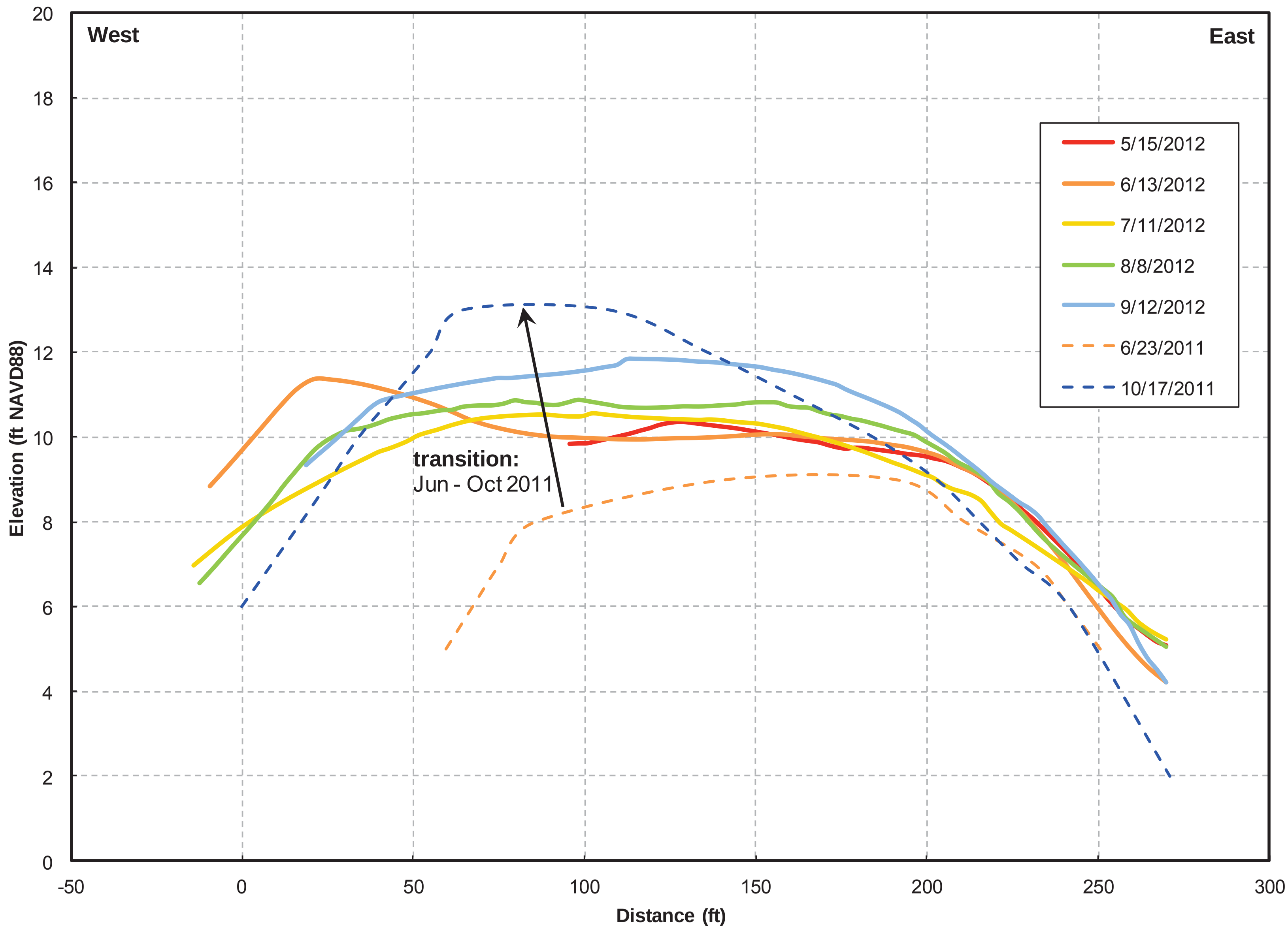
Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 7
Beach Transect 4



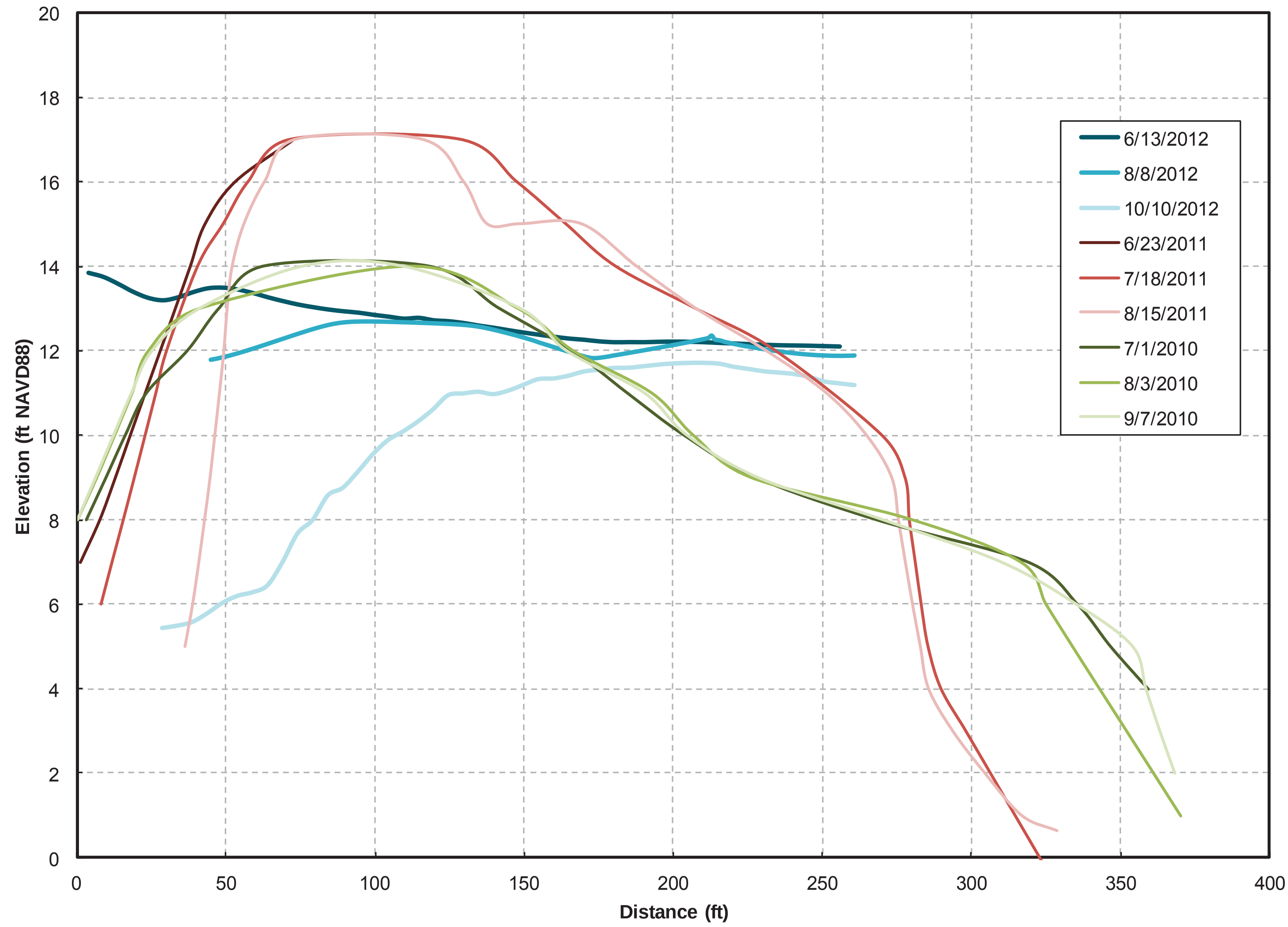
SOURCE: SCWA survey data

Figure 8
Beach Transect 3



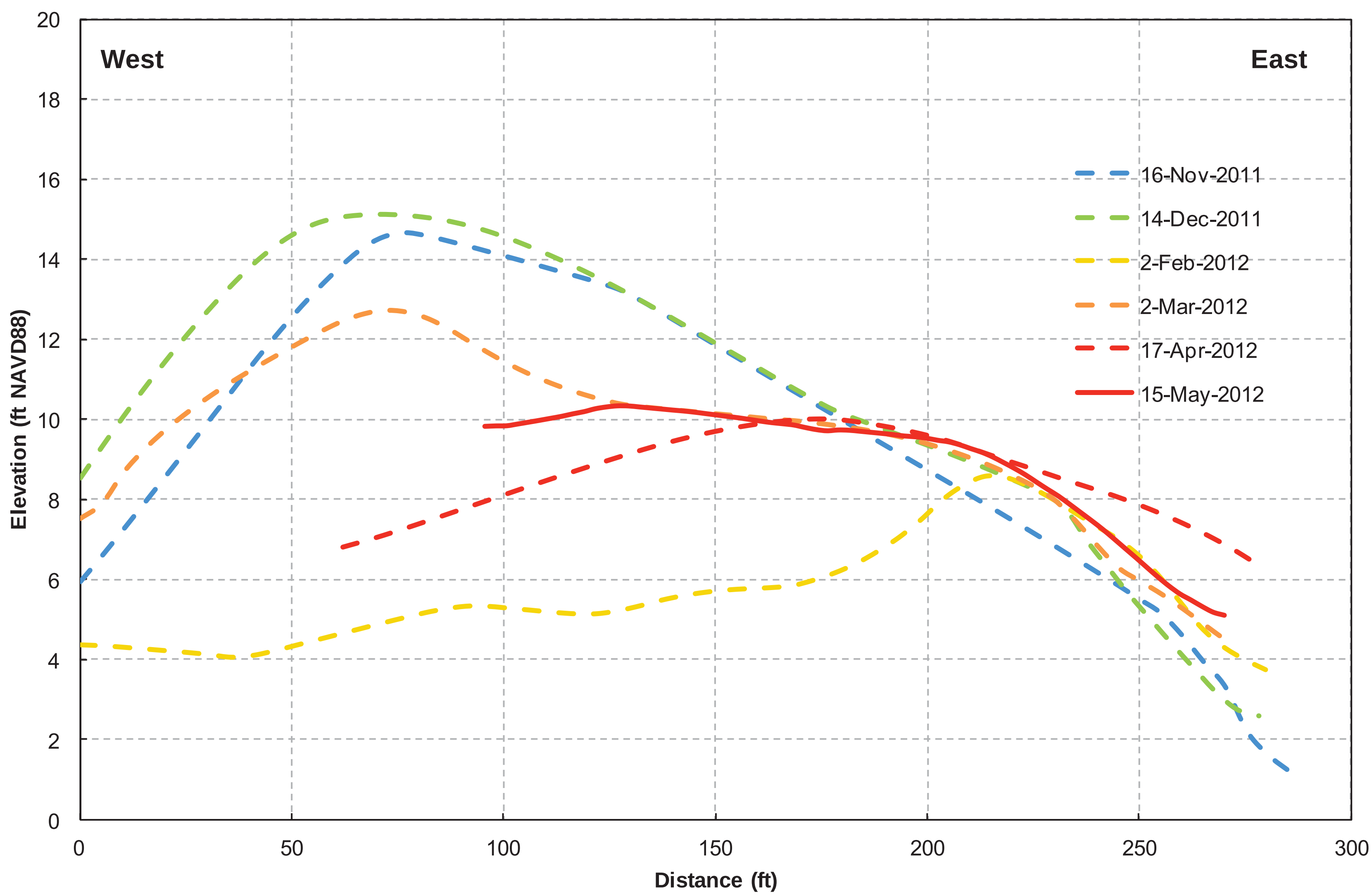
SOURCE: SCWA survey data

Figure 9
Beach Transect 2



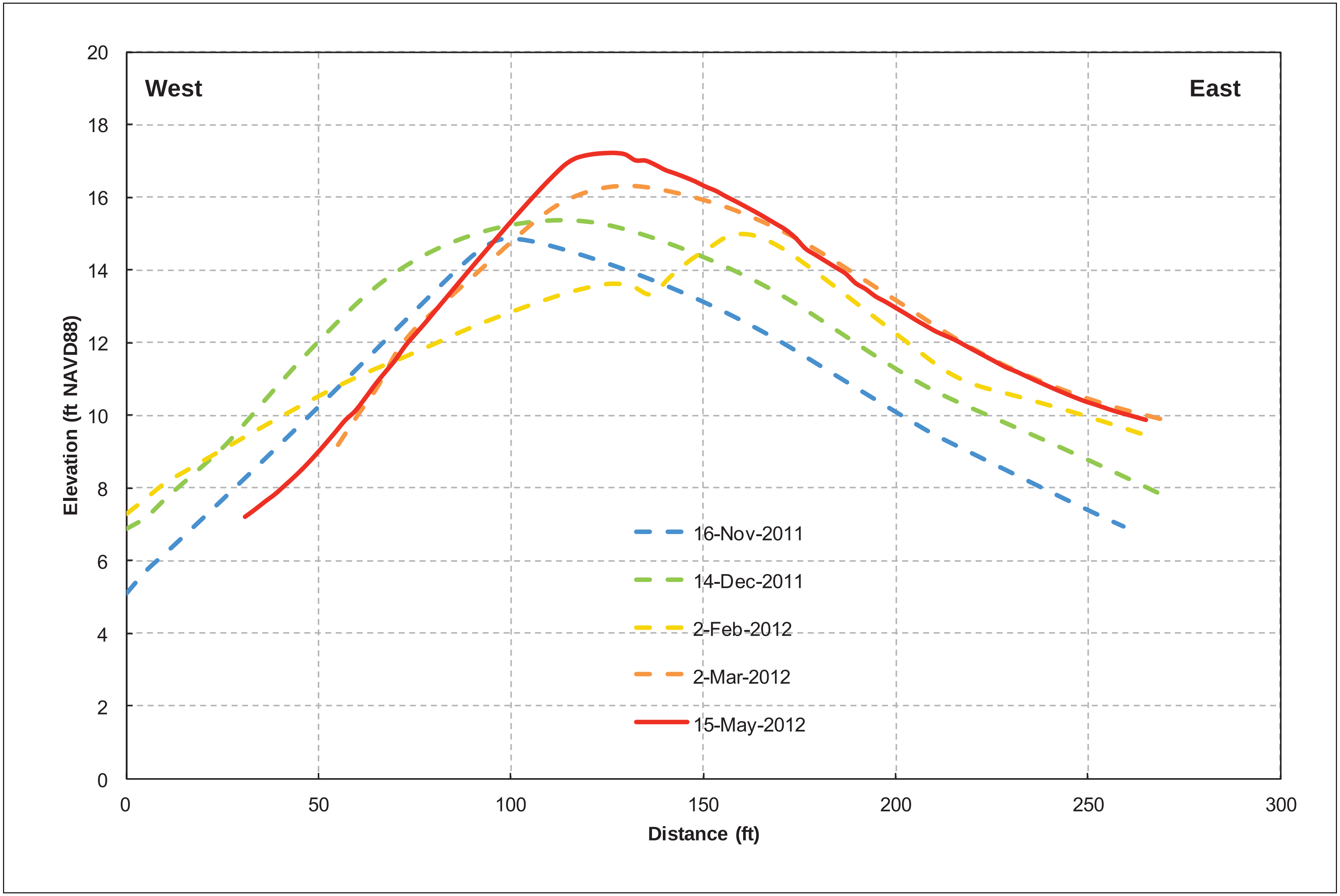
SOURCE: SCWA survey data

Figure 10
Beach Transect 0



SOURCE: SCWA survey data

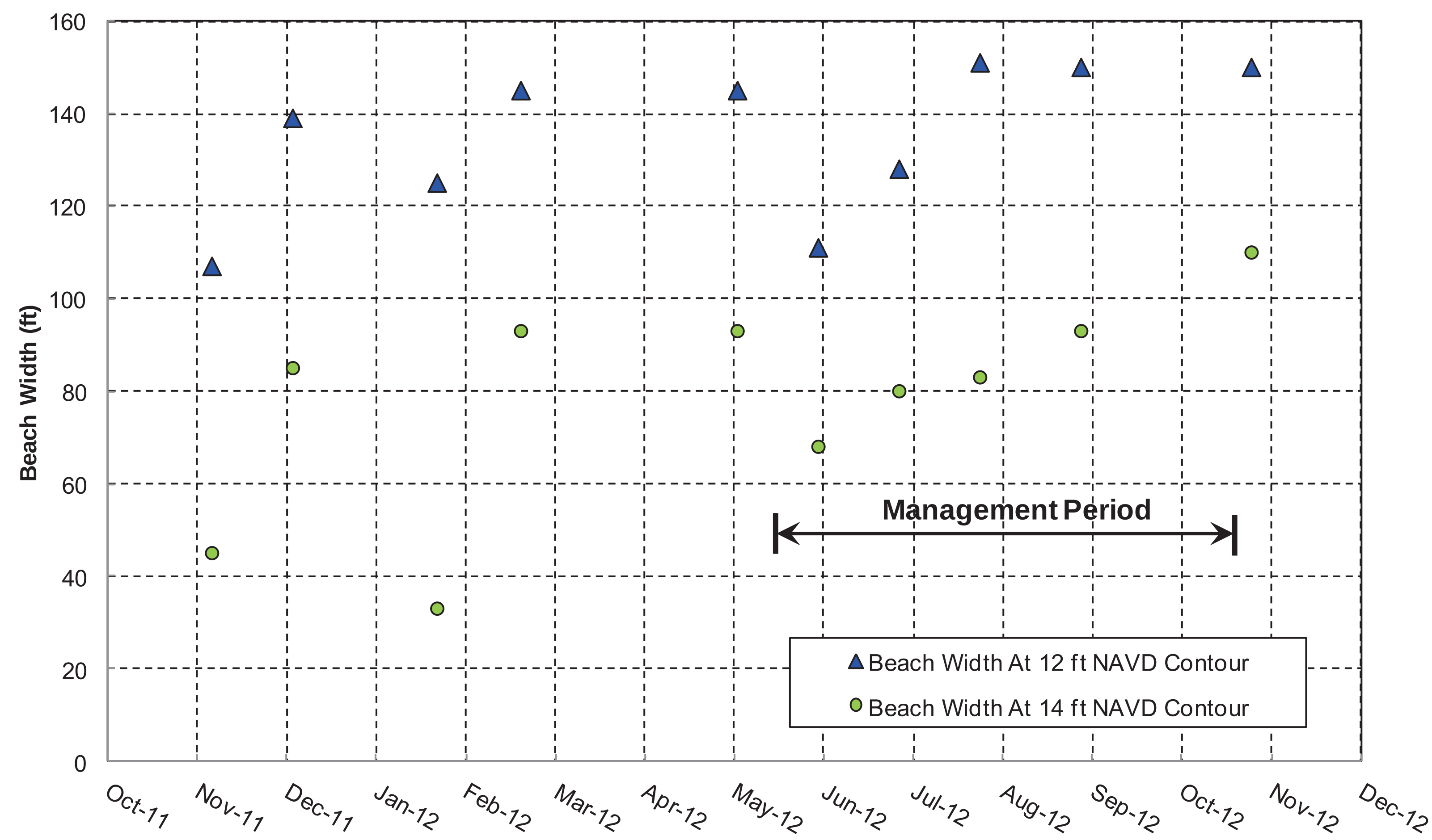
Figure 11
Nov 2011 to May 2012 topographic change at Beach Transect 2



SOURCE: SCWA survey data

Figure 12

Nov 2011 to May 2012 topographic change at Beach Transect 3



SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . D120709.00

Figure 13
Beach Width at Beach Transect 3.

Attachment H. Physical Processes During the 2013 Management Period

As required by the Russian River Biological Opinion, the Sonoma County Water Agency (Water Agency) has been tasked with managing a summer lagoon intended to improve salmonid habitat in the Russian River Estuary by creating an outlet channel while maintaining the current level of flood protection for properties adjacent to the estuary (NMFS, 2008). The adaptive management plan, described in the main body of this report, was developed by the Water Agency with assistance from ESA PWA and the resource agency management team in 2009 and revised annually from 2010 to 2014. Because of permit constraints, the Water Agency was only able to implement the plan beginning in 2010. The revised plan was in effect for 2013, but no opportunities for management action occurred during the management period.

During the 2013 management period, May 15th to October 15th, Water Agency staff regularly monitored current and forecasted estuary water levels, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. Although the inlet experienced several closures, an outlet channel was not implemented. The inlet was closed for the majority of the first two months of the management period as a result of two closure events. During this time, each closure ended when lagoon water levels increased, overtopped the beach berm, and scoured a new tidal channel. The first event self-breached in early June before water levels reached 7 ft NGVD, while the second event resulted in lagoon stage above 7 ft NGVD but self-breached in early July before an outlet channel could be implemented. The estuary remained fully tidal until it closed again in late September. This September-October event was ended with a manual breach on the last day of the management period to provide a pathway for migrating salmonids and to reduce water levels in advance of potential fall precipitation.

Even though no management actions were implemented to inform the adaptive management process, the physical conditions and inlet response during the management period are reviewed in this attachment to contribute to site understanding and to inform future management actions.

METHODOLOGY

This review of the 2013 outlet channel management period examined water levels, ocean wave conditions, ocean water levels, riverine discharge, beach topography, as well as inlet size and location. The sources for these parameters are listed in Table 1. These data were supplemented with personal observations and discussion with staff from the Water Agency, NMFS, CDFW, and the Bodega Marine Laboratory.

Table 1. Data Sources

Parameter	Source
Estuary water level (h_E)	Water Agency Jenner gage*
Wave height (H_s), period (T_a), and direction	CDIP Point Reyes buoy #029
Ocean water level (h_O)	NOAA Point Reyes #9415020
Russian River discharge (Q_f)	USGS Guerneville #11467000
Beach topography, ft NGVD	Water Agency monthly surveys
Inlet size and location	Water Agency and Bodega Marine Laboratory autonomous cameras

*Data transmission failure due to cellular network issues occurred for several periods throughout the management period.

INLET STABILITY PARAMETER AND CLOSURE RISK PROBABILITY

In addition to considering individual parameters, researchers at the Bodega Marine Laboratory have developed a combined parameter to evaluate the stability of the inlet's state, with the aim of predicting closure risk (Behrens et al., 2013). (Note that the inlet stability parameter does not differentiate between full closure and the perched conditions with a small outlet channel. When discussing this parameter, both states are referred to as a 'closure' in that tides are prevented from propagating into the estuary.) The inlet stability parameter presented by Behrens et al. (2013) quantifies the risk of inlet closure based on a sediment balance in the inlet. It considers the daily balance between wave-driven sediment import to the inlet and sediment export driven by tidal fluctuations. The wave-driven import is assessed using nearshore wave estimates derived from a transformation matrix and offshore buoy data (ESA PWA, 2012) and the latter is estimated from tide gage data within the estuary and a stage-storage relation derived from the available bathymetry. Using daily-average values of the stability parameter within the period 1999-2008, Behrens et al. (2013) showed that high-percentile values of the parameter are closely linked to the risk of the inlet closing within five days. As the percentile of the stability parameter increases, the risk of inlet closure within five days increases exponentially, from risks of roughly five percent when the parameter is at the 50th percentile to a risk of 80 percent when it is measured at the 99th percentile.

SUMMER AND FALL CLOSURES AND SELF-BREACHES

Time series of estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 1 for the entire management period. The lagoon water level time series (Figure 1a) summarizes the closure events at the beginning of the management period, as well as the subsequent tidal conditions and later closure events in fall. As shown in Figure 1d, discharge was low for most of the management period, dropping below 100 ft^3/s at the onset of June and not rising back significantly 100 ft^3/s until September, with the exception of a short rise in response to a late June rainfall. Flows as low as 85 ft^3/s during the closure in mid-June allowed the lagoon stage to remain steady at approximately 5 ft NGVD for over a week. Immediately following this steady period, a late-season rainstorm briefly increased flows into the lagoon to more than 200 ft^3/s, causing the lagoon stage to approach 8 ft NGVD and eventually self-breach. As in prior years, wave energy in the subsequent months of July-September was minimal (Figure 1b). The hourly significant wave height only consistently surpassed 8 ft in late September, a likely cause of the last closure event of the management period.

The conditions leading to inlet closure were consistent with the existing conceptual model described in Section 4 of the Management Plan. All closure events coincided with either moderately high waves (H_s > 6 ft) having periods greater than 10 s, or with neap oceanic tide ranges of less than approximately 5 ft. Moderately high waves coincided with the closure events in May, June, and October. All closure events also occurred during or shortly after neap tidal periods. Closure events that occurred in May and June are examined in more detail in Figure 2.

All closure events occurred with the inlet located adjacent to the jetty. In 2012, this positioning may have prevented perched conditions from arising by shielding this area of the beach from the wave-driven sediment deposition that caused closure, preventing the beach from accreting to a sufficient height to allow the desired outlet channel elevations from being attained. This appeared to be the case for the first closure event of the 2013 management season (Figure 2), which self-breached on June 3rd at a stage of roughly 6.5 ft NGVD. The low point in the beach berm that was subsequently overtopped and self-breached also persisted immediately adjacent to the jetty. However, the same late-June rain storm that increased lagoon stage during the subsequent closure event also coincided with several days of long period swell waves (Hs ~ 5 ft, Tp ~ 15 s) that built up the beach in this location, allowing the lagoon stage to rise to almost 8 ft NGVD (Figure 2) before self-breaching in early July. Closure events that occurred later in fall (Figure 3) were breached at or below a lagoon stage of 8 ft NGVD.

CLOSURE AND SELF-BREACH DYNAMICS

Of the three closure events that occurred within the management period, the second closure event (lasting approximately from June 7th until July 4th) provided the best opportunity for outlet channel implementation. This event also indicated that water levels and closures can be persistent if flows drop below a minimum level.

To better illustrate both the lagoon stage and beach morphology during this time, Figure 4 shows a sequence of photos of the inlet before and during this closure event. As was the case for all of the management period, the inlet was located next to the jetty. Five days prior to closure, on June 3rd, the barrier beach self-breached. Since this self-breach occurred during a period of neap oceanic tides, tidal scour probably enlarged the inlet at a reduced rate, leaving it more susceptible to closure. Figure 4a depicts the inlet when it was located next to the jetty several days before closure, indicating a width of less than roughly 40 ft. Nearshore waves having significant heights of 6-7 ft and periods of 9-12 seconds coincided with closure (Figure 2b, Figure 4b), and subsequently raised the berm near the jetty (Figure 4c). As discussed later, these waves built the berm higher next to the jetty than in previous years, which allowed the closure event to persist.

During the first week of closure, inflows (Figure 2d) were measured at 100 – 115 ft^3/s, and the increase in stage was roughly 0.2 – 0.4 ft/day. As inflows dropped to 80 - 100 ft^3/s over the next several weeks, the water level increase slowed until the lagoon reached a balance between inflows and the combined losses from beach seepage and evaporation (Figure 2a). Summer dams constructed during this time downstream of the Hacienda Bridge gage further reduced inflows to the estuary. This markedly slower water level increase is evidenced by the lack of movement of the water line (emphasized with red dashed line) over the twelve days between Figure 4c and Figure 4d. Rainstorm-derived inflows and possible wave overwash from June 25th -27th caused the water level to rise at roughly 0.4 ft/day. From June 28th until the self-breach event on July 3rd, the water level increase slowed to less than 0.2ft/day. The low point of the beach (where breaching typically occurs) was at the jetty (Figure 4e).

Unlike the 2012 management period, no natural outlet channels were formed near the jetty in 2013. However, as with 2012 and other previous years, the lowest portion of the beach was consistently located at the jetty. This persistent low portion is probably caused by wave sheltering by the jetty, which may have reduced berm build-up at the inlet's location, leaving a low point in the beach berm that was the site for subsequent overtopping and self-breaching.

The first event (lasting from May 23rd until June 3rd) and last event (lasting from September 24th until October 15th) of the 2013 management period were also unsuitable for implementing an outlet channel. The first event self-breached before the lagoon stage reached the 7 ft NGVD target stage. The second event just reached the target elevation at the end of the management period. Then, on the last day of the management period, the Water Agency artificially breached the beach to provide a pathway for migrating salmonids and to reduce water levels in advance of potential fall precipitation.

Four more closures occurred after the end of the management period in October–December 2013 (Figure 3). These events coincided with typical late-fall energetic swell waves, and each persisted for over a week, since inflows remained lower than 300 ft^3/s through the end of December. In consultation with the resource agencies, the Water Agency conducted its October and November artificial breaches to the north of Haystack Rock. The intent of this alignment was to discourage the inlet from re-establishing next to the jetty. However, after the inlet closed twice north of Haystack Rock, the December artificial breach was implemented closer to the jetty. This December breach location was selected to encourage the inlet to stay open longer for migrating salmonids and to ensure that the breaching stayed within the Water Agency's permitted excavation limits of 1,000 yd^3.

CLOSURE RISK PROBABILITY

The 5-day closure risk probability, a derivative of the inlet stability parameter described above, was hindcast for 2013 according to the method described in Behrens et al. (2013). This hindcast provides an indication of the utility of the stability parameter as a prediction tool for monitoring inlet conditions and planning management action. This parameter integrates wave and ocean forcing conditions, as well as estuary water levels, to provide greater predictive skill than just waves or ocean tides on their own. The stability parameter combines these factors, and the corresponding five-day closure risk time series exceeded 70 percent before each 2013 event (Figure 1e, Figure 2e, and Figure 3e). Data gaps in the Jenner gage record prevented closure risk predictions prior to the first closure event. Otherwise, the predicted probability of closure exceeded 70% 2-5 days in advance of each closure. In previous years, a prediction threshold of 50% was used, but there were several instances exceeding 50% in April and July of 2013 that did not result in closures.

TOPOGRAPHIC CHANGE

The Water Agency has conducted monthly surveys of Goat Rock State Beach that cover a region starting from the jetty and extending approximately 1,500 feet to the north. Typically, the surveys do not include bathymetry within the inlet because flow conditions in the inlet prevent safe access. Also, the survey extent can be limited by the Water Agency's compliance with its marine mammal incidental harassment authorization, which sets guidelines for the survey crew's approach to marine mammals hauled out on the beach. Water Agency survey staff collected spot elevations using RTK-GPS and then assembled these elevations into a set of contour lines at 1 ft intervals, as well as profiles along the beach berm crest, the ocean wetted edge, and the estuary water line. The survey elevations are reported in the NGVD29 vertical datum.

To characterize beach berm topographic conditions, ESA PWA assessed data from the Water Agency's 2010 (July to September), 2011 (May to October), 2012 (May to October), and 2013 (May to October) surveys. Survey transects from the 2012 analysis were reused (Figure 5), and include two transects backed by cliff (Figure 6 and Figure 7), two transects which extend into the estuary (Figure 8 and Figure 9), and two variations on a transect just north of the jetty (Figure 9).

This review focuses on the 2013 surveys, although the 2011 surveys are included for context. The 2013 topographic data were similar to those of 2012, when little morphologic change occurred throughout the management season. In contrast, surveys taken in 2010 and 2011 indicated that beach erosion and accretion occurred during the management period. The erosion was associated with inlet migration and subsequent accretion of the beach was associated with long-period swell waves. During the 2012 and 2013 management seasons, the inlet remained at the jetty and did not migrate north. Adjacent to the jetty groin, Transect 0 showed little monthly change in topography, but extensive inter-annual variability (Figure 10).

During the management period in 2013, the beach berm along Transects 1- 4 showed little variability, changing by less than one foot. This was particularly true during the months of May – September at Transects 1-2 (Figures 8-9) and Transect 4 (Figure 6). At each of these profiles, the change in beach profile from September to October was greater than for the rest of the management season. The only transect to experience more than one foot of change in elevation was Transect 3 (Figure 7), whose crest aggraded by 1.5 feet between the May 30th and June 13th surveys. The difference in monthly variability at each transect between 2013 and prior years can likely be tied to the difference in the extent of inlet migration. As an example, in 2011, the inlet migrated north of Haystack Rock during the winter, and returned to the jetty in late spring or early summer. This migration resulted in a lower beach profile at all transects. Then, over the course of the management period, the beach gradually built up to a typical summer profile. In contrast, the inlet never migrated north of Haystack Rock in 2013, even during peak winter and spring flows. As in 2012, this left the beach berm largely intact north of Haystack Rock and a lower terrace between Haystack Rock and the jetty groin. Since these northern transects started at a much higher elevation at the start of the management period, the vertical growth of the beach profiles at these locations were several feet less than during 2011 in the same locations.

Transect 0, which is located just north of and parallel to the jetty, was slightly lower than the other transects measured during the 2013 management period. Its crest was measured at roughly 15 ft NGVD both at the beginning and end of the management period, compared with crest elevations of 15-17 ft NGVD measured at the other transects. Figure 10 shows that this location is typically stable throughout the management period but varies from year to year, likely as a result of inlet migration, flood erosion, and berm building by winter waves. Compared with prior years, the berm at this location is lower than in 2011, but higher than in 2010 and 2012. As we have noted during previous reports, the lack of management period variability of this region suggests that the jetty shelters this portion of the beach from small to moderate waves that occur during the management period. Only the larger waves associated with winter storms may be sufficient to re-shape the beach berm near the jetty.

Beach berm crest profiles were collected by the Water Agency for the first time in 2013. These data make it possible to discern important changes in beach shape along the length of the berm from the northern beach access point to the jetty. Along-beach trends in crest elevation generally indicate along-beach trends in wave energy and the influence of inlet migration and breaching.

Figure 11 shows that the same minimal change in crest elevation was apparent throughout the length of the beach north of Transect 1. Although the crest elevation changed by as much as 2 ft in some areas, there was a distinct pattern in the along-shore crest height that remained roughly the same throughout the management period. The beach crest was lowest south of Transect 1, where the inlet resided. At Transects 1 and 2, a set of ridges remained in place with peak elevations at 17-18 ft NGVD, while the crest was generally lower (14-17 ft NGVD) and had less of a consistent shape north of Transect 2. Wave runup generally has less influence for higher beach profiles, since it becomes less likely that a given wave will overtop the crest. The higher variability north of Transect 2 is probably a reflection of the fact that the beach was lower in this area, and was more susceptible to change from the limited summer and fall waves.

Changes to the beach shape were much larger after the end of the 2013 management period, as shown in Figure 12. This is probably attributable to greater wave energy and relocation of the inlet. Wave energy increased dramatically in November and December, both in height and period. Although changes to the crest height were still minor during these months, by January 16th 2014, the crest had been built as high as 19-20 ft NGVD north of Transect 4. At Transects 1 and 2, the crest ridges shifted in the along-beach direction, but the peak heights remained similar to August.

Manual breaching of the inlet north of Haystack Rock on October allowed the inlet to carve a 400-500 wide swath within the beach, centered roughly at Transect 3. The inlet then closed again and later breached at the jetty. By December 12th, waves had rebuilt the crest to a height of 10-12 feet within the swath. By January 1, 2014, this segment of the beach that the inlet had occupied in October and November was indistinguishable from the rest of the beach crest profile.

BEACH WIDTH

To provide additional information about the beach morphology, ESA PWA assessed the beach width using the Water Agency survey data. Figure 13 shows the evolution of the beach width at Transect 3 during both the 2012 and 2013 management periods. During winter months, the beach was often eroded at Transect 3 to the point that the beach crest was below 12 ft NGVD, so that the width was effectively zero. Apart from this seasonal erosion, there was no marked trend in the beach width. In 2013, the width at 12 ft NGVD varied between 80 and 120 ft, and was generally less than 65 ft wide at the 14 ft NGVD contour. This was smaller than in 2012, when it varied from 110-150 ft NGVD at the 12 ft contour and was less than 110 ft at the 14 ft contour. This interannual difference may be attributable to differences in fall-spring wave energy (and thus beach building), or possibly to differences in inlet position.

LESSONS LEARNED AND RECOMMENDATIONS

Based on 2013 observations of the estuary, associated physical processes, and the Water Agency's planning for outlet channel management, we note the following lessons about implementing the outlet channel management plan.

CONCEPTUAL MODEL

- The beach north of the inlet saw little change from the 16-18 ft NGVD elevations established in 2012. Near the jetty, the berm was lowered by inlet migration while undergoing beach building.
- The influence of inlet breaching or migration north of the jetty can lead to erosion of a wide swath of beach, several times larger than the width of the channel. An erosion swath of 400-500 was observed following the Agency breach on October 15th.
- Similar to the winter of 2011-12, the inlet never migrated north of Haystack Rock during winter 2012-13, and returned to the jetty in early spring, much earlier than in most years. This inlet alignment is not common, but has been observed in past years (Behrens et al., 2009).
- Peak annual river discharge has remained below 40,000 ft^3/s for 8 consecutive years, a streak unmatched in the 70-year flow record. This may have a connection to the recent lack of inlet migration to the north.
- The beach width in 2013 at Transect 3 (near Haystack Rock) was smaller than in 2012. The interannual decline was larger than changes to beach width at this location within the 2013 management season alone. This may suggest that beach width is more closely tied to seasonal changes in inlet behavior and offshore waves than to shorter-term changes.

OUTLET CHANNEL FEASIBILITY

- The jetty may shelter the inlet, making closure less likely and also limiting berm growth, which then maintains a low point for self-breaching. When the inlet is in a fully or muted tidal condition, options for management become considerably more difficult to implement.
- Late June closure included a 10-day period when lagoon water levels were nearly constant at approximately 5 ft NGVD because low flows measured at Hacienda Bridge (80-100 ft^3/s) and construction of summer dams reduced flows into the estuary to the point that they were balanced by seepage. An unusual early summer rain then boosted discharge to more than 200 ft^3/s, causing self-breach at approximately 8 ft NGVD.
- Once lagoon water levels reach the low point of the beach crest elevation, the lagoon self-breached. This behavior highlights the susceptibility of a sand bed outlet channel to scour, limiting conveyance capacity.
- Post-management period, the Water Agency breached the inlet north of Haystack Rock. This alignment was not continued because repeated closure threatened Chinook migration and the enlarged beach berm restricted breaching to within the permitted excavation volume.

ESA PWA

- Over the first three years of effort to implement the outlet channel adaptive management plan, only one closure (July 2010), has been suited for outlet channel management action.

COMMUNICATIONSAND PROTOCOLS

- Since full set of permits was not in effect, the Water Agency was required to seek authorization for each breaching event, which occasionally caused delayed operations.
- Although the perched lagoon episodes did not evolve to the point that management action was warranted, the Water Agency began planning management actions as soon as the episodes occurred. Planning included heightened observations of inlet conditions by Water Agency staff, email updates to inform the resource management group, and pre-implementation meetings at the project site to refine plans for management action.

MONITORING

- The Water Agency's monthly survey methods were modified to collect specified profiles, such as the beach berm ridge line, wetted edge (beach side), and water edge (estuary side).

REFERENCES

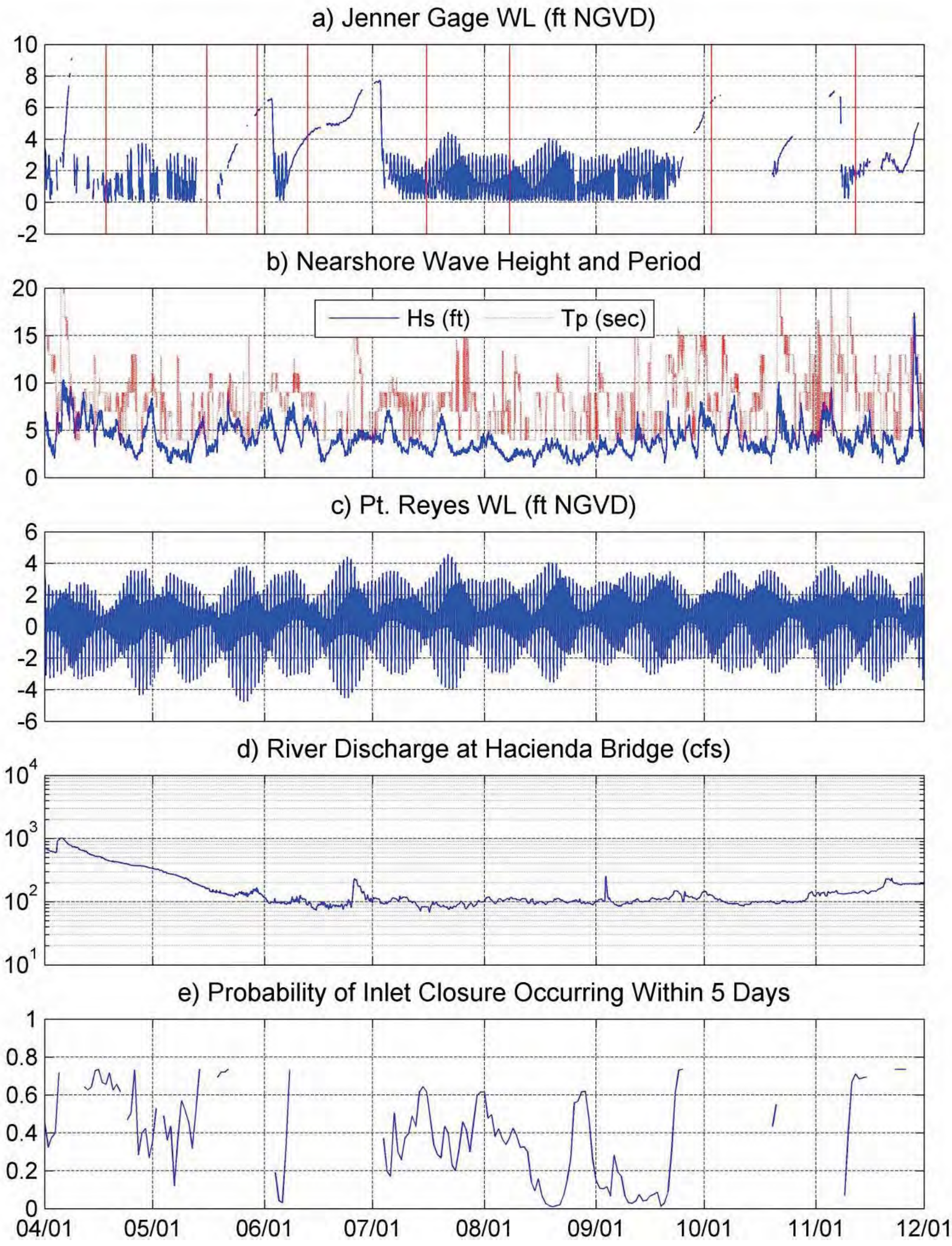
Behrens, D., Bombardelli, F., Largier, J. and E. Twohy. 2009. Characterization of time and spatial scales of a migrating rivermouth. Geophysical Research Letters. Vol. 36, L09402, doi:10.1029/2008GL037025.

Behrens, Dane K., Fabián A. Bombardelli, John L. Largier, and Elinor Twohy. 2013. "Episodic Closure of the Tidal Inlet at the Mouth of the Russian River — A Small Bar-Built Estuary in California." *Geomorphology* 189 (May): 66–80. doi:10.1016/j.geomorph.2013.01.017.

ESA PWA. 2012. Feasibility of alternatives to the Goat Rock State Beach jetty for managing lagoon water surface elevations: Draft existing conditions report. Submitted to Sonoma County Water Agency.

National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed.

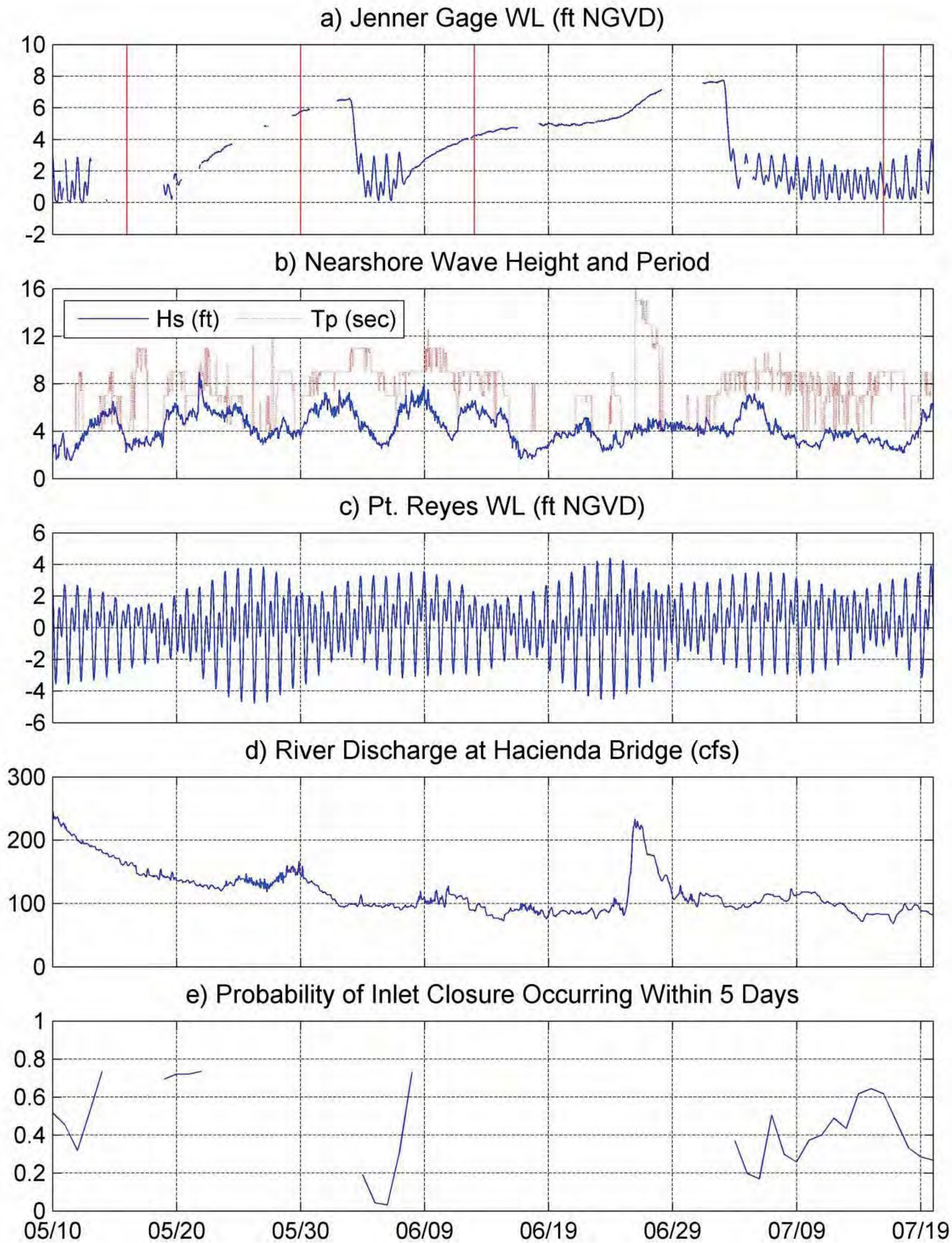
Weigel, R. 1992. Oceanographical Engineering.



SOURCE:

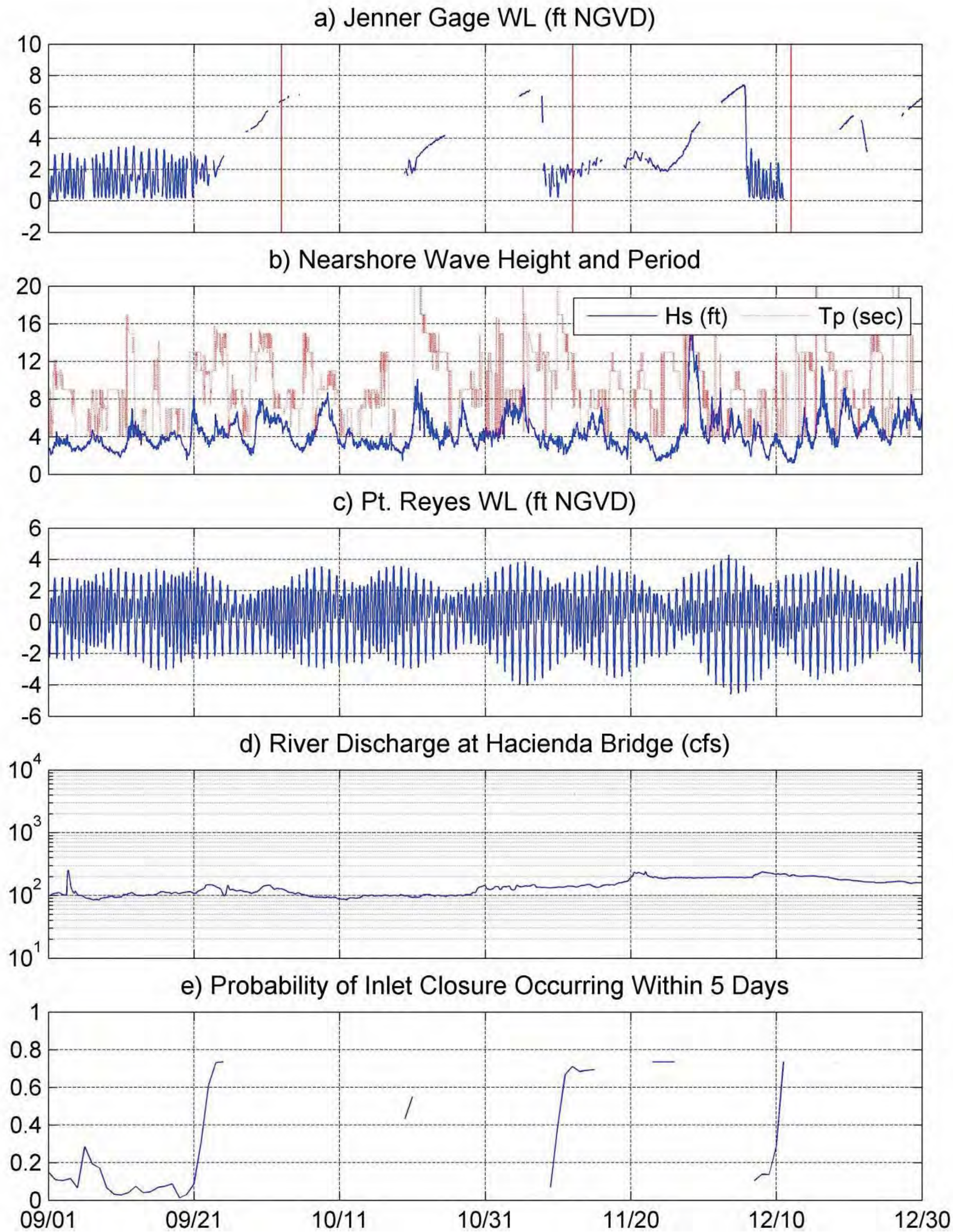
a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 1
Estuary, Ocean, and River Conditions Compared with Closure Probability: April – November 2013



SOURCE:
- a) Jenner gage water level provided by SCWA; red bar = beach survey
- b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
- c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
- d) River discharge provided by USGS (Guerneville #11467000)
- e) Five-day closure probability provided after Behrens et al. (2013)

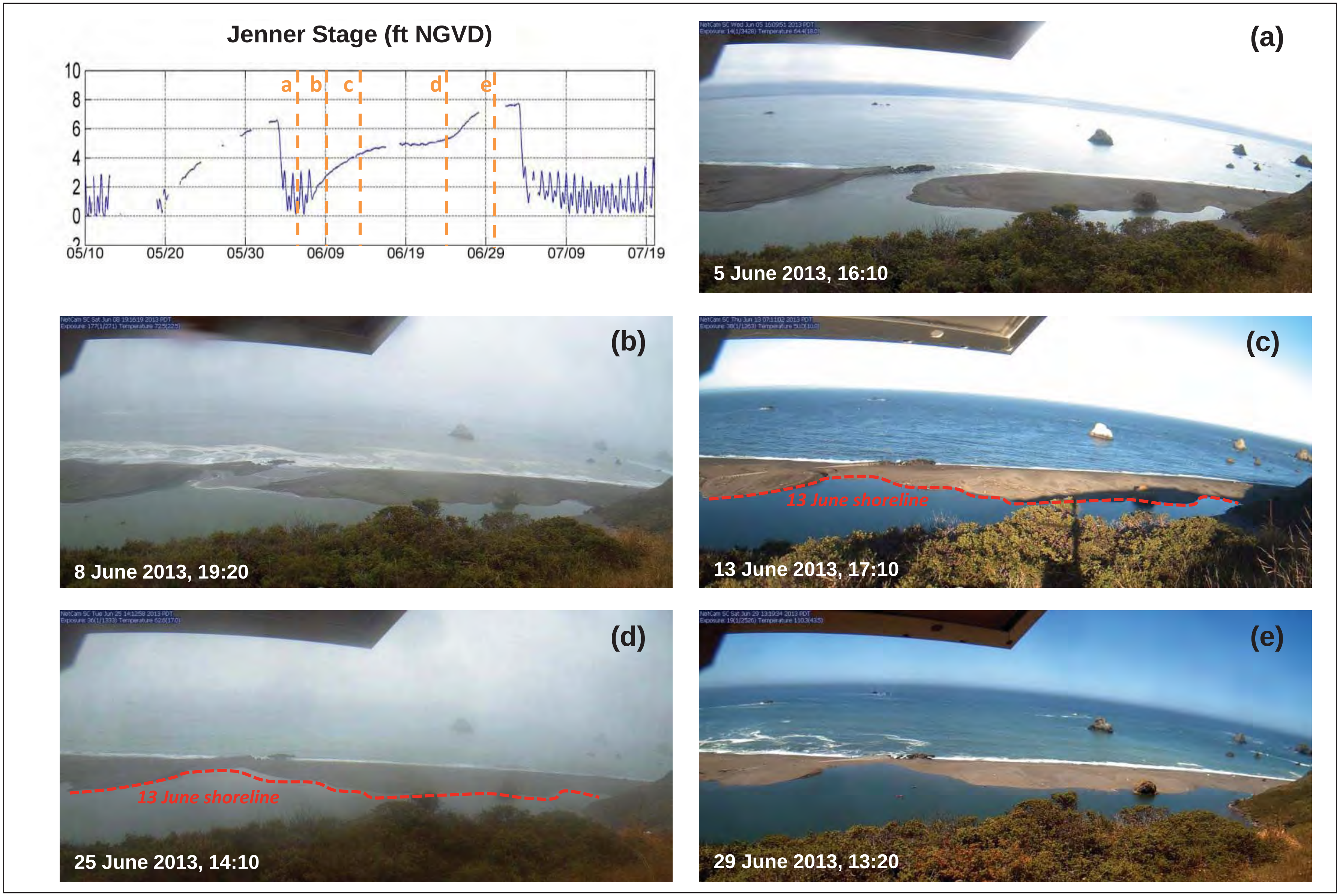
Figure 2
Estuary, Ocean, and River Conditions Compared with Closure Probability: May – July 2013



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 3
Estuary, Ocean, and River Conditions Compared with Closure Probability: September – December 2013



SOURCE: Russian River stationary observation camera (BML)

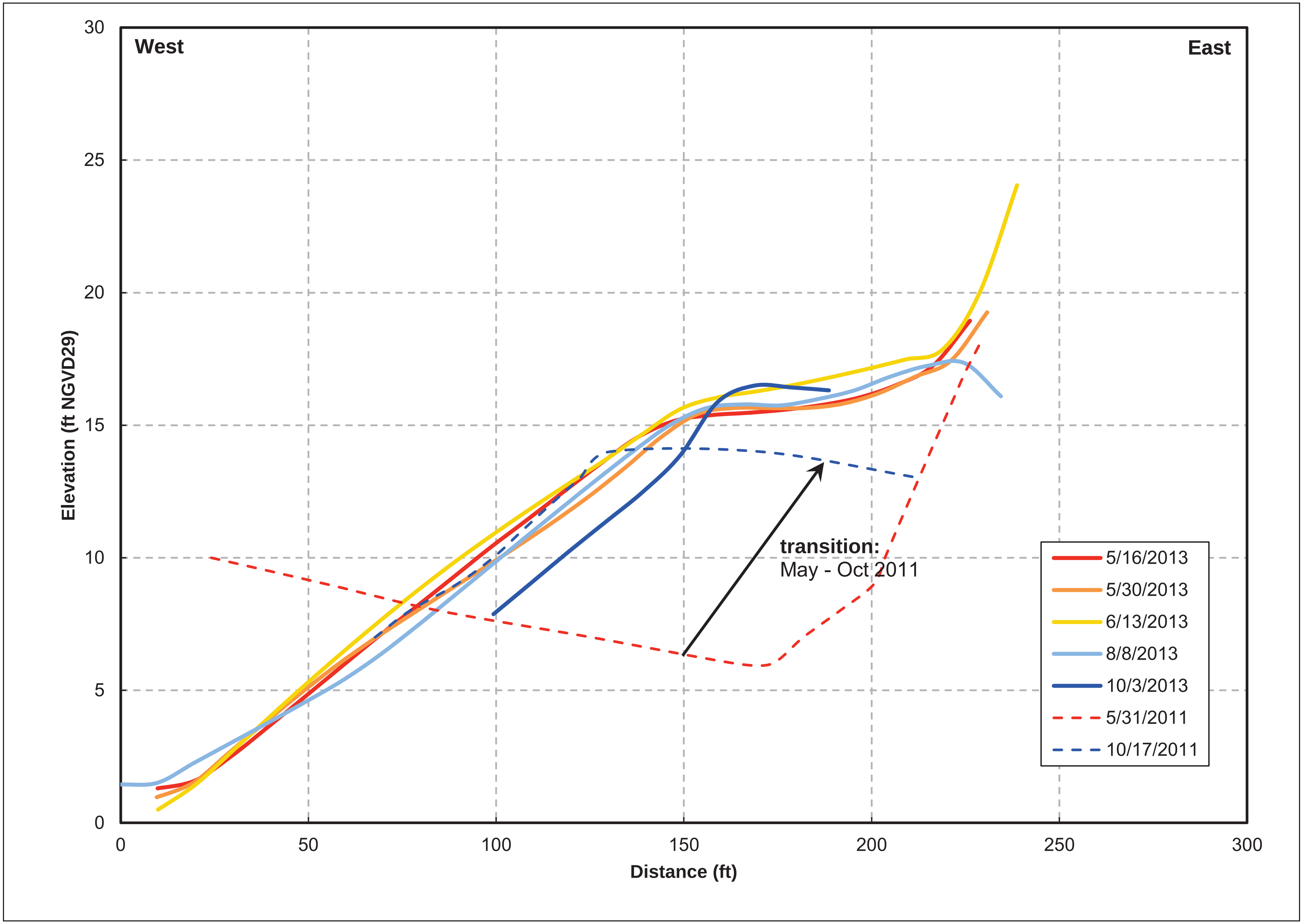
Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 4
Inlet Closure Event in June-July 2013

SOURCE: image from USDA NAIP

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 5
Beach Transect Locations

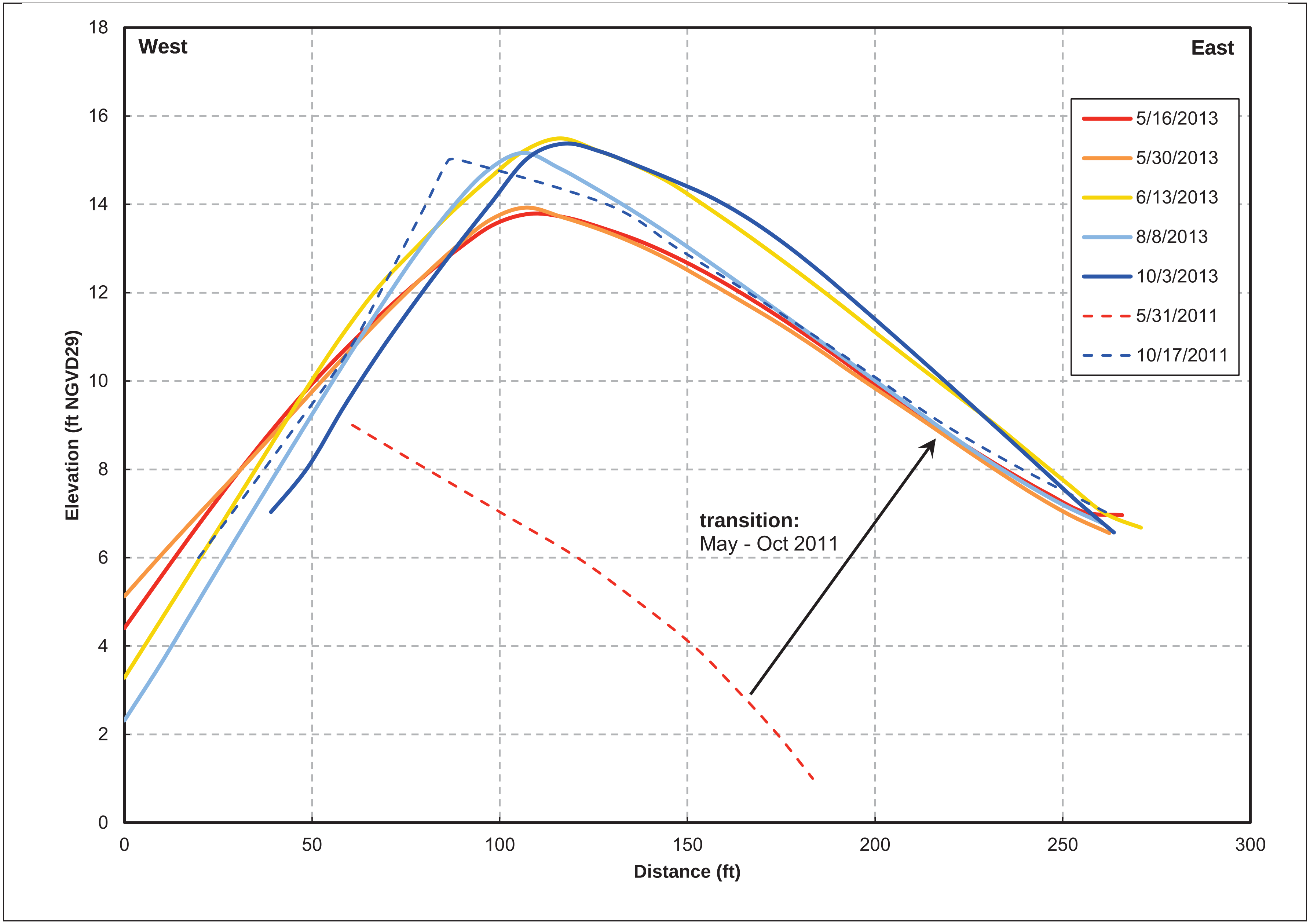


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 6

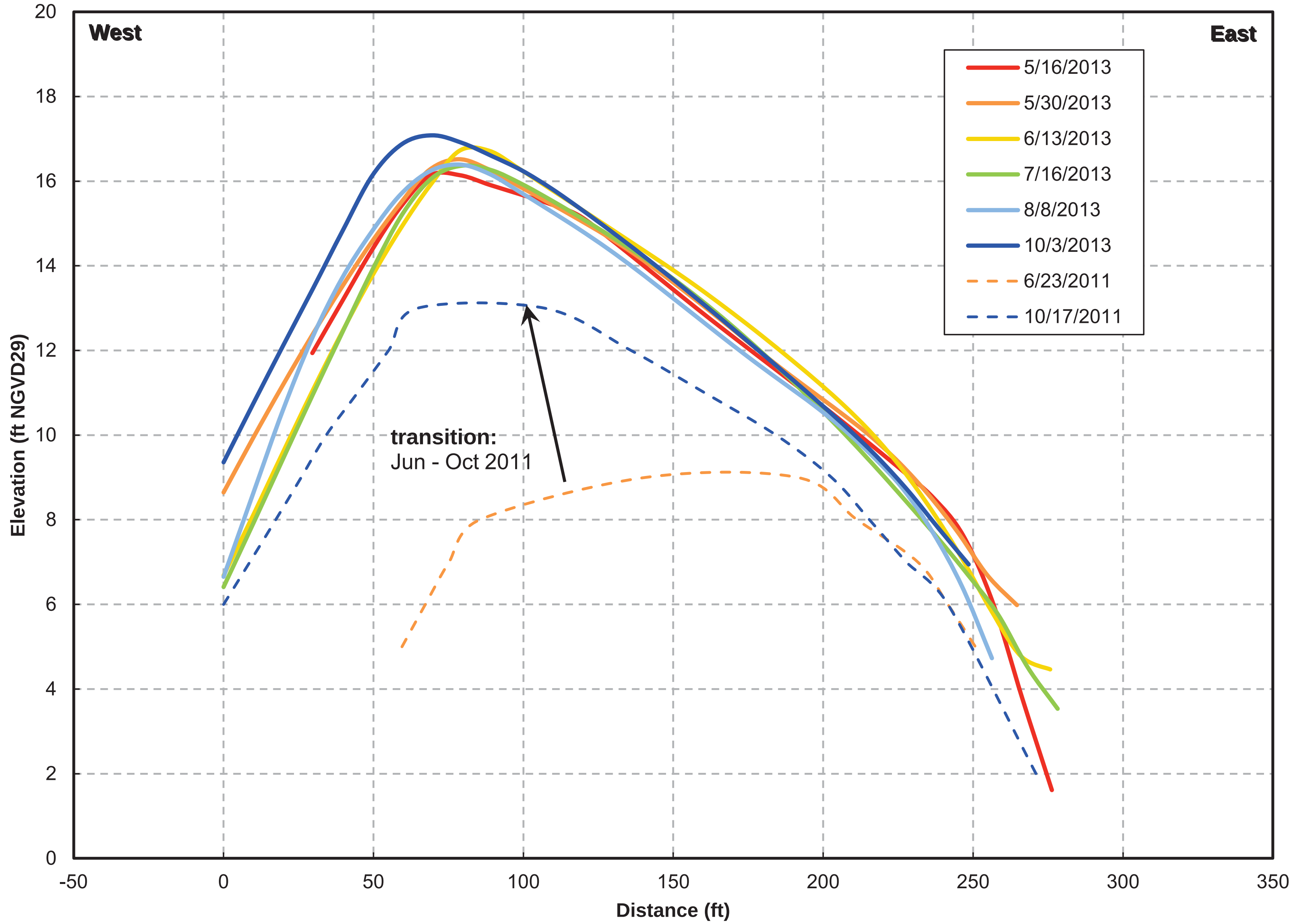
Beach Transect #4



SOURCE: Russian River stationary observation camera (BML)

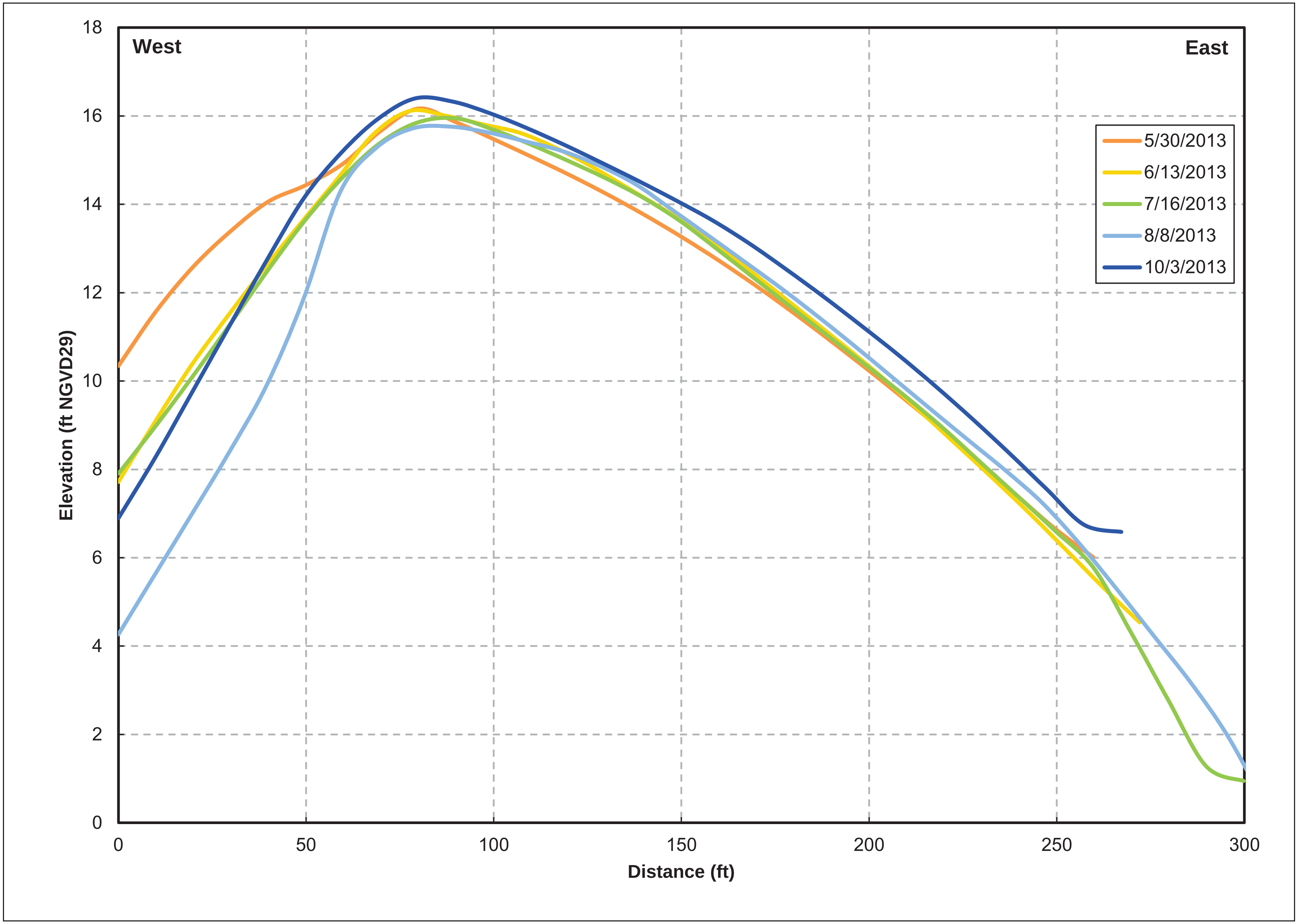
Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 7
Beach Transect #3



SOURCE: Russian River stationary observation camera (BML)

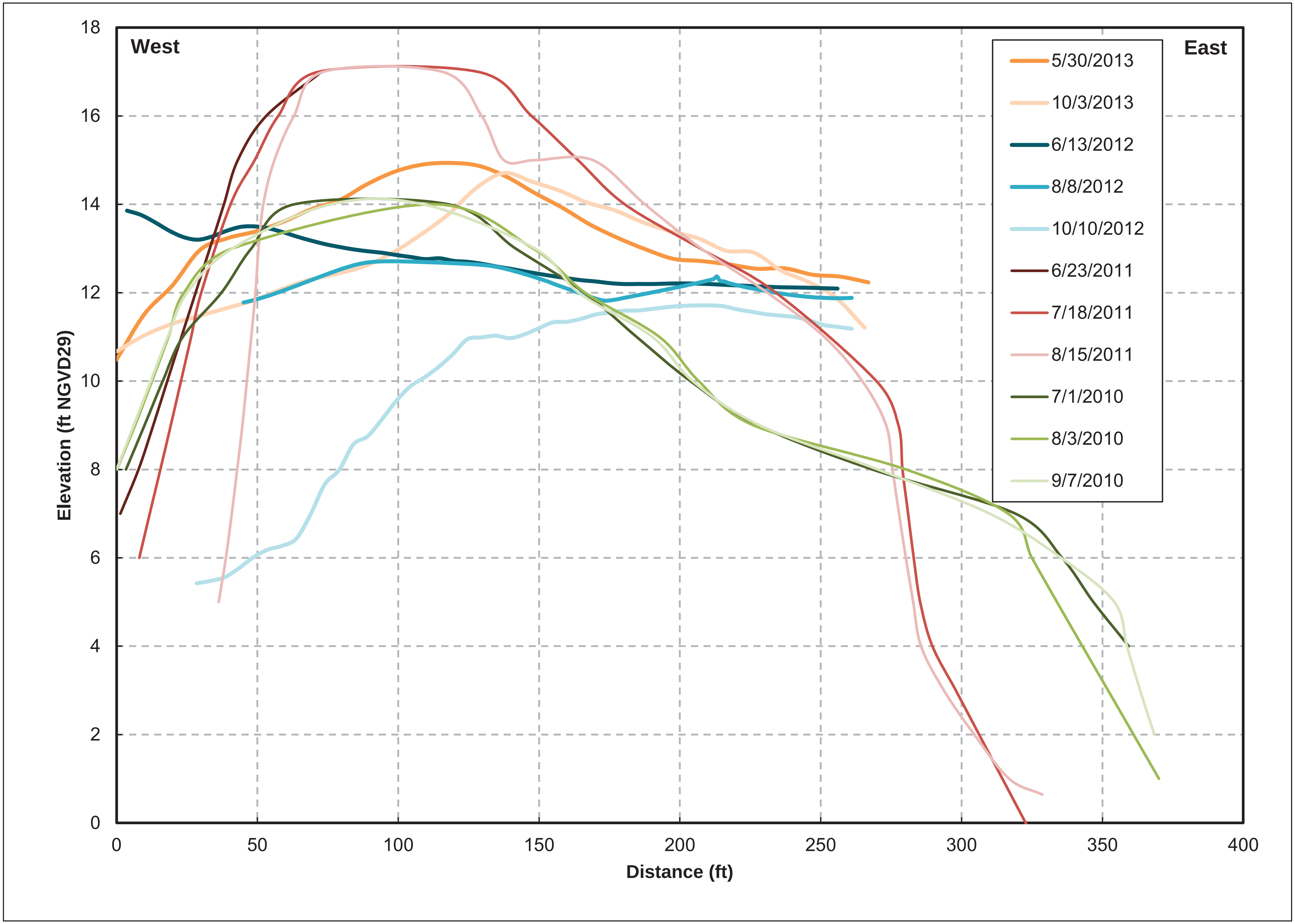
Figure 8
Beach Transect #2



SOURCE: Russian River stationary observation camera (BML)

Russian River Estuary Outlet Channel Management Plan . DW01958

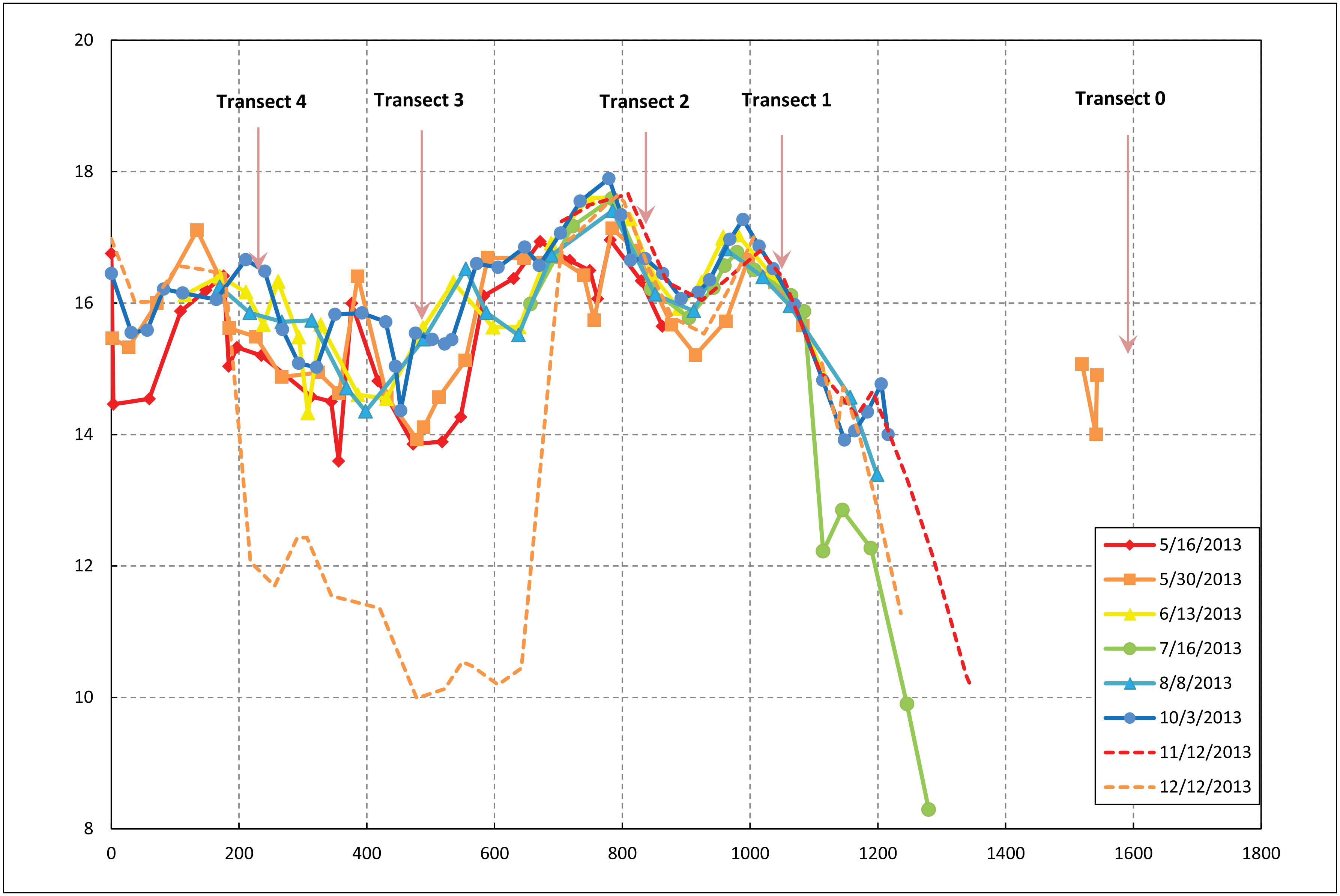
Figure 9
Beach Transect #1



SOURCE: Russian River stationary observation camera (BML)

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 10
Beach Transect #0

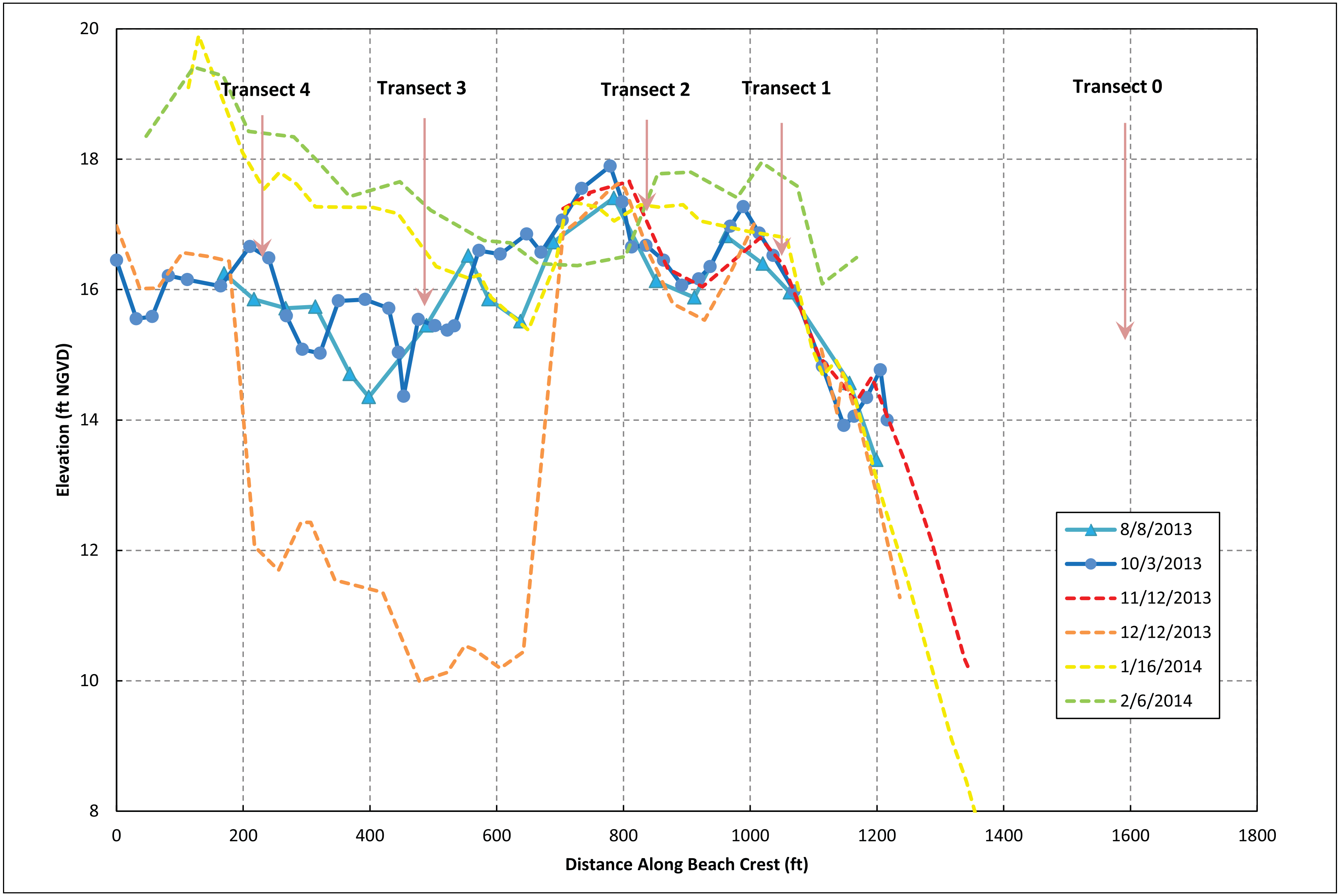


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 11

Beach Crest Profiles During the 2013 Management Period.

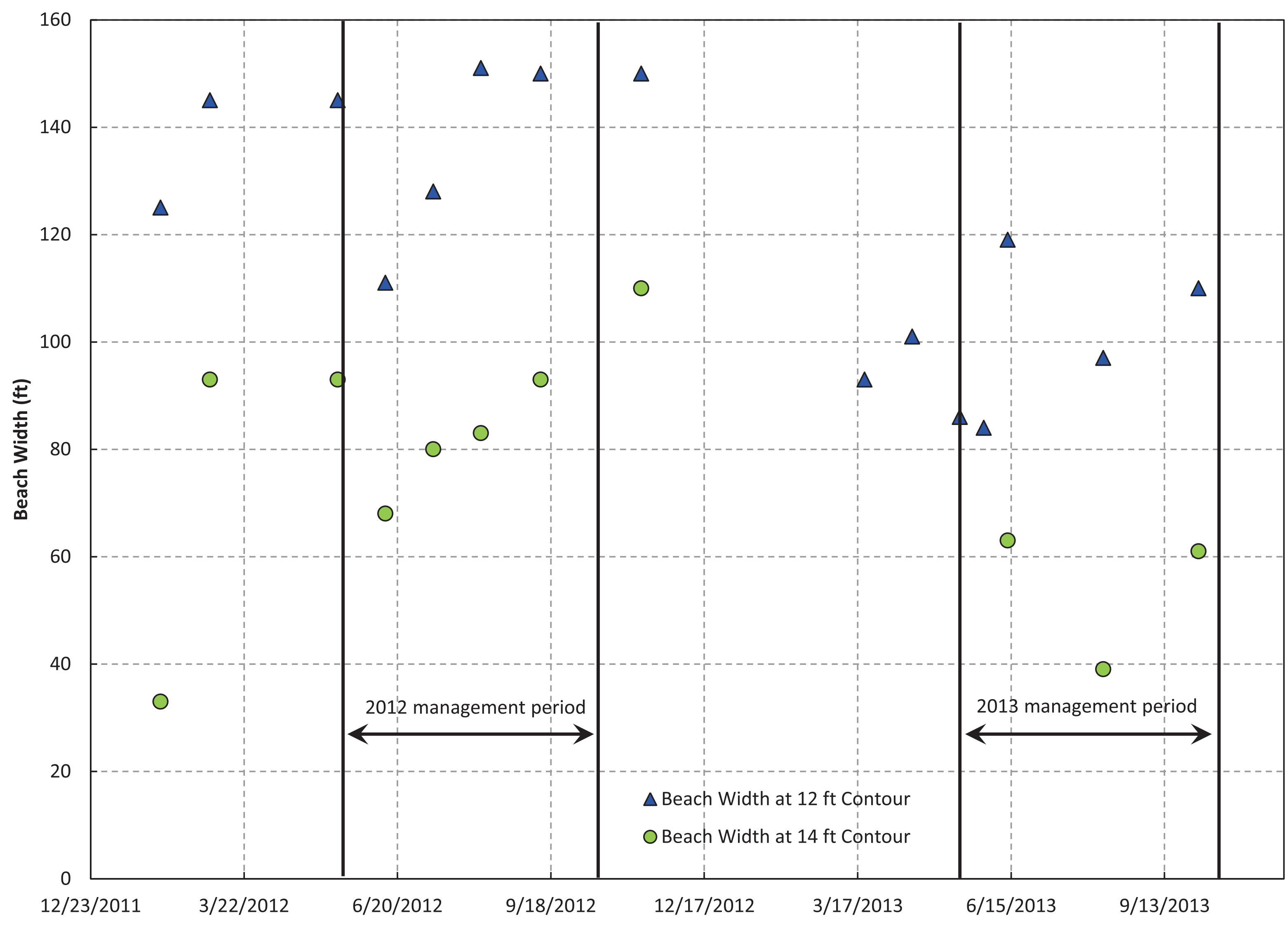


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 12

Beach Crest Profiles From August 2013 to February 2014.



SOURCE: SCWA survey data

Figure 13
Beach Width During 2012 and 2013 Management Periods.

Attachment I. Physical Processes During the 2014 Management Period

As required by the Russian River Biological Opinion, the Sonoma County Water Agency (Water Agency) has been tasked with managing the Russian River Estuary to facilitate summer lagoon conditions to improve salmonid habitat. The goal is to meet this need by creating an outlet channel while also maintaining the current level of flood protection for properties adjacent to the estuary (NMFS, 2008). The adaptive management plan, described in the main body of this report, was developed by the Water Agency with assistance from ESA PWA and the resource agency management team in 2009 and revised annually from 2010 to 2015. Because of permit constraints, the Water Agency was only able to implement the plan beginning in 2010. The revised plan was in effect for 2014, but no opportunities for management action occurred during the management period.

During the 2014 management period, May 15th to October 15th, Water Agency staff regularly monitored current and forecasted estuary water levels, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. Although several short-lived closure events occurred throughout late April and early May, the first four months of the management period experienced only tidal conditions. An extended closure event began on September 17th. Because of reduced inflows, the lagoon's stage rose slowly and did not reach an appropriate level for enacting the outlet channel until the end of the management period. Except for a few days immediately after artificial breaches, the lagoon remained closed from late September through late November.

Even though no management actions were implemented to inform the adaptive management process, the physical conditions and inlet response during the management period are reviewed in this attachment to contribute to site understanding and to inform future management actions.

METHODOLOGY

This review of the 2014 outlet channel management period examines water levels, ocean wave conditions, ocean water levels, riverine discharge, and beach topography, as well as inlet size and location. The sources for these parameters are listed in Table 1. These data were supplemented with personal observations and discussion with staff from the Water Agency, NMFS, CDFW, and the Bodega Marine Laboratory.

Table 1. Data Sources

Parameter	Source
Estuary water level (h_E)	Water Agency Jenner gage*
Wave height (H_s), period (T_a), and direction	CDIP Point Reyes buoy #029
Ocean water level (h_O)	NOAA Point Reyes #9415020
Russian River discharge (Q_f)	USGS Guerneville #11467000
Beach topography, ft NGVD	Water Agency monthly surveys
Inlet size and location	Water Agency and Bodega Marine Laboratory autonomous cameras

*Data transmission failure due to cellular network issues occurred for several periods throughout the management period.

INLET STABILITY PARAMETER AND CLOSURE RISK PROBABILITY

In addition to considering individual parameters, researchers at the Bodega Marine Laboratory have developed a combined parameter to evaluate the stability of the inlet's state, with the aim of predicting closure risk (Behrens et al., 2013). (Note that the inlet stability parameter does not differentiate between full closure and the perched conditions with a small outlet channel. When discussing this parameter, both states are referred to as a 'closure' in that tides are prevented from propagating into the estuary.) The inlet stability parameter presented by Behrens et al. (2013) quantifies the risk of inlet closure based on a sediment balance in the inlet. It considers the daily balance between wave-driven sediment import to the inlet and sediment export driven by tidal fluctuations. The wave-driven import is assessed using nearshore wave estimates derived from a transformation matrix and offshore buoy data (ESA PWA, 2012) and the latter is estimated from tide gage data within the estuary and a stage-storage relation derived from the available bathymetry. Using daily-average values of the stability parameter within the period 1999-2008, Behrens et al. (2013) showed that high-percentile values of the parameter are closely linked to the risk of the inlet closing within five days. As the percentile of the stability parameter increases, the risk of inlet closure within five days increases exponentially, from risks of roughly five percent when the parameter is at the 50th percentile to a risk of 80 percent when it is measured at the 99th percentile.

SUMMER AND FALL CONDITIONS

Time series of estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 1 for the entire management period. The lagoon water level time series (Figure 1a) summarizes the closure events at the beginning of the management period, as well as the subsequent tidal conditions and later closure events in fall. As shown in Figure 1d, discharge was low for most of the management period, dropping from 7,000 ft^3/s on April 2nd to below 100 ft^3/s on May 21st. In mid-July, flows briefly reached 200 ft^3/s and remained above 100 ft^3/s for about a week. Afterwards, flows slowly declined until they reached a minimum of 55 ft^3/s on October 7th. As in prior years, wave energy was minimal in much of the management period. A late season swell event ($H_s > 8$ ft, $T_p > 14$s) occurred in late June, and may have led to the subsequent week of muted tides in the lagoon, but did not lead to full inlet closure. A gap in Pt Reyes wave buoy data for the dominant period (T_p) for parts of September and October prevented nearshore transformation of waves during this time. At the end of the management season, high wave events overtopped the beach berm, delivering enough water to the lagoon to increase the daily rises in lagoon stage to 0.4-0.8 ft during the late-season closure event. Overtopping is visible in photographs taken by the river mouth overlook camera. These large waves also prevented breaching equipment from accessing the beach.

The conditions leading to inlet closure were consistent with the existing conceptual model described in Section 4 of the Management Plan. All closure events coincided with either moderately high waves ($H_s > 6$ ft) having periods greater than 10 s, or with neap oceanic tide ranges of less than approximately 5 ft, with the exception of the September closure event, when nearshore waves could not be estimated. Moderately high waves coincided with the closure events in April and May. The September closure event occurred during a neap tide. The artificial breach events that occurred on October 22nd and November 17th were coincident with neap tides and large to moderate waves, and were followed by closure within less than one day. The artificial breach event on November 26th happened during a spring tide, and was not followed by closure. The persistent closure conditions from September through November are examined in more detail in Figure 2.

As in 2012 and 2013, all closure events occurred when the inlet was adjacent to the jetty. In former years, this positioning may have prevented perched conditions from arising by shielding this area of the beach from the wave-driven sediment deposition that caused closure, preventing the beach from accreting to a sufficient height to allow the desired outlet channel elevations from being attained. This may have been the case for the September closure event in 2014 as well. Wave overwash in mid-October did appear to provide enough volume to raise the lagoon stage to a level requiring artificial breaching, but the same wave overwash also made work on the beach impossible, and occurred too late in the management season for a channel to be created.

LATE-SEASON CLOSURE EVENT

The only event that would have provided an opportunity for implementing the outlet channel occurred on September 17th. Inflows generally were below 100 ft^3/s throughout the event, allowing the stage to remain lower than 7 ft NGVD for almost a month of closure. The largest increases in stage happened on September 25th and October 12th due to wave overwash. The overwash raised the stage by about three quarters of a foot. Otherwise the weak inflows allowed the stage to rise at a very slow pace; the stage increased from roughly 5.0 ft NGVD on September 26th to approximately 6.8 ft NGVD on October 11th, and average increase of about 0.1 feet per day. Flows during this time were less than 85 ft^3/s and dipped to as low as 55 ft^3/s.

To better illustrate both the lagoon stage and beach morphology during this time, Figure 3 shows a sequence of photos of the inlet before and during this closure event. As was the case for all of the management period, the inlet was located next to the jetty. Figure 3a depicts the inlet when it was located next to the jetty several days before closure, indicating a width of less than roughly

40 ft. Nearshore waves could not be estimated for the week of closure, but are likely to have played a role, since waves generally begin to increase in energy in September. Neap tide conditions were present during the week of closure, with the oceanic tide range measured at approximately 4 feet (Figure 2c). Figure 3d shows extensive wave overwash surging over the beach berm and into the lagoon.

Unlike the 2012 management period, no natural outlet channels were formed near the jetty in 2014. However, as with 2012 and other previous years, the lowest portion of the beach was consistently located at the jetty. This persistent low portion is probably caused by wave sheltering by the jetty, which may have reduced berm build-up at the inlet's location, leaving a low point in the beach berm that was the site for subsequent overtopping and natural breaching.

CLOSURE RISK PROBABILITY

The 5-day closure risk probability, a derivative of the inlet stability parameter described above, was hindcast for 2014 according to the method described in Behrens et al. (2013). This hindcast provides an indication of the utility of the stability parameter as a prediction tool for monitoring inlet conditions and planning management action. This parameter integrates wave and ocean forcing conditions, as well as estuary water levels, to provide greater predictive skill than just waves or ocean tides on their own. The stability parameter combines these factors, and the corresponding five-day closure risk time series exceeded 50 percent before most 2014 events (Figure 1e). The gap in nearshore wave estimates in September was filled with offshore wave heights and periods, which are a poorer estimate of nearshore conditions. Since at least one day of tidal conditions are needed to predict closure, many of the closure events could not be predicted, since they occurred less than one day after breaching. Otherwise, the predicted probability of closure exceeded 50% 2-5 days in advance of most other closures.

TOPOGRAPHIC CHANGE

The Water Agency has conducted monthly surveys of Goat Rock State Beach that cover a region starting from the jetty and extending approximately 1,500 feet to the north. Typically, the surveys do not include bathymetry within the inlet because flow conditions in the inlet prevent safe access. Also, the survey extent can be limited by the Water Agency's compliance with its marine mammal incidental harassment authorization, which sets guidelines for the survey crew's approach to marine mammals hauled out on the beach. Water Agency survey staff collected spot elevations using RTK-GPS and then assembled these elevations into a set of contour lines at 1 ft intervals, as well as profiles along the beach berm crest, the ocean wetted edge, and the estuary water line. The survey elevations are reported in the NGVD29 vertical datum.

To characterize beach berm topographic conditions, ESA PWA assessed data from the Water Agency's 2010 (July to September), 2011 (May to October), 2012 (May to October), 2013 (May to October), and 2014 (May to October) surveys. Profiles include two transects backed by cliff (Figure 5 and Figure 6), two transects which extend into the estuary (Figure 7 and Figure 8), and two variations on a transect just north of the jetty (Figure 9 and Figure 10).

This review focuses on the 2014 surveys, although the 2011 surveys are included for context in some figures. The 2014 topographic data were similar to those of 2012 and 2013 in that the northernmost profiles underwent little morphologic change during the management season. However, in 2014 the southernmost profiles underwent more morphologic change than in those years, similar to the results from the 2010 and 2011 management seasons.

At profiles 3 and 4, the beach is backed by cliff, and undergoes morphologic changes when the inlet migrates north during floods and returns south to the jetty in spring or summer. In 2010 and 2011, migration in this area led to a sequence of erosion and accretion at these sites during the management period. The erosion seen in those years was associated with inlet migration and subsequent accretion of the beach was associated with long-period swell waves. During the 2012-2014 management seasons, the inlet remained at the jetty and did not migrate north, leading to an especially stable profile at Profile 4 (Figure 5). Profile 3 was also stable, but steepening in October led to changes in elevation on the order of 1-2 feet at the crest and along the beach face (Figure 6).

Compared with 2012 and 2013, Profiles 1 and 2 were much more variable. At Transect 2 (nearest to Haystack Rock), the beach profile was stable from May through August, and then grew vertically and moved landward in September (Figure 7). The largest change was between the September and October surveys, when the crest grew by roughly 2 feet. This type of seasonal growth is apparent in previous years, and is expected as wave energy increases seasonally. While Transect 1 underwent similar changes, it was more strongly influenced by proximity to the inlet throughout the summer. It was lowest in July and August, when the inlet was fully tidal. It extended seaward along the beach face from August to September and added an additional 1-2 feet vertically throughout the entire profile between September and October, reflecting the closure event.

Transect 0, which is located parallel to the jetty, was slightly higher than transect 1 in 2014, and showed a large shift in morphology at the end of summer (Figure 9). In previous years, it was more typical to see limited change throughout the management season at this transect, but large interannual variability (Figure 10). In 2014, it was mostly stable until August, and then grew seaward by over 50 feet between August and September. Its crest remained at roughly 14.5-15.0 ft NGVD despite this shift. This seaward growth is likely related to an abundance of northwesterly swell (Figure 2) that arrived during this month. Further growth between September and October was probably made possible by the combined waves and extended closure event.

Beach berm crest profiles were collected by the Water Agency for the first time in 2013 and collected again in 2014. These data make it possible to discern important changes in beach shape along the length of the berm from the northern beach access point to the jetty. Along-beach trends in crest elevation generally indicate along-beach trends in wave energy and the influence of inlet migration and breaching.

Figure 11 shows that through September, the change in crest elevation was minimal throughout the length of the beach north of Transect 1. By October, the crest elevation increased by as much as 3 ft in some areas. The beach crest was lowest south of Transect 1, where the inlet resided. At Transects 1-4, the crest profile shape remained essentially the same from May to September, with the dominant ridge pattern not shifting laterally. The along-crest ridge pattern also shifted laterally, with the new peak (18.0 ft NGVD) located along Transect 3. The beach was highest between Transects 3 and 4, peaking at 16-18 ft NGVD and minimum of 12.5-14.0 ft NGVD, north of Transect 4.

BEACH WIDTH
To provide additional information about the beach morphology, ESA PWA assessed the beach width using the Water Agency survey data. Figure 12 shows the evolution of the beach width at Transect 3 during the 2012-2014 management periods. In previous years during winter months, the beach was often eroded at Transect 3 to the point that the beach crest was below 12 ft NGVD, so that the width was effectively zero. In 2012 and 2013, apart from this seasonal erosion, there was no marked trend in the beach width. In 2014, the beach was wider than the previous two years, with peak width at the beginning of the management season (Figure 12). The width steadily decreased from 198 at 12 ft NGVD and 130 at 14 ft NGVD in May to 170 and 111 ft NGVD, respectively, in October. The shift appeared to be a result of beach face steepening, a typical summer process.

JENNER STAGE EXCEEDANCE
The Biological Opinion (NMFS, 2008) sets a target for estuary water levels “a daily minimum water surface elevation of 3.2 feet [NGVD] during 70% of the year.” To facilitate this target, the Biological Opion notes “Absent river flood flows and historic mechanical breaching practices, NMFS expects cross shore transport of sand by wave action will be sufficient to maintain the bar at this elevation.”

In 2014, the daily minimum water surface elevation exceed 3.2 ft NGVD roughly 33% of the year (Figure 13). For comparison, Figure 13 also includes hourly lagoon stage (exceeded 3.2 ft NGVD for roughly 46% of the year) and hourly Point Reyes stage (exceeded 3.2 ft NGVD for roughly 4% of the year). Data gaps at the Jenner Gage influence the exceedance curve, but BML camera photographs suggest an open mouth during most of the periods when stage data were missing, so the exceedance curves for the estuary are likely biased high, meaning that stage exceeded 3.2 ft NGVD for less of the year. This low amount of perched conditions results from the inlet maintaining open conditions throughout the summer of 2014. As with several of the years since 2010, lack of closure in June or July led to prolonged open conditions, as July and August waves were too small to cause closure. As explained in previous annual updates, if the inlet does not close in late spring, it is likely that open-inlet conditions will persist as a result of the seasonally weak waves. Since no closures occurred in late spring in 2014, an outlet channel could not be made, which would have presumably had the intended effect of causing prolonged perched conditions.

LESSONS LEARNED AND RECOMMENDATIONS

Based on 2014 observations of the estuary, associated physical processes, and the Water Agency's planning for outlet channel management, we note the following lessons about implementing the outlet channel management plan.

CONCEPTUAL MODEL

- The beach north of the inlet saw little change from the 16-18 ft NGVD elevations established in 2013. Near the jetty, the berm was lowered by inlet migration while undergoing beach building.
- Similar to the winters of 2011-12 and 2012-2013, the inlet never migrated north of Haystack Rock during winter 2013-14, and returned to the jetty in early spring, much earlier than in most years. This inlet alignment is not common, but has been observed in past years (Behrens et al., 2009).
- Peak annual river discharge has remained below 40,000 ft^3/s for 9 consecutive years, a streak unmatched in the 70-year flow record. This may have a connection to the recent lack of inlet migration to the north.
- The beach width in 2014 at Transect 3 (near Haystack Rock) was larger than in 2013. This may suggest that beach width is closely tied to inlet migration – the lack of migration north of Haystack Rock for several years has allowed the beach to grow at this end of the littoral cell.

REFERENCES

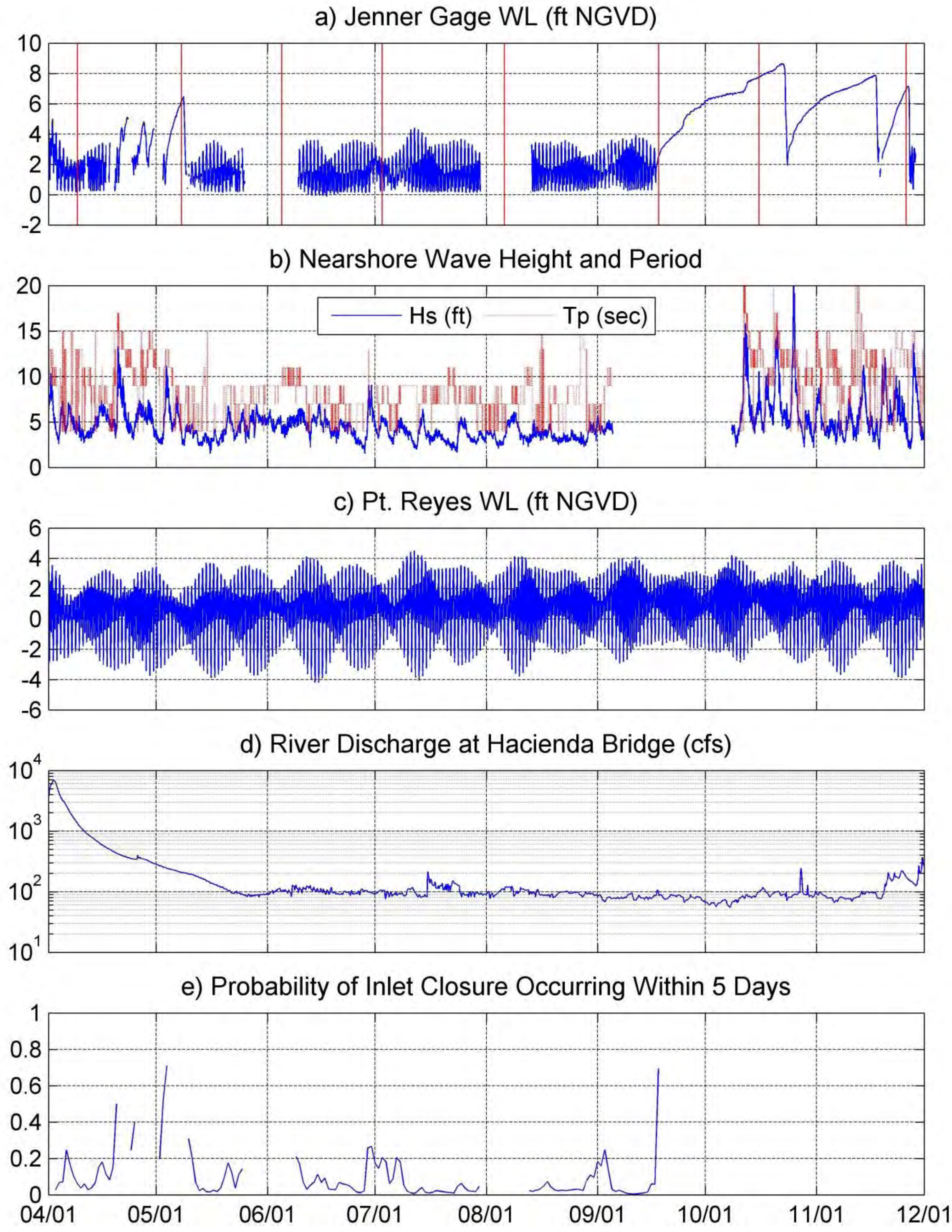
Behrens, D., Bombardelli, F., Largier, J. and E. Twohy. 2009. Characterization of time and spatial scales of a migrating rivermouth. Geophysical Research Letters. Vol. 36, L09402, doi:10.1029/2008GL037025.

Behrens, Dane K., Fabián A. Bombardelli, John L. Largier, and Elinor Twohy. 2013. "Episodic Closure of the Tidal Inlet at the Mouth of the Russian River — A Small Bar-Built Estuary in California." *Geomorphology* 189 (May): 66–80. doi:10.1016/j.geomorph.2013.01.017.

ESA PWA. 2012. Feasibility of alternatives to the Goat Rock State Beach jetty for managing lagoon water surface elevations: Draft existing conditions report. Submitted to Sonoma County Water Agency.

National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed.

Weigel, R. 1992. Oceanographical Engineering.

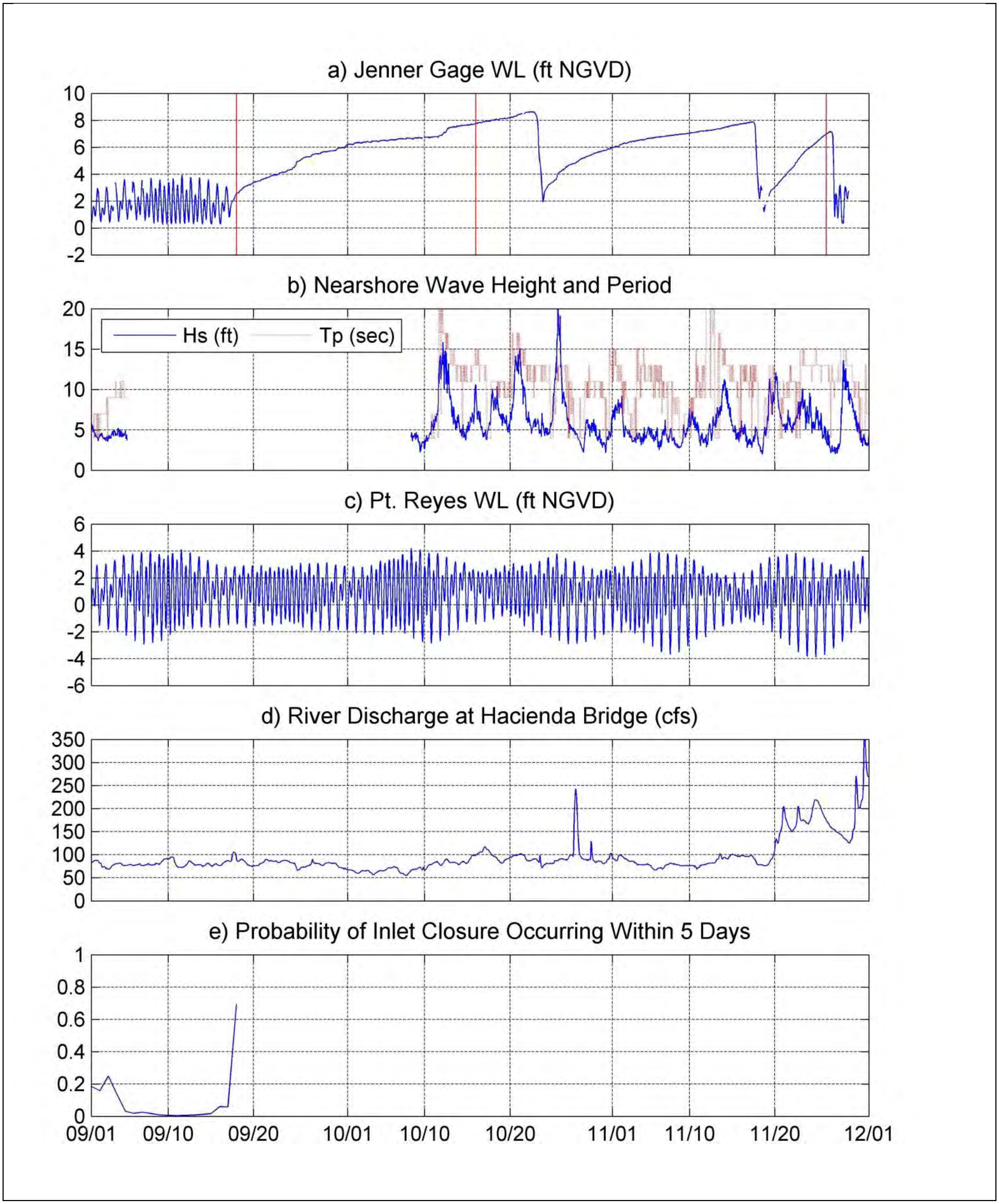


SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 1

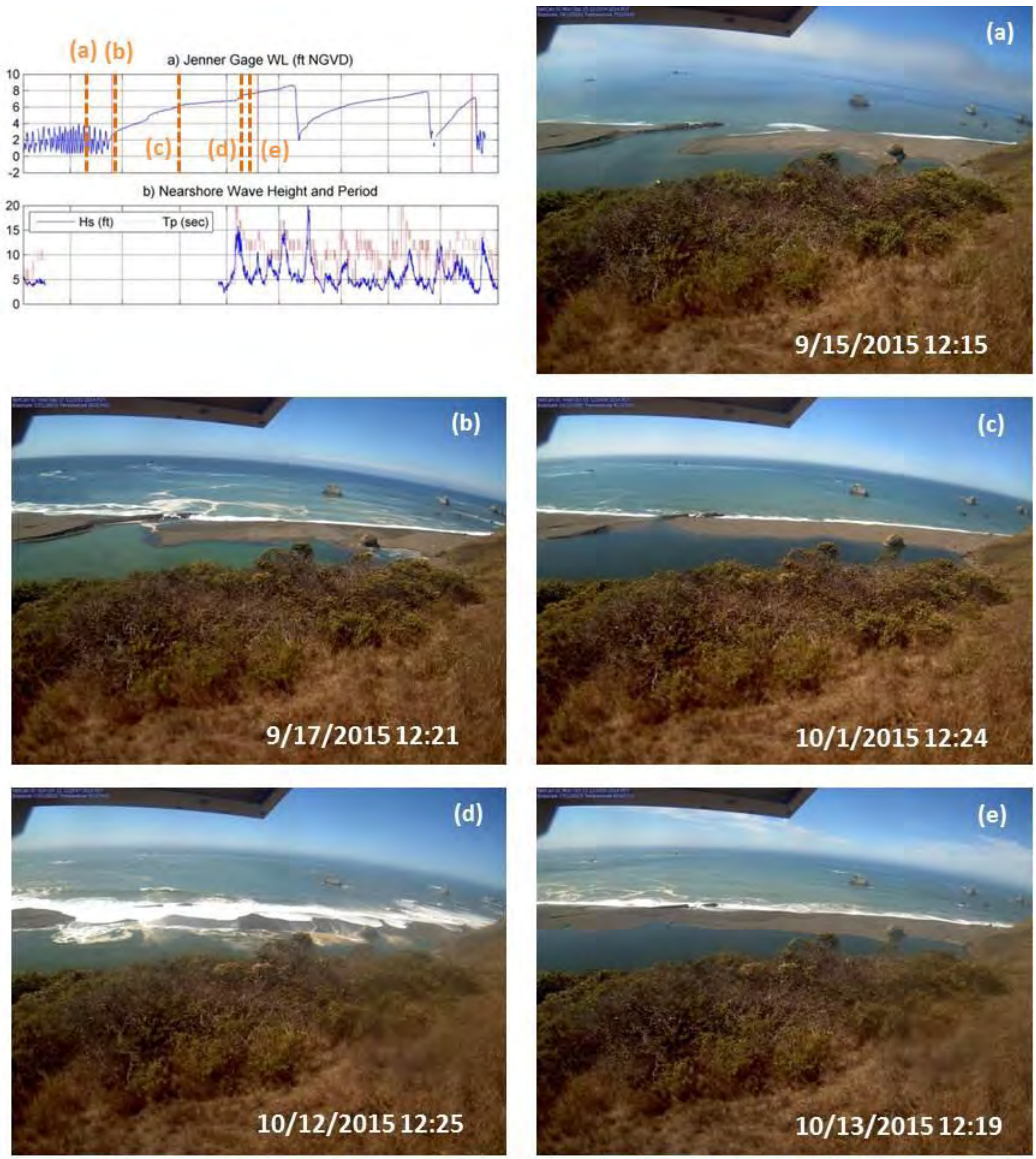
Estuary, Ocean, and River Conditions Compared with Closure Probability: April – November 2014



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 2
Estuary, Ocean, and River Conditions Compared with Closure Probability: September – November 2014



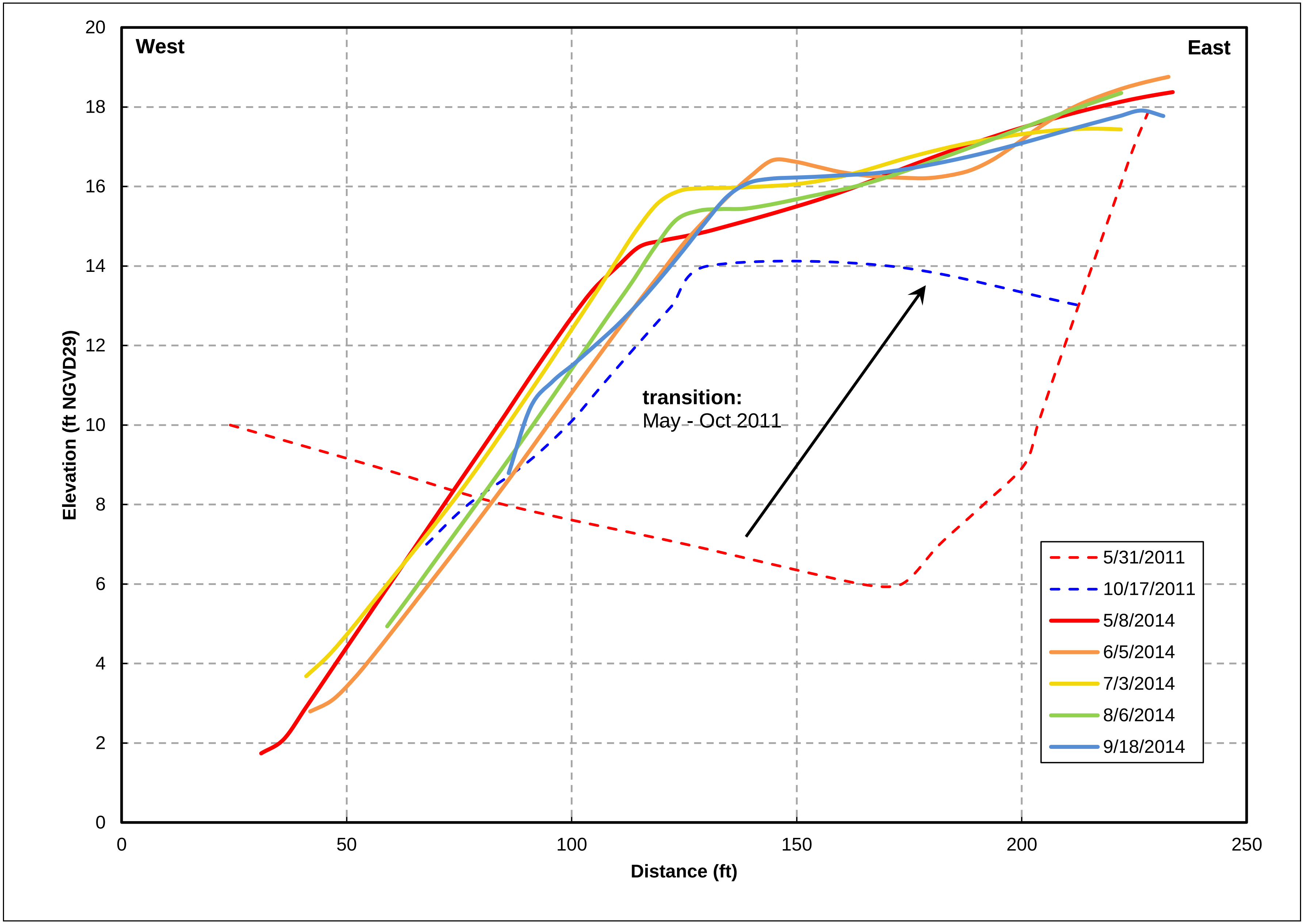
SOURCE: SCWA camera

Figure 3
Russian River camera photographs showing some of the key morphologic influences during the September-October 2014 closure event.

SOURCE: image from USDA NAIP

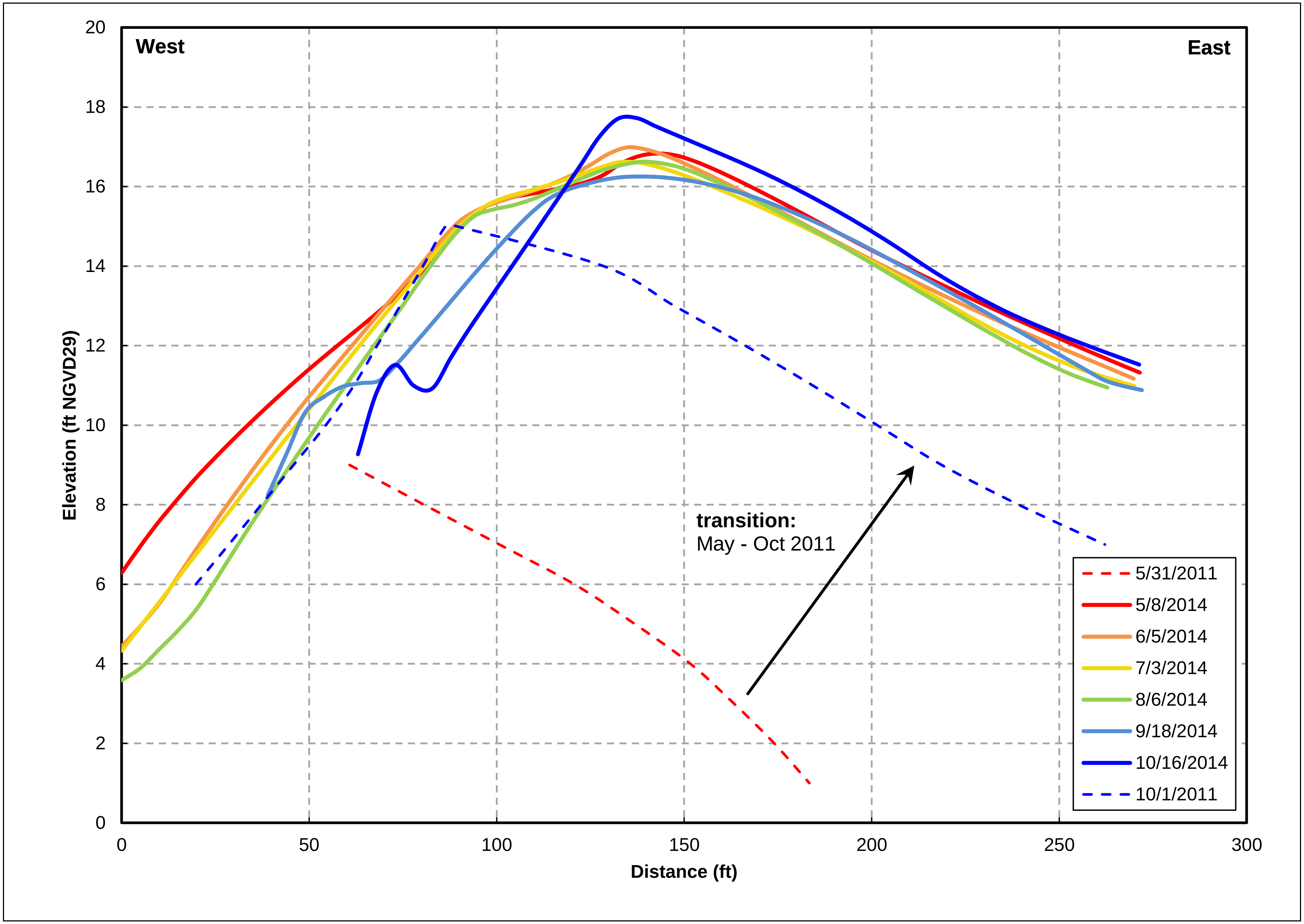
Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 4
Beach Transect Locations



SOURCE: SCWA survey data

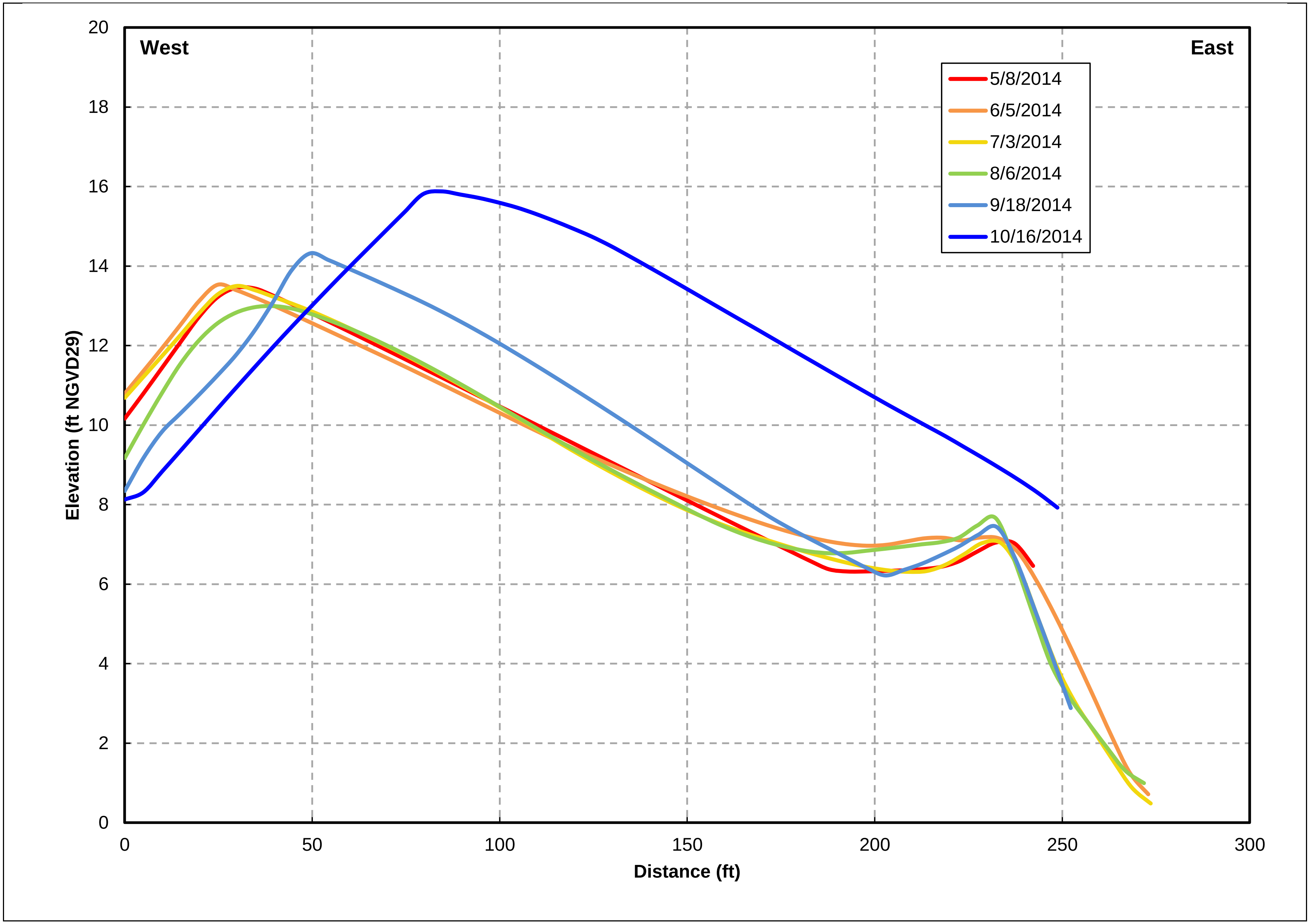
Figure 5
Beach Transect #4



SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 6
Beach Transect #3

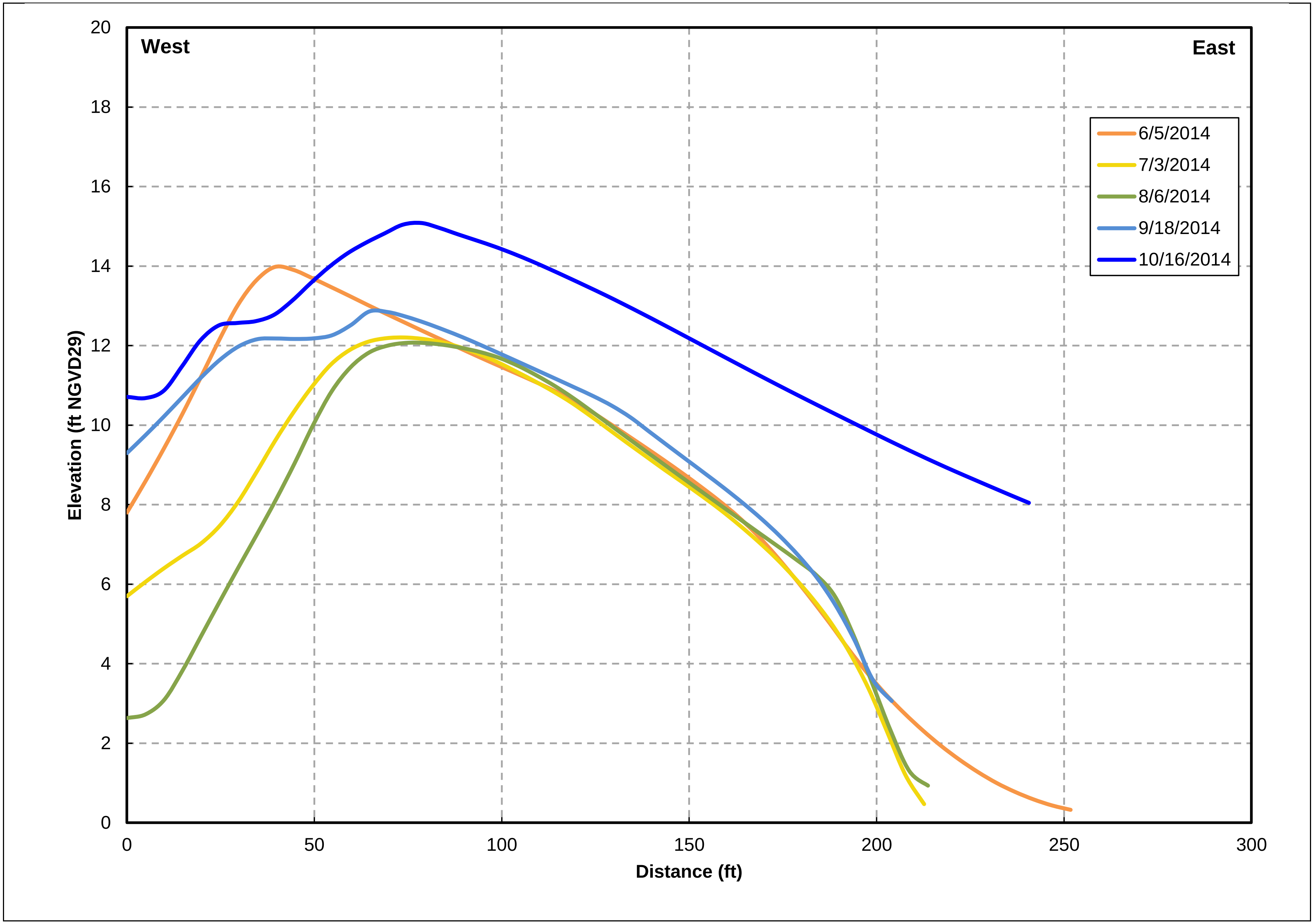


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

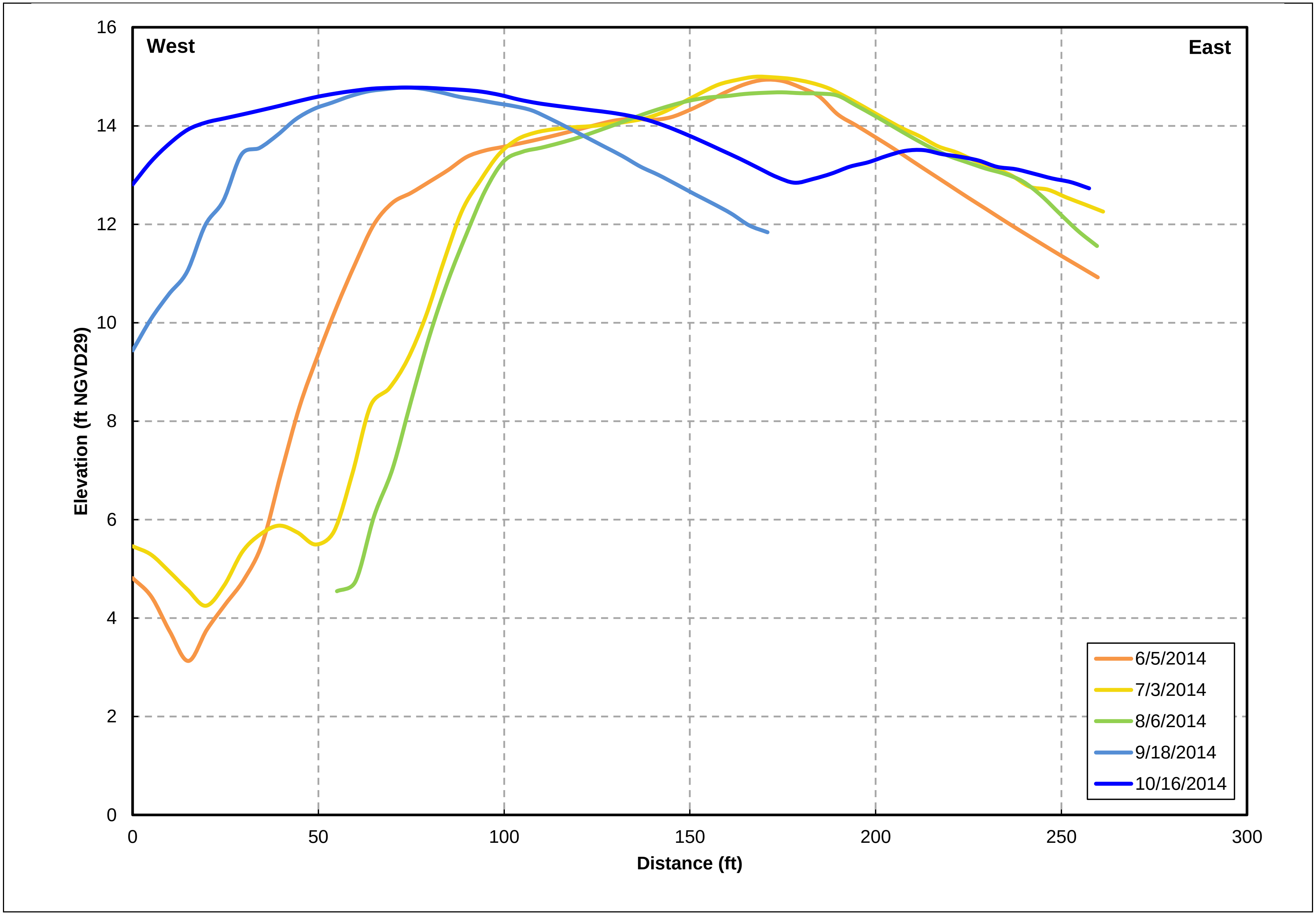
Figure 7

Beach Transect #2



SOURCE: SCWA survey data

Figure 8
Beach Transect #1

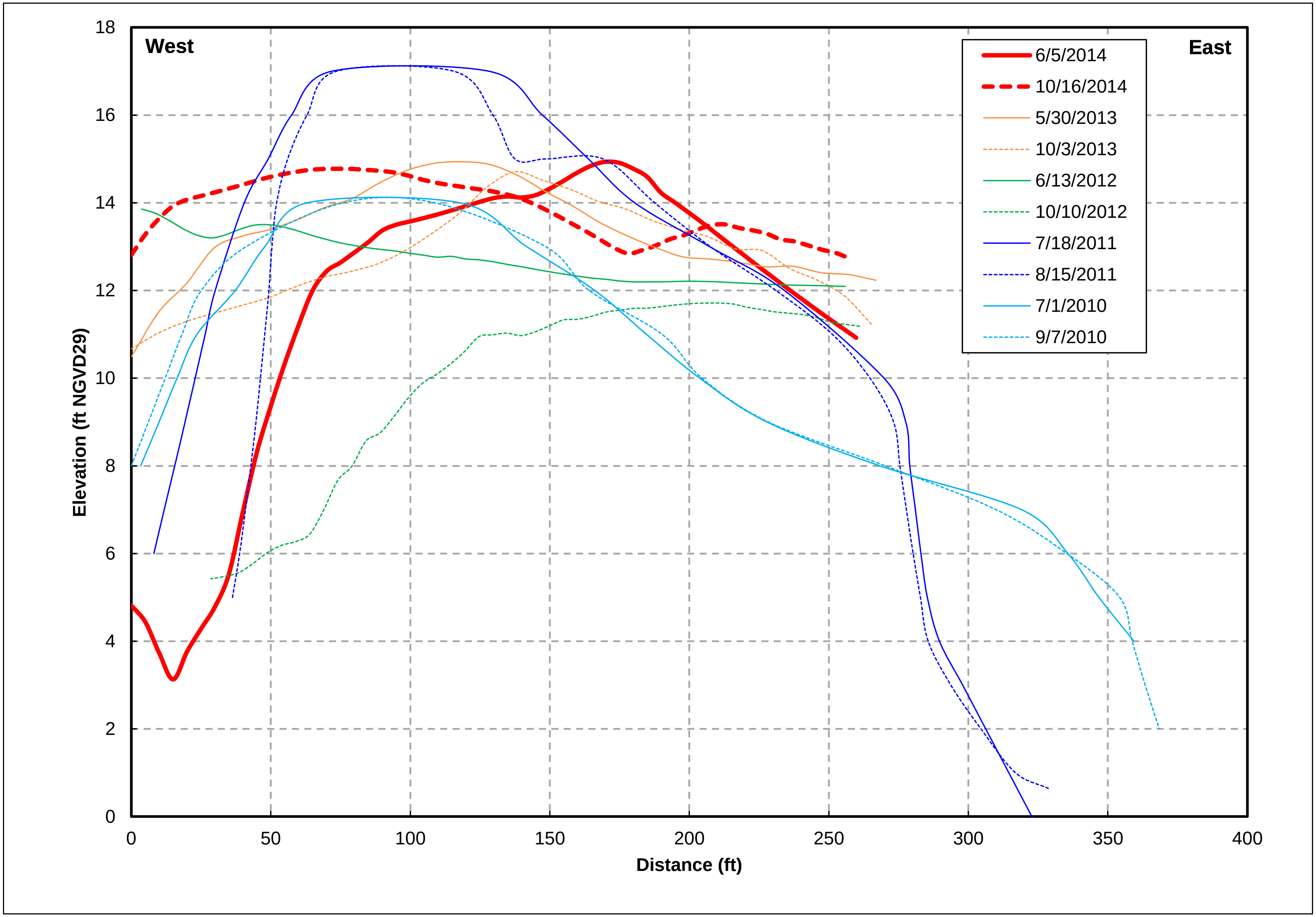


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 9

Beach Transect #0 from 2014 management period.



SOURCE: SCWA survey data

Figure 10

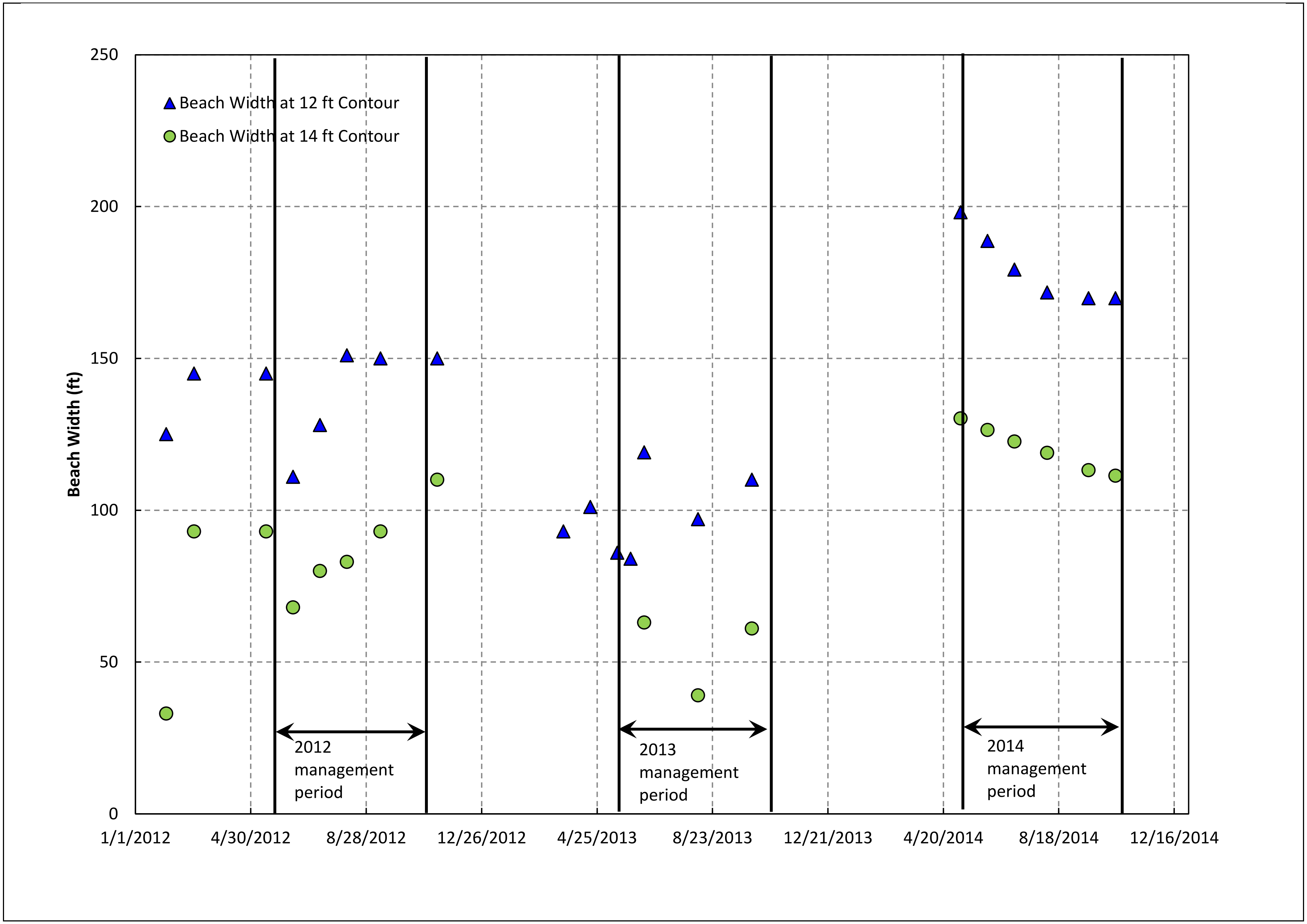
Beach Transect #0 from 2010-2014 management periods.

SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 11

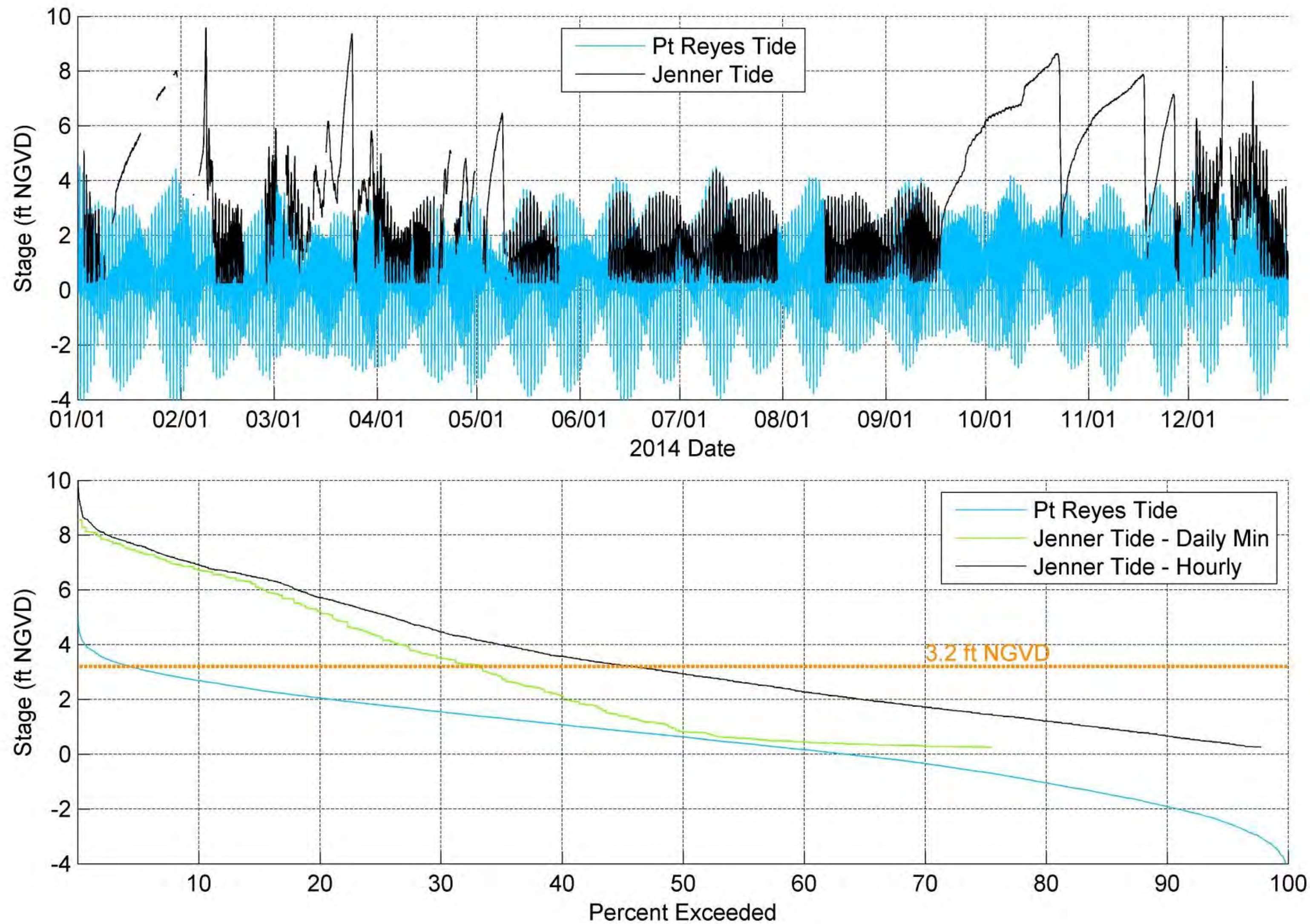
Beach Crest Profiles During the 2014 Management Period.



SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 12
Beach Width During 2012-2014 Management Periods.



SOURCE: SCWA Jenner Gage and NOAA Pt Reyes tide data

Figure 13
Russian River Estuary stage exceedance for 2014.

Attachment J. Five-Year Review of Physical Processes Affecting the Russian River Estuary

1 Introduction

As required by the Russian River Biological Opinion (Biological Opinion) (NMFS 2008), the Sonoma County Water Agency (Water Agency) has been tasked with managing the Russian River Estuary (RRE) to facilitate summer lagoon conditions to improve salmonid habitat. Because of permit constraints, the Water Agency was only able to implement the Russian River Estuary Outlet Channel Adaptive Management Plan (RREAMP) beginning in 2010, and the Plan has continued for six years.

ESA has been asked to conduct a five-year review of the physical processes related to the RREAMP for the years 2010-2014. The goals of this review are to examine the physical processes that influenced the mouth from 2010 to 2014, to compare these conditions to prior years, and to communicate findings for refining the management plan.

To meet these goals, our approach includes the following steps:

- **Compile Data:**
    - Collect gaged and previously reported data
    - Process digital photographs from the Water Agency's time lapse camera operated by the Bodega Marine Laboratory (BML)
- **Analyze with existing methods:**
    - Model the lagoon mouth with the statistical closure probability model of Behrens et al. (2013)
    - Model the lagoon mouth using the lagoon quantified conceptual model (QCM) (ESA 2016, Behrens et al. 2015)
- **Development of new methods:**
    - Obtain mouth morphology data from the BML camera and incorporate into modeling.
    - Use the lagoon QCM to determine whether the mouth position and shape influence its state (open, closed, or perched).
    - Use statistical methods to identify which external conditions may have prevented successful implementation of the outlet channel.

Within this memorandum, these steps are organized into sections on data compilation (Section 2), data comparison of pre- and post-2010 conditions (Section 3), model comparison of pre- and post-2010 conditions (Section 4), and key findings (Section 5).

2 Data Compilation

Comparison of pre- and post-2010 conditions in the Russian River Estuary is possible because of the relative wealth of data at the site. Decades of gaged oceanographic and watershed runoff conditions are available, alongside an extensive record of mouth condition. More recently, the Water Agency has conducted topographic beach measurements since 2010. This section summarizes the data sources and describes the collection of data from the BML camera installed in 2011.

2.1 Inventory

Figure 1 summarizes the data available after 2010 and Table 1 lists the data sources. Gaged river flow, wave, and tide conditions are readily available both before and after 2010. The time series of wave conditions at Point Reyes was translated to a time series of nearshore wave conditions using wave transformation matrices derived from a numerical wave model (ESA 2016). Inside the estuary, the Jenner water level gage has operated continuously since 1999, with the exception of several gaps during periods of gage maintenance. In addition to continuous gage measurements, monthly beach topographical surveys have been collected regularly by the Water Agency since the summer of 2010. A time lapse camera installed in 2011 has complemented the survey data, providing images of the mouth twice each hour. As described in Section 2.2, the camera's photographs can be used to estimate mouth shape and position to compare directly with beach survey data. Mouth shape and position are also intermittently available prior to 2010, derived from near-daily photographs taken since 1991 (Behrens et al. 2013). Daily mouth conditions ('open' or 'closed') have been measured continuously since 1974 by Jenner residents and the Water Agency.

Table 1. Data Sources

Parameter	Source
Estuary water level	Water Agency Jenner gage
Wave height, period, direction, and power	CDIP Point Reyes buoy #027
Ocean water level	NOAA Point Reyes #9415020
Russian River discharge near Guerneville	USGS Hacienda Br Gage #11467000
Beach topography	Water Agency monthly surveys
Mouth size and location	• 2000-2011: BML • 2011-2014: Water Agency and Bodega Marine Laboratory autonomous cameras

2.2 Image analysis for inlet morphology

Prior to 2010, daily photographs were taken manually by a Jenner resident at the overlook point east of the mouth. Although the pictures were taken at slightly different times and locations each day, they were used to estimate basic dimensions of the mouth, such as its width, length, and position north of the groin (Behrens et al. 2013). This was possible because several landmarks (e.g. the jetty groin and Haystack Rock) are visible in every photograph, and their locations are fixed, and can be used to roughly scale the inlet size. The Biological Opinion requires that a fixed camera at the mouth for monitoring purposes. To fulfill this requirement, the Water Agency installed a camera at the mouth and later contracted with BML in 2011 to operate the camera on the hillside above the estuary, which now takes images twice an hour during daylight hours, enabling a more automated approach.

Using the Matlab image processing toolbox, a routine was developed to generate time series of inlet dimensions (Figure 2). This process involves (1) performing a geometric transformation of each image using fixed landmarks, to translate the original oblique images to plan view, (2) extracting a series of transects parallel to the beach on the plan view image, and (3) detecting the size and position of the inlet based on the intensity of the blue pixels along each transect. Inlet dimensions derived from this approach are discussed in Section 3.

3 Data Comparison of Pre- and Post-2010 conditions

This section discusses differences in physical processes before and after the Biological Opinion was adopted in 2009, based on gaged data, topographical survey data, and mouth morphology data derived from the Estuary camera. Table 2 provides summary statistics of many of these data. These data provide context for the management conditions for implementing the outlet channel after 2010 by comparing pre- and post- 2010 conditions.

Table 2. Summary of data and model outputs from 2000 to 2014.

Year	Jenner Stage (ft NGVD)		Mean Wave Power at Groin (lbf*ft/ft*s x 1000)	Watershed Runoff		Mouth Closure			Mouth Position	Lagoon QCM Predictions
	Mean	% exceeding 3.2 ft		Total Inflow per Water Year (Acre-feet x 1000)	Peak Winter Flow (ft^3/s)	No. of Closure Events	No. of Days Closed	Mean 5-day Closure Risk	% of Time Spent Next to Groin	Predicted Number of Perched Overflow Days
2000	2.52	30	70	714	37,900	15	63	0.18	33	0
2001	3.12	43	78	1287	24,700	10	62	0.16	50	0
2002	2.56	32	58	1564	44,000	9	35	0.10	28	1
2003	2.04	19	57	2084	57,600	3	17	0.11	45	0
2004	2.28	22	49	1167	63,400	7	47	0.14	66	1
2005	2.32	26	69	2944	21,900	5	32	0.11	44	0
2006	1.92	19	69	1305	86,000	5	11	0.09	50	12
2007	2.03	20	64	987	29,800	10	47	0.17	44	0
2008	2.44	29	60	570	36,600	11	77	0.20	4	5
2009	2.32	25	59	1095	22,400	8	61	0.15	18	0
2010	2.31	30	88	2039	37,900	3	37	0.16	--	14
2011	1.63	13	65	586	37,300	7	22	0.16	78	2
2012	2.23	21	71	1100	26,800	13	54	0.25	77	0
2013	2.53	28	45	365	38,400	12	110	0.13	73	0
2014	3.29	44	83	496	18,900	8	133	0.13	76	0
Mean: 2000-2014										
	2.37	27	66	1220	38,900	8	54	0.15	49	2.3
Mean: 2000-2009										
	2.35	27	63	1370	42,430	8	45	0.14	38	1.9
Mean: 2010-2014										
	2.40	27	70	917	31,860	9	71	0.17	76	3.2

3.1 Coastal and Fluvial Conditions

Oceanic tide conditions (not shown in Table 2) were the least variable of the gaged data at the site since these are largely a function of astronomic variables and only minimally affected by climatic variations. The tidal water levels varied only slightly from year to year. Figures 3 and 4 show ocean tides during the periods 2000-2014 and 2010-2014, respectively.

Wave conditions in 30 ft depth adjacent to the groin were more variable. The mean wave power from 2000 to 2014 near the groin was roughly 65,000 lbf*ft/ft*s. The strongest waves occurred in 2010 and 2014, with 134 and 127 percent of the 2000-2014 mean, respectively. Wave power was lowest in 2004 and 2013 at 69 and 75 percent of the 2000-2014 mean, respectively (Table 2). Mean wave power was about 10 percent higher in 2010-2014 than in the period from 2000 to 2009.

Watershed runoff at Guerneville was the most variable of the gaged data. Average total inflows from 2000 to 2014 were roughly 1.2 million acre-feet per water year (Oct. 1 – Sep. 30) at the USGS Guerneville gage. Three of the four driest years after 2000 occurred after the Biological Opinion was issued, in the 2011, 2013, and 2014 water years. Total inflows during these years were 30 to 50 percent of the post-2000 average. Most of the wettest years after 2000 happened before the Biological Opinion, with the 2003 and 2005 water years having 170 and 240 percent of the post-2000 average, respectively. Overall, the 2010-2014 mean of annual inflows is about 33 percent lower than for the period 2000-2009.

3.2 Estuary Stage

In contrast to ocean tides, tides within the Russian River Estuary vary significantly from year to year. As pointed out by NMFS (2008), persistence of water levels above the typical tidal range (usually during mouth closure events or brief one-way overflow) are thought to improve estuarine salmonid rearing habitat by creating a perched, fresh or brackish lagoon. Managing the mouth as an overflow channel in summer is intended to facilitate or prolong periods of these high water levels. The Biological Opinion (NMFS 2008) set a goal of maintaining a daily minimum of at least 3.2 ft NGVD (roughly oceanic MHHW) within the estuary for at least 70 percent of the year.

To understand the year to year variability, and to test whether the estuary stage met the goals of the Biological Opinion, we collected water levels from the SCWA Jenner gage from 2000 to 2014 and summarized the data using annual exceedance curves (Figure 5). On average, water levels were slightly higher in 2010-2014 than in 2000-2009. There were no years when water levels exceeded the level of 3.2 ft NGVD for more than 70 percent of the year. Across all years, the percent exceedance of 3.2 ft NGVD varied between 13 and 44 percent. Years with higher average water levels corresponded to higher number of closure days. Higher water levels also typically corresponded to low watershed runoff and/or and higher wave power (Table 2).

These summary statistics of the lagoon stage are affected by: (1) sensor data gaps and (2) sensor cutoff of low tides. Gaps in the stage data due to sensor maintenance or poor cellular service connectivity occur in most years and sometimes last several weeks. Since the timing of these gaps is unrelated to the mouth state, we assume that these do not have a large impact on the summary statistics. However, sensor cutoff introduces a bias in the exceedance curves. The Jenner gage does not collect tide data below -0.5 ft NGVD because of its fixed location on a pier.

BML water level measurements in 2010 and 2011 confirm that the estuary stage drops several feet below this level during open-mouth conditions (Largier and Behrens 2010). Although measurements taken when the Jenner gage was cutoff were excluded from this analysis, the lack of the lower stage data mean that the exceedance curves in Figure 5 are biased upwards, so that the estuary stage actually spends less than the reported 13-44 percent of the year above 3.2 ft NGVD.

3.3 Beach morphology

The monthly Water Agency beach topographic surveys were combined with the image analysis described in Section 2.2 to compare beach and mouth conditions side by side. We use them here to understand the beach conditions relevant for implementing an outlet channel after 2009.

The available camera and survey data show that the beach normally erodes in winter, when watershed runoff is highest and the mouth widens to cover most of the beach between the groin and the bluffs, a mouth width of about 1,000 ft. When peak runoff surpasses a threshold of roughly 40,000-50,000 cfs, most of the beach is eroded, providing a 'reset' to the system and pushing sediment offshore. When flows recede after these large events, the beach re-forms, and the mouth is usually located at the north end of the beach. In most years, it then migrates south to the groin during the spring or, more rarely, summer (Behrens et al. 2009; ESA 2016). Once the mouth reaches the groin, the beach begins to re-build further under spring swell waves. The monthly surveys show that the beach crest remains fairly stable in summer when wave power declines, and then increases again in fall when waves once again become more energetic. Eventually the berm crest reaches an equilibrium height set by waves, and further growth is limited (ESA 2016).

Prior to the Biological Opinion, this seasonal beach erosion and building cycle happened almost every year, but monthly survey data were not available to examine it in detail. After the Biological Opinion, this cycle was only observed in the 2011 management season, as described by ESA (2016). Peak annual flows have been less than 43,000 ft^3/s at Guerneville since 2007, which is an unprecedented length of time in the historical record. When winter floods remain below this level, some of the beach remains intact, and erosion of the beach depends on how extensively the mouth migrates in response to waves. The effect of these reduced peak floods has been more limited seasonal beach erosion and migration extent.

Figures 6 to 9 compare the beach crest, width, and mouth position since 2010 at four transects along the beach. At the transect nearest to the groin (Figure 6), the data indicate that the mouth's frequent location near the groin has at times limited berm growth. Away from the mouth, at the northern end of the beach (Figures 8-9), the berm crest and width have grown steadily since 2011, punctuated by brief periods of erosion when the mouth migrated briefly toward the north during the weak winter floods in recent years.

The location of the mouth near the groin after 2010 from the years before 2010. Table 2 indicates the percent of the year that the mouth spent at the groin since 2000. Since 2010, the mouth has been located at the groin for more than 75 percent of the year on average, compared with less than 40 percent prior to 2010. This increase in time spent at the groin is in spite of the Water Agency efforts to conduct its artificial breaches further north when feasible. Although survey data are not available for the earlier period, it can be inferred that an impact of this change has been less beach building adjacent to the groin. This location was usually the lowest part of the berm crest during the management season, and the preferential location for mouth self-breaches.

4 Model Comparison of Pre- and Post-2010 conditions

4.1 Closure Risk Index

Since wave and river conditions vary inter-annually, the timing of closure events also differs from year to year. This is especially apparent when examining conditions early in the management period, in May and June. In most years, a few short-lived closure events occur in May and June, after which tides alone are sufficient to maintain an open inlet throughout the summer as wave power has dropped off. Although wave power dips in the months of June-August, strong swell events occasionally arrive at Goat Rock State Beach (GRSB) in June and early July and encourage mouth closure events. Depending on the fluvial discharge, these closure events may be brief, or they may last several weeks, as in 2010 and 2014.

The inclination toward inlet closure can be estimated and compared for different years. In the short-term (e.g. less than 5-7 days), the chance of inlet closure can be estimated with good confidence based on daily estimates of the tidal prism in the estuary and the mean daily wave power in the nearshore zone (Behrens et al. 2013). The tidal prism and wave power are compared in a way that produces a dimensionless “closure likelihood” index that forecasts the chance of closure occurring within five days. As the index increases (i.e. as the influence of waves begins to dominate over the influence of tides), the risk of the inlet closing increases. Since this does not account for freshwater runoff, it can be interpreted as a tool for measuring the short-term inclination toward closure, but is not intended to forecast the length of closure events or the number of closure days per year.

Figure 10 (upper panel) shows that this approach is a good measure of closure risk in the short-term. Values of the index lower than the 50th percentile from 2000 to 2014 had risks of closure well below 10 percent, and values higher than the 99th percentile carried risks of 70-80 percent. It is difficult to predict closure above this accuracy without accounting for other factors that are difficult to measure, such as inlet shape and inlet sheltering from the groin.

Applying this model to the period from 2000 to 2014, we find that the risk of closure was slightly higher after 2010 than before (Figure 10: lower panel). The difference is small: for a given day of the year, the chance of closing within five days is 14.6 percent before 2010, and 17.9 percent after 2010. Within the management period, the chances of closure are smaller due to the weaker waves, at 11.6 percent and 16.4 percent for a given day, respectively. The higher risk of closure after 2010 reflects a difference in the wave climate: nearshore wave power was about seven percent higher from 2010 to 2014 than from 2000 to 2010.

4.2 Lagoon Quantified Conceptual Model

One of the difficulties in studying outlet channel conditions in the Russian River Estuary is that managed outflow conditions do not have a precedent in the recent historical record. The goal of implementing the outlet channel is to provide freshwater habitat for salmonids by limiting tidal exchange in the lagoon and perching the lagoon above ocean levels by facilitating outflow over the beach after the mouth has closed. Despite the lack of experiential data of this type of approach, naturally perched conditions provide a natural analogue, although they are rare.

The data summarized in Section 3 show how environmental conditions have differed in the Russian River Estuary before and after the Biological Opinion, but it is difficult to look at perched conditions directly from the data, for a few reasons:

- None of the individual data sources can explain on their own whether a persistent outlet channel was any more or less likely after 2010 (Table 2).
- It is difficult to find natural perched overflow conditions in the historical record when using only the lagoon stage and photographs as a guide.
- For outflow conditions lasting only a day or two, velocity measurements in the channel or a model of the lagoon mouth are needed to assess whether the channel is experiencing perched outflow.

To account for the last point, we built a lagoon model that accounts for the interconnected lagoon hydrology and mouth morphology. This model can be used to assess how likely the mouth was to be perched before and after 2010. This lagoon 'quantified conceptual model ' (lagoon QCM) was previously developed and tested by ESA (2013, 2015) at a number of sites, including the Russian River Estuary. It is described in more detail by Behrens et al. (2015). The model is a time-series water balance that uses watershed runoff and nearshore tides and waves as boundary conditions. Using these inputs, the model predicts a time series of lagoon stage and mouth/beach elevation, allowing the system to cycle through tidal, closed, and perched overflow conditions in response to the boundary conditions. The lagoon QCM also includes the process of mouth migration, empirically relating the migration rate to the alongshore wave power vector. Migration is important to include because it encourages closed or perched conditions by lengthening the channel, slowing velocities, and exposing the mouth to more deposition from waves. Migration is thought to be one natural precursor to perched and closed conditions (Behrens et al. 2009).

To test the model accuracy, we ran the lagoon QCM for the years 2000-2014 and compared the modeled mouth condition, lagoon stage, and mouth position time series against observations. The model predicted an average of 59 closure days per year from 2000 to 2014 compared to the 54 observed by the Water Agency (Figure 11). The seasonality of mouth closures (less closure in winter and summer, more closure in spring and fall) is well captured by the model (Figure 11). The model also performs well when using the lagoon stage frequency as a test (Figure 11). Modeled stage frequency above 5 ft NGVD is biased slightly upward since the model over-predicted closure conditions. The seasonal migration cycle described in Section 3.3 is reproduced in most years (Figure 12), although the model sometimes predicted that the mouth would return south to the groin earlier than was observed in some years.

Perched overflow is identified in the model when the following conditions are met:

- Only outflow (seaward-directed) flows occur for at least 24 hours
- The lagoon stage perched higher than oceanic MHHW for at least 24 hours

Using these rules, we observed perched conditions in the model results for about half of the years from 2000 to 2014 (Table 2). Perched conditions normally happened in the week immediately before closure, and did not persist for more than several days at a time, as was previously interpreted from the water level data (see RREAMP, Section 5). The years with the most perched conditions were 2006 (12 days), 2008 (5 days) and 2010 (14 days). This is supported by the RREAMP's Table 3 (ESA PWA, 2016), which describes perched conditions in 2006 and 2008, suggesting that more favorable conditions were present in those years. On average, the model predicted slightly more perching (3.2 days per year) after 2010 than before (1.9 days per year), with no days of perched conditions predicted in the years 2012-2014 (Table 1). This difference is insignificant when considering that perched conditions usually accounted for less than two percent of the time series in an average year.

5 Summary and Findings

To provide context for the results outlined above, it is important to summarize the conceptual model for the implementing the outlet channel, which is also discussed in the main body of the RREAMP. In order for the outlet channel to be successfully implemented, a number of conditions need to be met:

(1) A natural closure must occur within the management season of May 15-October 15,
(2) The beach must build high enough that water levels can rise to perched levels,
(3) Water levels must reach 5.5 feet NGVD29 or higher,
(4) The beach must be accessible to construction equipment,
(5) The channel must be constructed within an excavation allotment of 2000 yd^3,
(6) Once the channel is constructed, flows exiting through the channel must be slow enough to prevent scouring,
(7) Wave power adjacent to the mouth must be low enough that the channel does not close.

Since 2010, channel implementation has been prevented most often by conditions 1, 2, 4, and 7. In 2010, the outlet channel was implemented briefly in July, and was subsequently closed off due to wave action. In 2011, closure did not occur until the end of the management season. More recently, closures have occurred early in the management season, but beach conditions have prevented implementation, since the lowest elevation of the beach crest was sometimes below 7 feet NGVD29. This has been especially clear in both the 2014, and more recently, 2015 management seasons (see Attachments and I and K to ESA PWA, 2016), when the mouth repeatedly self-breached before beach management could take place. Unsafe beach conditions for construction has also prevented implementation in most years since 2010.

In dry years (e.g. 2014), when river inflows have been less, closures have lasted a month or more because of the reduced inflows. However, the lagoon water levels continually increase even in dry years, and may receive pulses of wave overwash that boost the rate of rise. This trend of continually increasing water levels during closure suggest that, in the absence of an outlet channel, the inflow into the estuary always exceeds the outflow, such that the estuary will eventual self-breach or require artificial breaching.

5.1 Findings

Key findings from pre- (2000-2009) and post-(2010-2014) Biological Opinion conditions include the following:

Jenner Stage:

- The water level has not been perched above 3.2 ft NGVD29 more than 44 percent in any year since 2000.
- The average percent of time above 3.2 ft NGVD29 is 27 percent, both before and after 2010.

(Note: these percentages are biased high because the Jenner gage's observations are cutoff for low water levels.)

Data comparison:

- Conditions have been more favorable for closure within the management season since 2010: Wave power has been about 10 percent higher, and the number of days closed throughout the year was about 60 percent higher than prior to 2010.
- Watershed runoff has been favorable since 2010 for encouraging closure and for outlet channel flows: Flows from 2011-2014 were dramatically lower than in prior years.
- Peak winter flows have been 25 percent lower after 2010 than before, and peak flows have not exceeded 43,000 ft^3/s since 2006.
- The mouth has spent more than 75 percent of the year adjacent to the groin since 2010, compared with less than 40 percent before. This may be partly caused by the weak winter floods. We infer that this has resulted in a lower minimum beach crest elevation near the groin, which then serves as the location for self-breaching.

Model comparison:

- Mouth closure has been only slightly more likely after 2010 than from 2000 to 2009. The July 2010 managed outlet channel ended in a natural mouth closure.
- The lagoon QCM model suggests that perched conditions were slightly more likely after 2010 than before.

Overall, coastal and watershed conditions have been more favorable for implementing an outlet channel after 2010. However since mouth migration appears to have been limited by weak winter floods, the mouth has frequently occupied the segment of beach immediately adjacent to the groin. The consequence of this has been weaker beach building at this location and a lower beach crest elevation as a result. This has made self-breaching prevalent throughout the management season, especially preventing implementation of the outlet channel in recent years.

6 *References*

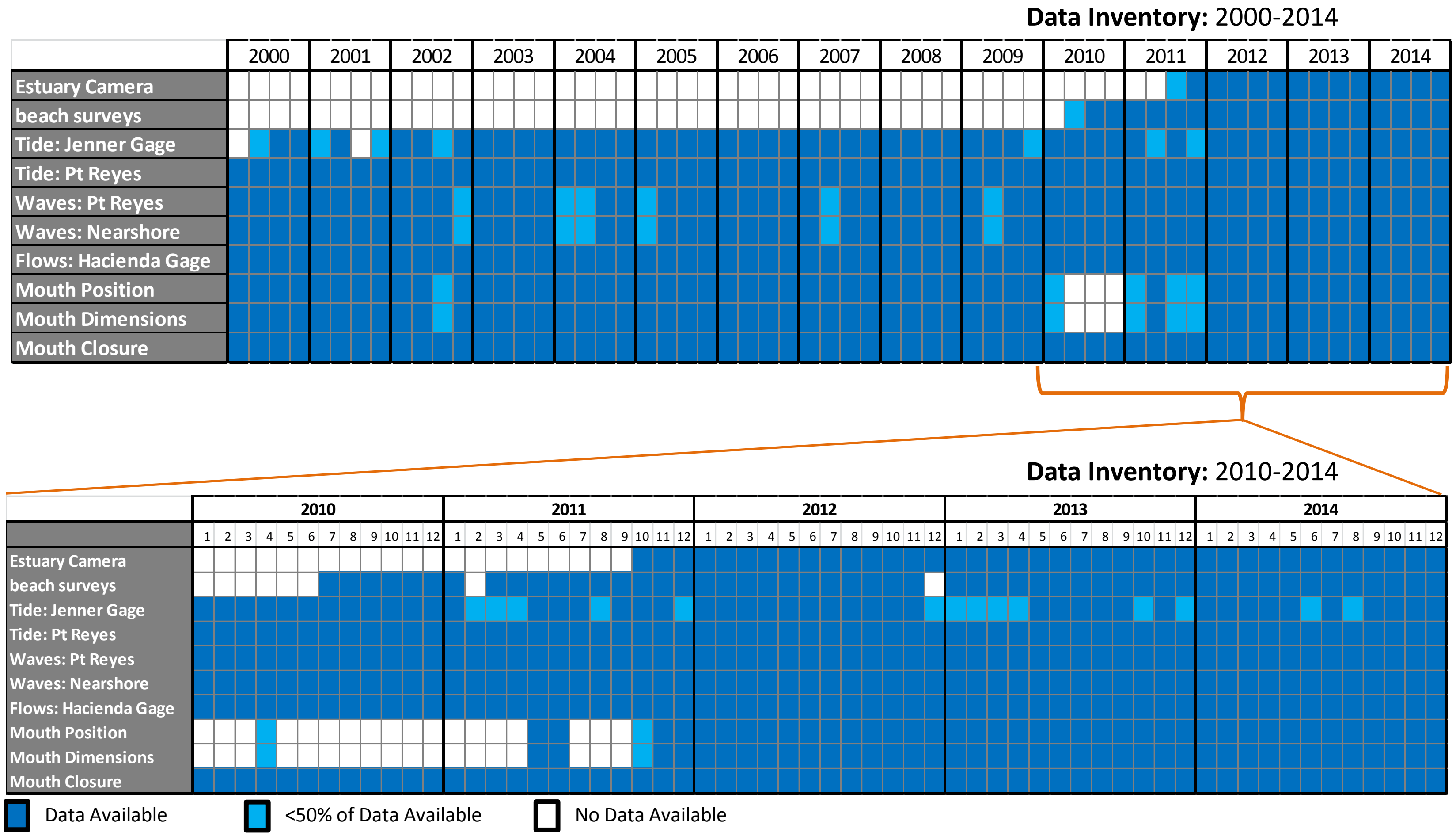
Behrens, D., Bombardelli, F., Largier, J. and E. Twohy. 2009. Characterization of time and spatial scales of a migrating rivermouth. Geophysical Research Letters. Vol. 36, L09402, doi:10.1029/2008GL037025.

Behrens, Dane K., Fabián A. Bombardelli, John L. Largier, and Elinor Twohy. 2013. “Episodic Closure of the Tidal Inlet at the Mouth of the Russian River — A Small Bar-Built Estuary in California.” Geomorphology 189 (May): 66–80. doi:10.1016/j.geomorph.2013.01.017.

ESA. 2016. Feasibility of alternatives to the Goat Rock State Beach jetty for managing lagoon water surface elevations. Prepared for the Sonoma County Water Agency.

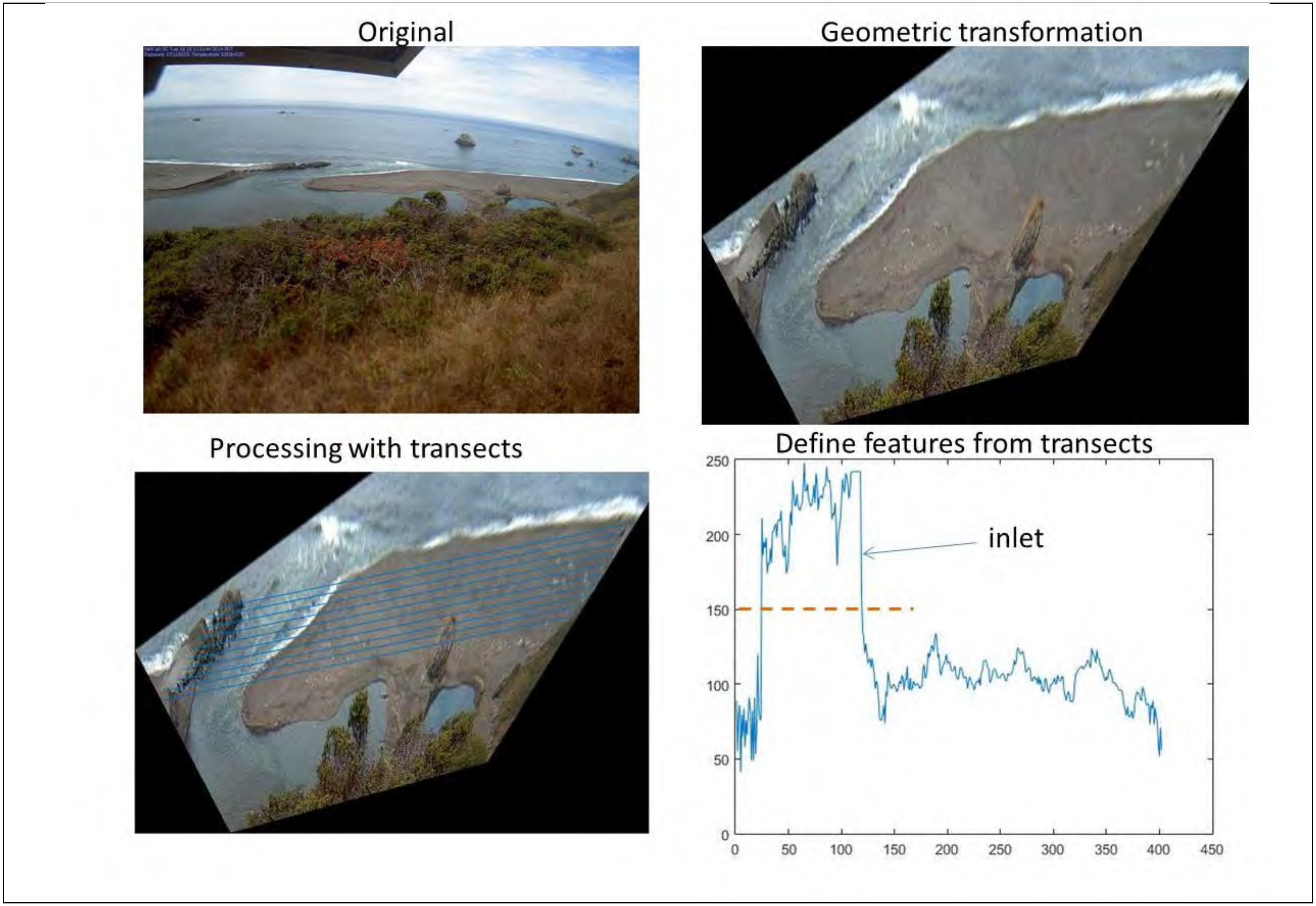
ESA PWA. 2016. Russian River Estuary Adaptive Management Plan. Prepared for the Sonoma County Water Agency.

National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed.



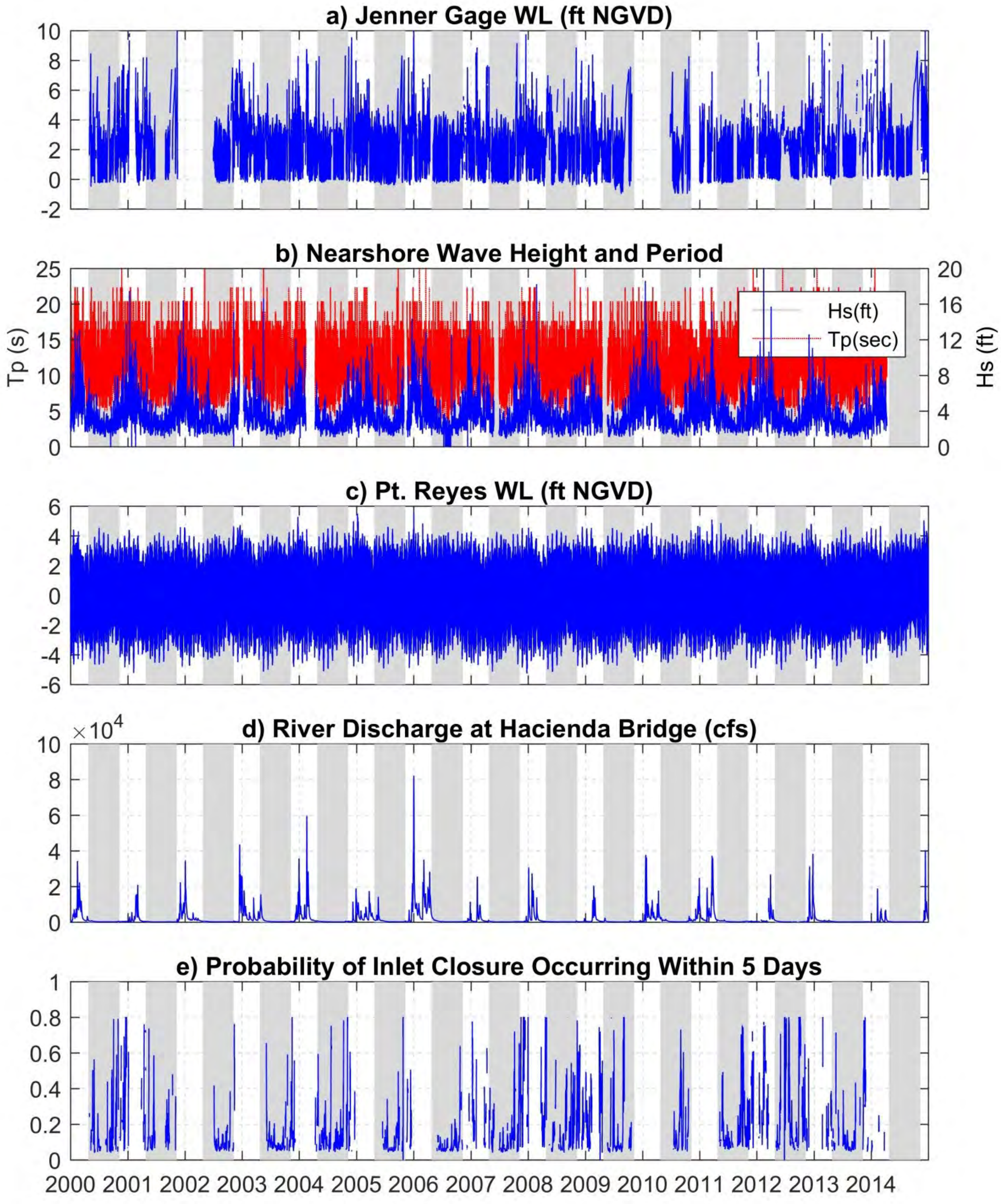
NOTE: See Table 1 for data sources

Figure 1
Data inventory for the Russian River Estuary for **(top)** 2000-2014 and **(bottom)** 2010-2014.



NOTE: Image source: BML

Figure 2
Summary of processing technique to obtain mouth morphologic data from the BML camera.



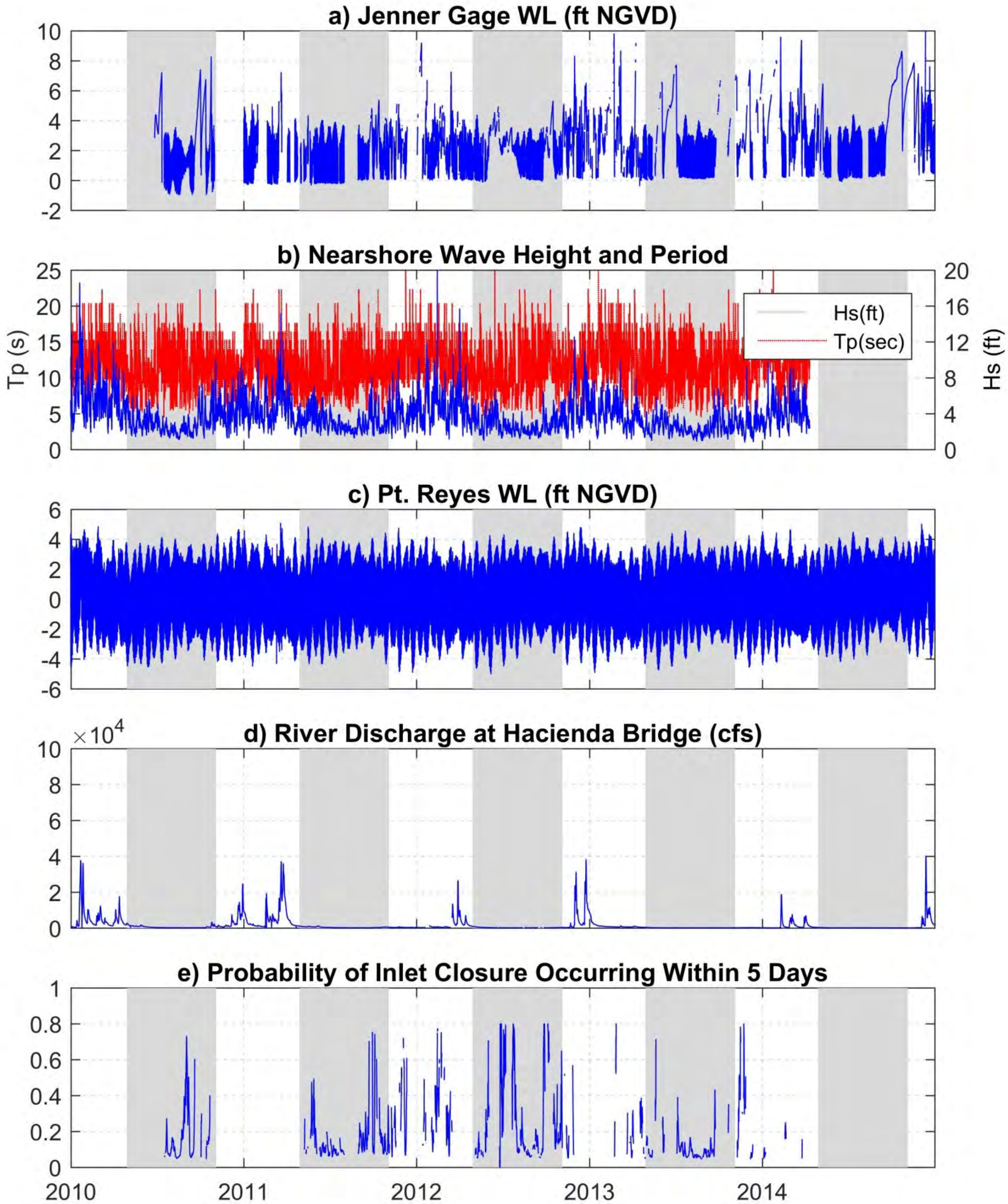
SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

NOTE: grey bands represent management period of May 15-October 15

Figure 3

Estuary, Ocean, and River Conditions Compared with Closure Probability: 2000-2014.

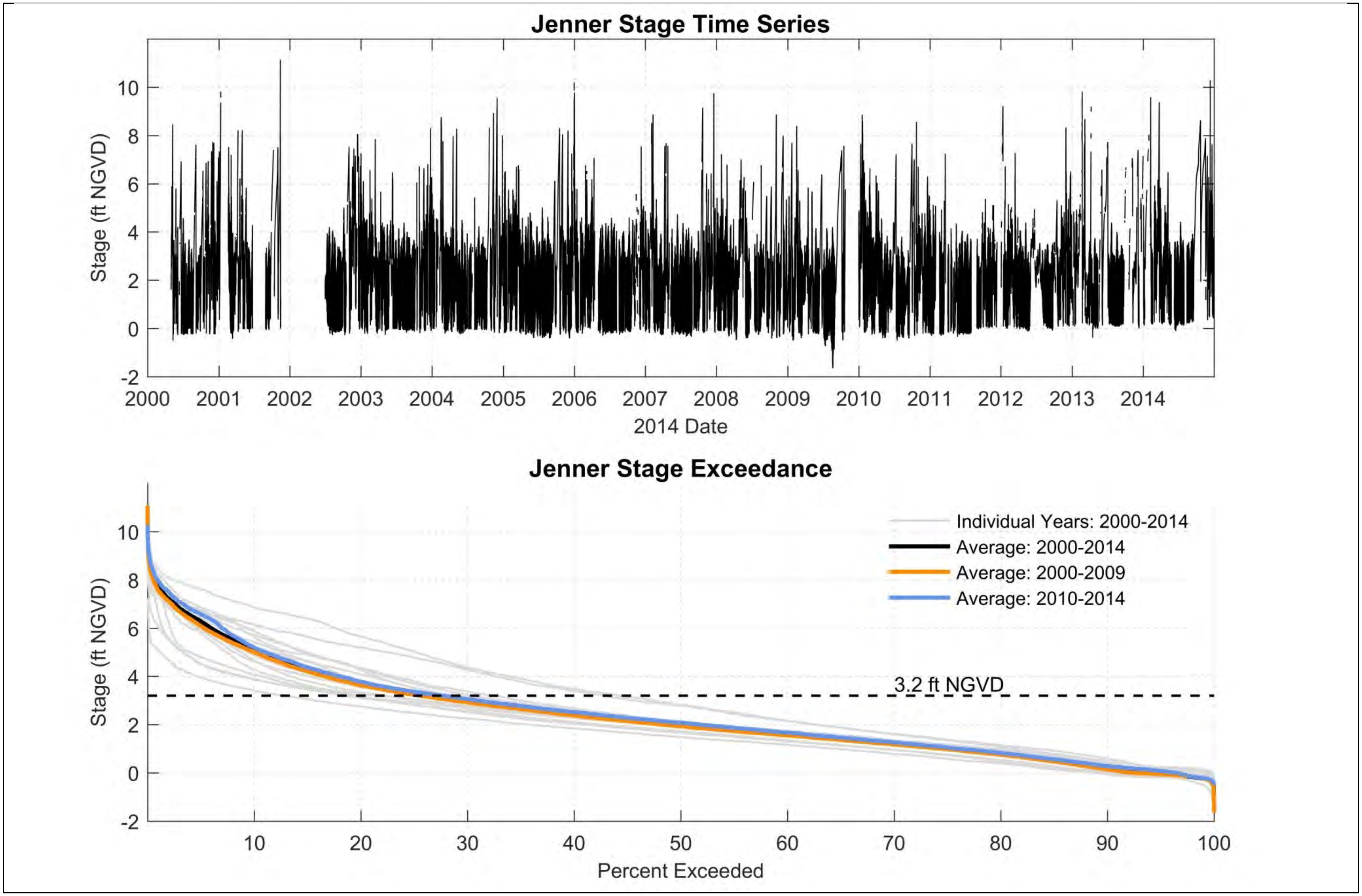


SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

NOTE: grey bands represent management period of May 15-October 15

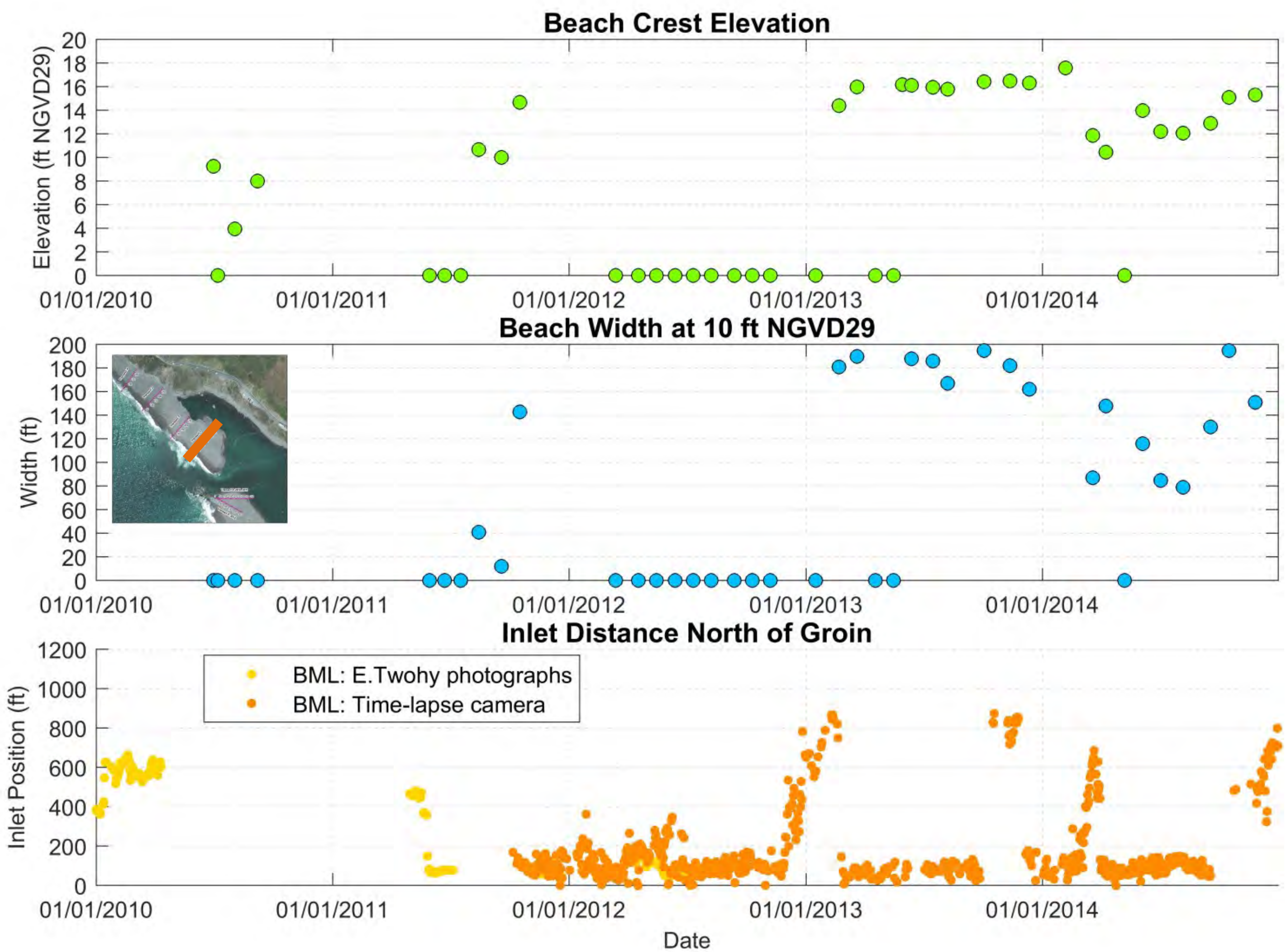
Figure 4
Estuary, Ocean, and River Conditions Compared with Closure Probability: 2010-2014



Source: Water Agency Jenner Gage

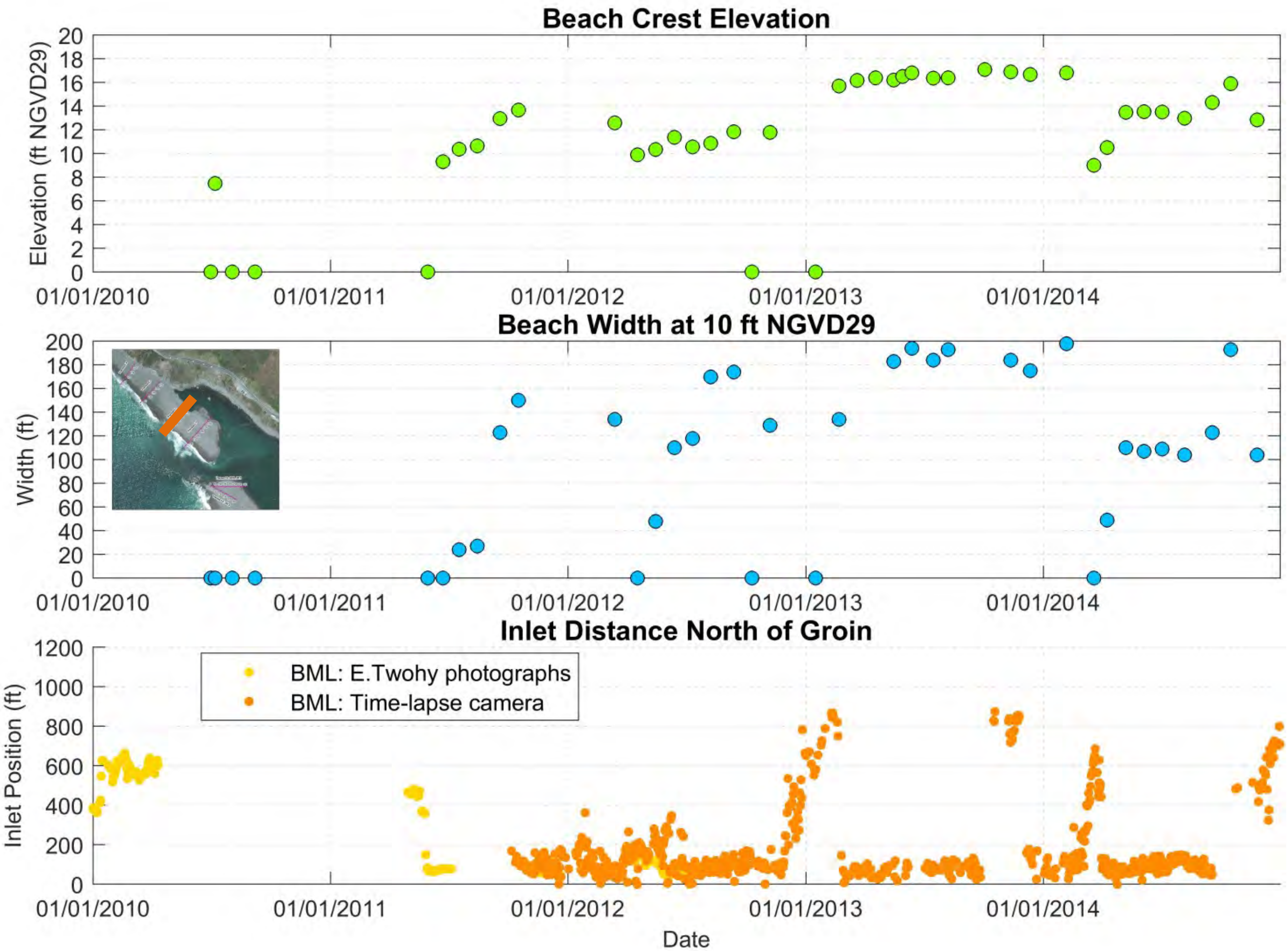
Figure 5

Russian River Estuary stage **(top)** time series and **(bottom)** exceedance curves.



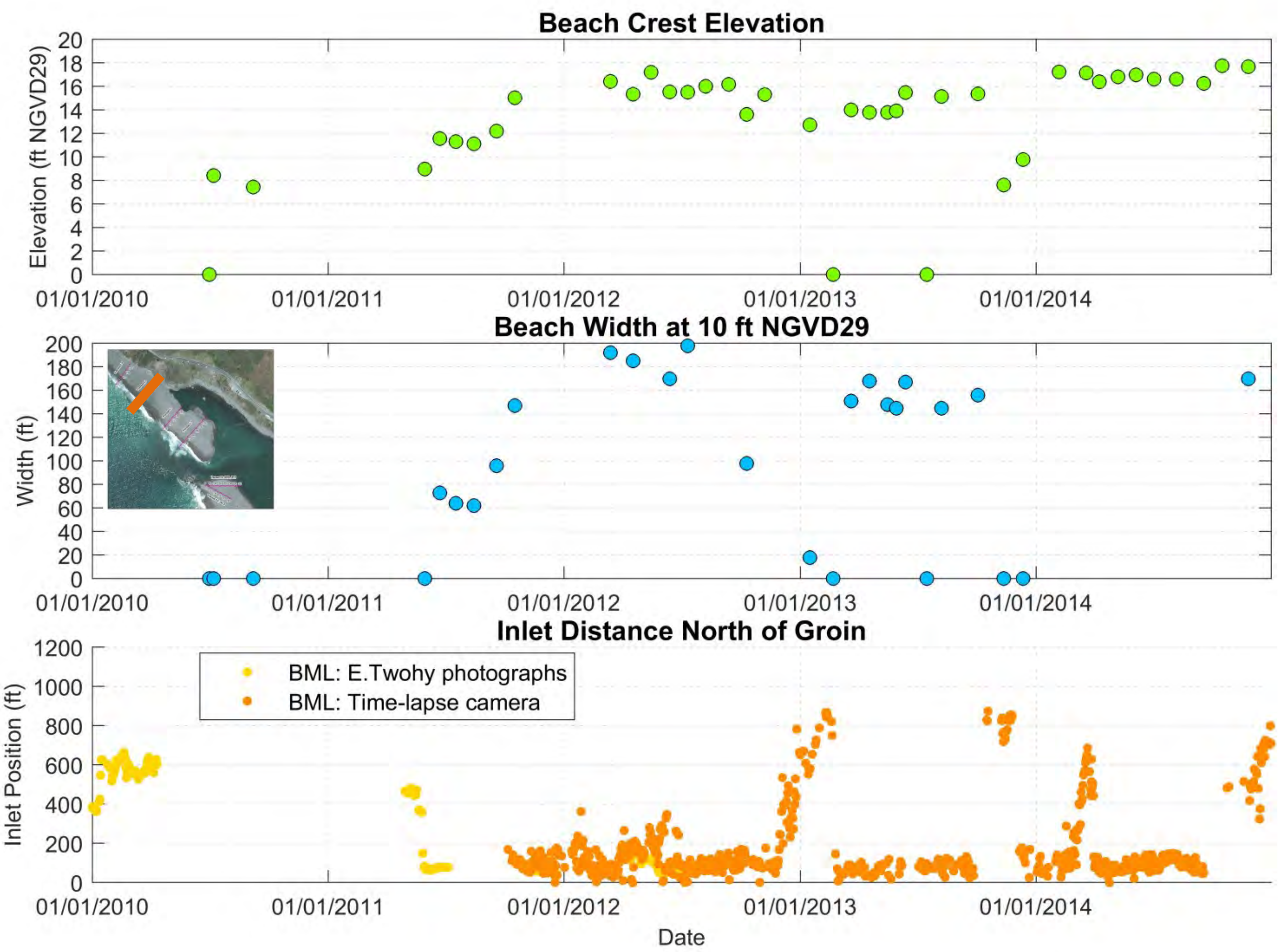
SOURCE: Water Agency Topographic Surveys, ESA processing of BML camera

Figure 6
Summary of **(top)** monthly beach crest and **(middle)** beach width at Transect 1, measured from Water Agency surveys, compared with **(bottom)** Mouth position.



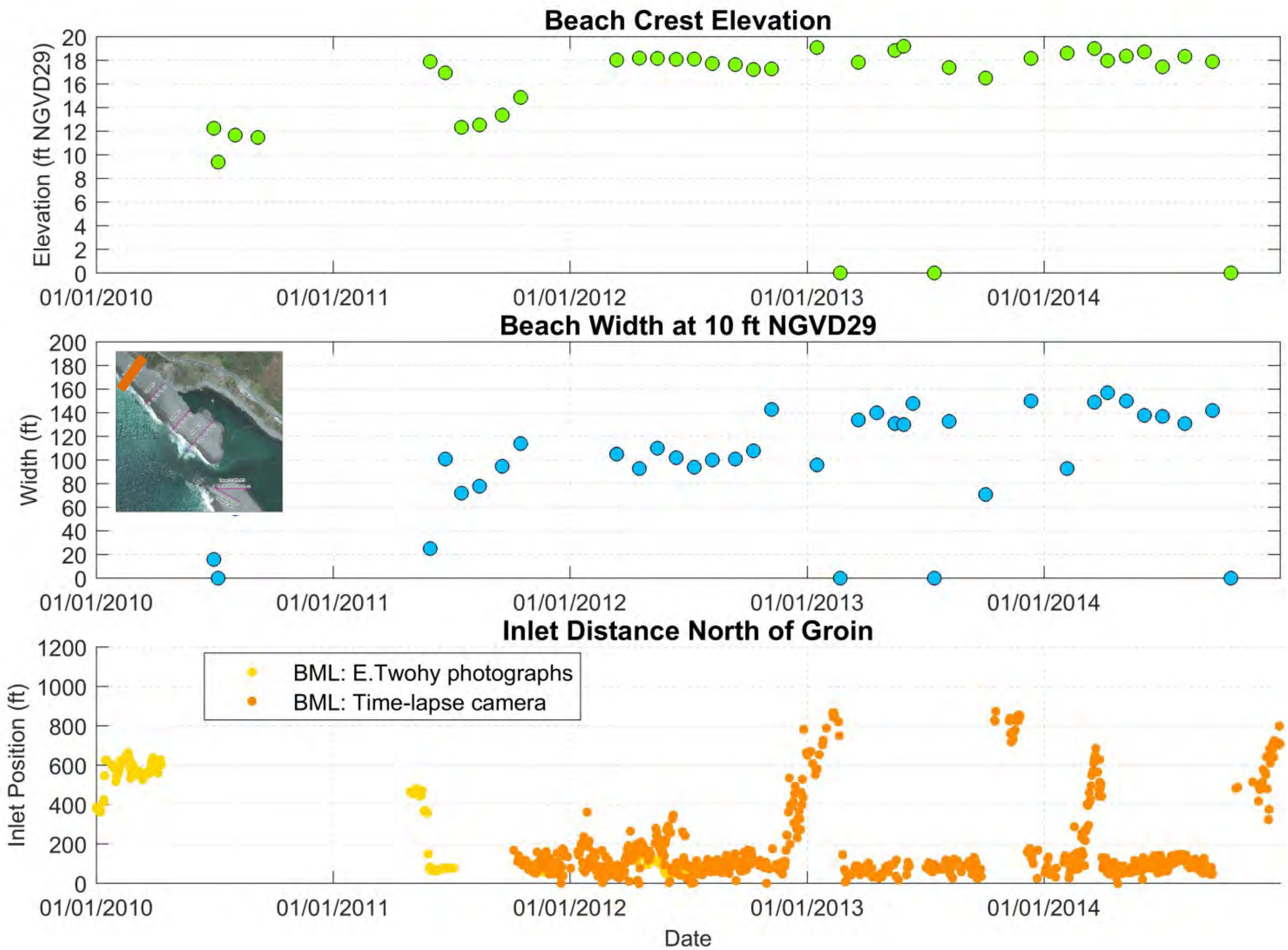
SOURCE: Water Agency Surveys, ESA processing of BML camera

Figure 7
Summary of **(top)** monthly beach crest and **(middle)** beach width at Transect 2, measured from Water Agency surveys, compared with **(bottom)** Mouth position.



SOURCE: Water Agency Topographic Surveys, ESA processing of BML camera

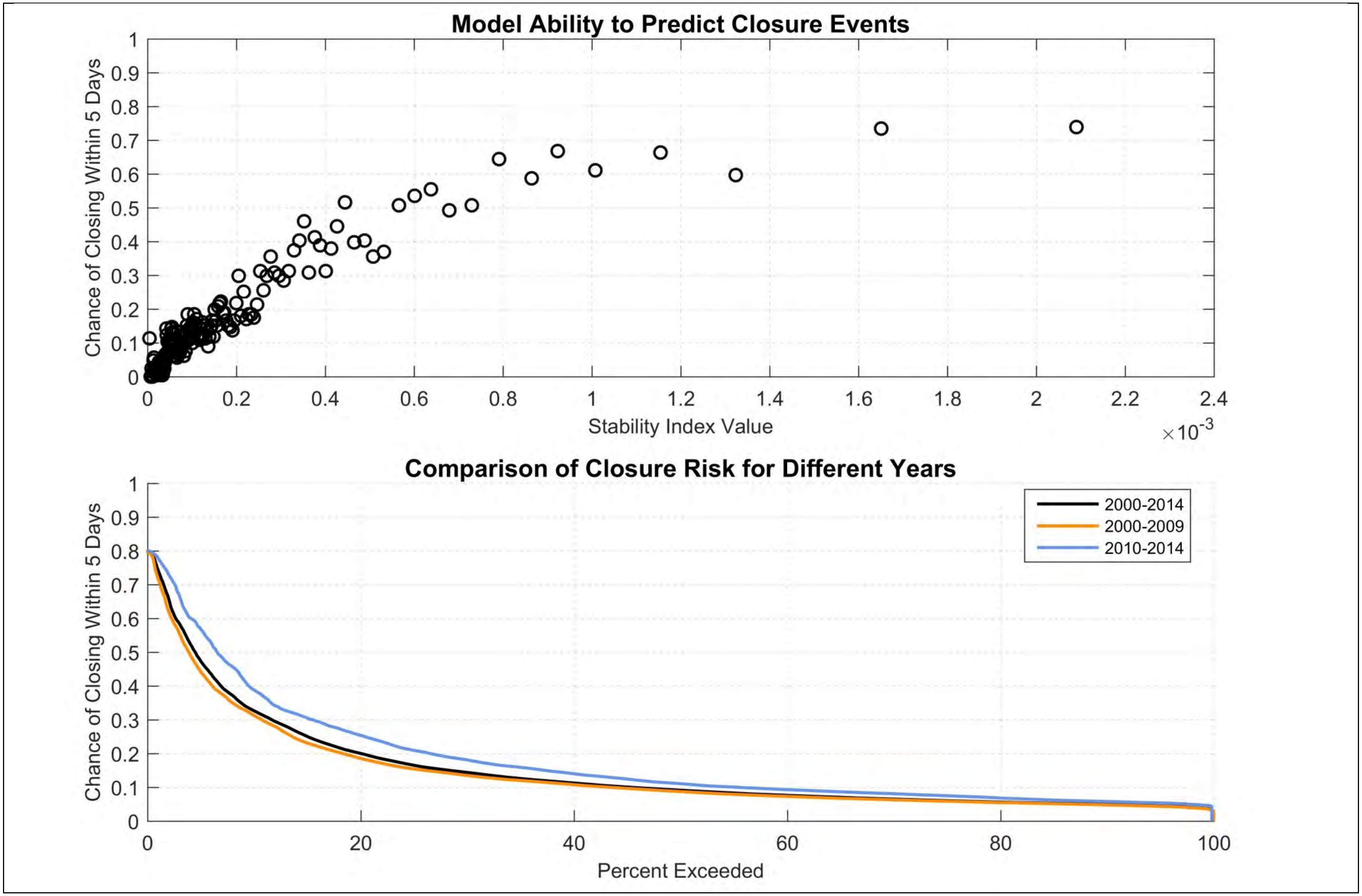
Figure 8
Summary of **(top)** monthly beach crest and **(middle)** beach width at Transect 3, measured from Water Agency surveys, compared with **(bottom)** Mouth position.



SOURCE: Water Agency Topographic Surveys, ESA processing of BML camera

Figure 9

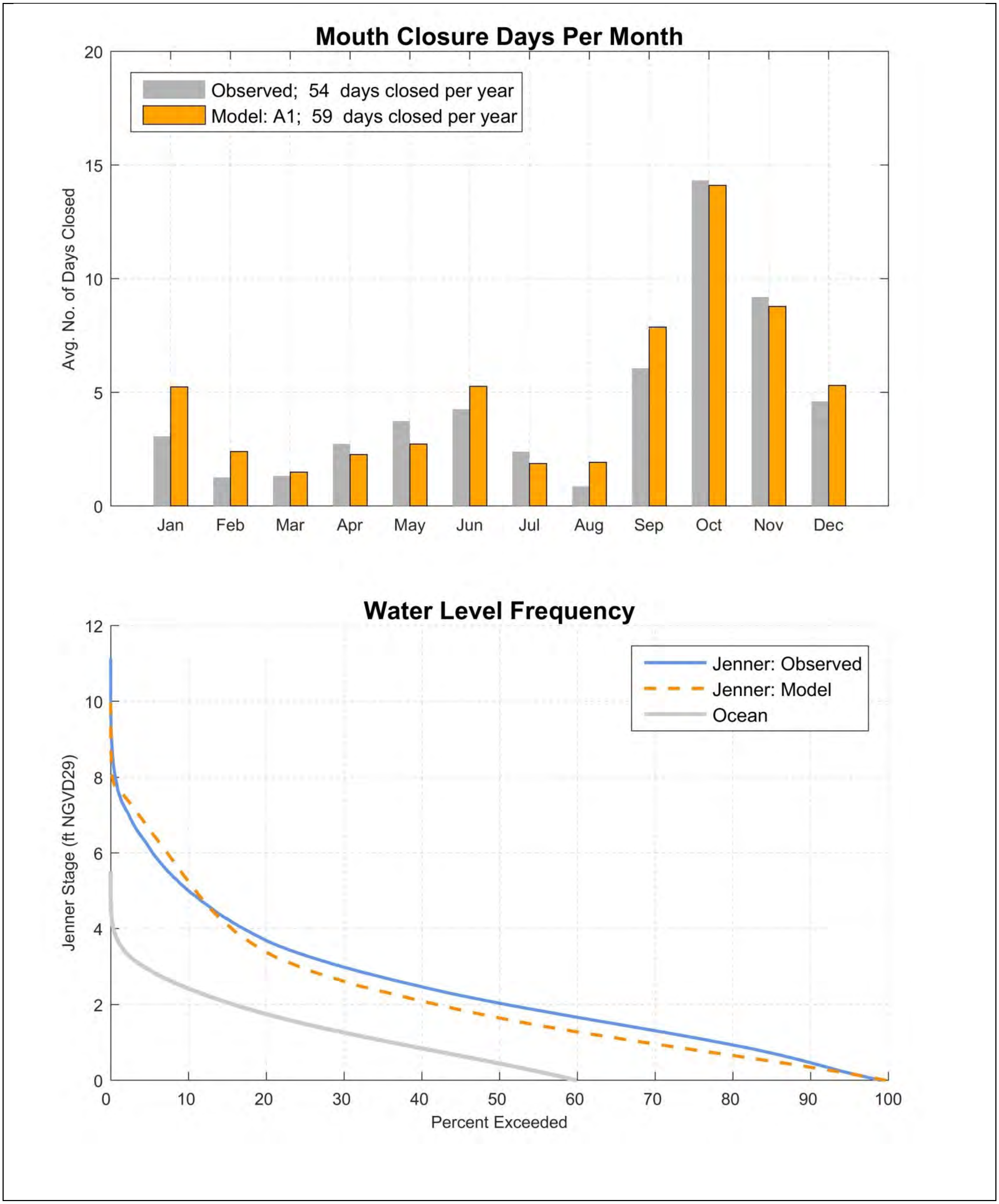
Summary of **(top)** monthly beach crest and **(middle)** beach width at Transect 4, measured from Water Agency surveys, compared with **(bottom)** Mouth position.



NOTE: Behrens et al. (2013) model

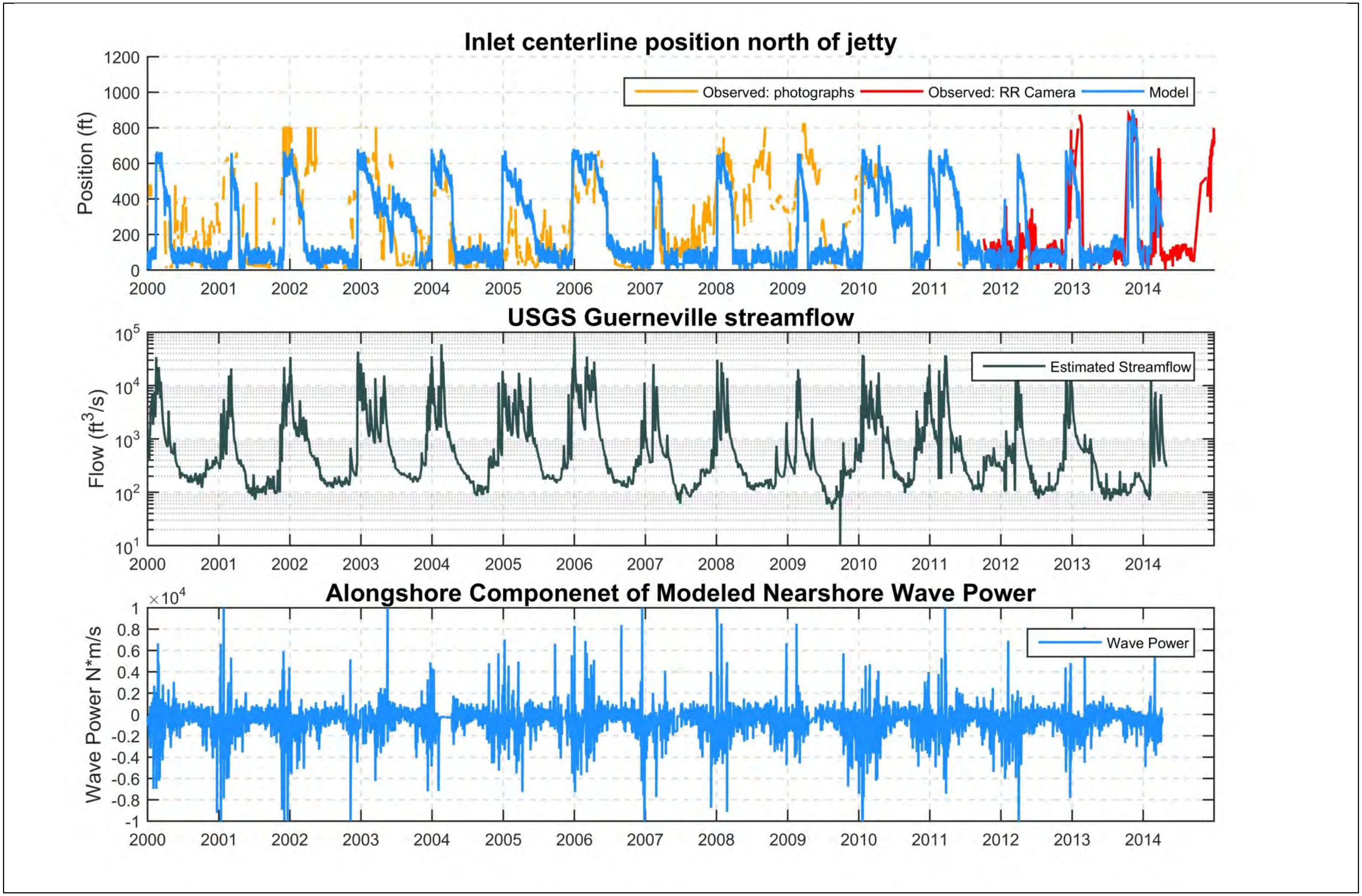
Figure 10

Test of model accuracy **(top)** and comparison of five-day closure risk before and after BO **(bottom).**



SOURCE: ESA Lagoon QCM model

Figure 11
Comparison of modeled and observed number of days closed per month **(top)** and comparison of modeled and observed Jenner stage exceedance **(bottom).**



SOURCE: ESA Lagoon QCM model

Figure 12
Comparison of modeled versus observed mouth position **(top),** compared with river flow **(middle)** and alongshore wave power vector component **(bottom).**

Attachment K. Physical Processes During the 2015 Management Period

As required by the Russian River Biological Opinion, the Sonoma County Water Agency (Water Agency) has been tasked with managing the Russian River Estuary to facilitate summer lagoon conditions to improve salmonid rearing habitat. The goal is to meet this need by creating an outlet channel while also maintaining the current level of flood protection for properties adjacent to the estuary (NMFS, 2008). The adaptive management plan, described in the main body of this report, was developed by the Water Agency with assistance from ESA PWA and the resource agency management team in 2009 and revised annually from 2010 to 2015. Because of permit constraints, the Water Agency was only able to implement the plan beginning in 2010. The revised plan was in effect for 2015, but no opportunities for management action occurred during the 2015 management period.

During the 2015 management period, May 15th to October 15th, Water Agency staff regularly monitored current and forecasted estuary water levels, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. Although a 20-day closure event started in late May (Figure 1), the mouth self-breached before an outlet channel could be created. The estuary was then tidal for several months until it closed again in early September for the first of two approximately month-long closures (Figure 2). The closure starting on September 8th self-breached on October 3rd, before water levels could reach 7 ft NGVD29. The closure starting on October 10th lasted until November 2nd, outside of the management period, and ended with artificial breaching (Figure 3). Similar to 2014, the mouth was predominantly closed for the fall season, with only several days of open-mouth conditions between closures (Figure 2).

Prior to the management period, a March 27th-31st closure ended with artificial breaching conducted north of Haystack Rock (Figure 3). After the management period, closures from November 2nd – 5th and November 13th – 23rd also ended with artificial breaching just north of the jetty (Figure 3). A closure event that began on December 2nd led to flooding in Jenner. After the mouth closed, wave overwash and river discharge rapidly increased the water levels in the lagoon. Wave overwash conditions made the beach inaccessible to construction equipment for several days starting on December 8th, thereby preventing artificial breaching. For safety reasons, power was shut off to the Visitor's Center, which also shut down the water level gage. By comparing photographs of the inundated areas with ground survey and LiDAR, ESA estimated that water levels in Jenner reached a peak of approximately 12.25 ft NGVD29 before the estuary self-breached on December 13th.

Even though no outlet channel management was implemented to inform the adaptive management process, the physical conditions and inlet response during the management period are reviewed in this attachment to contribute to site understanding and to inform future management actions.

METHODOLOGY

This review of the 2015 outlet channel management period examines water levels, ocean wave conditions, ocean water levels, riverine discharge, and beach topography, as well as inlet size and location. The sources for these parameters are listed in Table 1. These data were supplemented with personal observations and discussion with staff from the Water Agency, NMFS, CDFW, and the Bodega Marine Laboratory.

In prior years, the Point Reyes buoy provided offshore wave data. In 2015, the Point Reyes wave buoy data were not available during the management season. Data from the next closest CDIP buoy at Cape Mendocino were used instead. The Cape Mendocino buoy data were transformed to estimate nearshore wave estimates at the mouth of the Russian River. The Point Arena data are reported less frequently than the Point Reyes buoy's wave data. Neither buoy was online after mid-September.

Table 1. Data Sources

Parameter	**Source**
Estuary water level (h_E)	Water Agency Jenner gage
Wave height (H_s), period (T_a), and direction	CDIP Cape Mendocino buoy #094
Ocean water level (h_O)	NOAA Point Reyes #9415020
Russian River discharge (Q_f)	USGS Guerneville #11467000
Beach topography, ft NGVD	Water Agency monthly surveys
Inlet size and location	Water Agency and Bodega Marine Laboratory autonomous cameras

INLET STABILITY PARAMETER AND CLOSURE RISK PROBABILITY

In addition to considering individual parameters, researchers at the Bodega Marine Laboratory have developed a combined parameter to evaluate the stability of the inlet's state, with the aim of predicting closure risk (Behrens et al., 2013). (Note that the inlet stability parameter does not differentiate between full closure and the perched conditions with a small outlet channel. When discussing this parameter, both states are referred to as a 'closure' in that tides are prevented from propagating into the estuary.) The inlet stability parameter presented by Behrens et al. (2013) quantifies the risk of inlet closure based on a sediment balance in the inlet. It considers the daily balance between wave-driven sediment import to the inlet and sediment export driven by tidal fluctuations. The wave-driven import is assessed using nearshore wave estimates derived from a transformation matrix and offshore buoy data (ESA PWA, 2016) and the latter is estimated from tide gage data within the estuary and a stage-storage relation derived from the available bathymetry. Using daily-average values of the stability parameter within the period 1999-2008, Behrens et al. (2013) showed that high-percentile values of the parameter are closely linked to the risk of the inlet closing within five days. As the percentile of the stability parameter increases, the risk of inlet closure within five days increases exponentially, from risks of roughly five percent when the parameter is at the 50th percentile to a risk of 80 percent when it is measured at the 99th percentile.

SUMMER AND FALL CONDITIONS

Time series of estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 1 for the entire management period. The lagoon water level time series (Figure 1a) summarizes the closure events at the beginning of the management period, as well as the subsequent tidal conditions and later closure events in fall (Figure 2). As shown in Figure 1d, flows at Guerneville dropped to 100 ft^3/s by roughly July 1st, which was more than a month later than in 2014. These higher flows contributed to the rate of water surface elevation increase during the May-June closure event. During this closure, construction equipment access could not access the beach north of the groin due to the lagoon's position and the steep drop-off on the north side of the groin (Figure 4). Therefore, no beach management was scheduled and the lagoon filled to the beach crest and self-breached.

From July to October, flows were mostly below 100 ft^3/s, and dipped below 70 ft^3/s for parts of late July, September and October. As in prior years, wave energy was minimal through the summer months.

Since waves were derived in 2015 from the Point Arena buoy instead of the Point Reyes buoy, and both of these buoys were off-line after mid-September, only a qualitative assessment of the events causing closure in 2015 was made. In prior years, closure events typically coincided with either moderately high waves ($H_s > 6$ ft) having periods greater than 10 s, or with neap oceanic tide ranges of less than approximately 5 ft. The May-June closure event happened during a neap tide cycle but during a period of relatively weak ($H_s < 5$ ft), but long period (~15 sec) waves. Moderately high waves and a neap tide cycle coincided with the closure event that began on September 8th. The persistent closure conditions from September through November are examined in more detail in Figure 5.

As in the years 2012 through 2014, all closure events occurred when the inlet was adjacent to the jetty's groin. In years prior to 2015, this positioning may have prevented perched conditions from arising by shielding this area of the beach from the wave-driven sediment deposition that caused closure, preventing the beach from accreting to a sufficient height to allow the desired outlet channel elevations from being attained. This may have been the case for the May-June and September closure events in 2015 as well.

LATE-SEASON CLOSURE EVENT

During the late-season closure that began with closure on September 8th, inflows were below 100 ft^3/s throughout most of the event, but rose slightly above 100 ft^3/s from September 15th-21st after a rainfall event and the removal of summer dams. Despite this, the lagoon stage remained lower than 7 ft NGVD for almost a month of closure. In contrast to the prolonged September 2014 closure event, no wave overwash events were apparent, and lagoon stage rose slowly throughout

26 days of closure. Like the May-June closure, construction equipment could not access the beach north of the groin during this closure (Figure 4b). The mouth self-breached near the groin on October 4th, at a stage of approximately 6.7 ft NGVD29.

To better illustrate both the lagoon stage and beach morphology during this time, Figure 5 shows a sequence of photos of the inlet before and during this closure event. As was the case for all of the management period, the inlet was located next to the groin. Figure 5a depicts the inlet when it was located next to the groin on the day of closure. Figure 5b-e shows that the beach grew only minimally during the 26-day closure event, setting up a self-breach at less than 7 ft NGVD29.

Unlike the 2012 management period, no natural outlet channels were formed near the groin in 2015. However, as with 2012 and other previous years, the lowest portion of the beach was consistently located at the groin. This persistent low portion is probably caused by wave sheltering by the groin, which may have reduced berm build-up at the inlet's location, leaving a low point in the beach berm that was the site for subsequent overtopping and self-breaching.

CLOSURE RISK PROBABILITY

The 5-day closure risk probability, a derivative of the inlet stability parameter described above, was hindcast for 2015 according to the method described in Behrens et al. (2013). This hindcast provides an indication of the utility of the stability parameter as a prediction tool for monitoring inlet conditions and planning management action. This parameter integrates wave and ocean forcing conditions, as well as estuary water levels, to provide greater predictive skill than just waves or ocean tides on their own. The stability parameter combines these factors, and the corresponding five-day closure risk time series exceeded 50 percent before most 2015 events (Figure 1e). Wave data were not available for the October closure event, so the stability parameter could not be calculated for that event. Otherwise, the predicted probability of closure exceeded 50% 2-5 days in advance of most of the other closures in 2015.

TOPOGRAPHIC CHANGE

The Water Agency has conducted monthly surveys of Goat Rock State Beach that cover a region starting from the groin and extending approximately 1,500 feet to the north. The surveys do not include bathymetry within the inlet because flow conditions in the inlet prevent safe access. Also, the survey extent can be limited by the Water Agency's compliance with its marine mammal incidental harassment authorization, which sets guidelines for the survey crew's approach to marine mammals hauled out on the beach. Water Agency survey staff collect spot elevations using RTK-GPS and then assemble these elevations into a set of contour lines at 1-ft intervals, as well as profiles along the beach berm crest, the ocean wetted edge, and the estuary water line. The survey elevations are reported in the NGVD29 vertical datum.

To characterize beach berm topographic conditions, ESA PWA assessed data from the Water Agency's 2010 (July to September), 2011 (May to October), 2012 (May to October), 2013 (May to October), 2014 (May to October), and 2015 (May to October) surveys. Profiles include two transects backed by cliff (Figure 7and Figure 8), two transects which extend into the estuary (Figure 9 and Figure 10), and two variations on a transect just north of the groin (Figure 11 and Figure 12).

This review focuses on the 2015 surveys, although the 2011 surveys are included for context in some figures. The 2015 topographic data were similar to those of 2012-2014 in that the northernmost profiles underwent little morphologic change during the management season. In 2014 the southernmost profiles underwent more morphologic change than in previous years, similar to the results from the 2010 and 2011 management seasons. This was not the case for 2015, as Figures 9 and 10 show that the beach was mostly stable throughout the management season.

At profiles 3 and 4, the beach is backed by cliff, and typically undergoes morphologic changes when the inlet migrates north during floods and returns south to the groin in spring or summer. In 2010 and 2011, migration in this area led to a sequence of erosion and accretion at these sites during the management period. The erosion seen in those years was associated with inlet migration and subsequent accretion of the beach was associated with long-period swell waves. During the 2012-2014 management seasons, the inlet remained near the groin and did not migrate north, leading to an especially stable profile at Profiles 3 and 4. In 2015, the inlet did migrate to the north during winter floods, but it returned to the groin by February, allowing the beach at the northern end to build up under energetic waves during the spring season before the management period. Thus, the beach shape at Profiles 3 and 4 were as stable as in 2012-2014, albeit for a different reason than in those years. This suggests that the northern portion of the beach will be stable under two cases, (1) if the inlet does not migrate to the north during winter, and (2) if the inlet returns to the groin before winter has ended.

Compared with 2014, Profiles 1 and 2 were much less variable, and were more similar to the conditions seen in 2012 and 2013. At Transect 2 (nearest to Haystack Rock), the beach profile was stable early in the management season, and then grew by several feet from August to October (Figure 9). This type of seasonal growth is apparent in previous years, and is expected as wave energy increases seasonally in the fall. Transect 1 experienced both erosion (July-August) and growth (August-October), as it was more strongly influenced by the inlet throughout the summer. It was lowest in August, when the inlet was fully tidal. Despite the variability shown in Figure 10, the crest was relatively stable between 11.5 and 14 ft NGVD29 throughout the management season.

Transect 0, which is located parallel to the groin, had a stable shape throughout 2015, but the western beach face shifted eastward throughout the management season (Figure 11). This may be a response to steady erosion from the inlet, which was tidal throughout the summer. The crest remained steady at 12-13 ft NGVD29. As shown in Figure 12, Transect 0 typically sees limited change during the management season and larger inter-annual variability.

Beach berm crest profiles have been collected by the Water Agency since 2013. These data make it possible to discern important changes in beach shape along the length of the berm that is north of the groin. Along-beach trends in crest elevation are generally consistent with the along-beach trend of wave energy increasing to the north and the influence of inlet migration and breaching at the south end of this section of beach.

Figure 13 shows that May through September, the change in crest elevation was minimal north of Transect 1. The beach crest was lowest south of Transect 1, where the inlet resided. As shown in Figures 7-11, most of the change to the crest resulted from seasonal beach building by waves in September and October. This may have been further encouraged by the extended closure events during this time.

BEACH WIDTH

To provide additional information about the beach morphology, ESA PWA assessed the beach width using the Water Agency survey data. Figure 14 shows the evolution of the beach width at Transect 3 during the 2012-2015 management periods. Beach width data were added for surveys that occurred outside of the management season. These provide more context for seasonal changes to beach width. In previous years during winter months, the beach was often eroded at Transect 3 to the point that the beach crest was below 12 ft NGVD, so that the width was effectively zero. In 2012 and 2013, apart from this seasonal erosion, there was no marked trend in the beach width. In 2014, the beach was wider than the previous two years, with peak width at the beginning of the management season (Figure 14). In December 2014, the inlet migrated north during winter floods for the first time since 2011. It returned to the groin by February. Although the northern transects (Transects 3 and 4) partially rebuilt due to wave action in spring, the effect of the migration appears to be a lower beach crest and smaller width at Transect 3 than in previous years. The beach width is effectively zero at 14 ft NGVD29 during the 2015 management season because the beach crest was below this elevation.

JENNER STAGE EXCEEDANCE

The Biological Opinion (NMFS, 2008) sets a target for estuary water levels "a daily minimum water surface elevation of 3.2 feet [NGVD] during 70% of the year." To facilitate this target, the Biological Opinion notes "Absent river flood flows and historic mechanical breaching practices, NMFS expects cross shore transport of sand by wave action will be sufficient to maintain the bar at this elevation."

In 2015, the daily minimum water surface elevation exceeded 3.2 ft NGVD roughly 30% of the year (Figure 15). For comparison, Figure 15 also includes hourly lagoon stage (exceeded 3.2 ft NGVD for roughly 40% of the year) and hourly Point Reyes stage (exceeded 3.2 ft NGVD for roughly 5% of the year). This amount of perched conditions results from the inlet maintaining open conditions throughout the summer of 2015. As with several of the years since 2010, lack of closure in July led to prolonged open conditions, as July and August waves were too small to cause closure. As explained in previous annual updates, if the inlet does not close in late spring, it is likely that open-inlet conditions will persist as a result of the seasonally weak waves. Since construction equipment could not access the beach during the 2015 closures, no management activities to facilitate an outlet channel could not be made and the closures ended with self-breaches.

LESSONS LEARNED AND RECOMMENDATIONS

Based on 2015 observations of the estuary, associated physical processes, and the Water Agency's planning for outlet channel management, we note the following lessons about implementing the outlet channel management plan.

CONCEPTUAL MODEL

- The beach north of the inlet remained steady between 11and 15 ft NGVD. This was lower than previous years since the inlet migrated north in early winter and later migrated south to the groin. Near the groin, the berm was lowered by inlet migration when not undergoing beach building.
- The inlet returned to the groin in late winter, much earlier than in most years. This inlet alignment is not common, but has been observed in past years (Behrens et al., 2009).
- Peak annual river discharge has remained below 43,000 ft^3/s for 9 consecutive years, a streak unmatched in the 70-year flow record. This lack of larger fluvial discharge may contribute to the predominant inlet location near the groin.
- The beach width in 2015 at Transect 3 (near Haystack Rock) was less than in 2014. This may suggest that beach width is closely tied to inlet migration – the lack of migration north of Haystack Rock for several years had previously allowed the beach to grow at this end of the littoral cell.

OUTLET CHANNEL FEASIBILITY

- Three mouth closure events occurred within the management season, a 20-day event in late May and early June, a 26-day event in September and October, and an event beginning in early October that extended past the management season. The first two events led to a self-breach. Implementing an outlet channel during these first two closures was not possible because the beach north of the groin was not accessible by construction equipment.
- As noted in previous years, once lagoon water levels reach the low point of the beach crest elevation, the lagoon self-breached. This behavior highlights the susceptibility of a sand bed outlet channel to scour, limiting conveyance capacity. The 2015 management season provided more evidence that the groin may shelter beach just north of the groin, reducing the chance of closure when the inlet is located in the groin's wave shadow. The groin's wave shadow may also limit berm growth, which then maintains a low point for self-breaching.

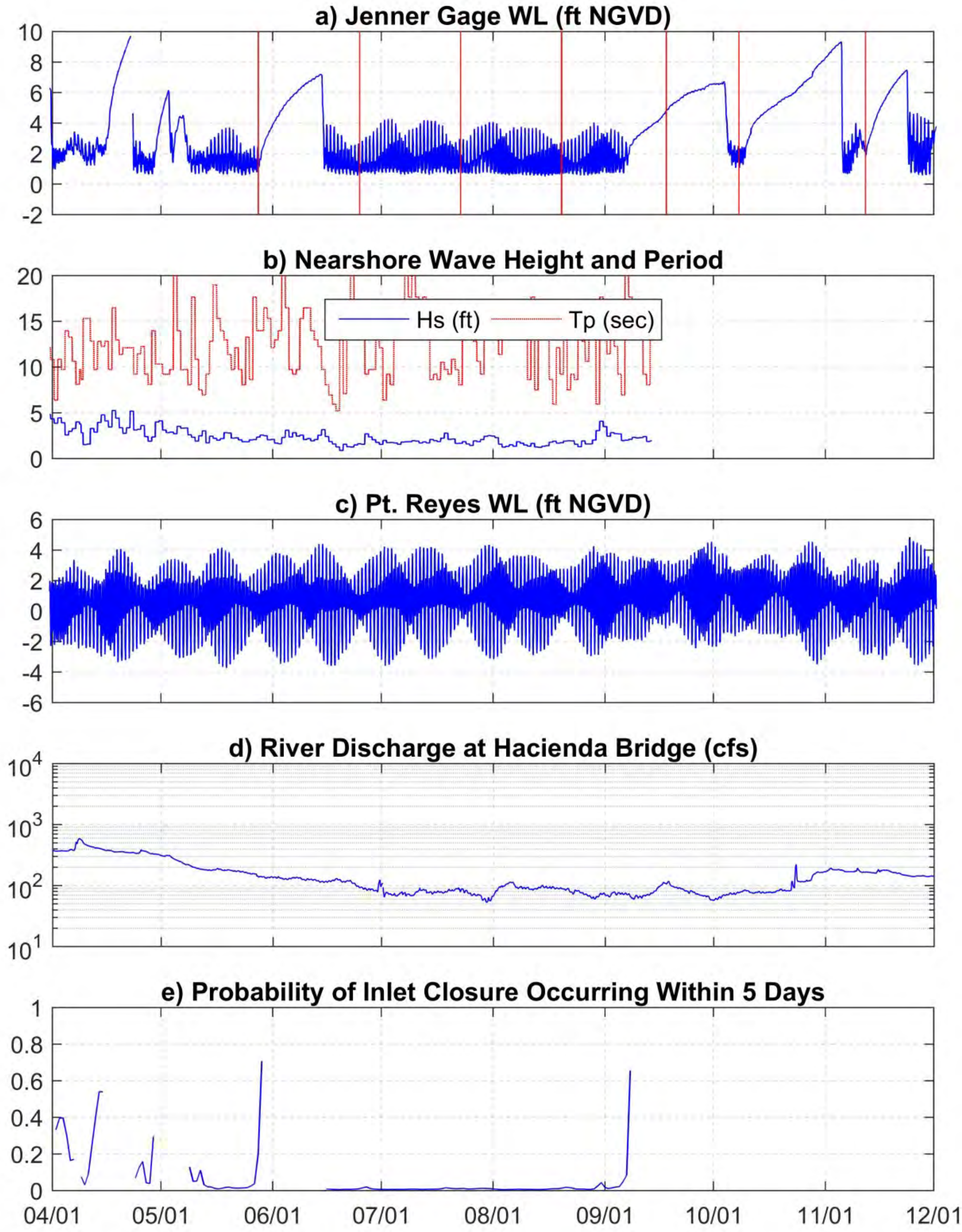
REFERENCES

Behrens, D., Bombardelli, F., Largier, J. and E. Twohy. 2009. Characterization of time and spatial scales of a migrating rivermouth. Geophysical Research Letters. Vol. 36, L09402, doi:10.1029/2008GL037025.

Behrens, Dane K., Fabián A. Bombardelli, John L. Largier, and Elinor Twohy. 2013. "Episodic Closure of the Tidal Inlet at the Mouth of the Russian River — A Small Bar-Built Estuary in California." *Geomorphology* 189 (May): 66–80. doi:10.1016/j.geomorph.2013.01.017.

ESA PWA. 2016. Feasibility of alternatives to the Goat Rock State Beach jetty for managing lagoon water surface elevations. Prepared for the Sonoma County Water Agency.

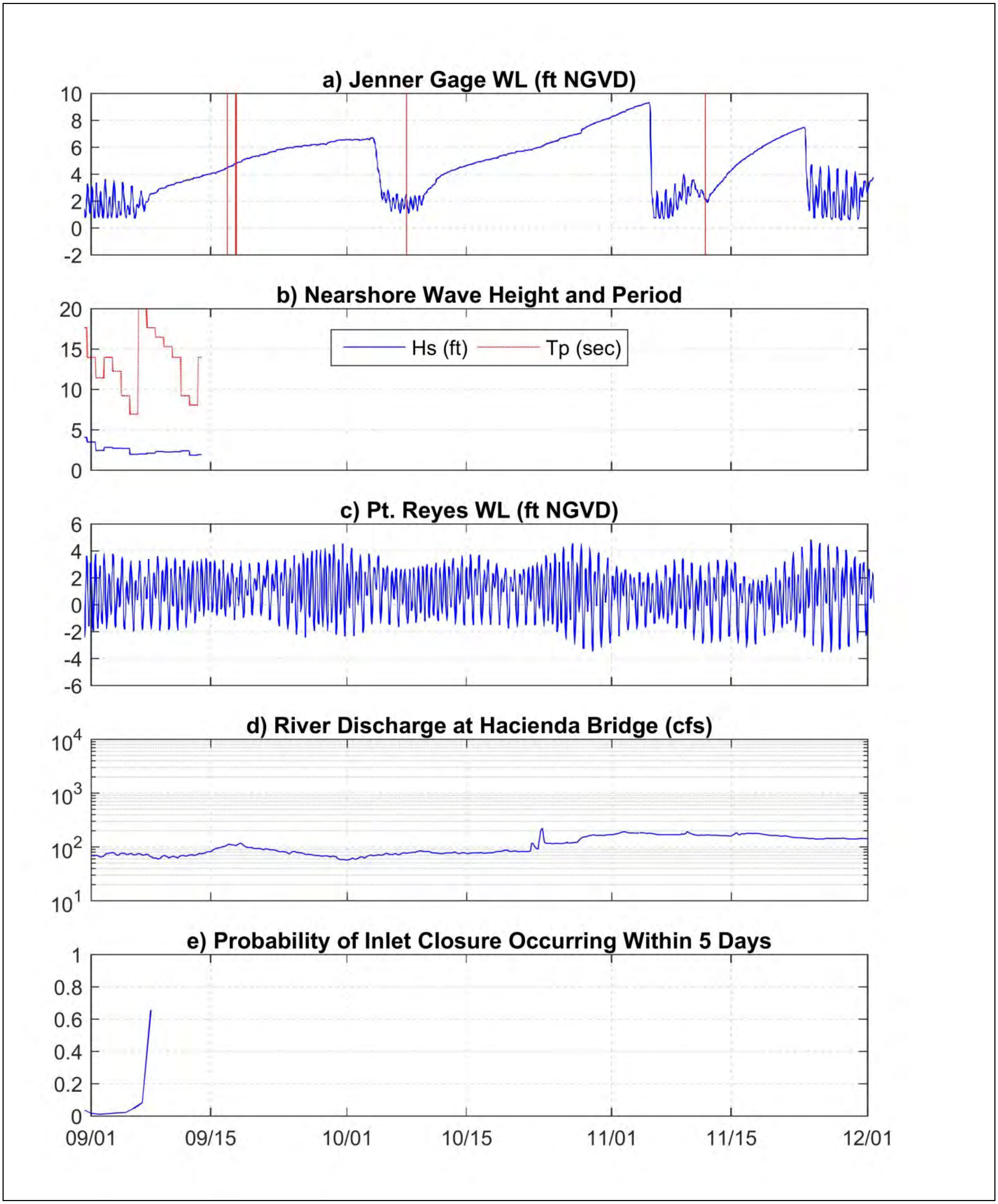
National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed.



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 1
Estuary, Ocean, and River Conditions Compared with Closure Probability: April – November 2015



SOURCE:
a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 2
Estuary, Ocean, and River Conditions Compared with Closure Probability: September – November 2015

SOURCE: SCWA

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 3

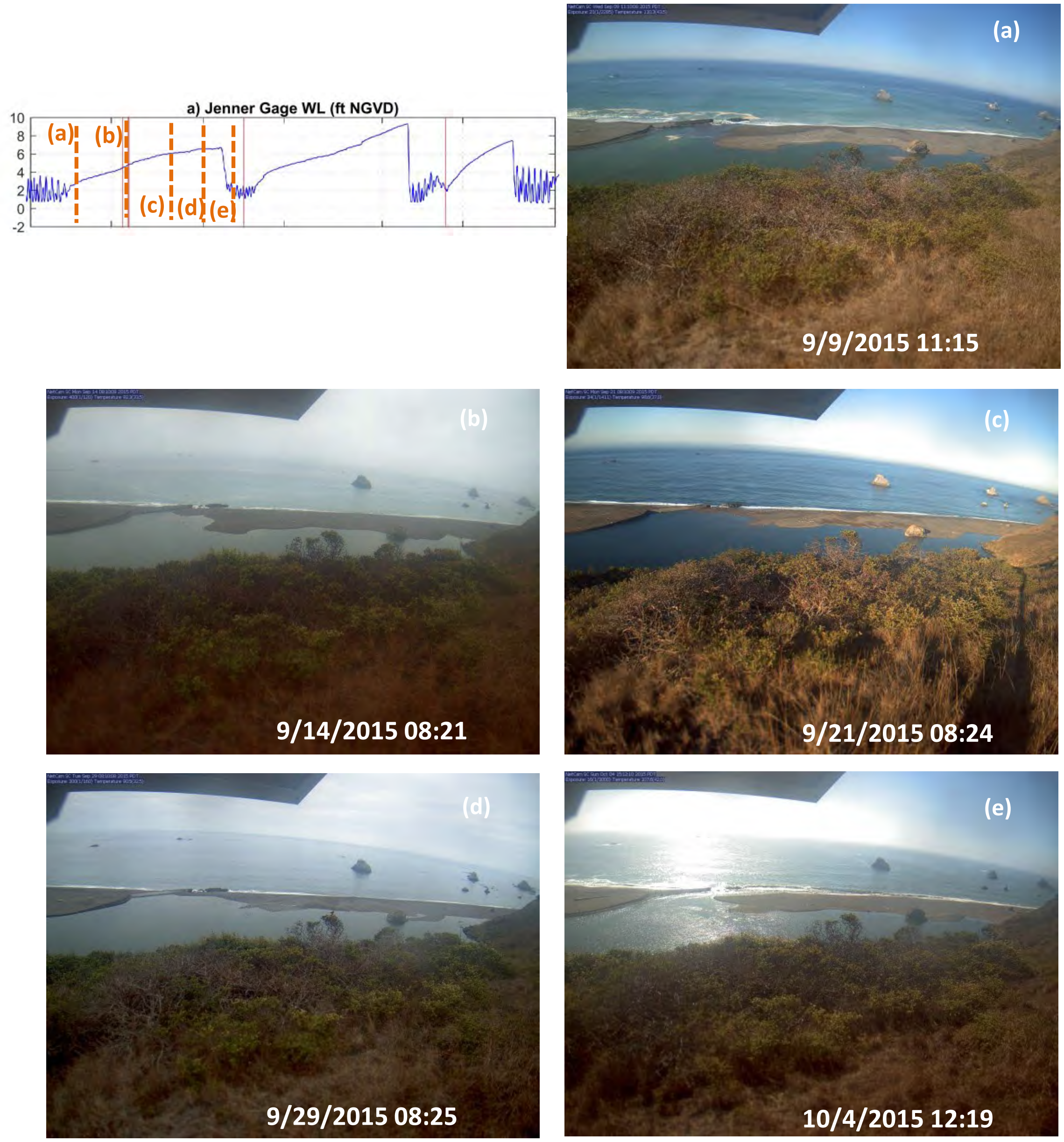
General location of pilot channel excavations for artificial breaching

a)

b)

SOURCE: SCWA camera

Russian River Estuary Outlet Channel Management Plan.
DW01958.06 **Figure 4**
Blocked Beach Access During Closures
a) June 4, 2015 b) September 29, 2015



SOURCE: SCWA camera

Figure 5

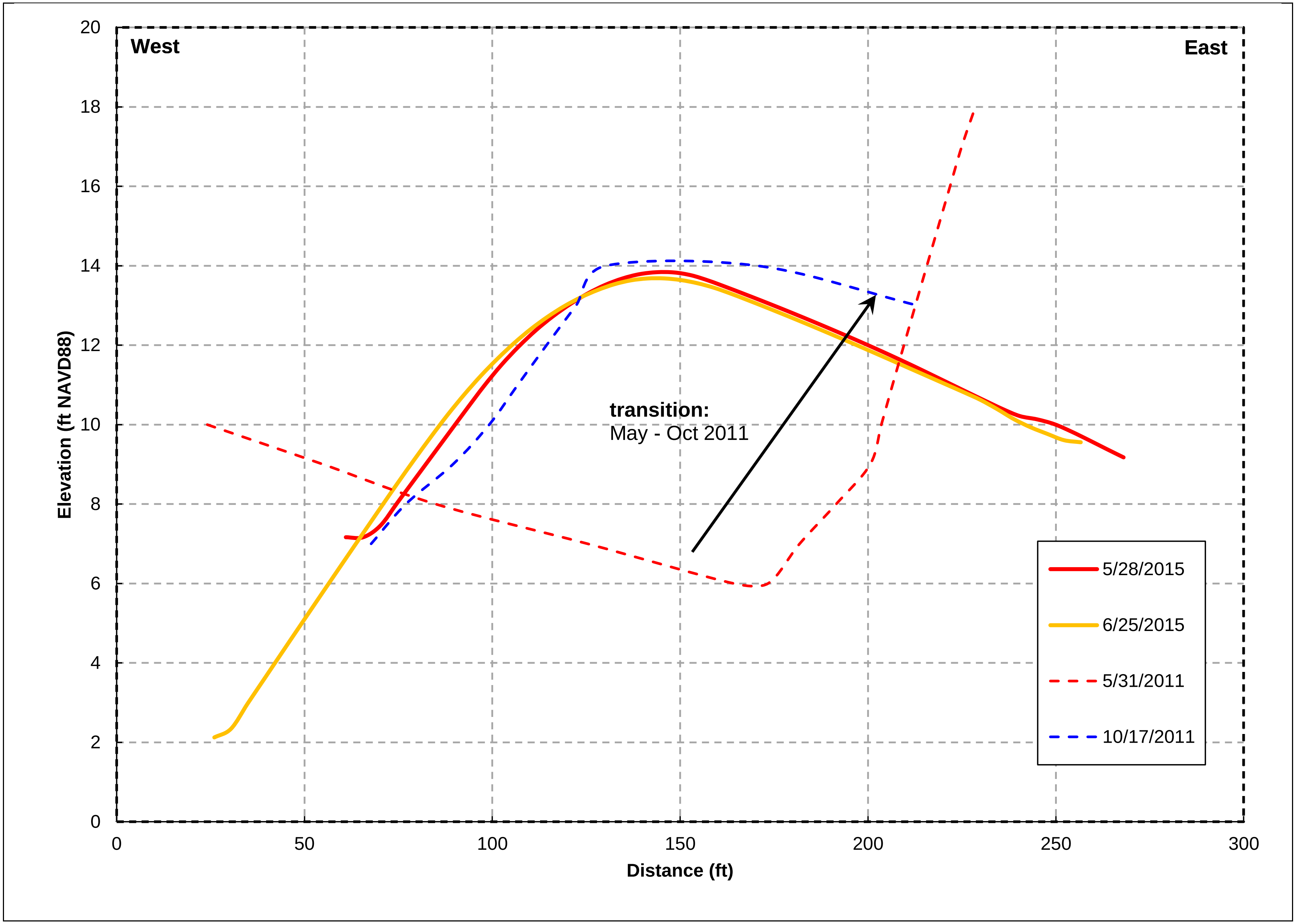
Russian River camera photographs showing some of the key morphologic influences during the September-October 2015 closure event.

SOURCE: image from USDA NAIP

Russian River Estuary Outlet Channel Management Plan . DW01958

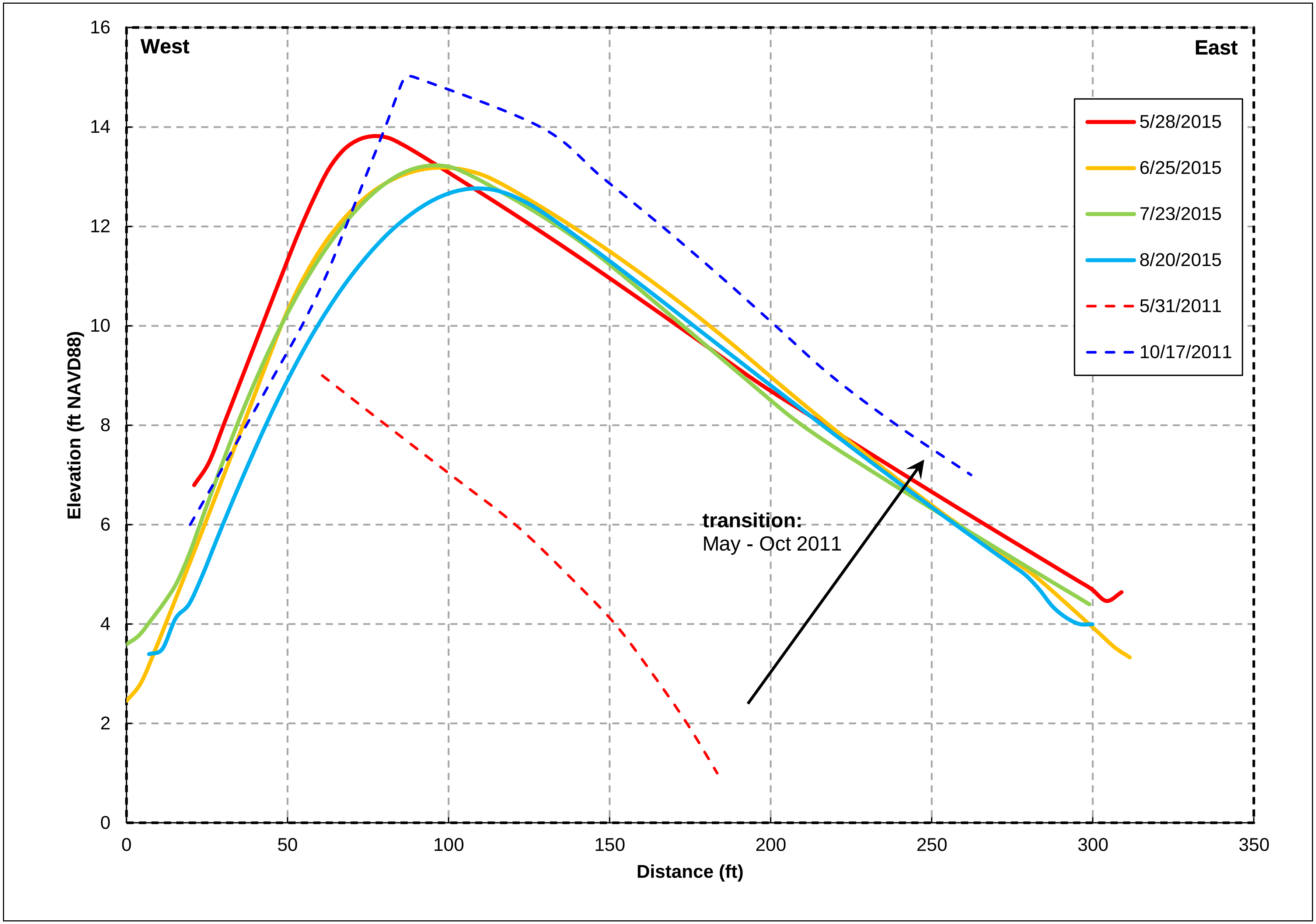
Figure 6

Beach Transect Locations



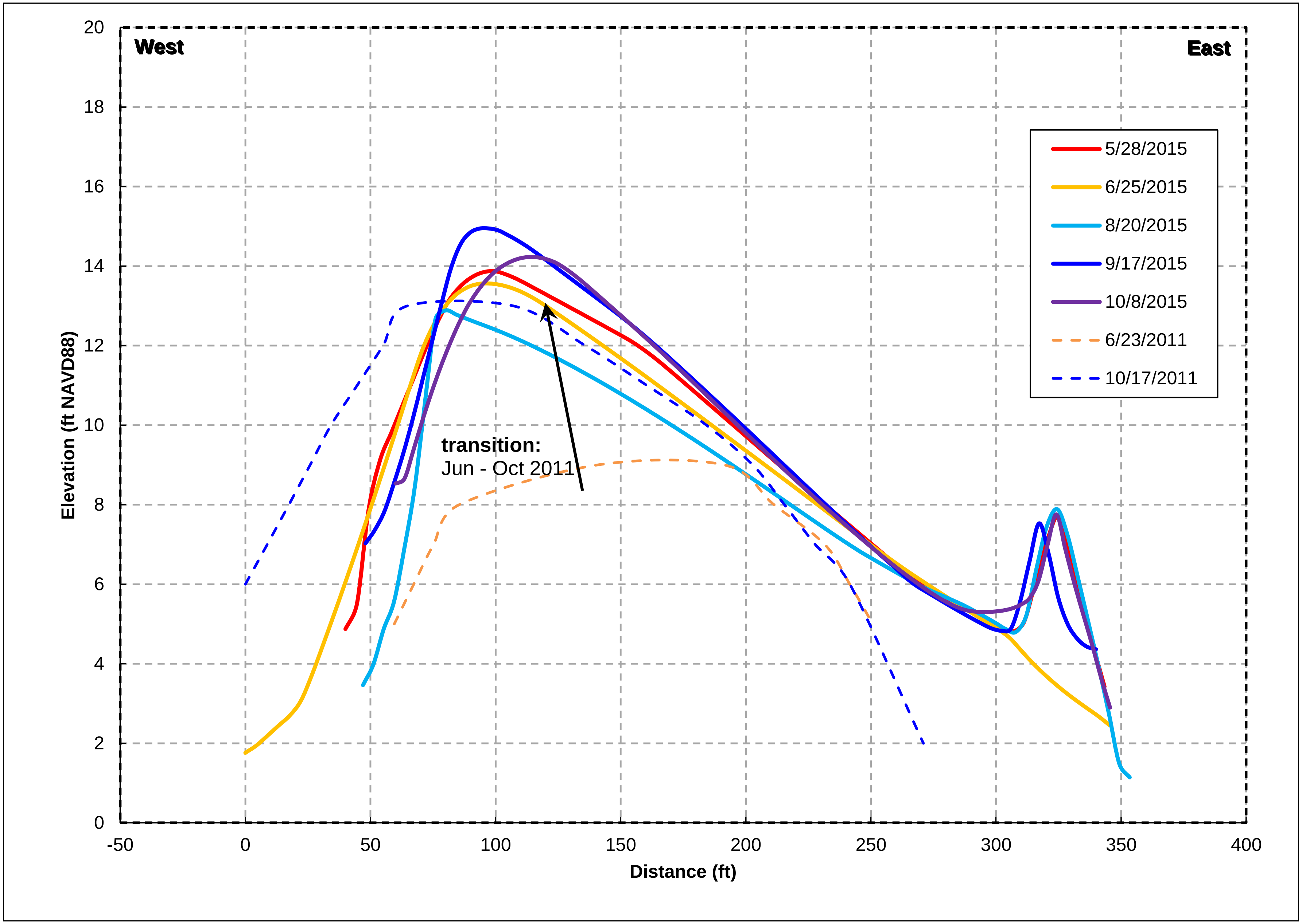
SOURCE: SCWA survey data

Figure 7
Beach Transect #4



SOURCE: SCWA survey data

Figure 8
Beach Transect #3

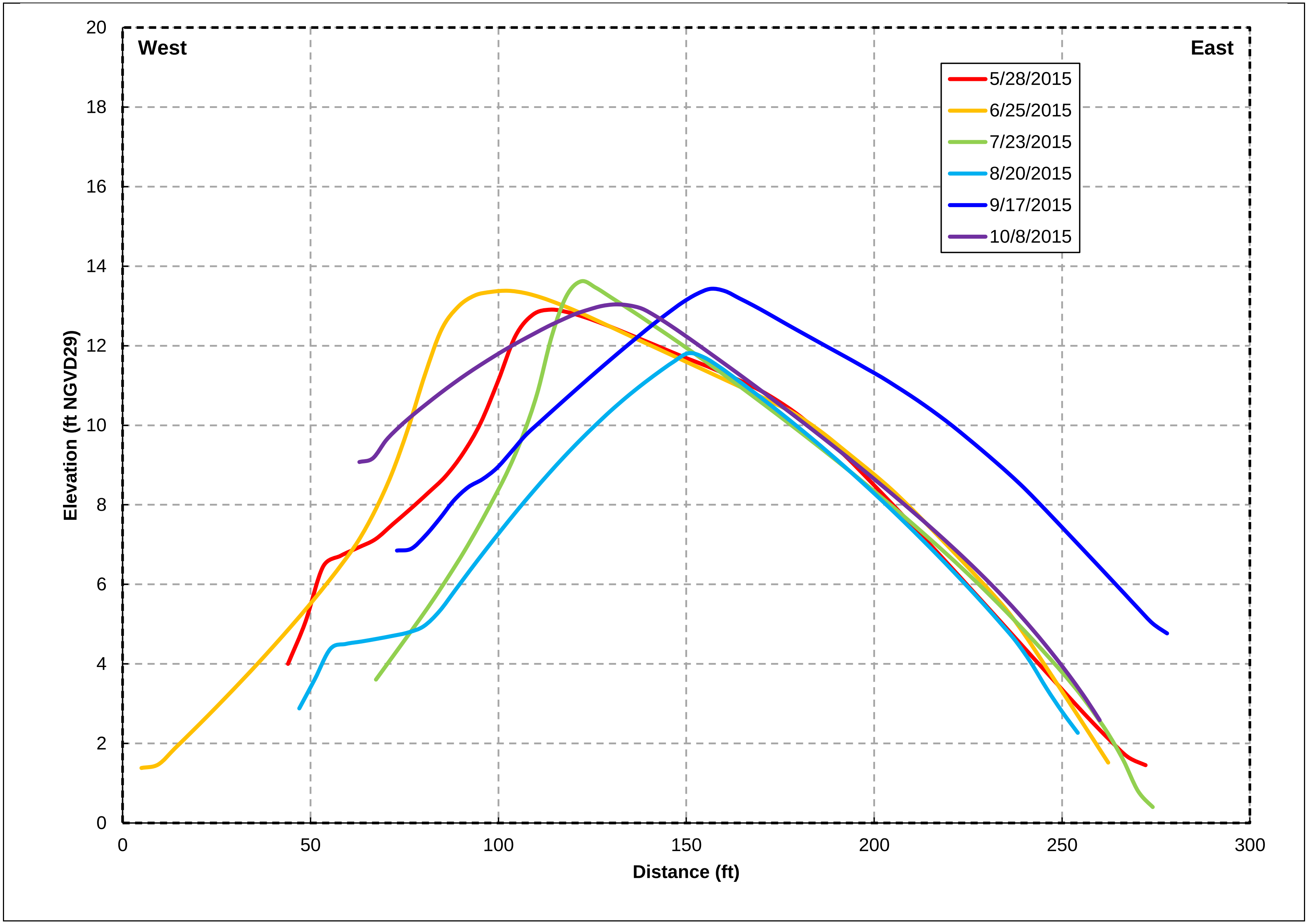


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 9

Beach Transect #2

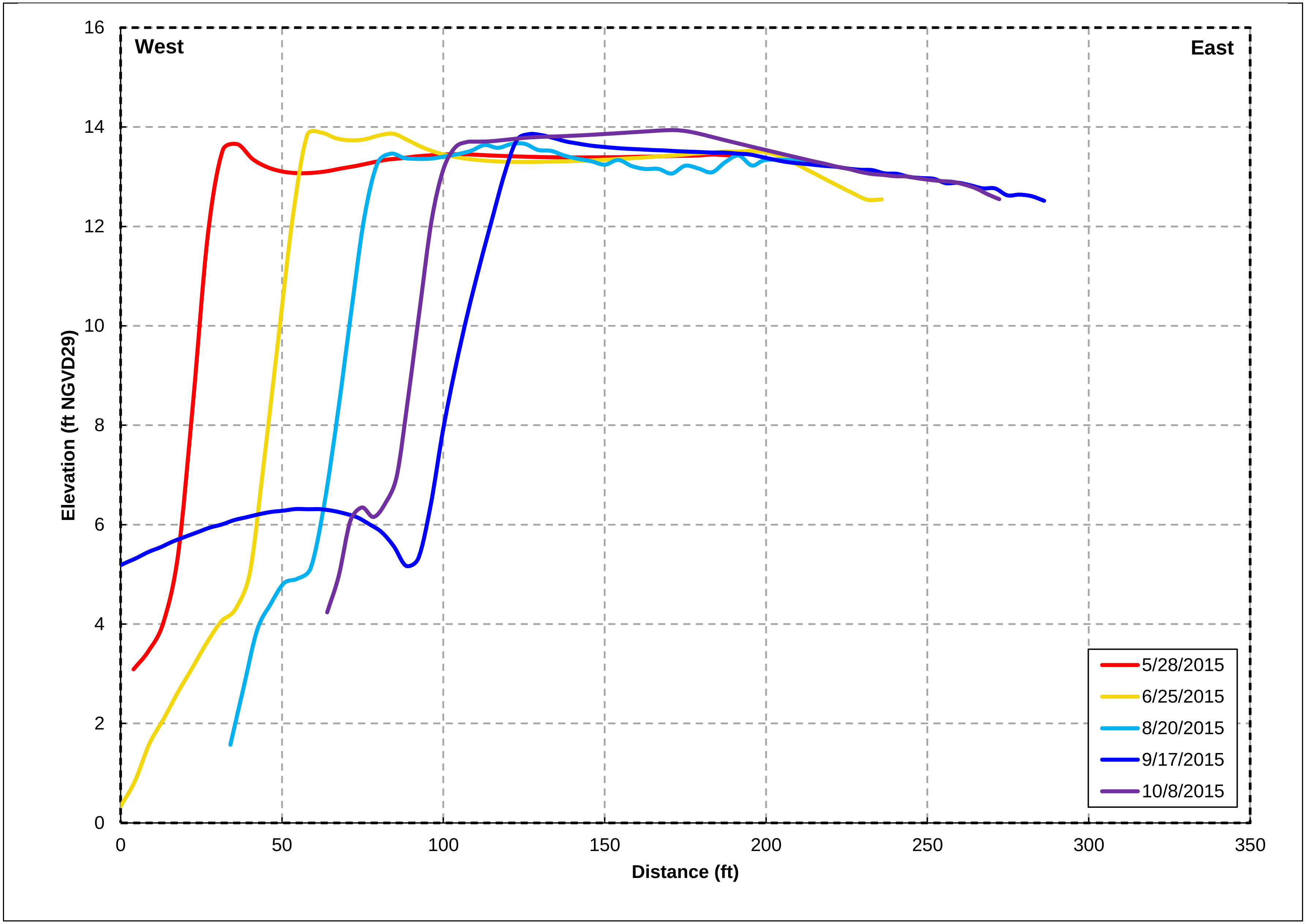


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 10

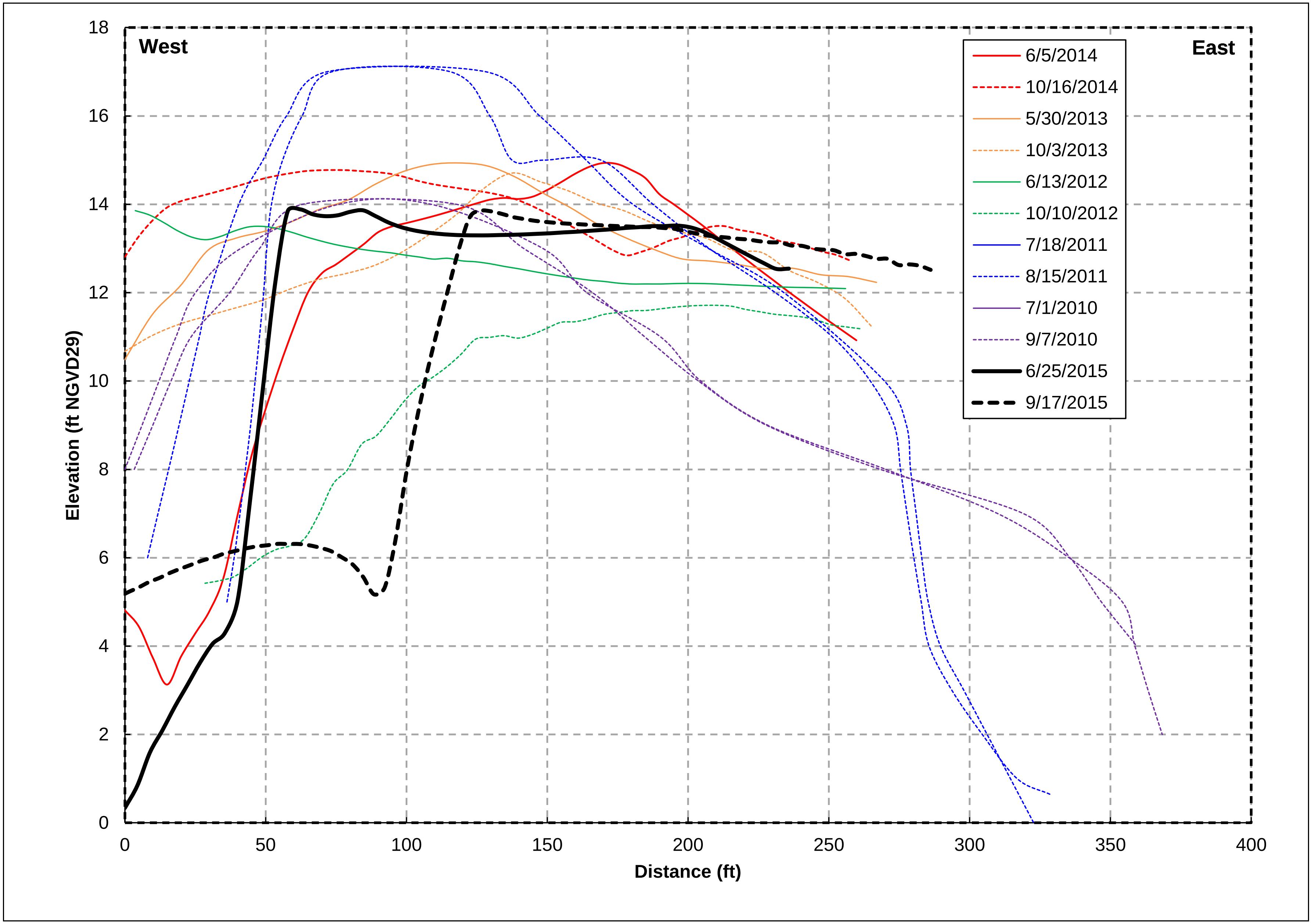
Beach Transect #1



SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

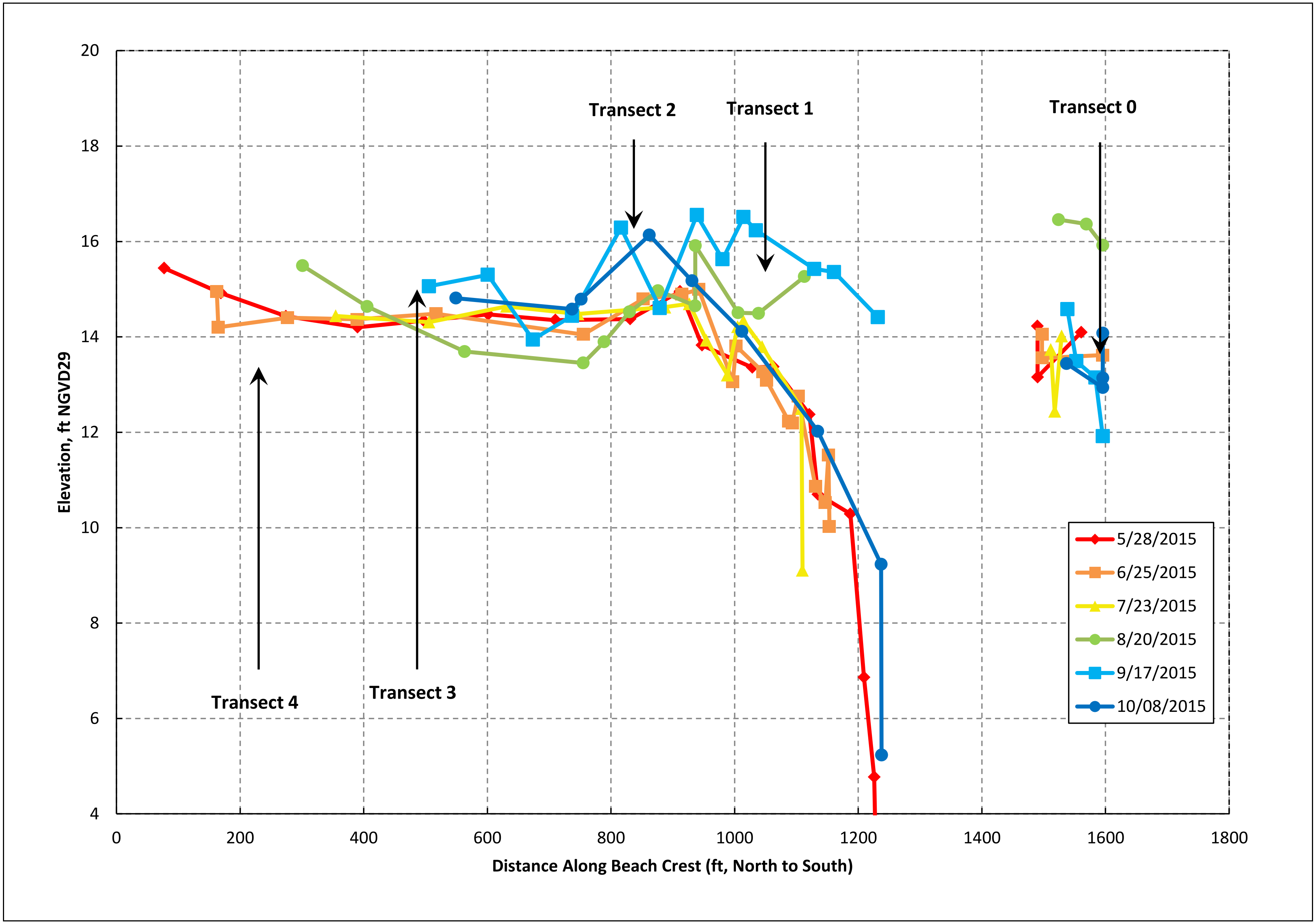
Figure 11
Beach Transect #0.



SOURCE: SCWA survey data

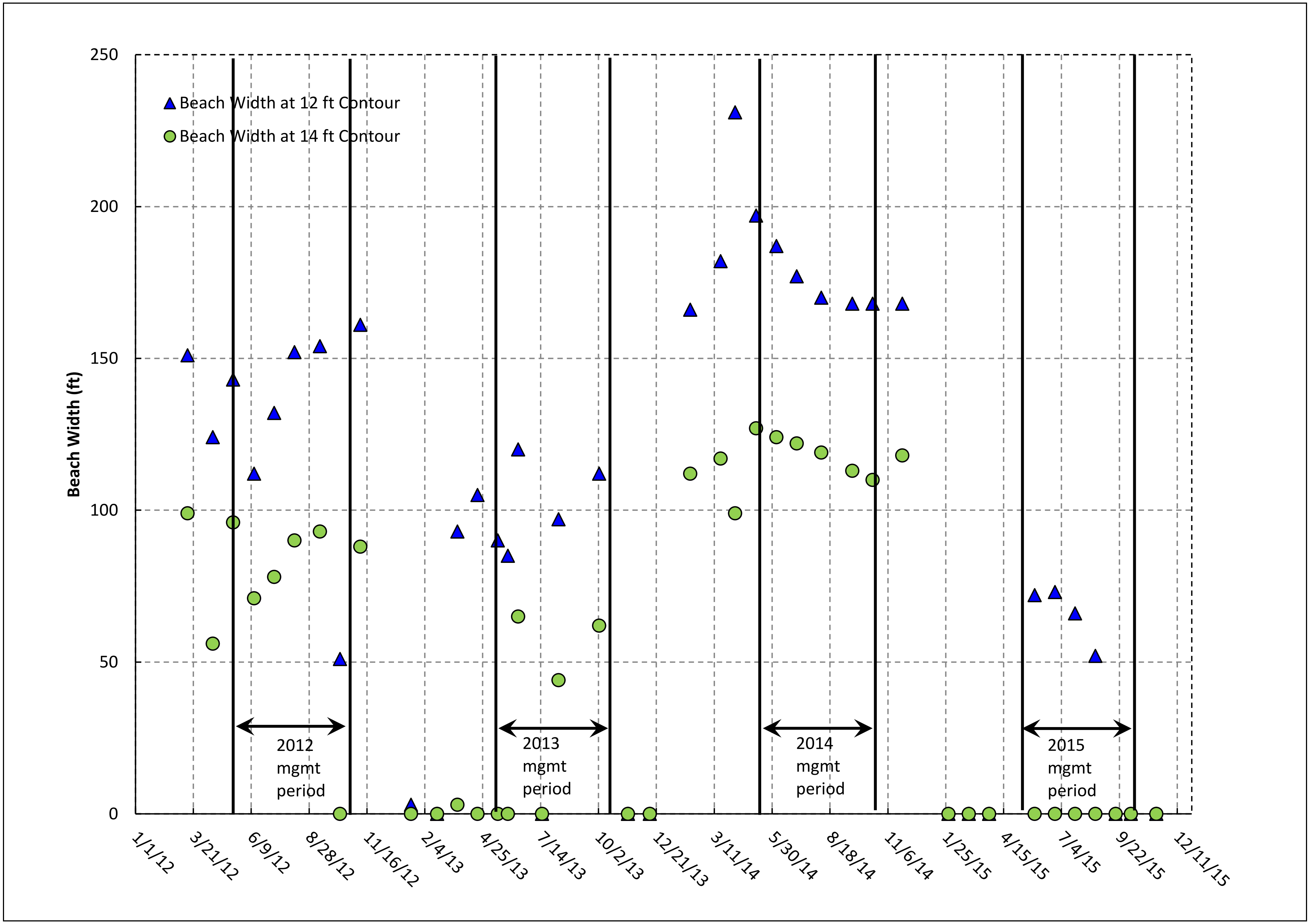
Figure 12

Beach Transect #0 from 2010-2015 management periods.



SOURCE: SCWA survey data

Figure 13
Beach Crest Profiles During the 2015 Management Period.

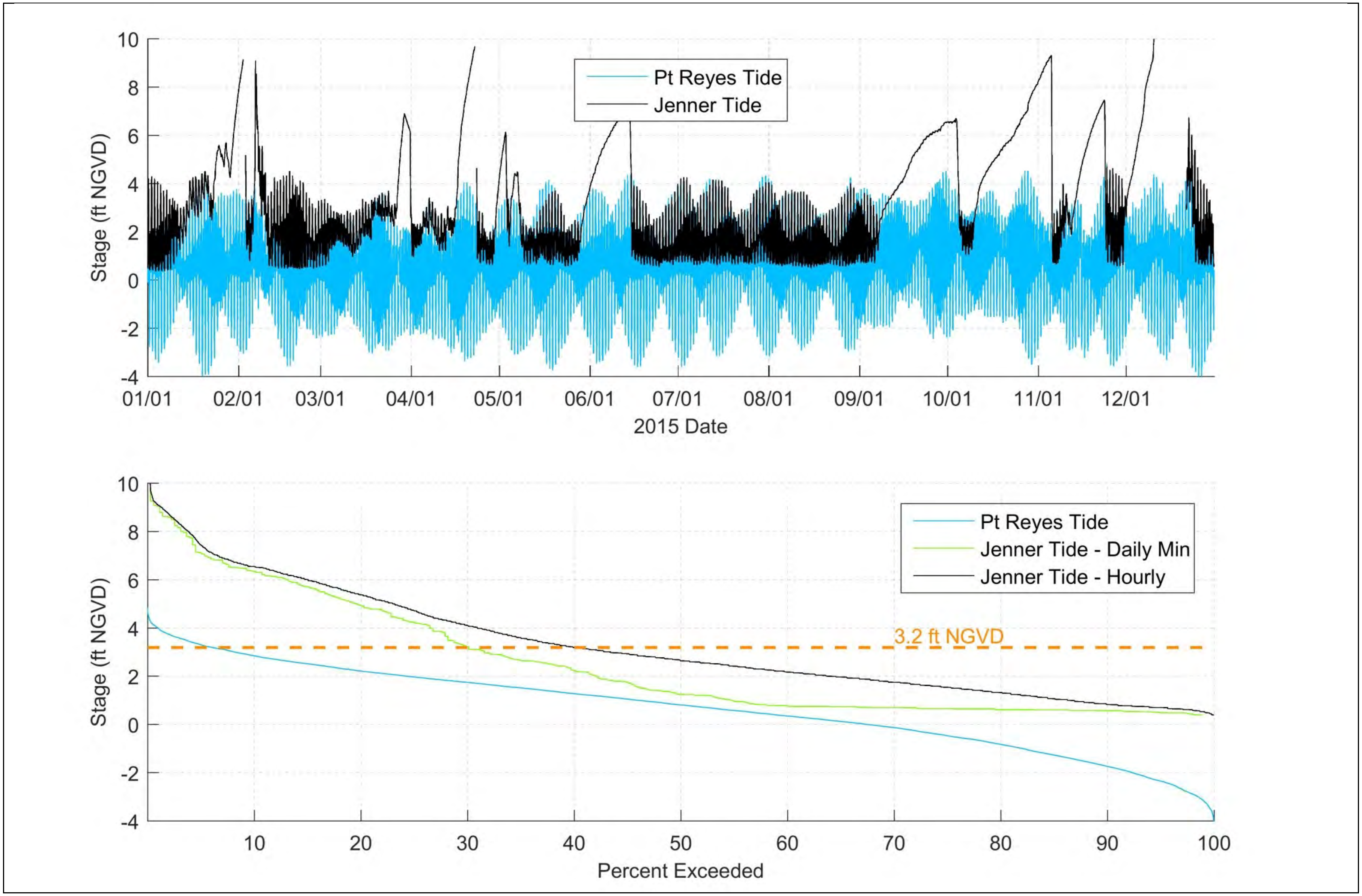


SOURCE: SCWA survey data

NOTE: width of zero indicates that the beach crest is below the elevation of 12 or 14 ft NGVD.

Figure 14

Beach Width During 2012-2015 Management Periods.



SOURCE: SCWA Jenner Gage and NOAA Pt Reyes tide data

Figure 15
Russian River Estuary stage exceedance for 2015.

Attachment L. Physical Processes During the 2016 Management Period

As required by the Russian River Biological Opinion, the Sonoma County Water Agency (Water Agency) has been tasked with managing the Russian River Estuary to facilitate summer lagoon conditions to improve salmonid rearing habitat. To meet this goal, the Biological Opinion calls for creating an outlet channel while also maintaining the current level of flood protection for properties adjacent to the estuary (NMFS, 2008). The adaptive management plan, described in the main body of this report, was developed by the Water Agency with assistance from ESA PWA and the Resource Agency Management Team in 2009 and revised annually from 2010 to 2016. Because of permit constraints, the Water Agency was only able to implement the plan beginning in 2010. Under the revised plan, an outlet channel was attempted twice in 2016, on June 7th and June 27th. In both instances, water flowing through the outlet channel scoured the channel and, within a day, caused self-breaching of the barrier beach.

During the 2016 management period, May 15th to October 15th, Water Agency staff regularly monitored current and forecasted estuary water surface elevations, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. Several inlet closure events occurred early in the management period: June 1st–7th, June 15th–27th, and July 1st–12th (Figures 1-3). Two additional inlet closure events occurred later in the management period: September 11th-30th and October 12th-20th (this event ended after the conclusion of the lagoon management period).

When the mouth closed on June 1st, flows at the Guerneville gauge were measured at 260 cfs, and these had tapered to 222 cfs by June 7th, when the outlet channel was excavated. The outlet channel was excavated approximately 580 feet northwest of the jetty (Figure 4), angled to the northwest, with a bottom width of approximately 25 feet, a channel length of approximately 230 feet, and a channel bottom elevation of 7 feet NGVD[1]. The estuary water surface elevation at the time of completion was 7.75 feet at the Jenner Visitor's Center, and the ocean tide level was approximately 1.9 feet and rising. The excavation was planned during rising tides in anticipation of rising tides conveying sand into the channel and thereby reducing the potential for self-breaching. Less than a day after the outlet channel excavation, the channel scoured open (Figure 5) and water surface elevations declined (Figure 2a).

Riverine flows continued to decline into June, and although waves were generally moderate, neap tide conditions in mid-June preceded another closure event on June 15th. Flows at the time of closure were measured at 193 cfs, and had declined to 151 cfs by June 27th. Excavation was implemented early on the morning of June 27th. The outlet channel was excavated approximately 80 feet north of the jetty (Figure 4), angled to the northwest and parallel to the jetty, with a bottom width of approximately 20 feet, a channel length of approximately 150 feet, and a channel

[1] All subsequent elevation measurements are also in NGVD (National Geodetic Vertical Datum).

bottom elevation of 7 feet (as measured by Water Agency surveyor staff). The estuary water surface elevation at the time of completion was 7.7 feet, and the ocean tide level was approximately 2 feet and declining. By the afternoon, the outlet channel was scoured open and self-breached (Figure 5), such that estuary water surface elevations had declined quickly and the estuary became tidal (Figure 2a).

The mouth closure lasting from July 1st to July 12th happened at lower flows (110-140 cfs), but self-breached when water surface elevations were just over 6 feet, before an outlet channel could be implemented.

As with most years from 2010 to 2015, the mouth remained open for the remainder of July and August. The next closure event occurred on September 11th, during a period of neap tides and relatively low-height (less than 4 ft), long-period (greater than 15 seconds) swell wave conditions. Flows were 95-140 cfs at the Guerneville gage during this closure event. A steep drop in topography adjacent to the jetty made the beach north of the jetty inaccessible to excavation equipment, and the mouth self-breached at a water surface elevation of 8.3 ft on September 30th. The only remaining closure event during the 2016 management period occurred on October 12th. The Guerneville discharge was 145 cfs at closure. Increasing flows and strong wave overwash contributed to rapid rise in estuary water surface elevation, and the mouth was artificially breached on October 20th, after the end of the management period, with estuary water surface elevation at 8.3 ft.

Apart from having two outlet channel implementations, the 2016 management period was also notable for having several periods of muted tidal conditions (tide range less than 1 ft). These occurred for roughly ten days prior to the June 1st closure event, and for approximately two weeks after the July 13th self-breach. Wave conditions were generally moderate at the beginning of both conditions, with heights below 5 ft and periods below 14 seconds, although both began during neap tidal conditions. Figure 3 illustrates the channel shape during both periods, as indicated by the Water Agency's time-lapse camera operated by the Bodega Marine Laboratory (BML).

METHODOLOGY

This review of the 2016 outlet channel management period examines estuary water levels, ocean wave conditions, ocean water levels, riverine discharge, and beach topography, as well as inlet size and location. The sources for these parameters are listed in Table 1. These data were supplemented with personal observations and discussion with staff from the Water Agency, National Marine Fisheries Service (NMFS), California Department of Fish and Wildlife (CDFW), and BML.

Table 1. Data Sources

Parameter	Source
Estuary water level, ft NGVD (h_E)	Water Agency Jenner gauge
Wave height (H_s), period (T_a), and direction	CDIP Cape Mendocino buoy #094
Ocean water level (h_O)	NOAA Point Reyes #9415020
Russian River discharge (Q_f)	USGS Guerneville #11467000
Beach topography, ft NGVD	Water Agency monthly surveys
Inlet size and location	Water Agency autonomous camera (operated by BML)

INLET STABILITY PARAMETER AND CLOSURE PROBABILITY

In addition to considering individual parameters, researchers at BML have developed a combined parameter to evaluate the stability of the inlet's state. This stability parameter is then used to predict closure (Behrens et al., 2013). Note that the inlet stability parameter does not differentiate between full closure and the perched conditions with an outlet channel. When discussing this parameter, both states are referred to as a 'closure' in that tides are prevented from propagating into the estuary. The inlet stability parameter presented by Behrens et al. (2013) considers the daily balance between wave-driven sediment import to the inlet and sediment export driven by tidal fluctuations. The wave-driven import is assessed using nearshore wave estimates derived from a transformation matrix and offshore buoy data (ESA PWA, 2016) and the latter is estimated from tide gauge data within the estuary and a stage-storage relation derived from the available bathymetry. Using daily-average values of the stability parameter within the period 1999-2008, Behrens et al. (2013) showed that the stability parameter correlates with the probability of the inlet closing within five days. As the percentile of the stability parameter increases, the probability of inlet closure within five days increases exponentially, from probability of roughly five percent when the parameter is at the 50th percentile to a probability of 80 percent when it is measured at the 99th percentile.

SUMMER AND FALL CONDITIONS

Time series of estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 1 for the entire 2016 management period. The lagoon water level time series (Figure 1a) summarizes the closure events at the beginning of the management period, as well as the subsequent tidal conditions and later closure events in fall. During the management period, Russian River flows were higher in 2016 than the previous drought years, 2013-2015. As shown in Figure 1d, flows at Guerneville did not drop to 100 cfs until the end of July, which was more than a month later than in 2015, and two months later than in 2014. In August, flows increased to just above 100 cfs and remained above that for the rest of the management period.

As in prior years, wave heights declined through July and August (Figure 1b). However, in prior years closure events typically coincided with either moderately high waves (greater than 6 feet) having periods greater than 10 seconds, or with neap oceanic tide ranges of less than approximately 5 feet. Although all five closure events in the 2016 management period occurred during neap tidal conditions, wave heights were generally less than 5 feet. Although less than 5 feet high, in all cases the waves were long-period swells, with periods of 12-17 seconds. Waves with longer periods are more effective at transporting sand on to shore and into the inlet.

CLOSURE PROBABILITY

The 5-day closure probability, a derivative of the inlet stability parameter described above, was hindcast for 2016 according to the method described in Behrens et al. (2013). This hindcast provides an indication of the utility of the stability parameter as a prediction tool for monitoring inlet conditions and planning management action. This parameter integrates wave and ocean forcing conditions, as well as estuary water levels, to provide greater predictive skill than just waves or ocean tides on their own. The predicted probability of closure exceeded 50% 2-5 days in advance of most of the closures in 2016 (Figure 1e).

TOPOGRAPHIC CHANGE

The Water Agency has conducted monthly surveys of Goat Rock State Beach that cover a region starting from the groin and extending approximately 1,500 feet to the north. The surveys do not include bathymetry within the inlet because flow conditions in the inlet prevent safe access. Also, the survey extent can be limited by the Water Agency’s compliance with its marine mammal incidental harassment authorization, which sets guidelines for the survey crew’s approach to marine mammals hauled out on the beach. Water Agency survey staff collect spot elevations using RTK-GPS and then assemble these elevations into a set of contour lines at 1-ft intervals, as well as profiles along the beach berm crest, the ocean wetted edge, and the estuary water line. The survey elevations are reported in the NGVD29 vertical datum.

To characterize beach berm topographic conditions, ESA PWA assessed data from the Water Agency’s 2016 surveys. Transects, whose location is shown in Figure 6, include two transects backed by cliff (Figure 7 and Figure 8), two transects that extend into the estuary (Figure 9 and Figure 10), and a transect just north of the groin (Figure 11).

In the spring before the 2016 management period, the beach crest elevation in the northern most part of the beach reached about 18 ft (Transect 3 in Figure 7 and Transect 4 in Figure 8). For the remainder of the management period, the northernmost transects underwent little morphologic change, similar to this region from 2012 to 2015. Transects 3 and 4 typically undergo morphologic changes when the inlet migrates north during floods and returns south to the jetty groin in spring or summer. In 2010 and 2011, inlet migration in this area led to a sequence of erosion and accretion at these sites during the management period. The erosion seen in those years was associated with inlet migration and subsequent accretion of the beach was associated with long-period swell waves. During the 2012 to 2015 management periods, the inlet remained near the groin and did not migrate north beyond Haystack Rock, leading to stable profile at Transects 3 and 4. In 2016, the inlet again migrated as far as Haystack Rock during high flows in March and April, but it returned to the groin by May, allowing the beach at the northern end to build up under energetic waves during the spring season before the management period. Thus, the beach shape at Transects 3 and 4 were as stable as from 2012 to 2015. This suggests that the northern portion of the beach will be stable during the management period when it has not been eroded by the inlet during the prior winter and spring.

Since the inlet migrated between Haystack Rock and the jetty prior to the 2016 management period, this southern stretch of the beach underwent growth throughout the management period. This is reflected in the profiles at Transect 2 (nearest to Haystack Rock) and Transect 1 (immediately north of the jetty). These are shown in Figures 9 and 10, respectively. This type of seasonal growth is apparent in previous years, and is expected as wave energy increases seasonally in the fall. The beach crest at Transect 1 grew approximately 3-4 feet from June to July, and was then stable through the rest of the season (Figure 10). The beach crest at Transect 2 grew approximately 4 feet from May to July, and was stable afterwards. When waves began to increase in size and period in the early fall, the beach grew an additional 1-1.5 feet, as shown by the September and October profiles (Figure 9).

Transect 0, which is located parallel to the groin, had a stable shape throughout the 2016 management period, but the western beach face shifted slightly eastward during the management period (Figure 11). This may be a response to steady erosion from the inlet, which was tidal throughout the latter half of summer. The crest remained steady at 12-14 ft NGVD29. As shown in Figure 12, Transect 0 typically sees limited change during the management period and larger inter-annual variability.

By early February 2017, substantial amounts of sand had been eroded from around the jetty, particularly around the groin. The landward end of the groin appears to have sustained damage, with rock from the groin dispersed to the adjacent beach. The amount of damage that may have occurred just in this winter is difficult to define, as there are not recent records of the groin's condition in the years just before this winter.

Beach berm crest elevations have been collected by the Water Agency since 2013. These data make it possible to discern important changes in beach shape along the length of the berm that is north of the groin. Along-beach trends in crest elevation are generally consistent with the along-beach trend of wave energy increasing to the north and the influence of inlet migration and breaching at the south end of this section of beach.

Figure 13 shows that May through September 2016, the change in crest elevation was minimal north of Transect 1. The beach crest was lowest south of Transect 3, where the inlet resided for the entire management period. Most of the change to the crest resulted from seasonal beach building by waves from May to July, and again from September to October. This may have been further encouraged by the extended closure events during this time.

BEACH WIDTH

To provide additional information about the beach morphology, ESA PWA assessed the beach width using the Water Agency survey data. Figure 14 shows the evolution of the beach width at

Transect 3 from 2010 to 2016. Beach width data were added for months outside of the management period to add context for seasonal changes. In previous years during winter months, the beach was often eroded at Transect 3 (north of Haystack Rock) to the point that the beach crest was below 12 ft NGVD, so that the width was effectively zero. This was the case in 2010, 2011, 2013, and 2015. The beach was widest in 2012 and 2014, when the mouth generally remained farthest to the south. These years also experienced the highest beach crest heights at Transect 3 (Figure 14). As already noted, the mouth migrated as far north as Haystack Rock in 2016, but returned south in April and May, allowing the northern section of the beach to remain in place. The beach width was greater than 160 feet and the crest was higher than 18 ft NGVD for the entire management period, making it difficult to implement an outlet channel north of Haystack Rock in 2016.

JENNER WATER SURFACE ELEVATION EXCEEDANCE

The Biological Opinion (NMFS, 2008) sets a target for estuary water levels "a daily minimum water surface elevation of 3.2 feet [NGVD] during 70% of the year." To facilitate this target, the Biological Opinion notes "Absent river flood flows and historic mechanical breaching practices, NMFS expects cross shore transport of sand by wave action will be sufficient to maintain the bar at this elevation."

In 2016, the daily minimum water surface elevation exceeded 3.2 ft NGVD roughly 24% of the year (Figure 15). For comparison, Figure 15 also includes hourly lagoon water surface elevation (exceeded 3.2 ft NGVD for roughly 38% of the year) and hourly Point Reyes water surface elevation (exceeded 3.2 feet NGVD for roughly 5% of the year). This percent time above 3.2 feet NGVD is consistent with the inlet maintaining open conditions throughout much of 2016. As explained in previous annual updates, if the inlet does not close in late spring or early summer, it is likely that open-inlet conditions will persist until wave energy increases in September or October. The 2016 management period saw three significant closure events in early summer, but unsuccessful implementation of an outlet channel prevented these from persisting for prolonged periods of time. As a result, even with these early summer events, water level exceedances did not differ much from the long-term average (Figure 5 in Attachment J).

LESSONS LEARNED AND RECOMMENDATIONS

Based on 2016 observations of the estuary, associated physical processes, and the Water Agency's planning for outlet channel management, we note the following lessons about implementing the outlet channel management plan.

CONCEPTUAL MODEL

- During the 2016 management period, the beach 200 feet north of Haystack Rock remained stable between 17 and 19 ft NGVD. This is significantly higher than in 2015, when the inlet was observed to migrate farther north, and the beach crest ranged from 11 to 15 ft NGVD. This reinforces the idea that lack of migration can allow the beach to reach higher and more stable crest elevations

- Peak annual river discharge has remained below 43,000 cfs for 10 consecutive winters (October 2007 to April 2016) preceding the management period, a streak unmatched in the 70-year flow record. This lack of larger fluvial discharge may contribute to the predominant inlet location near the groin.
- The beach width in 2016 at Transect 3 (near Haystack Rock) was similar to 2014 and wider than in 2015. This may suggest that beach width is closely tied to inlet migration – the lack of migration north of Haystack Rock for several years prior to 2015 had previously allowed the beach to grow at this end of the littoral cell.

OUTLET CHANNEL FEASIBILITY

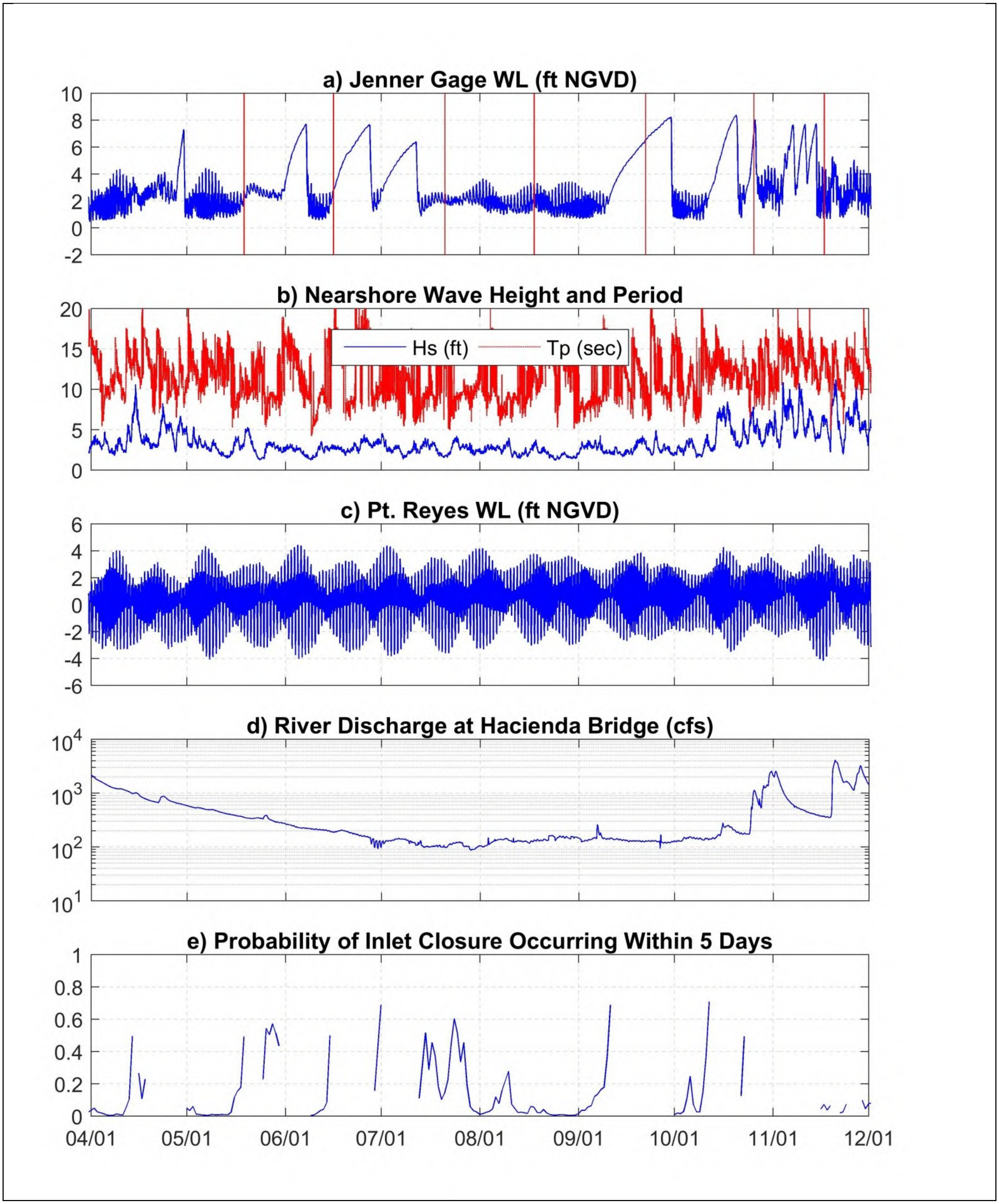
- Five inlet closure events occurred within the management period, two, 1-2 week long events in June, a 2-week long event in early July, and two, 1-3 week events in September and October. Outlet channels were excavated by the Water Agency during the first two events, but, in both cases, the outlet channel was observed to scour and self-breach within a day. The first outlet channel excavation occurred during rising ocean tides, but this was not sufficient to avoid self-breaching. The July and September events ended with self-breaches, as access was an issue due to steep beach topography adjacent to the groin. The last event led to an artificial breach, as the estuary water surface elevation approached flood stage and the event had persisted past the management period.
- Outlet channels were attempted in two locations in 2016, one within 100 feet of the groin, and another roughly 600 feet north of the groin. Siting of the outlet channels was influenced by lack of inlet migration north of Haystack Rock, which led to high (17-19 ft NGVD) crest elevations, well above the target elevation for outlet channels.

REFERENCES

Behrens, Dane K., Fabián A. Bombardelli, John L. Largier, and Elinor Twohy. 2013. "Episodic Closure of the Tidal Inlet at the Mouth of the Russian River — A Small Bar-Built Estuary in California." *Geomorphology* 189 (May): 66–80. doi:10.1016/j.geomorph.2013.01.017.

ESA PWA. 2016. Feasibility of alternatives to the Goat Rock State Beach jetty for managing lagoon water surface elevations. Prepared for the Sonoma County Water Agency.

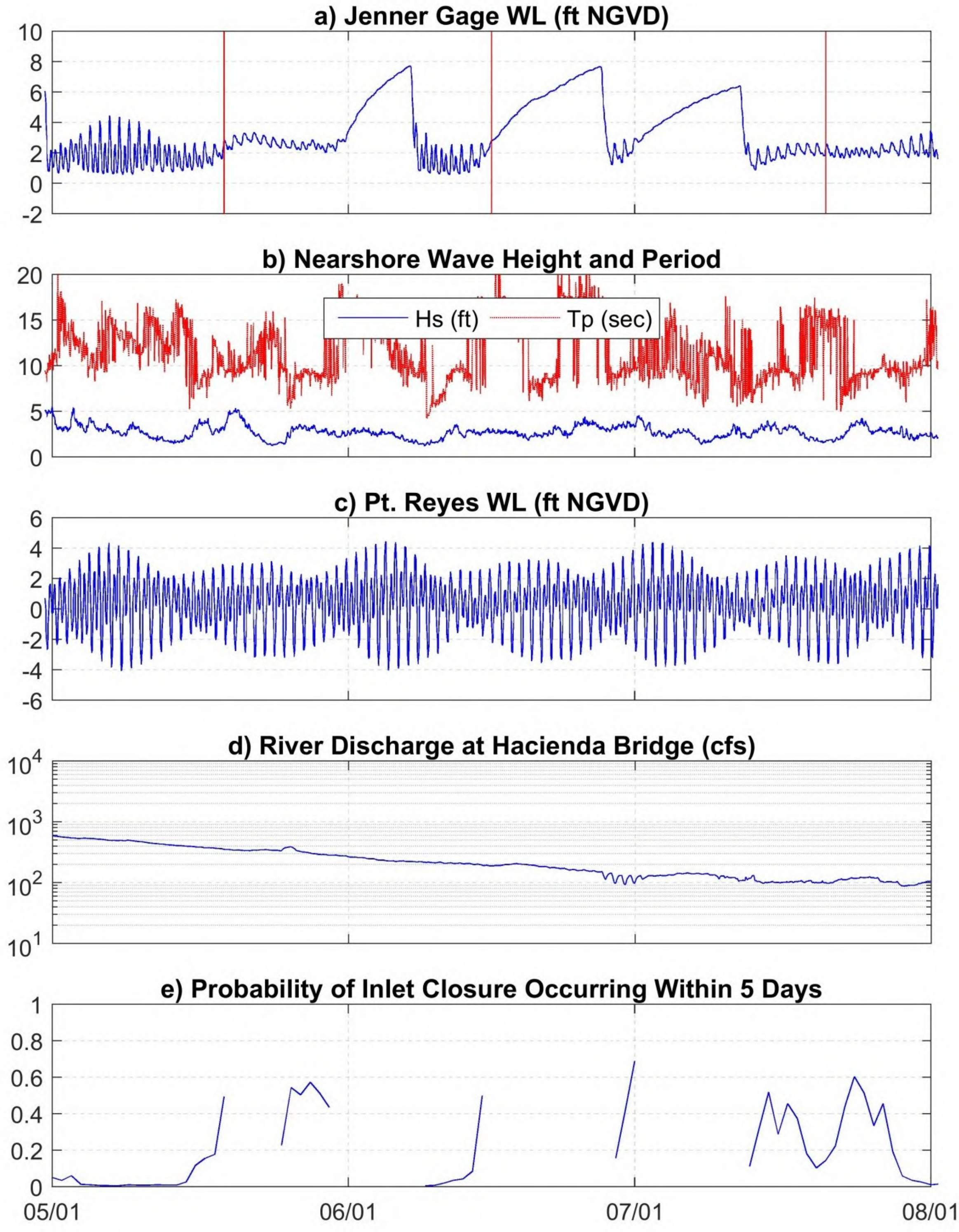
National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed.



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

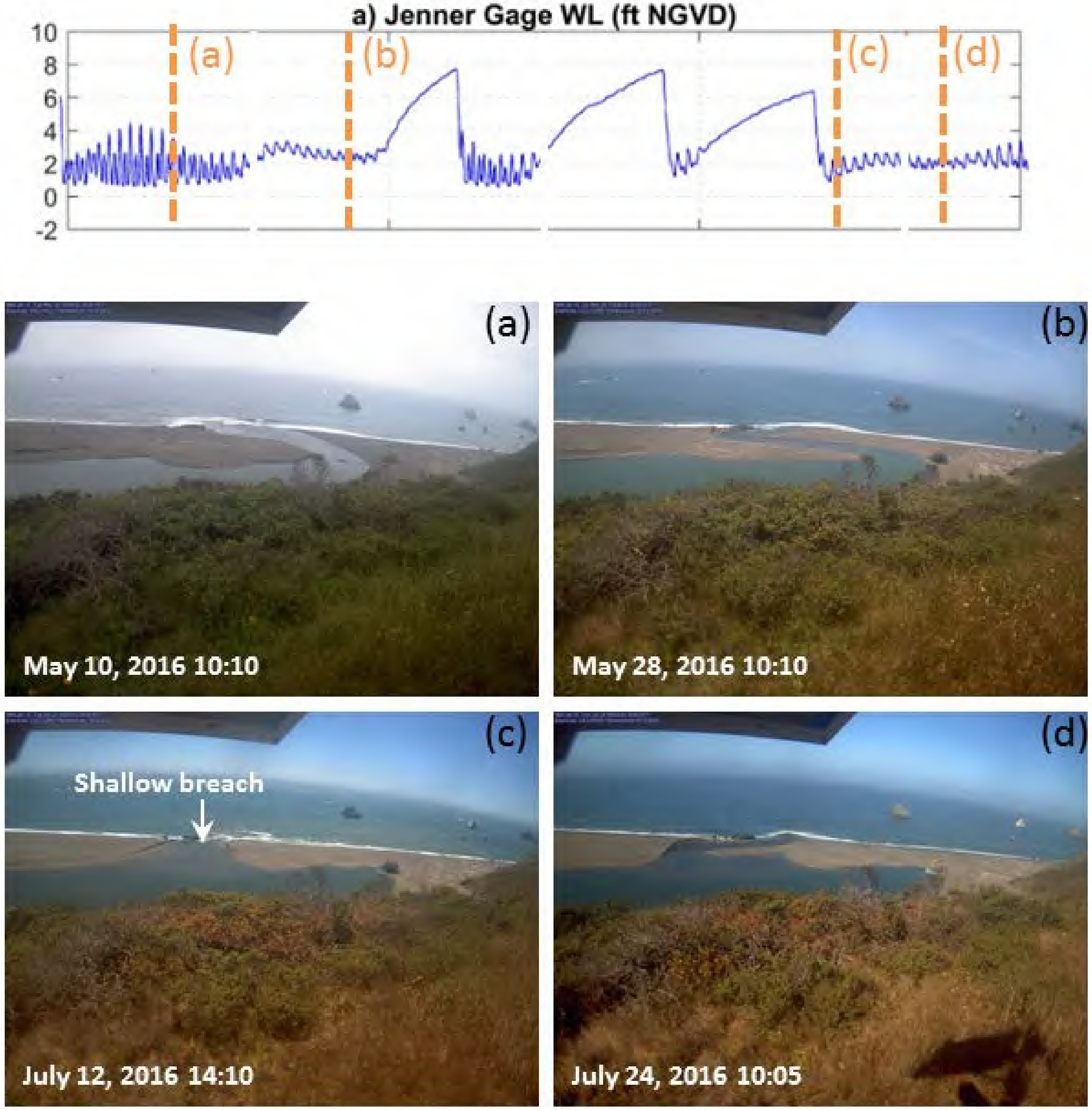
Figure 1
Estuary, Ocean, and River Conditions Compared with Closure Probability: April – November 2016



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 2
Estuary, Ocean, and River Conditions Compared with Closure Probability: May – July 2016

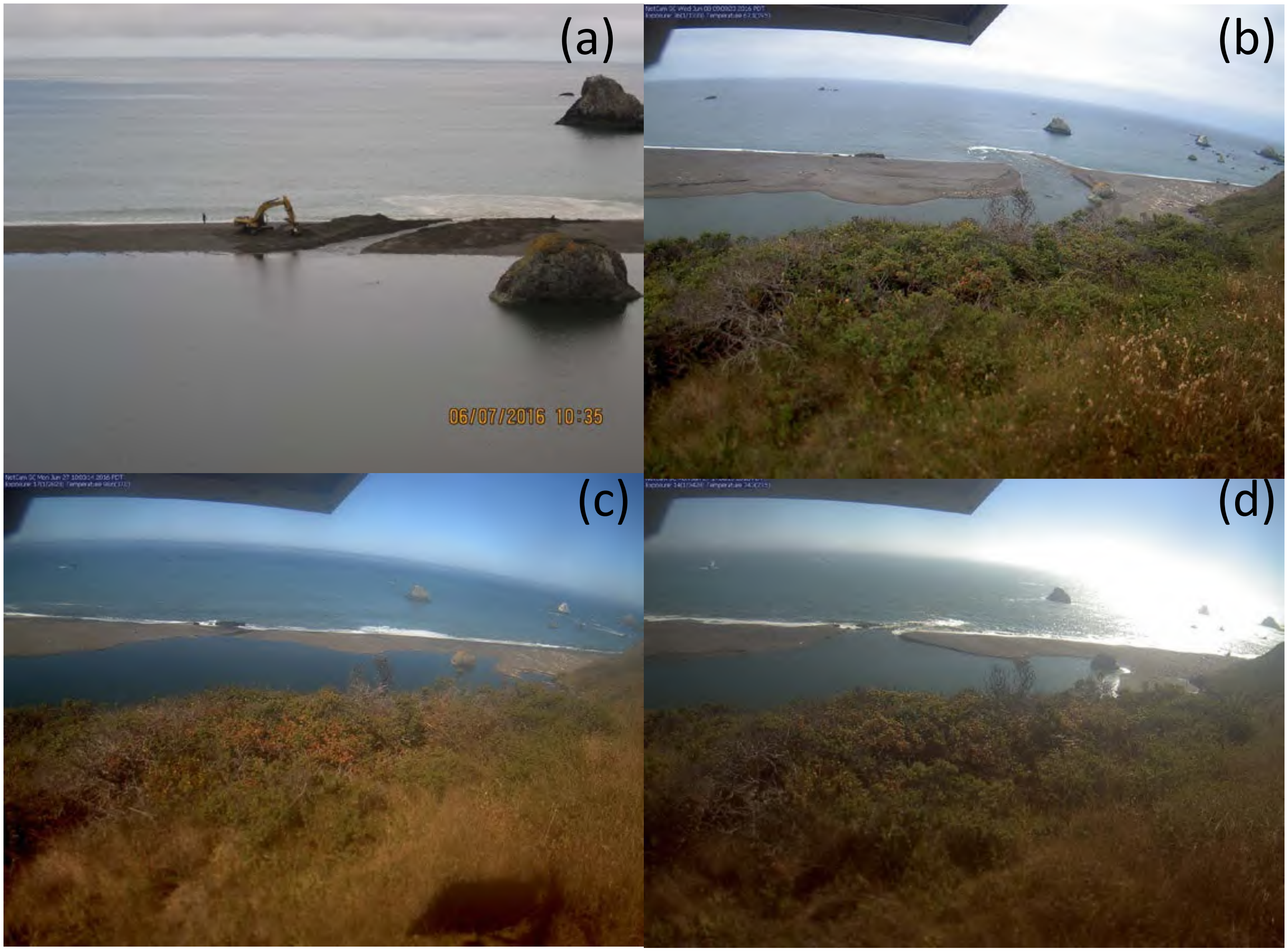


SOURCE: SCWA camera

Figure 3
Russian River camera photographs showing some of the muted tidal conditions observed in 2016.

SOURCE: SCWA

Figure 4
General location of outlet channel excavations for artificial breaching in 2016



SOURCE: BML camera

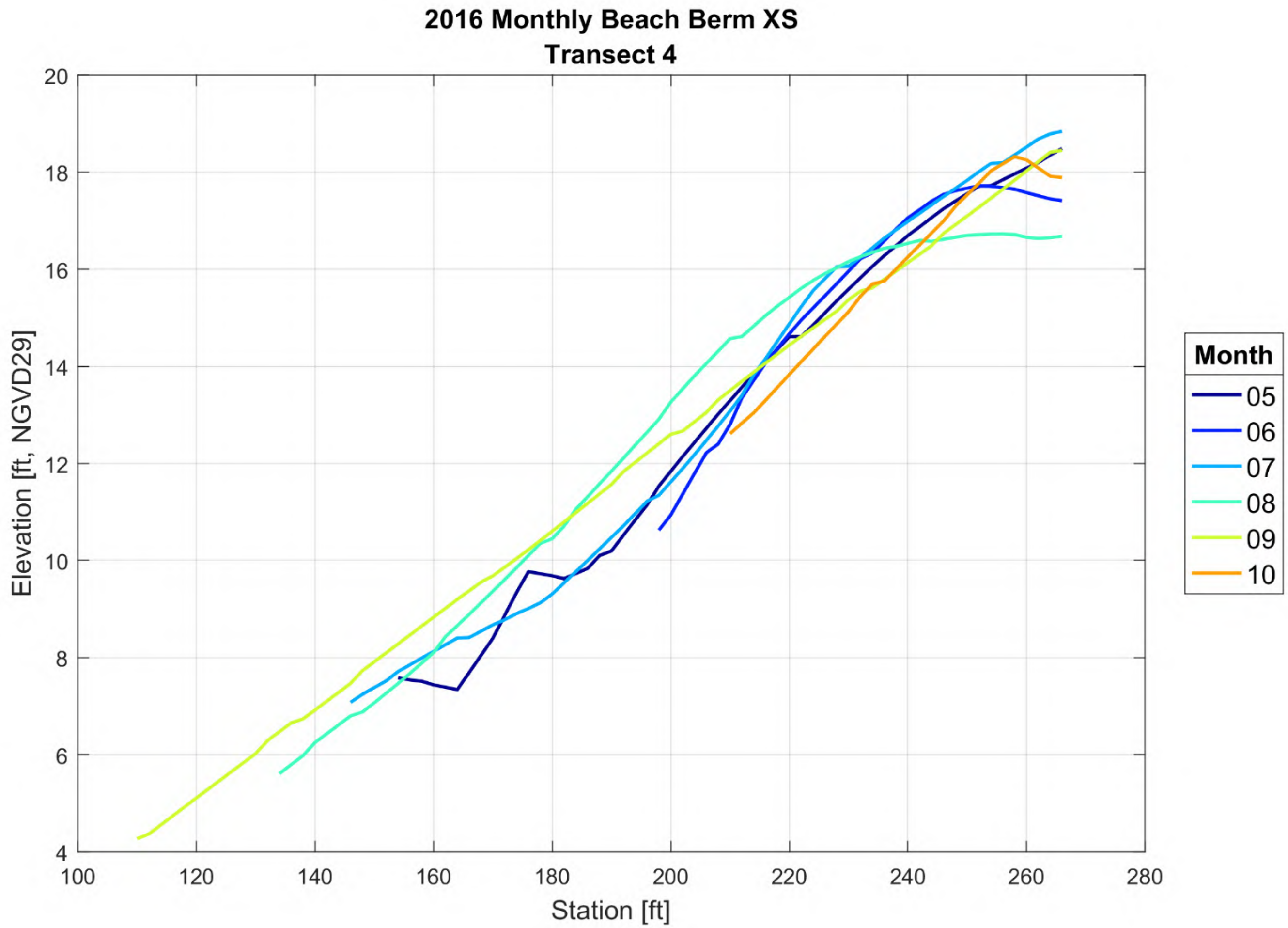
Figure 5

(a) Outlet channel after excavation on June 7th and (b) scoured inlet on June 8th, 2016. (c) Outlet channel after excavation on June 27th and (d) scoured inlet on June 27th.

SOURCE: image from USDA NAIP

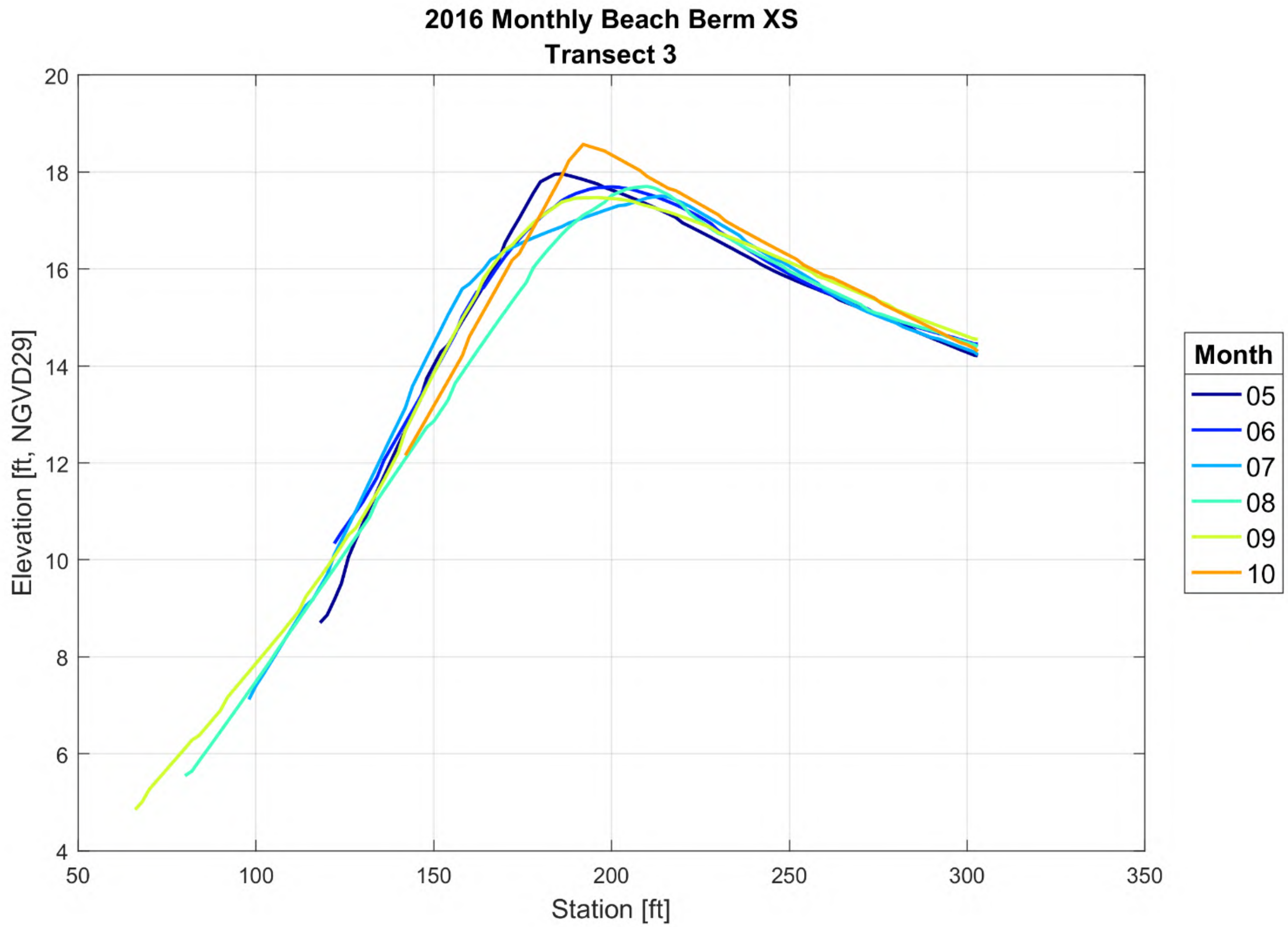
Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 6
Beach Transect Locations



SOURCE: SCWA survey data

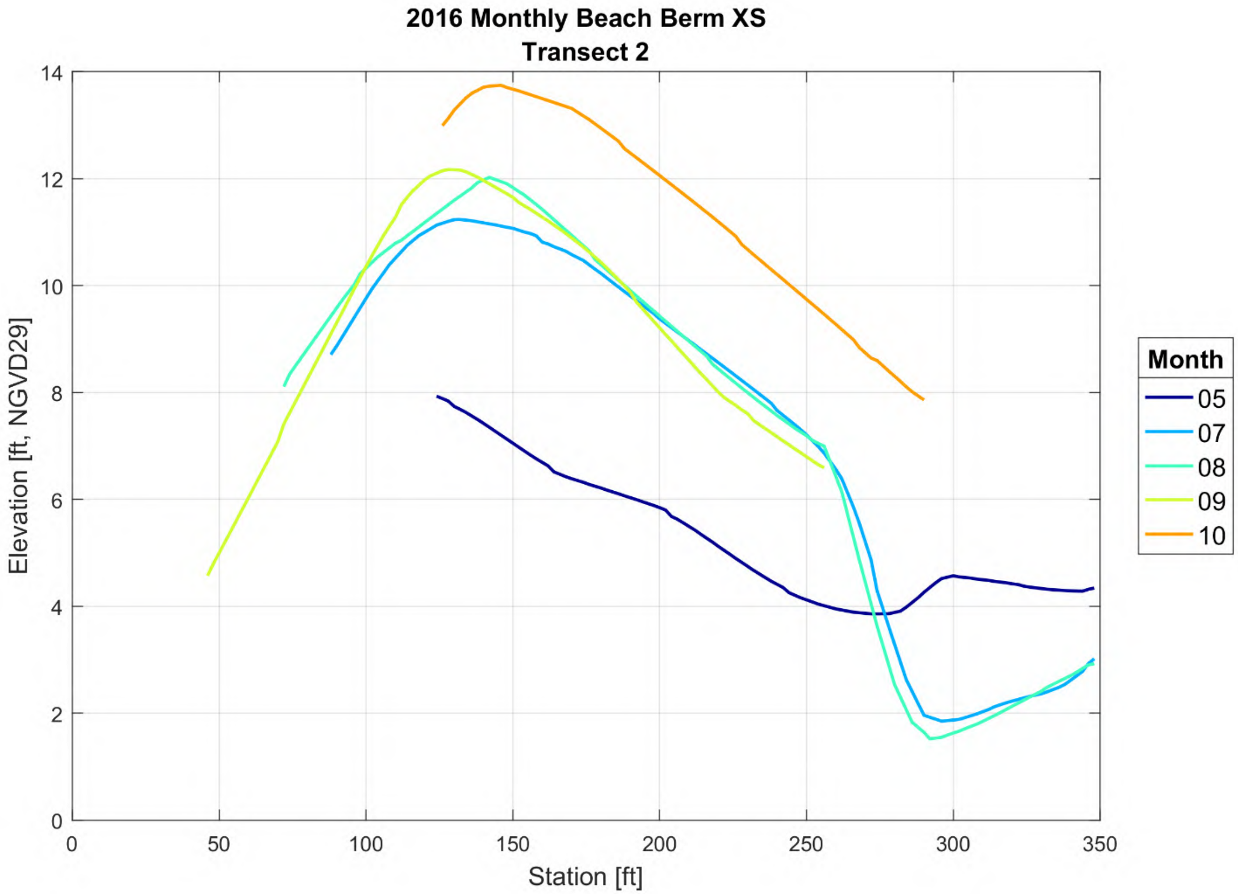
Figure 7
Beach Transect #4



SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 8
Beach Transect #3

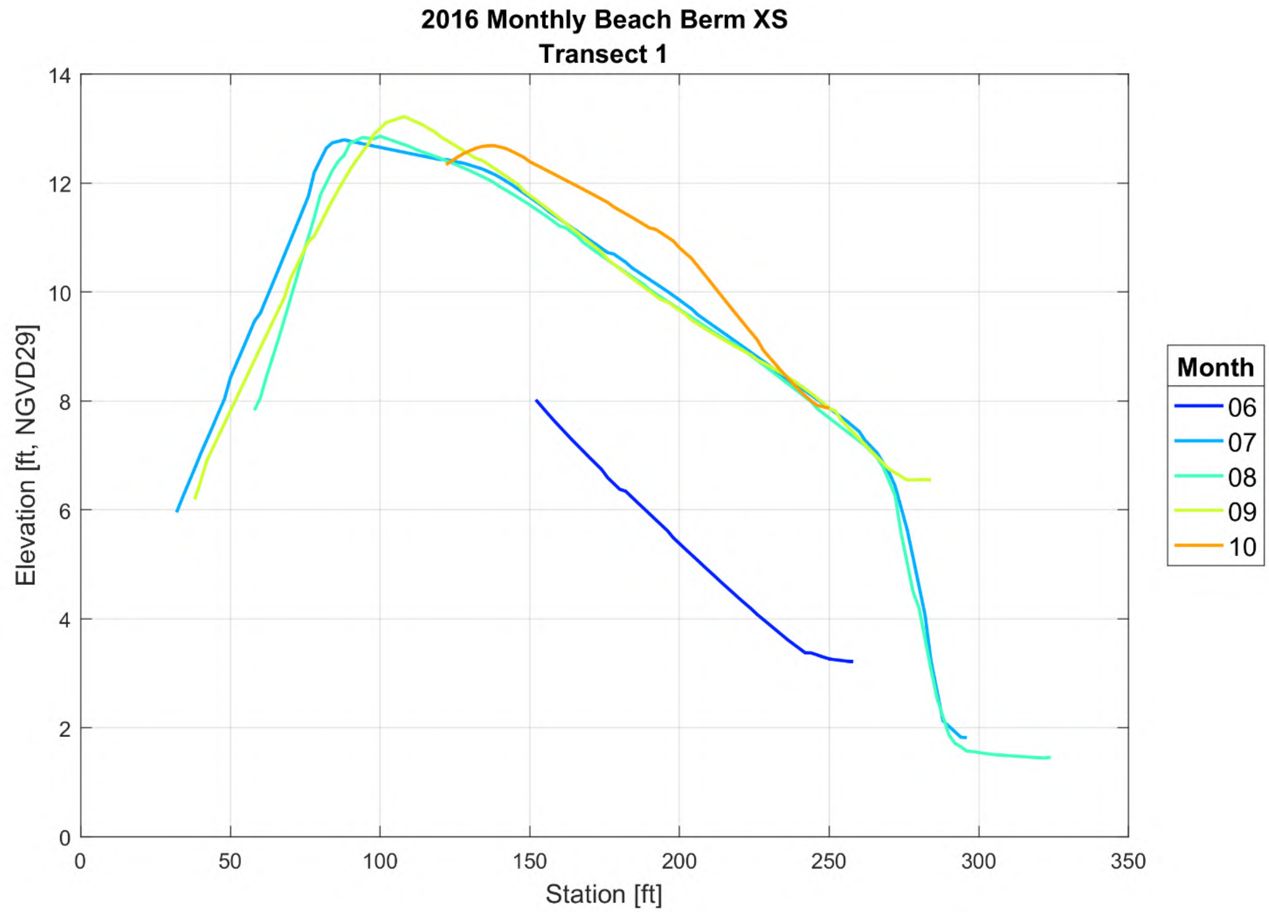


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

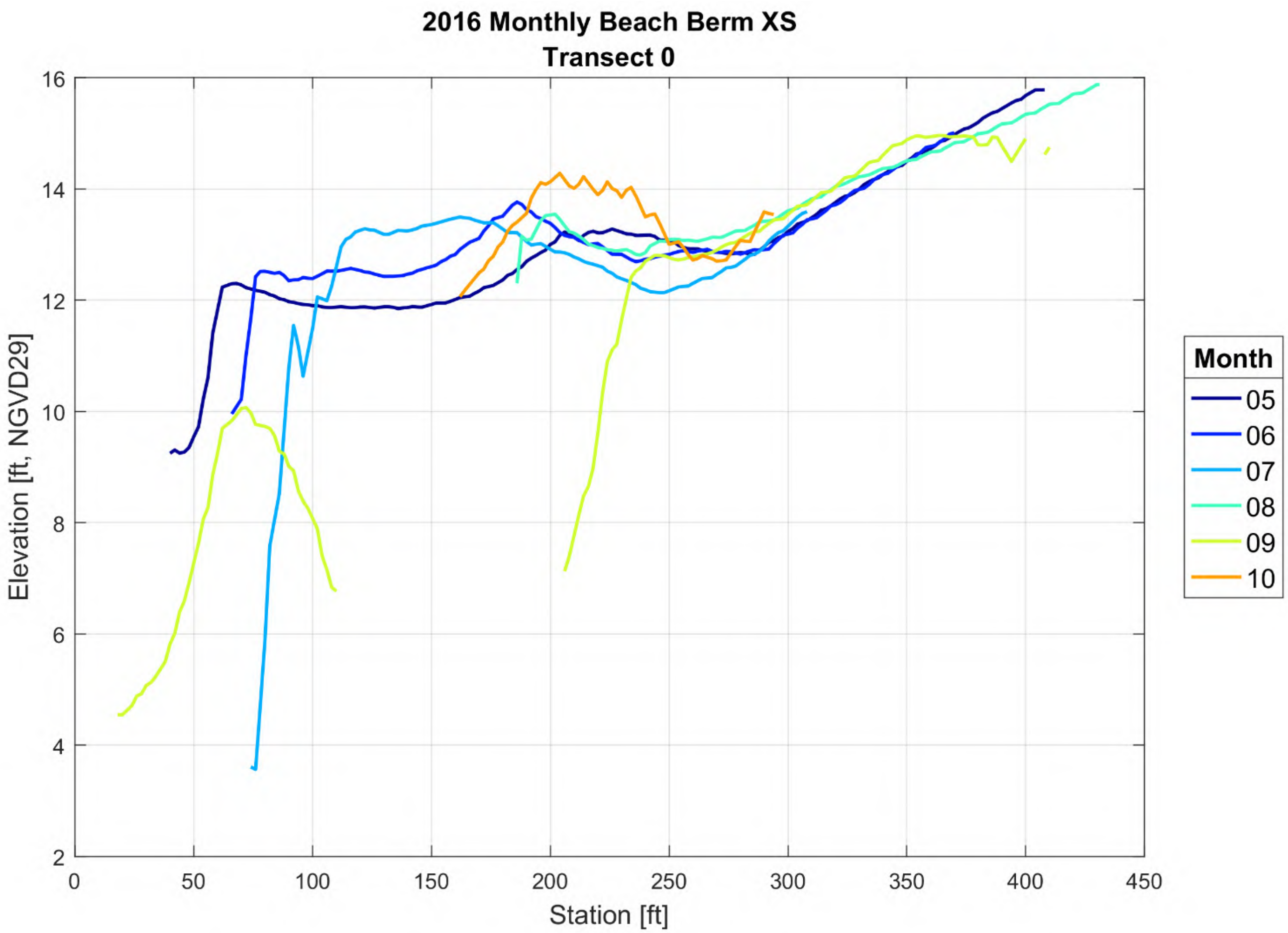
Figure 9

Beach Transect #2



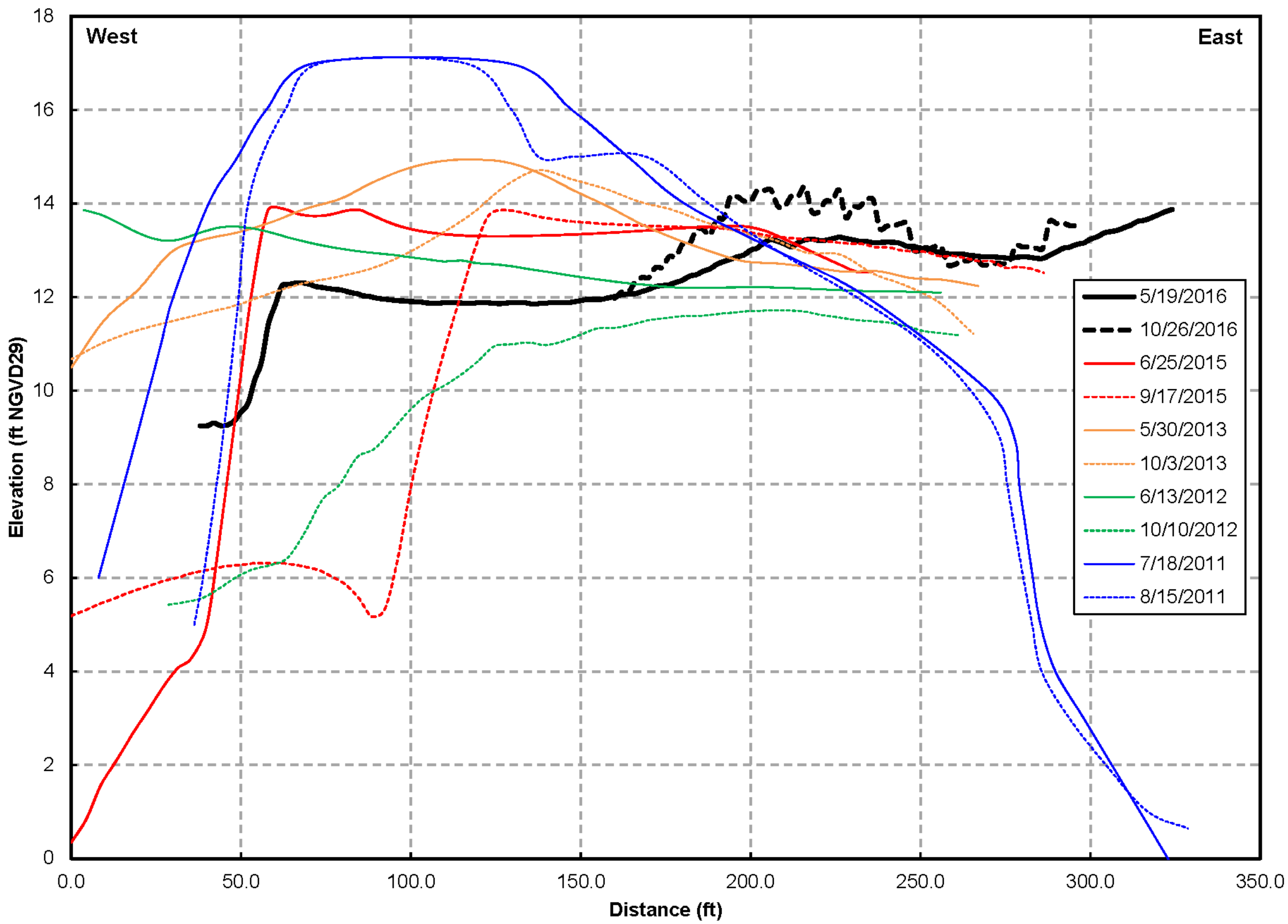
SOURCE: SCWA survey data

Figure 10
Beach Transect #1



SOURCE: SCWA survey data

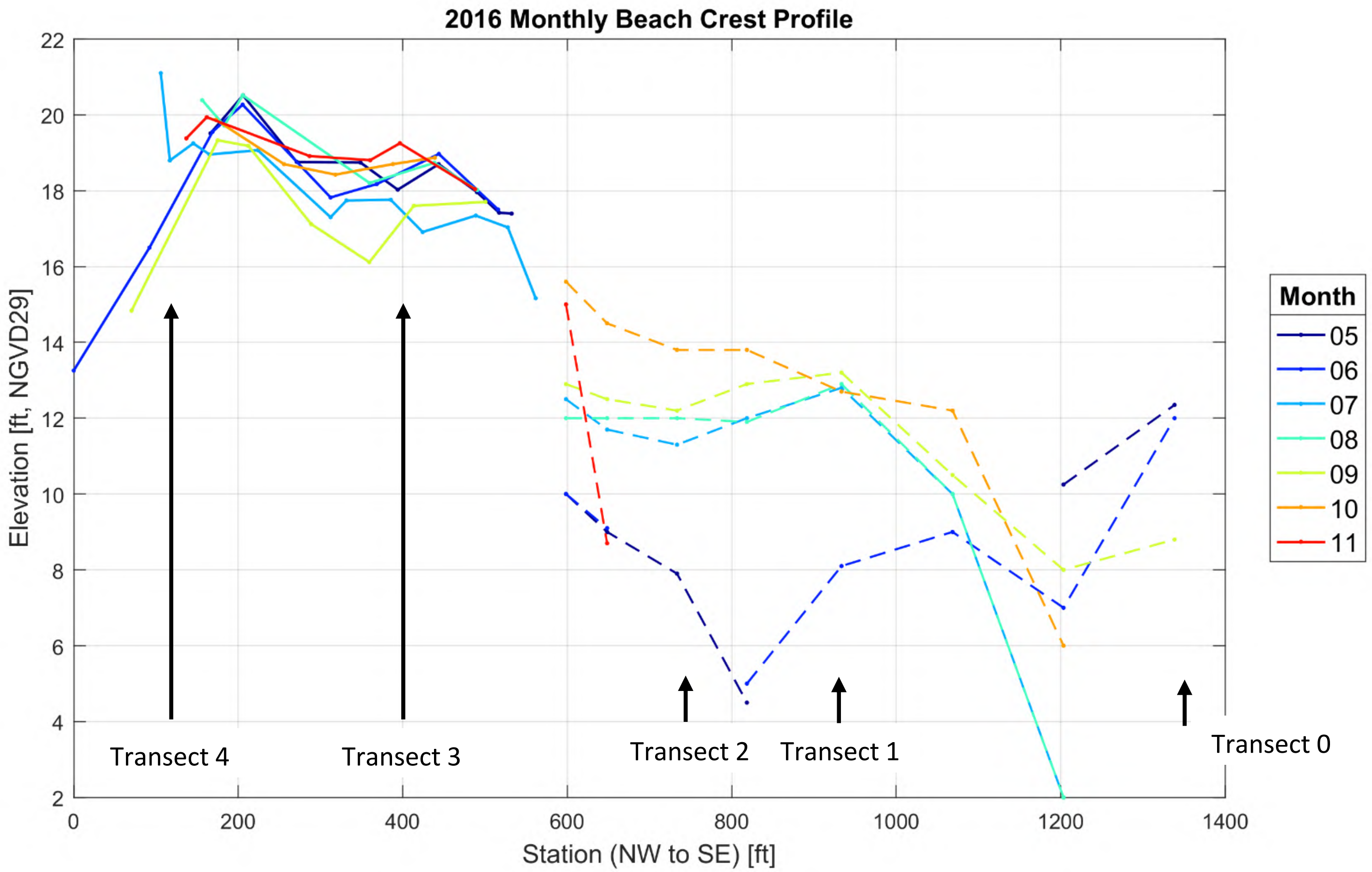
Figure 11
Beach Transect #0.



SOURCE: SCWA survey data

Figure 12

Beach Transect #0 from 2011-2016 management periods.

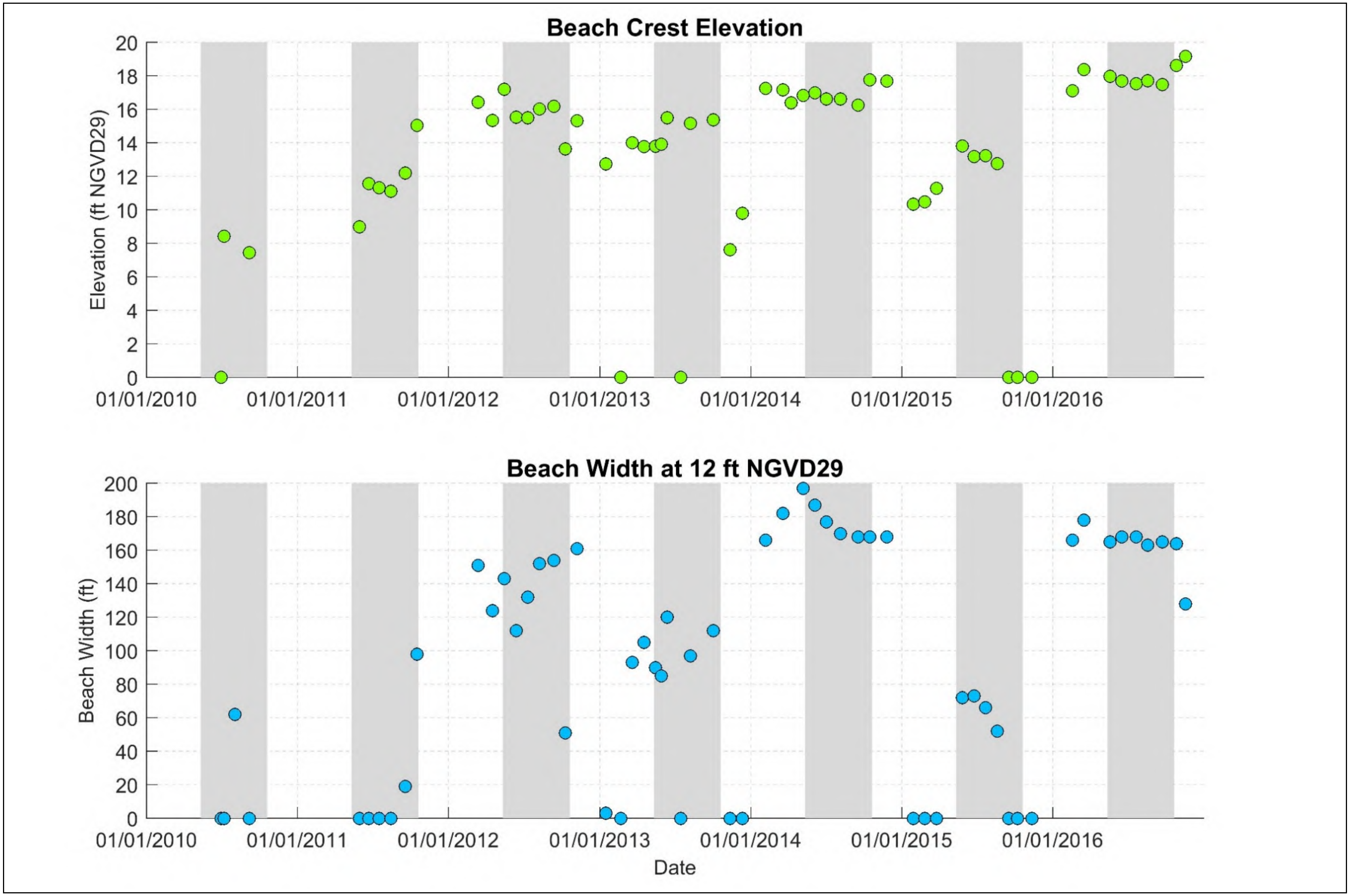


SOURCE: SCWA survey data

Note: Solid lines are from points identified as the beach crest during the monthly survey. Dashed lines are interpolated from surveyed points on the beach.

Figure 13

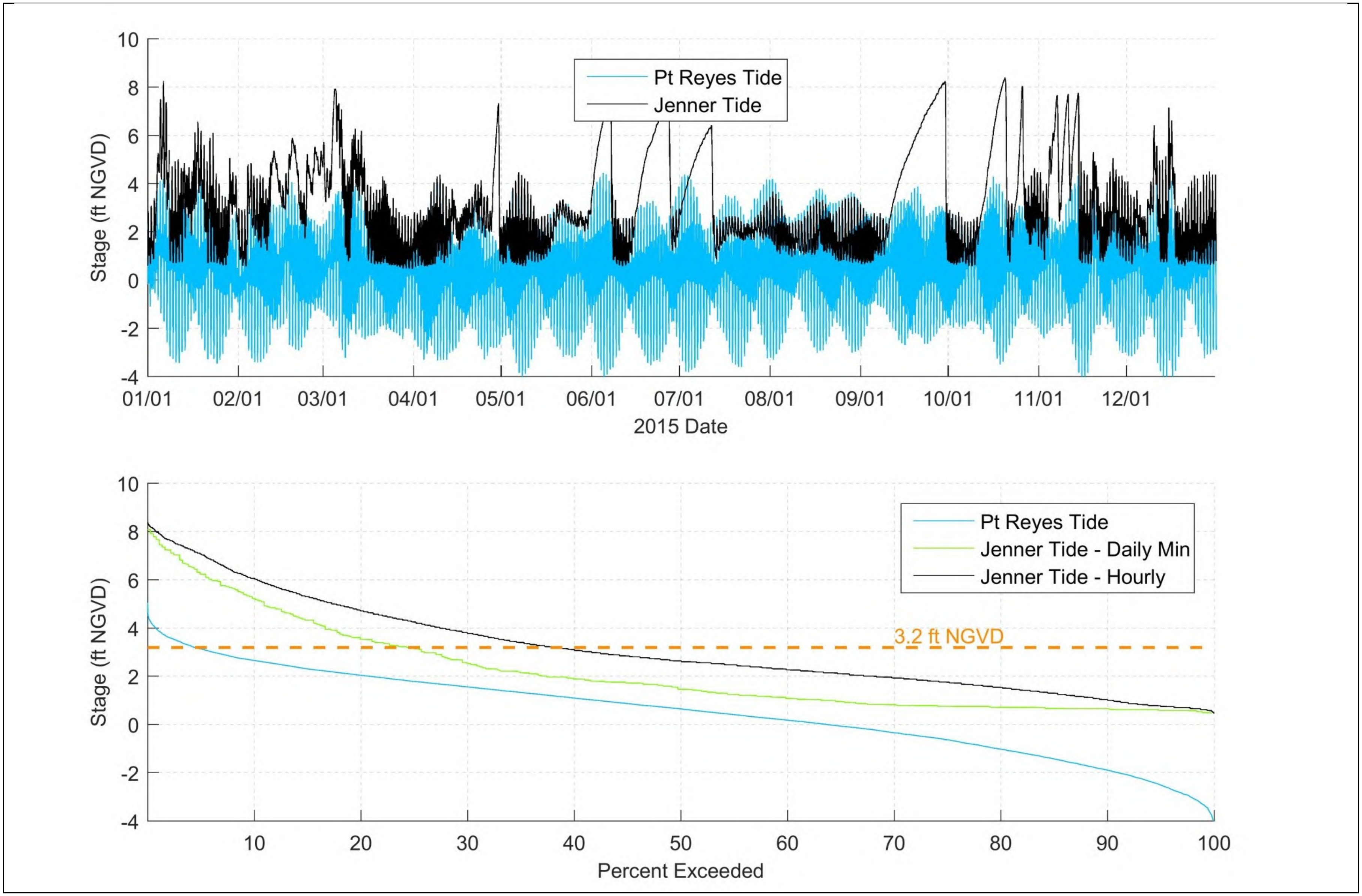
Beach Crest Profiles During the 2016 Management Period.



SOURCE: SCWA survey data

NOTES:
Beach crest elevation of zero indicates that the inlet is at Transect 3.
Beach width of zero indicates that the beach crest is below the elevation of 12 ft NGVD at Transect 3.

Figure 14
Transect 3 crest height and beach width (at 12ft NGVD elevation) from 2010 to 2016. Shaded areas represent management season.



SOURCE: SCWA Jenner Gage and NOAA Pt Reyes tide data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 15

Russian River Estuary stage exceedance for 2016.

Attachment M. Physical Processes During the 2017 Management Period

As required by the Russian River Biological Opinion, the Sonoma County Water Agency (Water Agency) has been tasked with managing the Russian River Estuary to facilitate summer lagoon conditions to improve salmonid rearing habitat. To meet this goal, the Biological Opinion calls for creating an outlet channel while also maintaining the current level of flood minimization for properties adjacent to the estuary (NMFS, 2008). The adaptive management plan, described in the main body of this report, was developed by the Water Agency with assistance from ESA PWA and the Resource Agency Management Team in 2009 and revised annually from 2010 to 2017. Because of permit constraints, the Water Agency was only able to implement the plan beginning in 2010. Under the revised plan, an outlet channel was attempted twice in 2017, on July 17th and September 28th. In the first instance, water flowing through the outlet channel scoured the channel and, within a day, caused self-breaching of the barrier beach. In the second, the outlet channel appeared to have been intermittent over a five-day period, and ended in a full breach, which may have been caused by beachgoers. During a breach period in late June, the mouth also formed a natural perched outlet channel for 7 days, before eventually closing.

During the 2017 management period, May 15th to October 15th, Water Agency staff regularly monitored current and forecasted estuary water surface elevations, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. Several inlet closure events occurred throughout the management period: July 4th–17th, August 5th–27th, September 12th-28th (an outlet channel was implemented, but the lagoon remained closed until October 3rd), and October 7th–19th (Figures 1-3).

Due to high flows in winter of 2016/2017, the mouth migrated north of Haystack Rock in 2017 (Figure 4). This set up conditions for a naturally-elongated channel in June, and influenced the beach growth pattern throughout the management season. The first closure of the season occurred after the mouth was naturally perched above tides from June 27th-July 4th (Figures 1, 2). High discharge in 2017 may have encouraged this condition because this northward location typically causes the inlet to elongate as flows draw down into summer conditions, leaving a long, more frictional channel. Thus, despite relatively high discharge to the Estuary in June (200-400 cfs), the mouth was constraining tides in the lagoon to a range of less than 2 feet for much of the month, possibly as a result of higher friction through the channel. A swell wave event with wave periods above 15 seconds occurred on June 22nd-23rd, causing the channel bed to shoal, and the water level in the lagoon to rise to above 3 feet NGVD. By June 27th, water levels were at 4 ft NGVD and slowly falling with minimal tidal fluctuations. Water levels declined to about 3 ft NGVD by July 4th, which suggests that flows were strong enough to erode bed sediments and that the natural outlet channel may not likely have persisted for long. On July 4th, another swell wave event occurred, closing the mouth.

The Water Agency monitored conditions closely throughout the early July closure event. Flows continued to decline to about 180 cfs by mid-July, and water levels at the Jenner gage increased to above 7 ft NGVD. Since the inlet had been located at the north end of the beach, rather than at the jetty like in the drought years of 2012-2015, the beach was able to grow quickly enough to allow the higher water levels to occur. The years in which the inlet remained near the jetty coincided with a multi-year drought, and may have been due, in part, to the relatively small size of wet season discharge which historically had caused the inlet to shift north (Behrens et al. 2009). In the drought years when the inlet had been located near the jetty, limited deposition from waves prevented the beach from growing to 7 ft NGVD or higher, or in other occasions prevented access of equipment to the site from the south.

An outlet channel was implemented on July 17th at 12:50 pm (Figure 5). Peak water levels at the Jenner Visitor Center prior to the event were 7.75 ft NGVD. The outlet channel was excavated approximately 1,000 feet northwest of the jetty in roughly the same location that the prior natural perched mouth had occurred (Figure 4). The channel had a width of 30 feet, length of 90 feet, and an invert elevation of approximately 7.2 ft NGVD. The excavation was planned during rising tides in anticipation of rising tides conveying sand into the channel and thereby reducing the potential for self-breaching. Less than a day after the outlet channel excavation, the channel scoured open (Figure 5) and water surface elevations declined.

The mouth remained open through the remainder of July (Figure 1), but a swell-wave event with wave periods above 15 seconds occurred for several days during the first week of August, leading to mouth closure on August 5th. During this time, river inflows were still relatively high for summer, at 150-180 cfs. Water levels rose more slowly than the prior event, but surpassed 7 ft NGVD by August 17th. Despite otherwise favorable conditions for outlet channel implementation, the beach berm was too narrow for safe access of equipment to the site. Water levels continued to rise to approximately 8.3 ft NGVD at the Jenner Visitors Center before the mouth self-breached on August 27th.

Swell wave conditions were present throughout September, and the mouth closed again on September 12th (Figure 3). Unlike the August event, long-period waves were consistently present, allowing the beach to widen and creating safer conditions for equipment to reach the site. Flows remained steady at 150-180 cfs. An outlet channel was implemented by the Water Agency on September 28th at 10:55 am. The channel was again located about 1,000 feet north of the jetty, where the outlet channel had naturally occurred in June. Compared to the July implementation, this channel was longer and wider, with a length of 150 feet and a width of 50 feet. The invert elevation was also higher, at 8.3 ft NGVD, which was approximately 0.3 feet above the lagoon water level at the time the channel was constructed. The intent of this design was to prolong the closure and freshwater/brackish water conditions for salmonid habitat, up until just below the flood stage of 9 ft NGVD. The plan was to allow lagoon water levels to increase to the outlet channel's elevation, at which time the outlet channel would serve as a 'release valve' to reduce the chance of flooding. Just as water levels reached the elevation of the outlet channel, the mouth breached on October 3rd. A photograph taken from the bluff indicates a narrow (<10 ft wide channel) and lower elevation channel located within the full outlet channel, which suggests that the narrower channel may have been excavated by beachgoers (Figure 6). Unfortunately, this possible interference obfuscates the potential performance of excavating an outlet channel above existing lagoon water levels.

The mouth closed again on October 7th, but an outlet channel could not be implemented prior to the end of the management season on October 15th. The Water Agency artificially breached on the mouth just north of Haystack Rock on October 19th, with estuary water levels reaching a peak of 8.38 ft NGVD.

Apart from having two outlet channel implementations and a period of naturally perched conditions, 2017 was also notable for having significant winter flows, which led to the mouth migrating to the north end of the beach. This led to a pronounced pattern of beach reset and re-growth along most of the site throughout the management season, which is described below. This is notable because in 2016, without mouth migration to the north, the beach north of Haystack Rock had grown as high as 18-19 ft NGVD by October.

METHODOLOGY

This review of the 2017 outlet channel management period examines estuary water levels, ocean wave conditions, ocean water levels, riverine discharge, and beach topography, as well as inlet size and location. The sources for these parameters are listed in Table 1. These data were supplemented with personal observations and discussion with staff from the Water Agency, National Marine Fisheries Service (NMFS), California Department of Fish and Wildlife (CDFW), and BML.

Table 1. Data Sources

Parameter	Source
Estuary water level, ft NGVD (h_E)	Water Agency Jenner gauge
Wave height (H_s), period (T_a), and direction	CDIP Cape Mendocino buoy #094
Ocean water level (h_O)	NOAA Point Reyes #9415020
Russian River discharge (Q_f)	USGS Guerneville #11467000
Beach topography, ft NGVD	Water Agency monthly surveys
Inlet size and location	Water Agency autonomous camera (operated by BML)

INLET STABILITY PARAMETER AND CLOSURE PROBABILITY

In addition to considering individual parameters, researchers at BML have developed a combined parameter to evaluate the stability of the inlet's state. This stability parameter is then used to predict closure (Behrens et al., 2013). Note that the inlet stability parameter does not differentiate between full closure and the perched conditions with an outlet channel. When discussing this parameter, both states are referred to as a 'closure' in that tides are prevented from propagating into the estuary. The inlet stability parameter presented by Behrens et al. (2013) considers the daily balance between wave-driven sediment import to the inlet and sediment export driven by tidal fluctuations. The wave-driven import is assessed using nearshore wave estimates derived from a transformation matrix and offshore buoy data (ESA PWA, 2016) and the latter is estimated from tide gauge data within the estuary and a stage-storage relation derived from the available bathymetry. Using daily-average values of the stability parameter within the period 1999-2008, Behrens et al. (2013) showed that the stability parameter correlates with the probability of the inlet closing within five days. As the percentile of the stability parameter increases, the probability of inlet closure within five days increases exponentially, from probability of roughly five percent when the parameter is at the 50th percentile to a probability of 80 percent when it is measured at the 99th percentile.

SUMMER AND FALL CONDITIONS

Time series of estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 1 for the entire 2017 management period. The lagoon water level time series (Figure 1a) summarizes the closure events at the beginning of the management period, as well as the subsequent tidal conditions and later closure events in fall. During the management period, Russian River flows were higher in 2017 than the previous drought years, 2013-2015. As shown in Figure 1d, flows at Guerneville never dropped below 100 cfs during the management season, which was common in most years after 2010.

As in prior years, wave heights declined through July and August (Figure 1b). However, there were several prolonged periods of swell wave conditions, which are the likely cause of the closure events that occurred in July and August.

CLOSURE PROBABILITY

The 5-day closure probability, a derivative of the inlet stability parameter described above, was hindcast for 2017 according to the method described in Behrens et al. (2013). This hindcast provides an indication of the utility of the stability parameter as a prediction tool for monitoring inlet conditions and planning management action. This parameter integrates wave and ocean forcing conditions, as well as estuary water levels, to provide greater predictive skill than just waves or ocean tides on their own. The predicted probability of closure exceeded 50% 2-5 days in advance of most of the closures in 2017 (Figure 1e).

TOPOGRAPHIC CHANGE

The Water Agency has conducted monthly surveys of Goat Rock State Beach that cover a region starting from the groin and extending approximately 1,500 feet to the north. The surveys do not include bathymetry within the inlet because flow conditions in the inlet prevent safe access. Also, the survey extent can be limited by the Water Agency’s compliance with its marine mammal incidental harassment authorization, which sets guidelines for the survey crew’s approach to marine mammals hauled out on the beach. Water Agency survey staff collect spot elevations using RTK-GPS and then assemble these elevations into a set of contour lines at 1-ft intervals, as well as profiles along the beach berm crest, the ocean wetted edge, and the estuary water line. The survey elevations are reported in the NGVD29 vertical datum.

To characterize beach berm topographic conditions, ESA assessed data from the Water Agency's 2017 surveys. Transects, whose location is shown in Figure 7, include two transects backed by cliff (Figure 8 and Figure 9), two transects that extend into the estuary (Figure 10 and Figure 11), and a transect just north of the groin (Figure 12).

Prior to the management season, the relatively wet conditions in the winter of 2017 eroded most of the beach, essentially resetting the berm and creating conditions for long-term re-growth of the berm throughout the management season. Since the adoption of the Biological Opinion (NMFS 2009), this has been a relatively rare occurrence due to persistent dry conditions after the 2011 management season. In relatively wet years, the mouth migrates north of Haystack Rock, and during peak flows, the mouth can encompass almost the entire distance between the jetty and the northern headland (Behrens et al. 2013). Between January and April 2017, there were four discharge events with peak flows measured at the USGS Hacienda Bridge gage that were above 35,000 cfs. In the past 11 years prior to 2017, the highest flow has only been 43,000 cfs. The highest event occurred on January 11th 2017, with peak flows measured at roughly 55,000 cfs. This was the first time that peak flows surpassed 43,000 cfs since 2006. Although flows had begun to decline by the beginning of the management season, they were still above 700 cfs on May 15th, compared to less than 300 cfs in most years from 2010-2017.

North of Haystack Rock, the presence of the inlet constrained the growth of the beach until June, which is illustrated for Transects 3 and 4 in Figures 8 and 9. The survey on July 11th, after the mouth had been closed for one week, the beach berm had begun to re-form, and had a crest of approximately 8.5 ft NGVD at Transect 4 and 8 ft NGVD at Transect 3. The next survey on August 10th showed a lower crest of 6.6 ft NGVD at Transect 4, and 6.3 ft NGVD at Transect 3, but this took place only 5 days after the mouth had closed on August 5th. Throughout the remainder of the year, the beach north of Haystack Rock grew steadily, reaching at least 10 feet at Transects 3 and 4 by September 26th, 11-13 feet by October 26th, 14 feet by November 22nd, and 16 feet by December 21st.

South of Haystack Rock, Transects 1 and 2 (Figures 10 and 11) showed a different seasonal pattern. While the beach was nonexistent in January at both locations due to high flows, the beach began to re-form in February and March at both transects, reaching 9 feet by March 16th at Transect 2 and 11 feet at Transect 1. The beach formed a steady summer profile at both locations from June to September, showing only small signs of growth. During this time, the crest was 8-9 feet at Transect 2 and 11-12 feet at Transect 1 (Figure 13). As fall progressed, the berm began to grow at both locations, surpassing 12 feet by November 22nd and 14 on December 21st at both locations.

Next to the Jetty, Transect 0 (Figure 12) showed a similar seasonal pattern to Transects 1 and 2, although it was the only location where the beach berm remained during the January survey, due to high flows eroding the beach farther north. The beach appeared to re-form at Transect 0 earlier than all other locations, with the beach reaching 12 feet on March 16th, whereas the presence of the inlet farther north limited berm growth at the other transects. The berm had a steady profile from May to August, and then began to degrade in September and October, and was nonexistent in November, which is due to the inlet relocating to the jetty at that time. As with all other transects, the peak was observed during the December 21st survey, reaching 14.1 feet.

BEACH WIDTH

To provide additional information about the beach morphology, ESA assessed the beach width using the Water Agency survey data. Figure 14 shows the evolution of the beach width at Transect 3 from 2010 to 2017. Beach width data were added for months outside of the management period to add context for seasonal changes. In previous years during winter months, the beach was often eroded at Transect 3 (north of Haystack Rock) to the point that the beach crest was below 12 ft NGVD, so that the width was effectively zero. This was the case in 2010, 2011, 2013, and 2015. The beach was widest in 2012 and 2014, when the mouth generally remained farthest to the south. These years also experienced the highest beach crest heights at Transect 3 (Figure 14). As already noted, the mouth migrated north of Transect 4 in 2017, a greater distance than was observed during the drought conditions from 2012 to 2015. This migration effectively removed the beach just prior to the management season, and it did not grow above 12 ft NGVD again until November. This is reflected in Figure 14, which indicates a width of zero at 12 ft NGVD through the management season.

JENNER WATER SURFACE ELEVATION EXCEEDANCE

The Biological Opinion (NMFS, 2008) sets a target for estuary water levels "a daily minimum water surface elevation of 3.2 feet [NGVD] during 70% of the year." To facilitate this target, the Biological Opinion notes "Absent river flood flows and historic mechanical breaching practices, NMFS expects cross shore transport of sand by wave action will be sufficient to maintain the bar at this elevation."

In 2017, the daily minimum water surface elevation exceeded 3.2 ft NGVD roughly 28% of the year (Figure 15), compared with 24% in 2016. For comparison, Figure 15 also includes hourly lagoon water surface elevation (exceeded 3.2 ft NGVD for roughly 41% of 2017, compared with 38% of 2016) and hourly Point Reyes water surface elevation (exceeded 3.2 feet NGVD for roughly 5% of the year).

LESSONS LEARNED AND RECOMMENDATIONS

Based on 2017 observations of the estuary, associated physical processes, and the Water Agency's planning for outlet channel management, we note the following lessons about implementing the outlet channel management plan.

CONCEPTUAL MODEL

- Flows of 55,000 cfs appear to be sufficient to cause the inlet to migrate north of Haystack Rock, which set up large-scale resetting of the berm. This was the first time that peak flows surpassed 43,000 cfs since 2006.
- As noted in earlier reports, natural outlet channel conditions (though rare and short-lived) are more likely to occur when the channel is naturally elongated, which was the case in June 2017 when the inlet was at the far north end of the beach. This natural channel was several hundred feet long, and likely longer than could be implemented within the allowable limit of excavation on the beach for managed outlet channel implementations.
- The natural outlet channel conditions observed from June 27th to July 3rd happened at relatively-low water levels (3-4 ft NGVD), and had a steady decline, suggesting that the channel would likely have eventually eroded to re-form an inlet if the mouth had not been closed on July 4th due to wave action.

OUTLET CHANNEL FEASIBILITY

- With the inlet located north of Haystack Rock, the beach between the inlet and the jetty gained elevation more rapidly in spring than in years when the inlet remained south, near the jetty. This added height was enabled the outlet channel implementation in early July.
- Rare closure events that occur in late summer (such as the early August 2017 event) may not have enough seasonal wave power to build a wide enough beach to access the site, even if discharge and other conditions are ideal.

REFERENCES

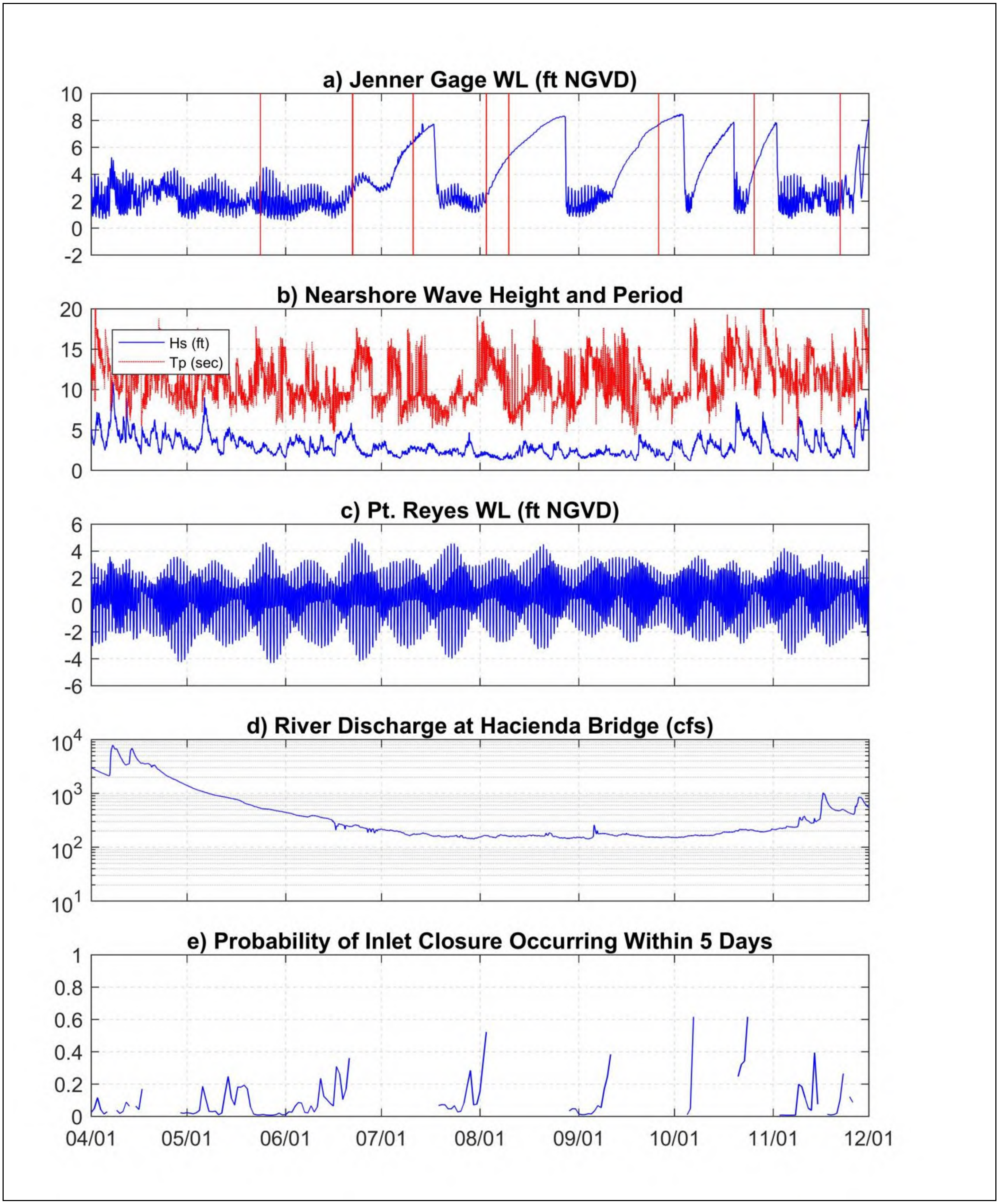
Behrens, D., Bombardelli, F., Largier, J. and E. Twohy. 2009. Characterization of time and spatial scales of a migrating rivermouth. Geophysical Research Letters. Vol. 36, L09402, doi:10.1029/2008GL037025.

Behrens, Dane K., Fabián A. Bombardelli, John L. Largier, and Elinor Twohy. 2013. "Episodic Closure of the Tidal Inlet at the Mouth of the Russian River — A Small Bar-Built Estuary in California." *Geomorphology* 189 (May): 66–80. doi:10.1016/j.geomorph.2013.01.017.

ESA PWA. 2016. Feasibility of alternatives to the Goat Rock State Beach jetty for managing lagoon water surface elevations. Prepared for the Sonoma County Water Agency.

National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed.

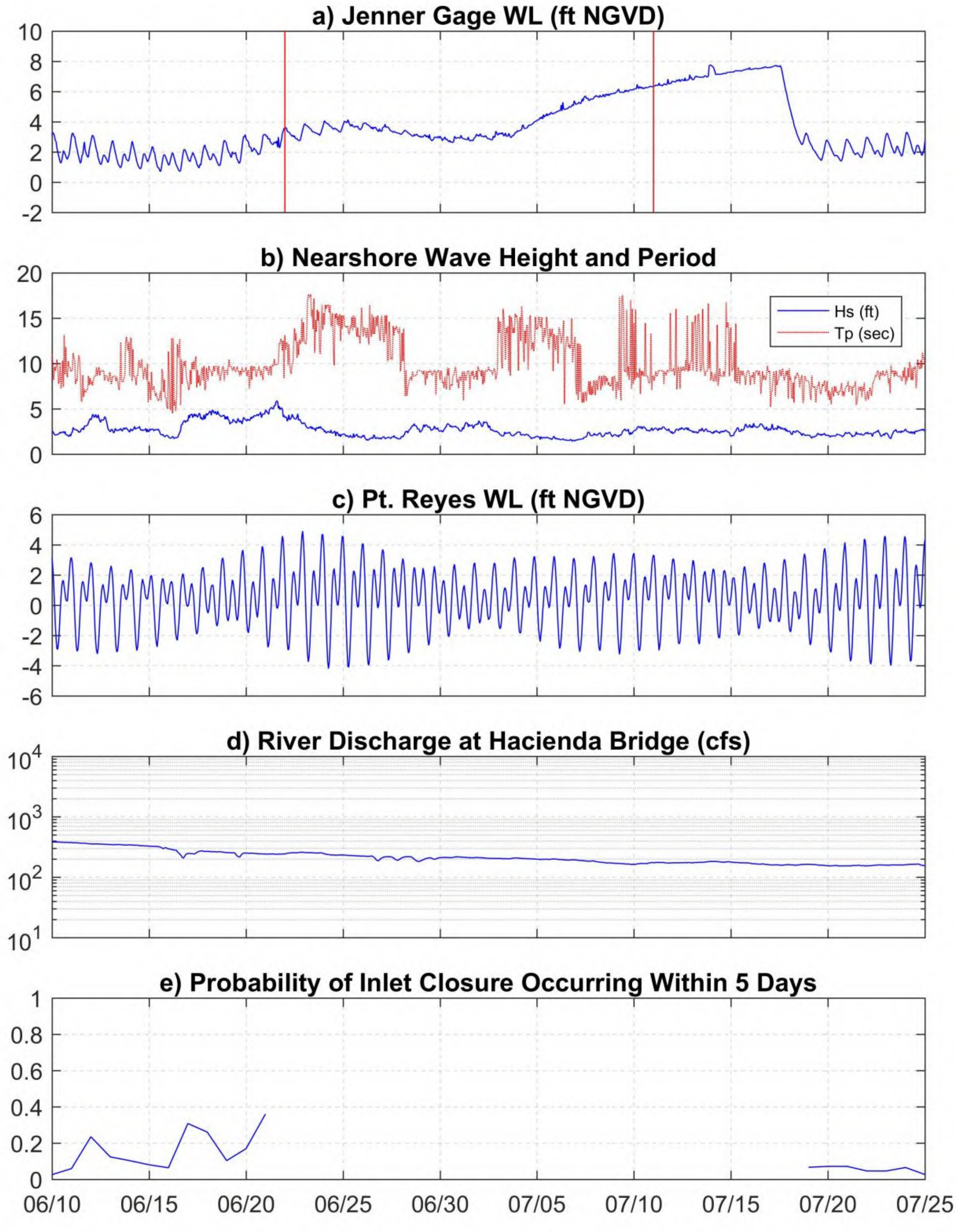
FIGURES



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

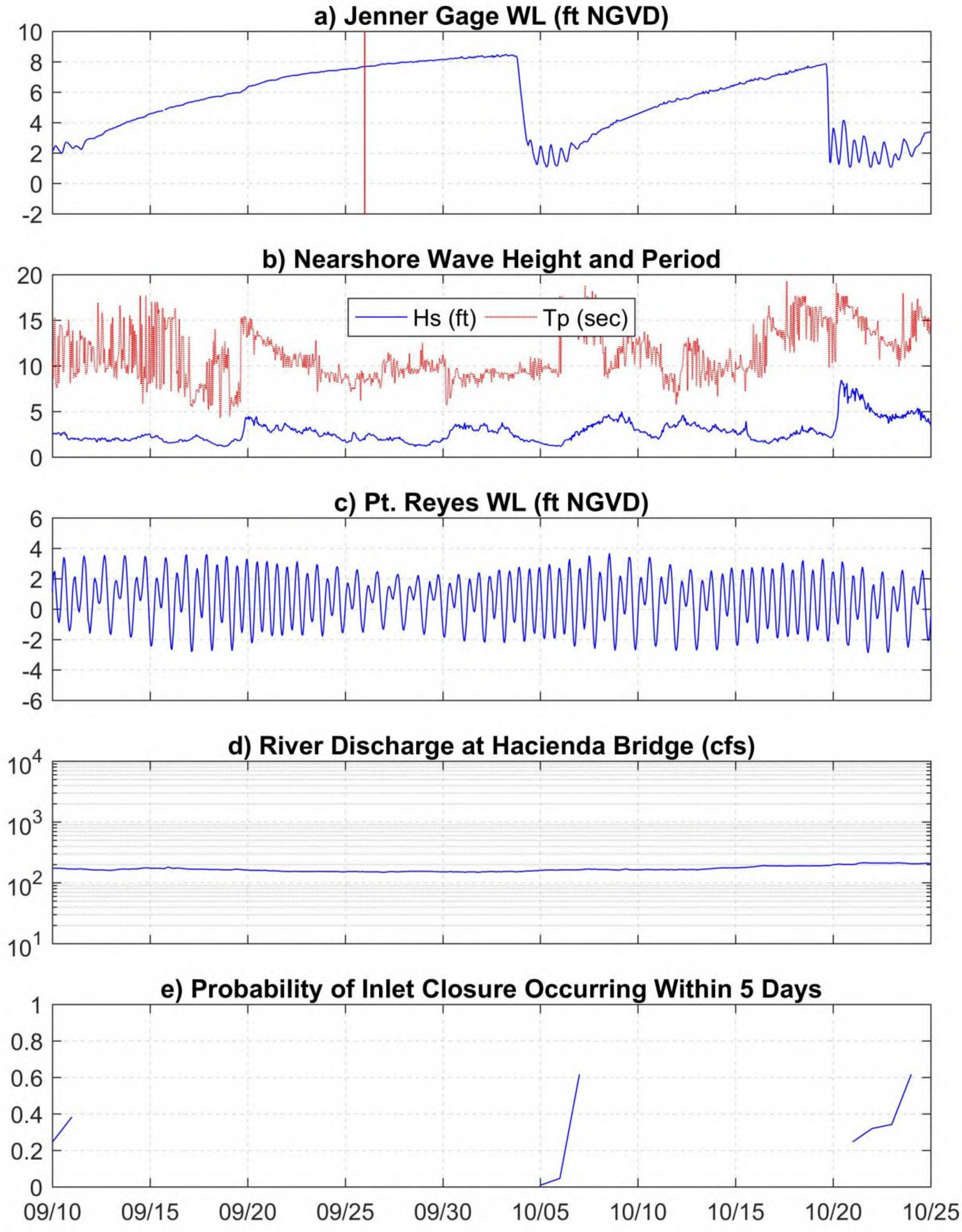
Figure 1
Estuary, Ocean, and River Conditions Compared with Closure Probability: April – November 2017



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

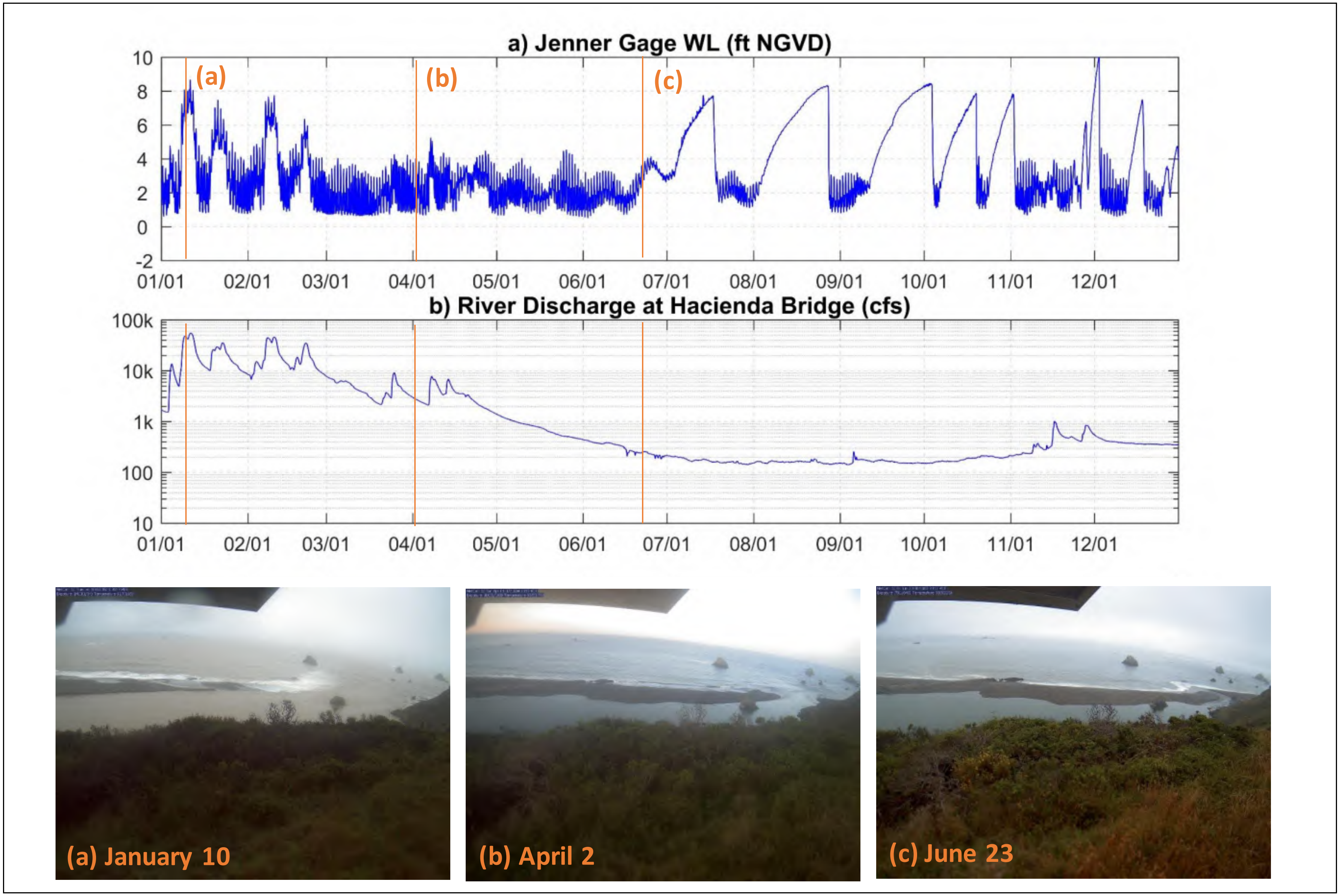
Figure 2
Estuary, Ocean, and River Conditions Compared with Closure Probability: June – July 2017



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

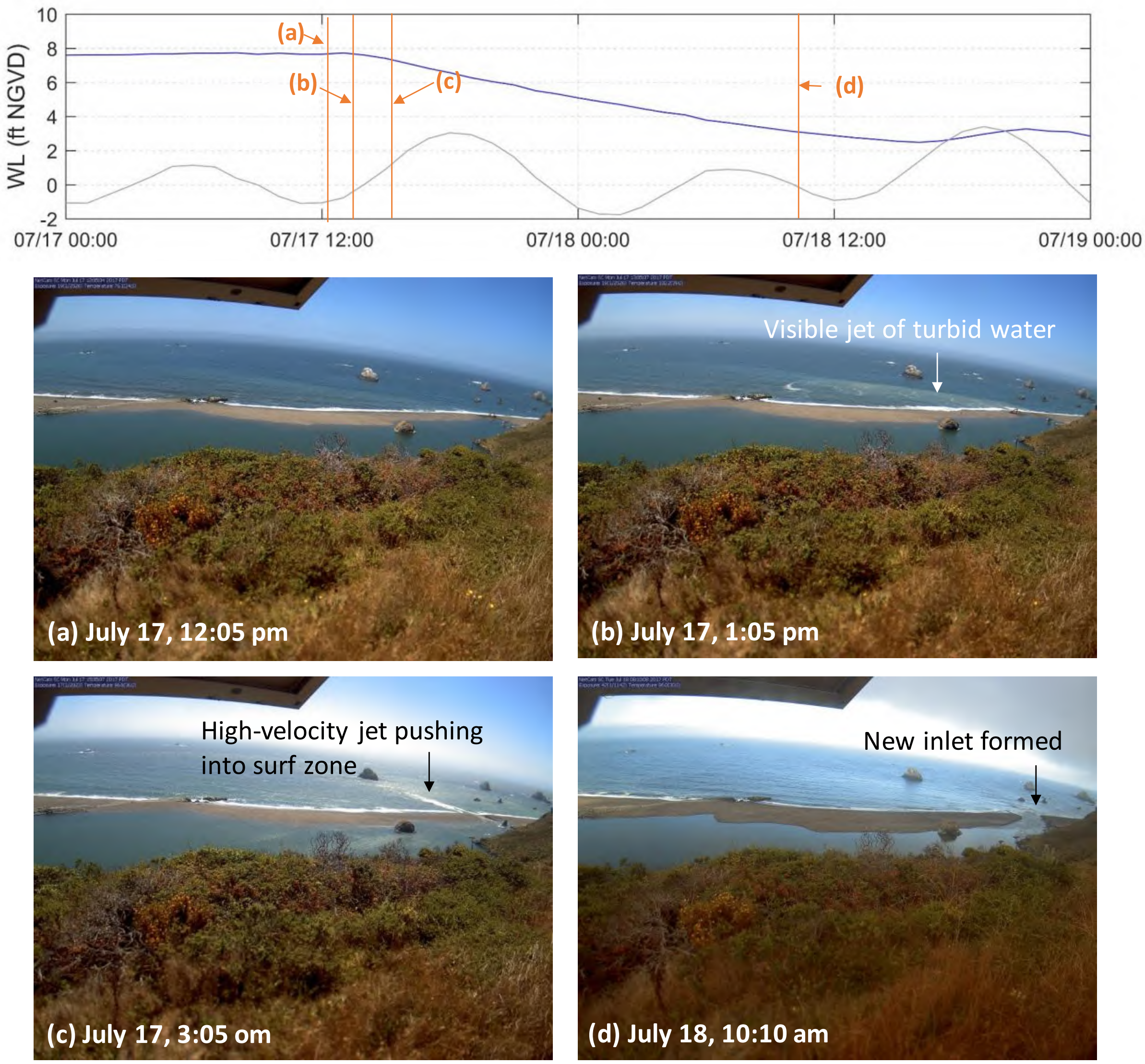
Figure 3
Estuary, Ocean, and River Conditions Compared with Closure Probability: September – October 2017



SOURCE: BML camera

Figure 4

(a) Russian River during fluvial flooding on January 10th, 2017, (b) During moderate discharge conditions on April 2nd, 2017, and (c) during natural perched conditions on June 23rd, 2017.



SOURCE: BML camera

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 5

Sequence of photographs depicting July 17th outlet channel implementation

SOURCE: image from J.Martini-Lamb

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 6

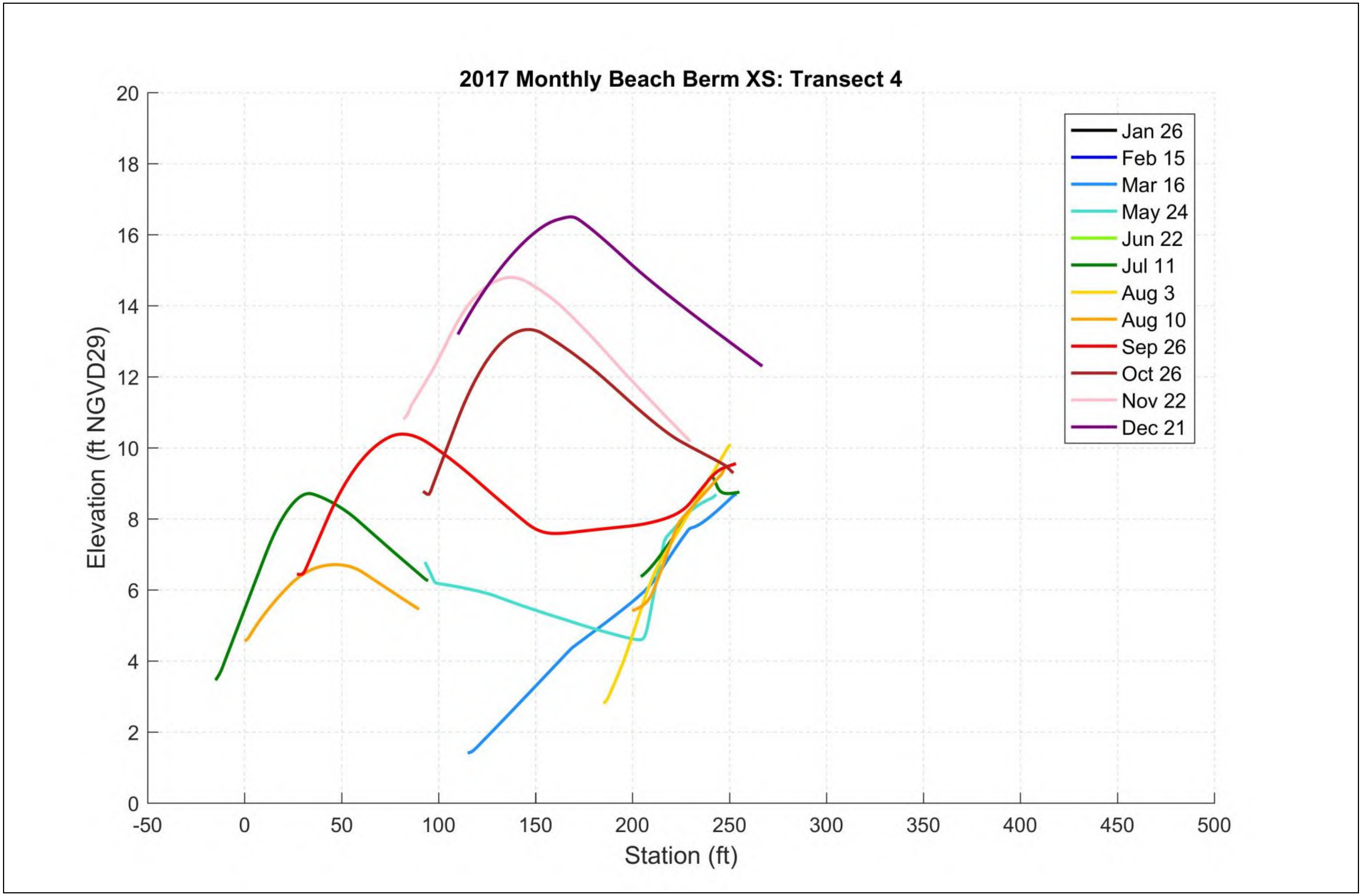
Photograph from October 3rd, 2017 showing conditions immediately after unplanned breach.

SOURCE: image from USDA NAIP

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 7

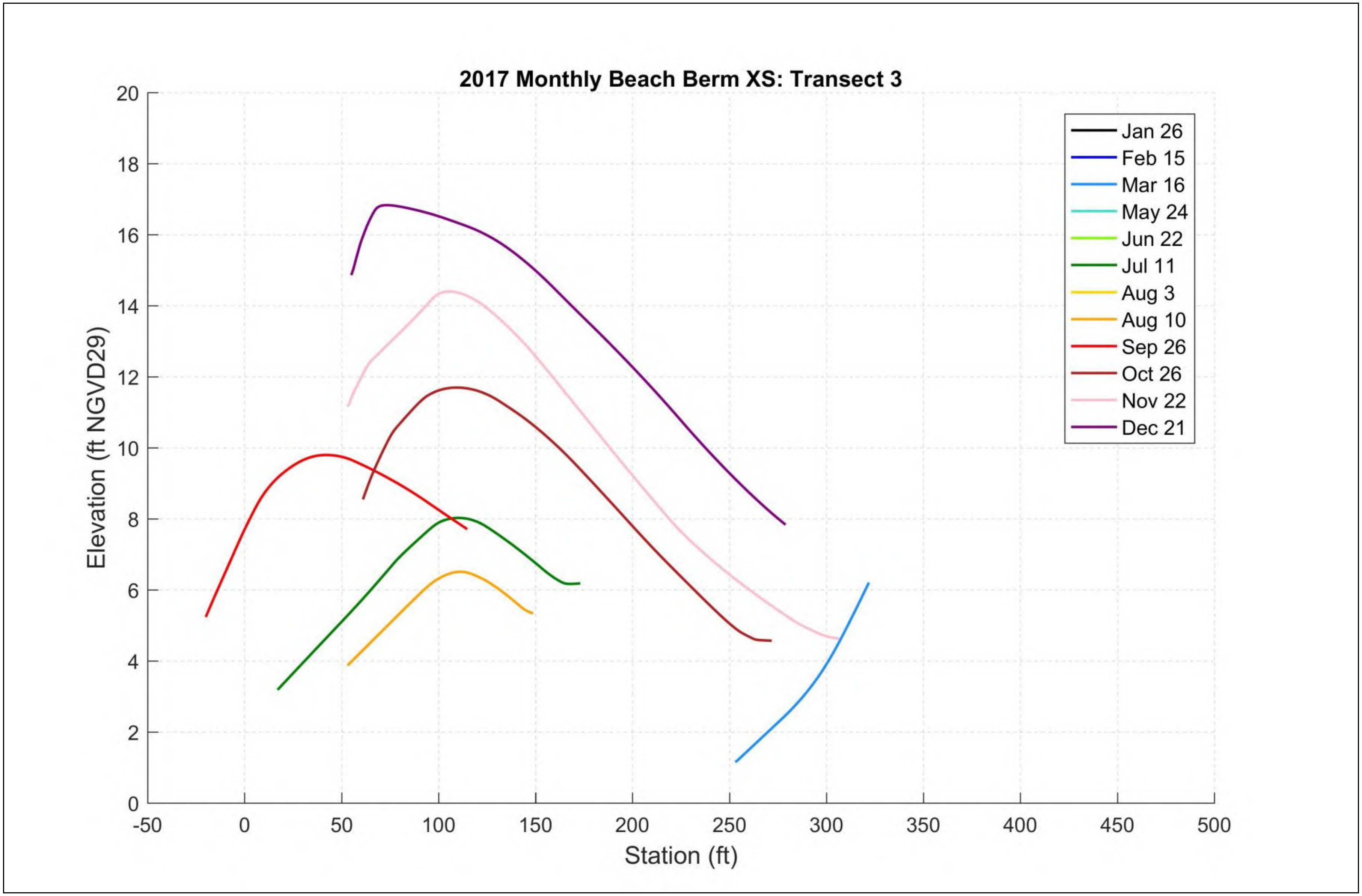
Beach Transect Locations



SOURCE: SCWA survey data

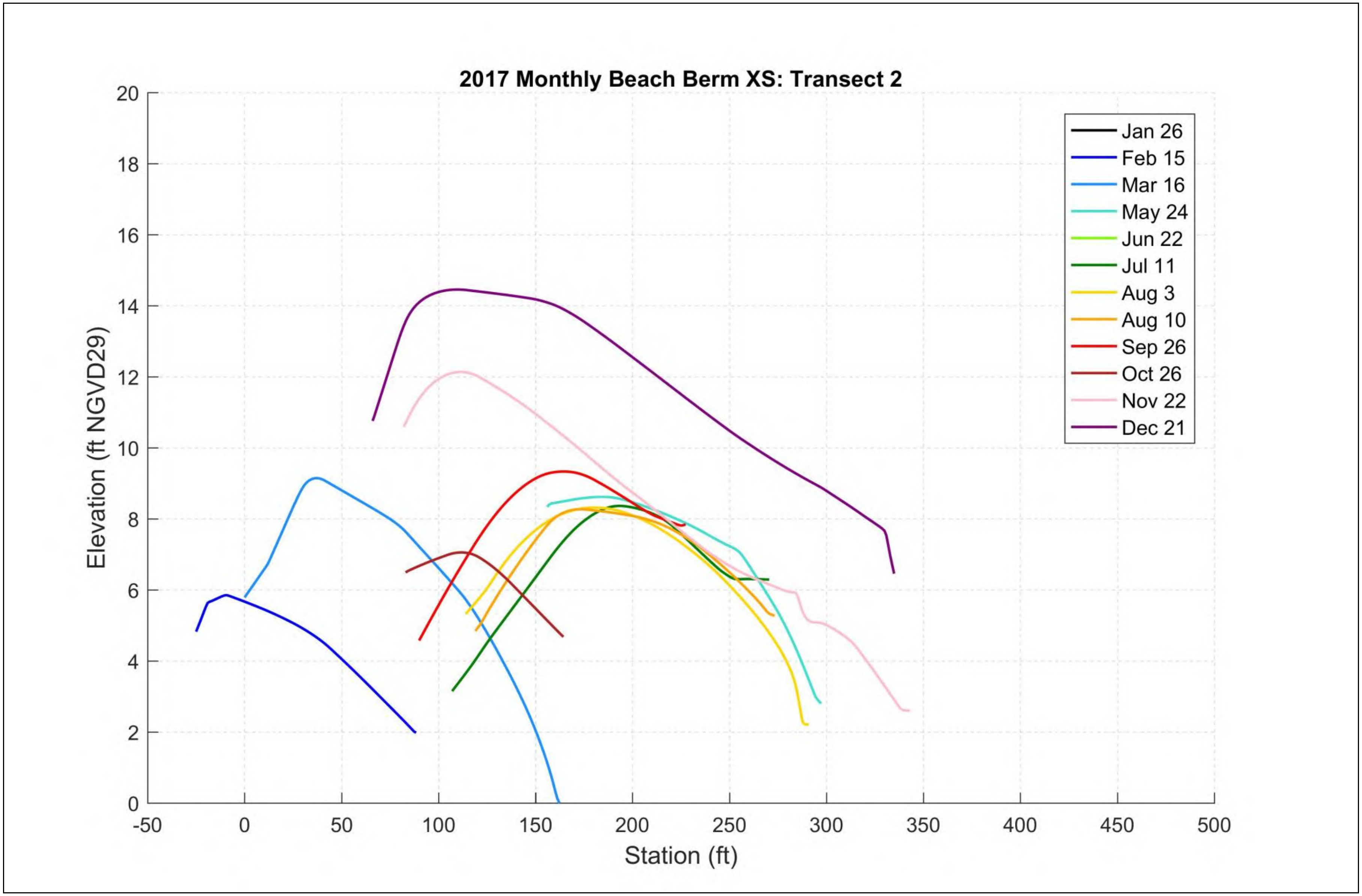
Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 8
Beach Transect #4



SOURCE: SCWA survey data

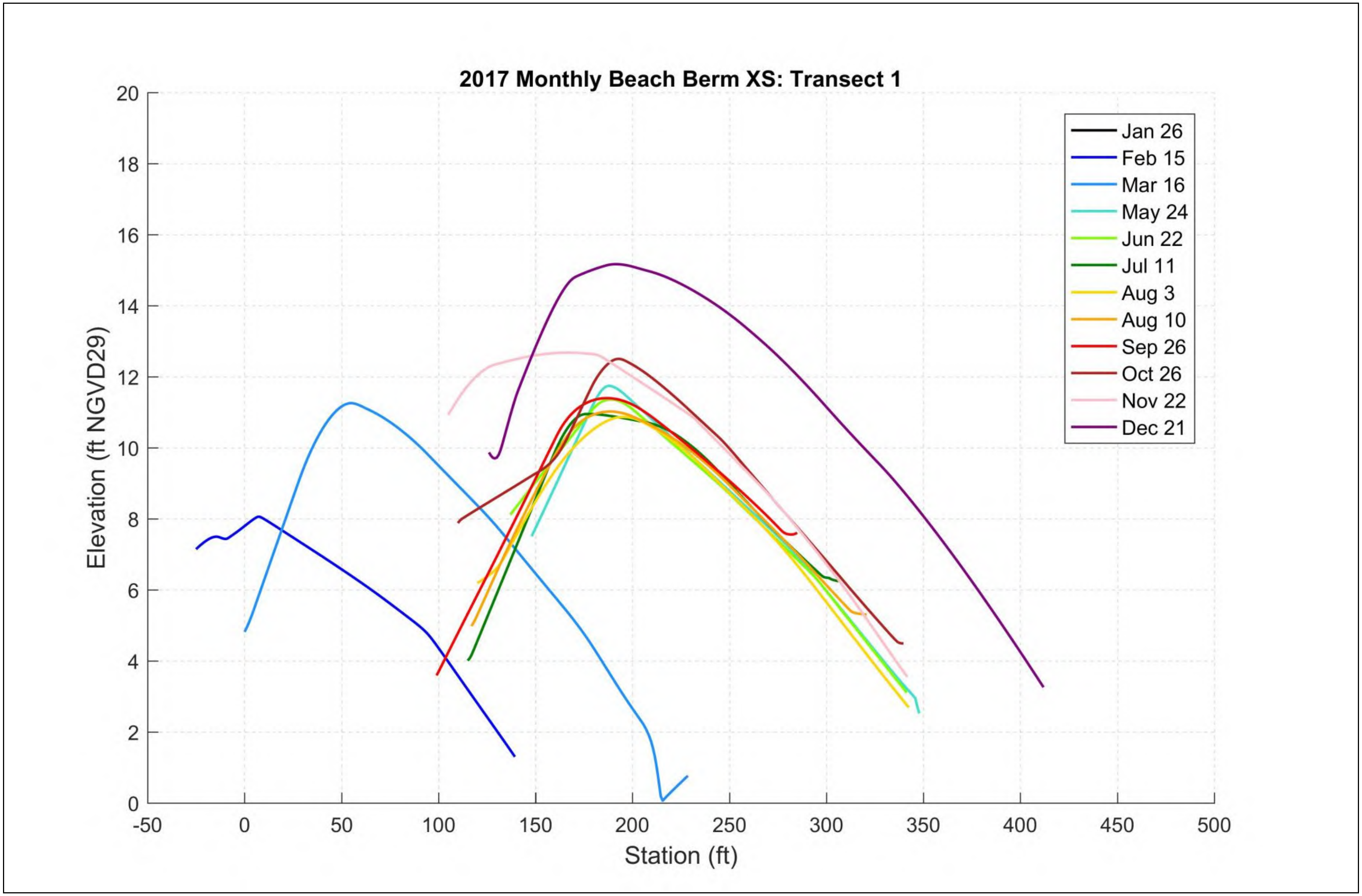
Figure 9
Beach Transect #3



SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

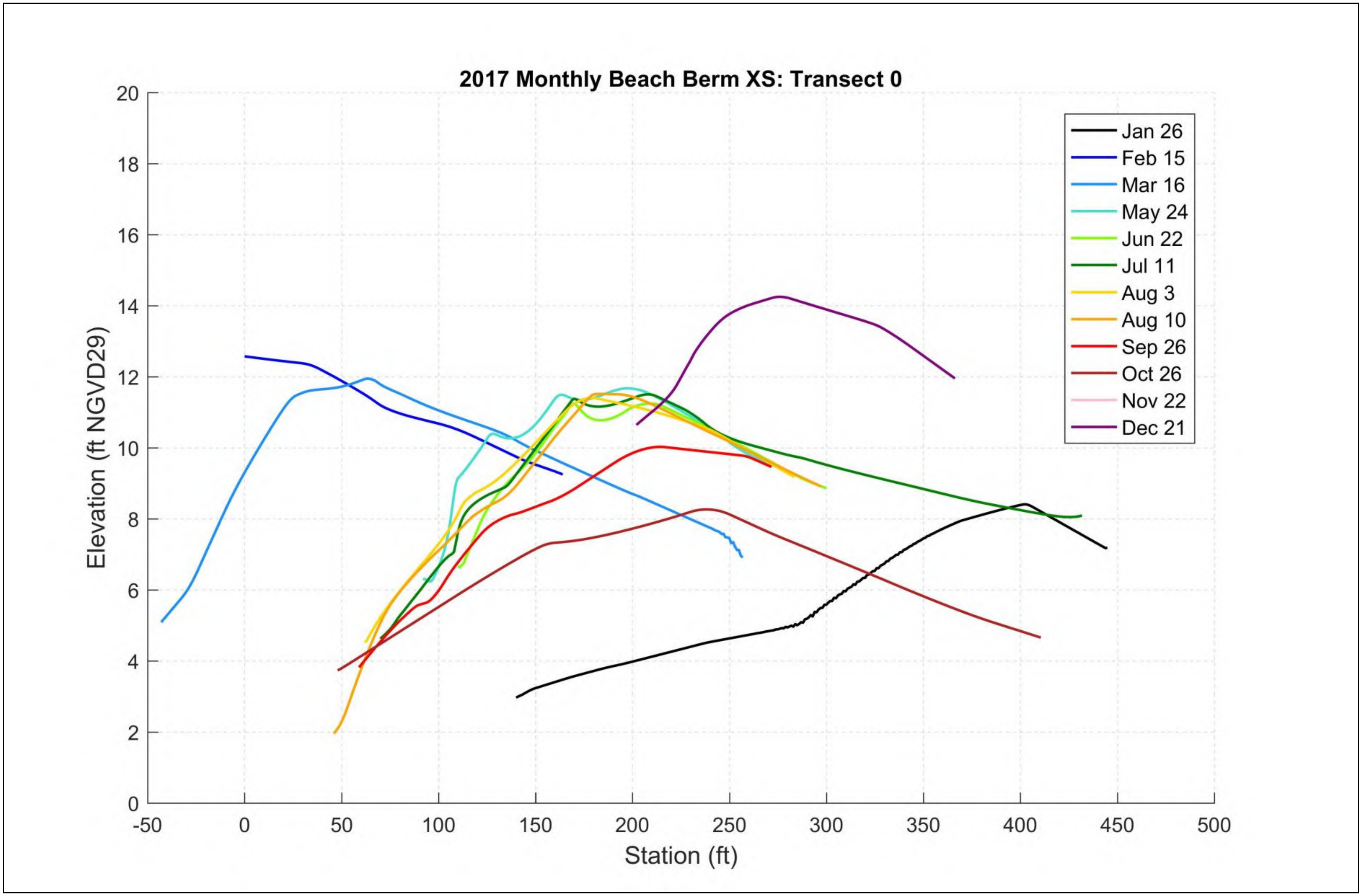
Figure 10
Beach Transect #2



SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

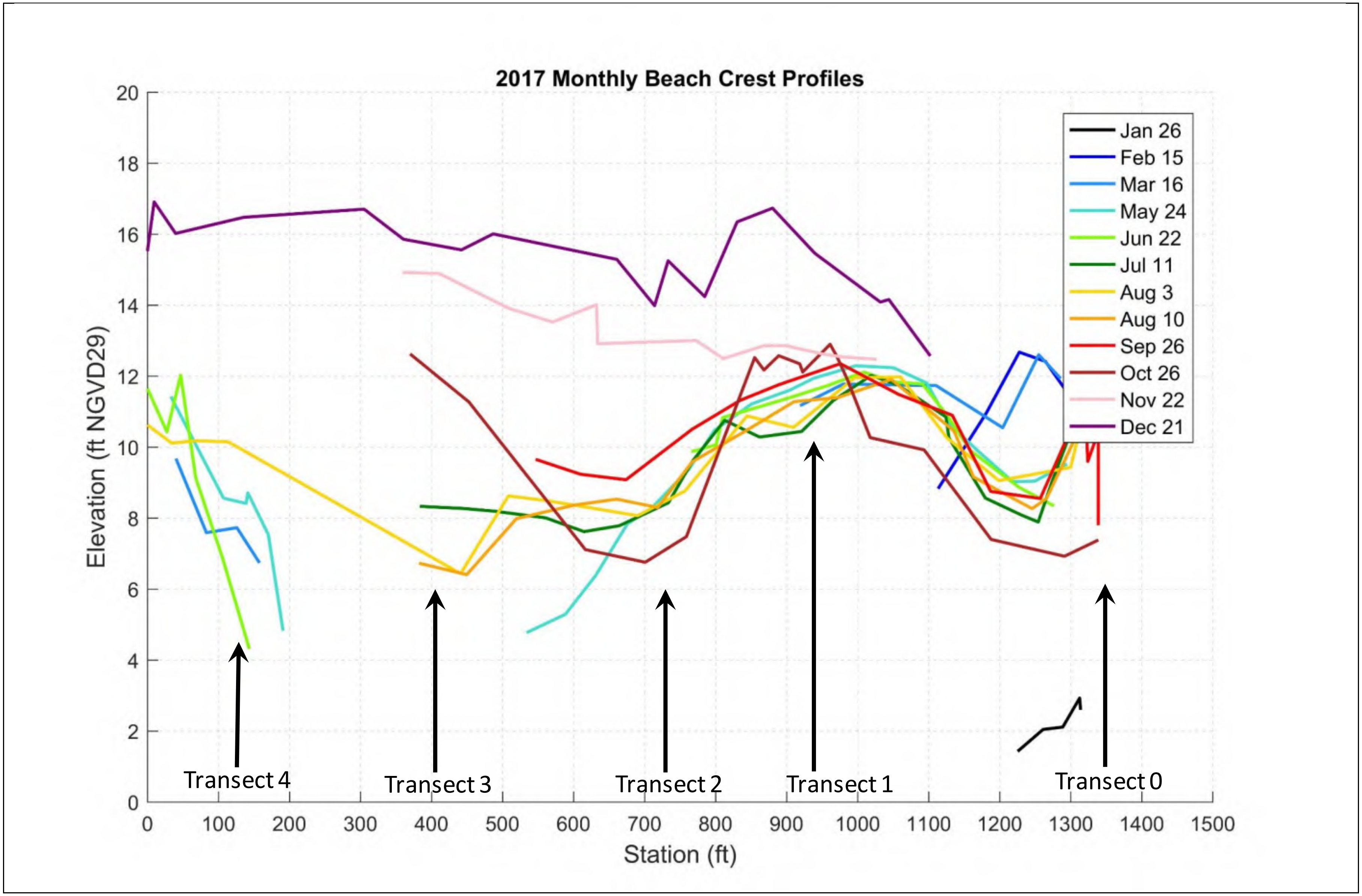
Figure 11
Beach Transect #1



SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 12
Beach Transect #0.

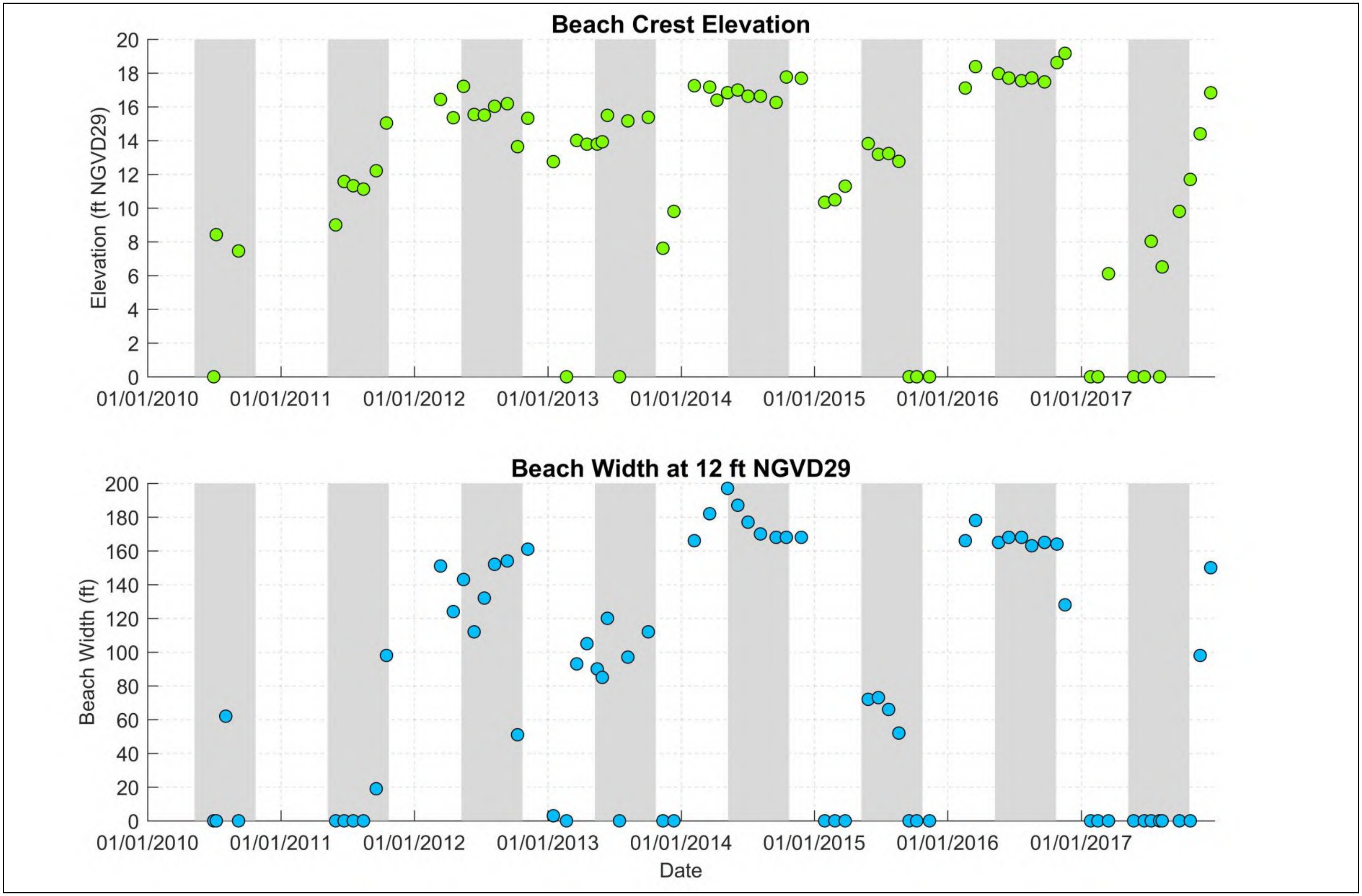


SOURCE: SCWA survey data

Note: Solid lines are from points identified as the beach crest during the monthly survey. Dashed lines are interpolated from surveyed points on the beach.

Figure 13

Beach Crest Profiles During the 2017 Management Period.

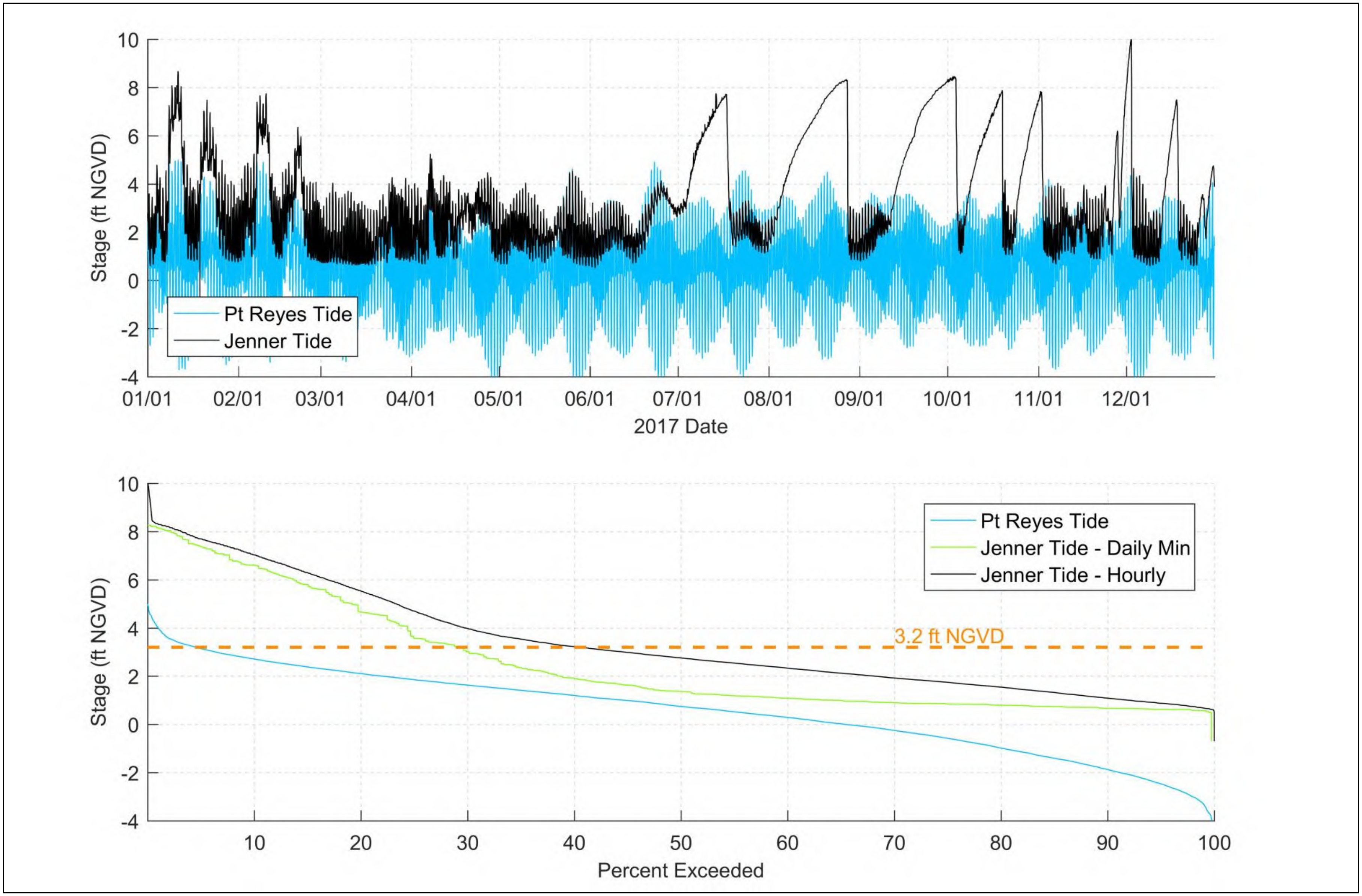


SOURCE: SCWA survey data

Note: width of zero indicates that the beach crest is below the elevation of 12 or 14 ft NGVD.

Figure 14

Transect 3 crest height and beach width (at 12ft NGVD elevation) from 2010 to 2017. Shaded areas represent management season.



SOURCE: SCWA Jenner Gage and NOAA Pt Reyes tide data

Figure 15

Russian River Estuary stage exceedance for 2017.

Attachment N. Physical Processes During the 2018 Management Period

As required by the Russian River Biological Opinion, the Sonoma County Water Agency (Sonoma Water) has been tasked with managing the Russian River Estuary to facilitate summer lagoon conditions to improve salmonid rearing habitat. To meet this goal, the Biological Opinion calls for decreasing marine influences in the estuary while also maintaining the current level of flood minimization for properties adjacent to the estuary (NMFS, 2008). The adaptive management plan, described in the main body of this report, was developed by the Sonoma Water with assistance from ESA and the Resource Agency Management Team in 2009 and revised annually from 2010 to 2018. Because of permit constraints, the Sonoma Water was only able to implement the plan beginning in 2010. In 2018, no beach management actions were undertaken, since the mouth of the estuary did not close within the management season.

During the 2018 management season, May 15th to October 15th, Sonoma Water staff regularly monitored current and forecasted estuary water surface elevations, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. Unlike the wet winter of 2016/2017, the winter of 2017/2018 was comparatively dry, with peak flows at the USGS Hacienda Bridge gauge only achieving peak flows of roughly 15,000 cu. ft. per second (cfs). As a result of these low discharge conditions, the inlet never migrated to the north end of the beach, and remained adjacent to the jetty's groin for the entire season. The mouth did not close during the 2018 management season, despite the dry conditions (Figure 1). During a high wave event in early May coincident with neap oceanic tides, the mouth nearly closed. For several days, the accumulation of sand in the mouth reduced the tide range in the estuary to about 1 foot, but the mouth scoured once the ocean tide range subsequently increased (Figure 2).

Several inlet closure events occurred in the fall, beginning on October 15th, the end of the management season (Figure 3). Although these occurred too late in the season to allow for beach management action to enhance habitat, they were notable for several reasons: the first event coincided with low runoff conditions and lasted for nearly 30 days, and the events in late November and mid-December coincided with exceptionally high wave events that made artificial breaching difficult and led to water levels approaching or just exceeding flood stage in the estuary.

After an uneventful summer, in which the inlet remained fully open to oceanic tides, a moderate swell wave event from October 6th to 9th, brought significant wave heights (Hs) of 5-6 feet and periods of roughly 15-17 seconds. Although this is not a particularly strong wave event, it was sufficient to deposit enough sand in the mouth to begin to mute the tide range in the estuary to less than 2 feet. Following this, swell waves with periods of 17-20 seconds arrived in the following week, and closed the mouth on October 15th. Even though the inlet had been located next to the groin, the swell waves were nonetheless able to close the inlet. The time lapse camera operated by the Bodega Marine Laboratory (BML) shows waves pushing through the gap at the offshore end of the groin and probably contributing sand to build the beach (Figure 4). The October closure event coincided with low discharge at the USGS Hacienda gauge (less than 110 cfs), which slowed the rise of water levels. The mouth self-breached on November 13th at an elevation of 8.5 feet NGVD.

Subsequent closure events occurred from:

- November 18th to 19th (ending in self-breach);
- November 20 (self-breach);
- November 29th to 30th (ending in self-breach);
- December 6th to 10th (ending in an artificial breach); and
- December 14th to 16th (ending in self-breach).

High waves during the last closure prevented equipment from being able to safely access the beach. Water levels in the estuary peaked at 10.92 feet NGVD at the time that the barrier beach self-breached.

METHODOLOGY

This review of the 2018 management period examines estuary water levels, ocean wave conditions, ocean water levels, riverine discharge, and beach topography, as well as inlet size and location. The sources for these parameters are listed in Table 1. These data were supplemented with personal observations and discussion with staff from the Sonoma Water, National Marine Fisheries Service (NMFS), California Department of Fish and Wildlife (CDFW), and BML.

Table 1. Data Sources

Parameter	Source
Estuary water level, ft NGVD (h_E)	Sonoma Water Jenner gauge USGS Highway 1 gauge #11467270
Wave height (H_s), period (T_a), and direction	CDIP Cape Mendocino buoy #094
Ocean water level (h_O)	NOAA Point Reyes #9415020
Russian River discharge (Q_f)	USGS Guerneville #11467000
Beach topography, ft NGVD	Sonoma Water monthly surveys
Inlet size and location	Sonoma Water autonomous camera (operated by BML)

INLET STABILITY PARAMETER AND CLOSURE PROBABILITY

In addition to considering individual parameters, researchers at BML have developed a combined parameter to evaluate the stability of the inlet's state. This stability parameter is then used to predict closure (Behrens et al., 2013). Note that the inlet stability parameter does not differentiate between full closure and the perched conditions with an outlet channel. When discussing this parameter, both states (closed and perched) are referred to as a 'closure' in that tides are prevented from propagating into the estuary. The inlet stability parameter presented by Behrens et al. (2013) considers the daily balance between wave-driven sediment import to the inlet and sediment export driven by tidal fluctuations. The wave-driven import is assessed using nearshore wave estimates derived from a transformation matrix and offshore buoy data (ESA PWA, 2016) and the latter is estimated from tide gauge data within the estuary and a stage-storage relation derived from the available bathymetry. Using daily-average values of the stability parameter within the period 1999-2008, Behrens et al. (2013) showed that the stability parameter correlates with the probability of the inlet closing within five days. As the percentile of the stability parameter increases, the probability of inlet closure within five days increases exponentially, from probability of roughly five percent when the parameter is at the 50th percentile to a probability of 80 percent when it is measured at the 99th percentile.

SUMMER AND FALL CONDITIONS

Time series of estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 1 for the entire 2018 management period. The lagoon water level time series (Figure 1a) summarizes the fully-tidal conditions in the estuary throughout summer, and also shows the closure events that occurred later in the fall. During the management period, Russian River flows were lower than during the wet 2017 conditions, and similar to the dry years of 2013-2015. As shown in Figure 1d, flows at Hacienda temporarily dropped below 100 cfs in late June, and were otherwise between 100 and 150 cfs for most of the period from July to late November.

As in prior years, wave heights declined in May and June and were lowest through July, August, and September (Figure 1b). Although there were swell events present in summer, most of these were associated with wave heights less than 5 feet, and these did not appear to result in significant deposition in the inlet. The location of the inlet next to the groin may have also played a role in limiting deposition within the inlet. However, beginning in October, when wave heights began to frequently exceed 5 feet and have periods of 12 seconds or more, the inlet began to experience shallowing and closure.

CLOSURE PROBABILITY

The 5-day closure probability, a derivative of the inlet stability parameter described above, was hindcast for 2018 according to the method described in Behrens et al. (2013). This hindcast provides an indication of the utility of the stability parameter as a prediction tool for monitoring inlet conditions and planning management action. This parameter integrates wave and ocean forcing conditions, as well as estuary water levels, to provide greater predictive skill than just waves or ocean tides on their own. The predicted probability of closure exceeded 50% 2-5 days in advance of most of the closures in 2018 (Figure 1e).

TOPOGRAPHIC CHANGE

The Sonoma Water has conducted monthly surveys of Goat Rock State Beach that cover a region starting from the groin and extending approximately 1,500 feet to the north. The surveys do not include bathymetry within the inlet because flow conditions in the inlet prevent safe access. Also, the survey extent can be limited by the Sonoma Water's compliance with its marine mammal incidental harassment authorization, which sets guidelines for the survey crew's approach to marine mammals hauled out on the beach. Sonoma Water survey staff collect spot elevations using RTK-GPS and then assemble these elevations into a set of contour lines at 1-ft intervals, as well as profiles along the beach berm crest, the ocean wetted edge, and the estuary water line. The survey elevations are reported in the NGVD29 vertical datum.

To characterize beach berm topographic conditions, ESA assessed data from the Sonoma Water's 2018 surveys. Transects, whose location is shown in Figure 5, include two transects backed by cliff (Figure 6 and Figure 7), and two transects that extend into the estuary (Figure 8 and Figure 9). Since the inlet was located next to the groin for the entire management season, no topography was collected near the groin, Transect 0.

Peak flows in the 2018 water year did not surpass 15,000 cfs, and the inlet remained next to the groin for the entire season. This contrasted with the prior years, when river flows exceeded 40,000 cfs and caused most of the beach between the groin and the northern headland to erode, creating conditions for long-term re-growth of the berm throughout the management season. As a result of the low river flows during the winter of 2017-2018, beach berm conditions to the north of the groin were relatively stable during the 2018 management season. In general, beach profiles were the most stable at the extreme northern end of Goat Rock State Beach, and showed more variability closer to the jetty.

Figure 6 shows survey profiles at the northernmost location, Transect 4, from January to November 2018. Both the beach width and crest height remained stable throughout the season, and the profile showed minimal signs of shifting landward during the fall, when waves became more powerful. The crest height varied from about 16.5 to 17 feet NGVD.

Similarly, at Transect 3 immediately north of Haystack Rock (Figure 7), the beach crest elevation varied within a narrow range, at 15.5 to 16.5 feet NGVD. Although the location of the profile (in the landward-seaward direction) remained stable, the beach face was steepest in the summer months, and slightly less steep in winter and late fall months. This is a typical response to heightened wave power in those seasons, which typically results in a flatter slope.

South of Haystack Rock, Transects 1 and 2 showed a stronger seasonal pattern. From January to August, the beach crest height at Transect 2 varied from 14 to 14.5 feet NGVD, and then experienced growth from September to November (Figure 8). By November, the crest had grown to 16.5 feet NGVD, roughly the same as the northern transects. At Transect 1 (Figure 9) the beach foreshore formed a complex shape, possibly as a result of interaction with the nearby inlet. The peak crest height varied from about 12.5 to 14.5 feet NGVD, peaking in November.

Figure 10 illustrates some of the same patterns described above, by showing the along-beach crest profiles from January to November. Although the elevations did not vary significantly at a given location, the crest declined with proximity to the inlet and groin. The inlet actively transports sediment throughout the year, and is known to have a direct impact on beach morphology (as described in previous yearly summaries). The beach is typically lowest near the inlet because the combined tidal and river flows erode beach sediment and transport it either offshore or into the estuary.

BEACH WIDTH

To provide additional information about the beach morphology, ESA assessed the beach width using the Sonoma Water survey data. Figure 11 shows the evolution of the beach width at Transect 3 from 2010 to 2018. Beach width data were added for months outside of the management period to add context for seasonal changes. In previous years during winter months, the beach was often eroded at Transect 3 (north of Haystack Rock) to the point that the beach crest was below 12 ft NGVD, so that the width was effectively zero. This was the case in 2010, 2011, 2013, 2015, and 2017. The beach was widest in 2012 and 2014, when the mouth generally remained farthest to the south. These years also experienced the highest beach crest heights at Transect 3 (Figure 11). As already noted, the inlet was located near the groin for the 2018 management season, so the beach to the north was not influenced by the inlet. This is reflected in Figure 11, which indicates a stable width of 140-170 ft at an elevation of 12 feet NGVD throughout the management season.

JENNER WATER SURFACE ELEVATION EXCEEDANCE

The Biological Opinion (NMFS, 2008) sets a target for estuary water levels "a daily minimum water surface elevation of 3.2 feet [NGVD] during 70% of the year." To facilitate this target, the Biological Opinion notes "Absent river flood flows and historic mechanical breaching practices, NMFS expects cross shore transport of sand by wave action will be sufficient to maintain the bar at this elevation."

In 2018, the daily minimum water surface elevation exceeded 3.2 ft NGVD roughly 12% of the year (Figure 12), compared with 28% in 2017 and 24% in 2016. For comparison, Figure 12 also includes hourly estuary water surface elevation (exceeded 3.2 ft NGVD for roughly 20% of 2018, compared with 41% of 2017 and 38% of 2016) and hourly Point Reyes water surface elevation (exceeded 3.2 feet NGVD for roughly 5% of the year).

Beginning in April 2018, water levels have also been available at the Highway 1 bridge, from USGS Station 11467270. Figure 12 compares the time series and exceedance curves for both water level data sets. In general, the USGS gauge shows lower water levels during tidal periods, since the Jenner gauge is located higher in the water column and cannot track the lowest tides. Water level statistics from the USGS gauge are not representative of the entire year, but statistics from the truncated dataset show similar levels of exceedance above 3.2 feet NGVD.

LESSONS LEARNED AND RECOMMENDATIONS

Based on 2018 observations of the estuary, associated physical processes, and the Sonoma Water's planning for outlet channel management, we note the following lessons about implementing the outlet channel management plan.

CONCEPTUAL MODEL

- As observed in similarly dry years from 2012 to 2015, peak 2018 winter flows of less than 40,000 cfs limited the inlet's northward excursion, and the inlet remained near the groin for the entire management period.
- As noted in earlier reports, ocean waves with sufficient power to move sand into the inlet are needed to close the river mouth. These wave conditions occur predominantly in the early part of the management season and again in the fall at the end of the season.

REFERENCES

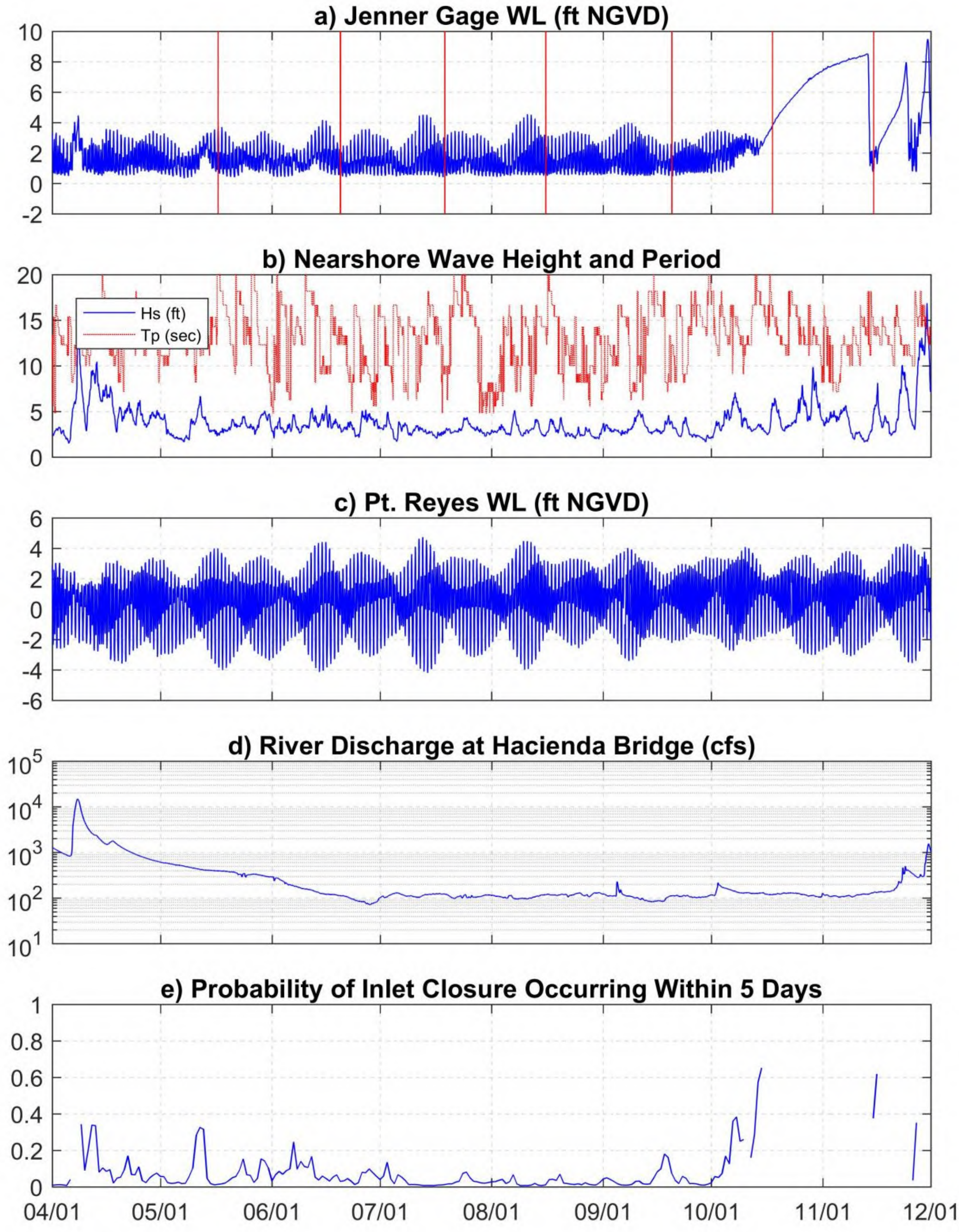
Behrens, D., Bombardelli, F., Largier, J. and E. Twohy. 2009. Characterization of time and spatial scales of a migrating rivermouth. Geophysical Research Letters. Vol. 36, L09402, doi:10.1029/2008GL037025.

Behrens, Dane K., Fabián A. Bombardelli, John L. Largier, and Elinor Twohy. 2013. "Episodic Closure of the Tidal Inlet at the Mouth of the Russian River — A Small Bar-Built Estuary in California." *Geomorphology* 189 (May): 66–80. doi:10.1016/j.geomorph.2013.01.017.

ESA PWA. 2016. Feasibility of alternatives to the Goat Rock State Beach jetty for managing lagoon water surface elevations. Prepared for the Sonoma County Water Agency.

National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed.

FIGURES

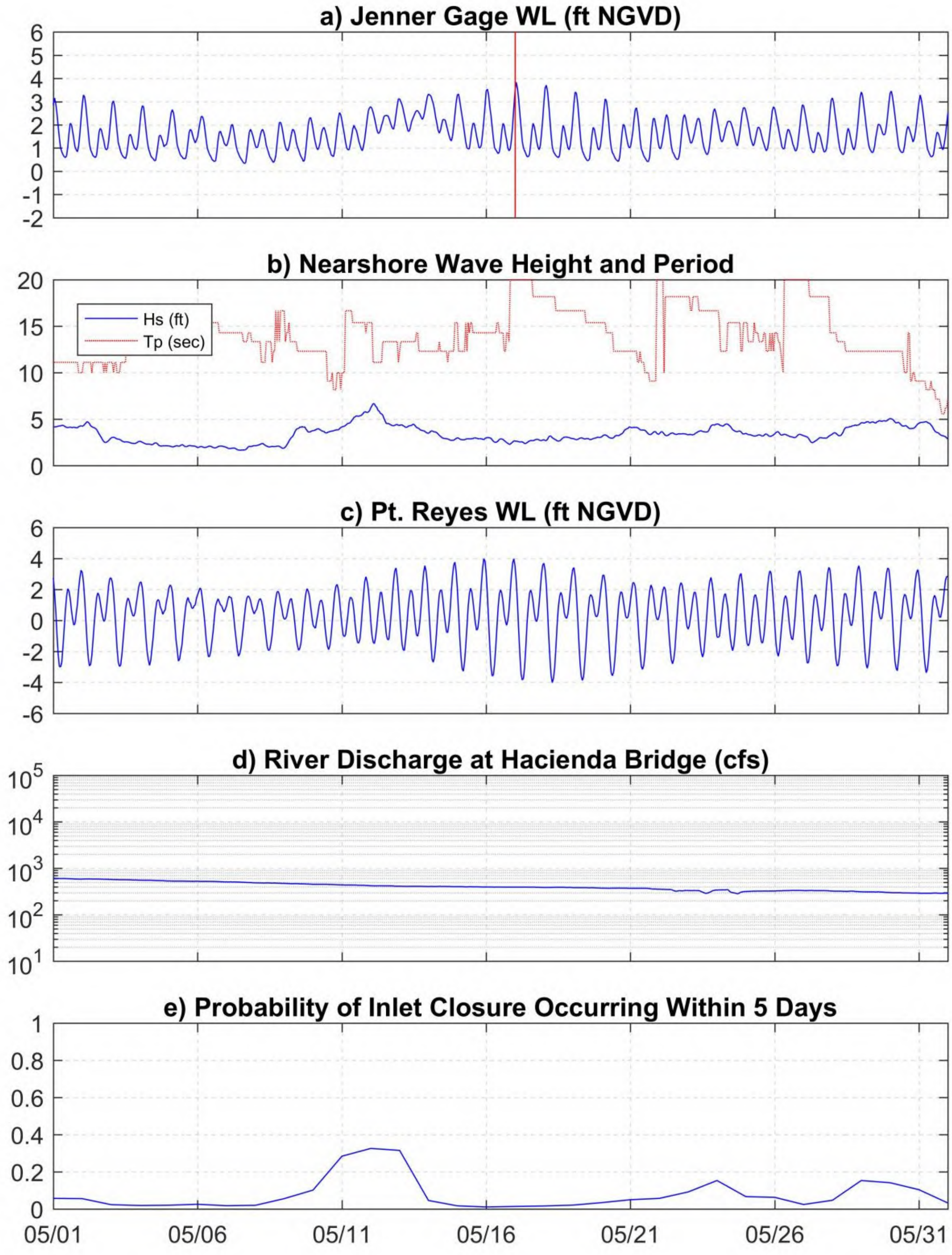


SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 1

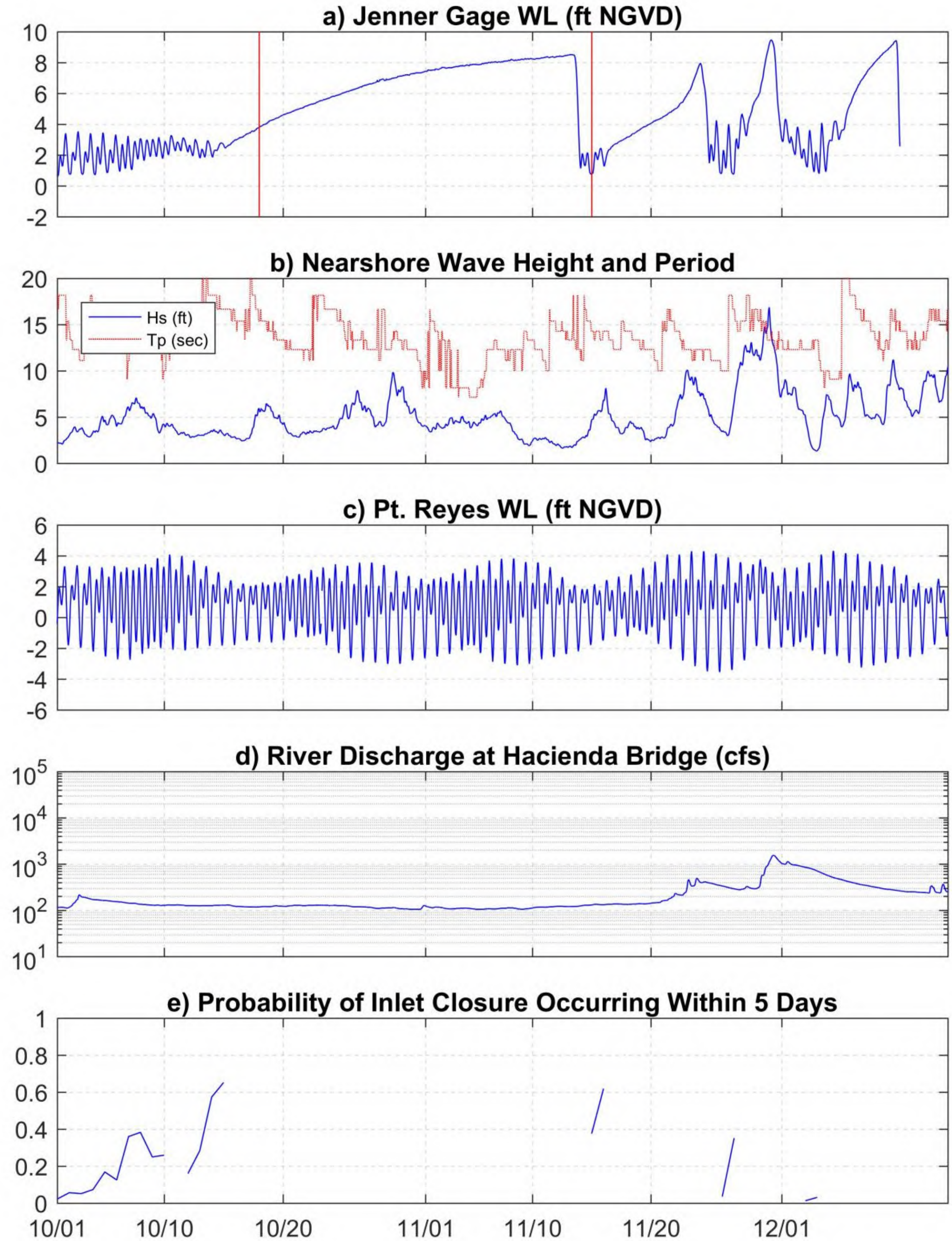
Estuary, Ocean, and River Conditions Compared with Closure Probability: April – November 2018



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

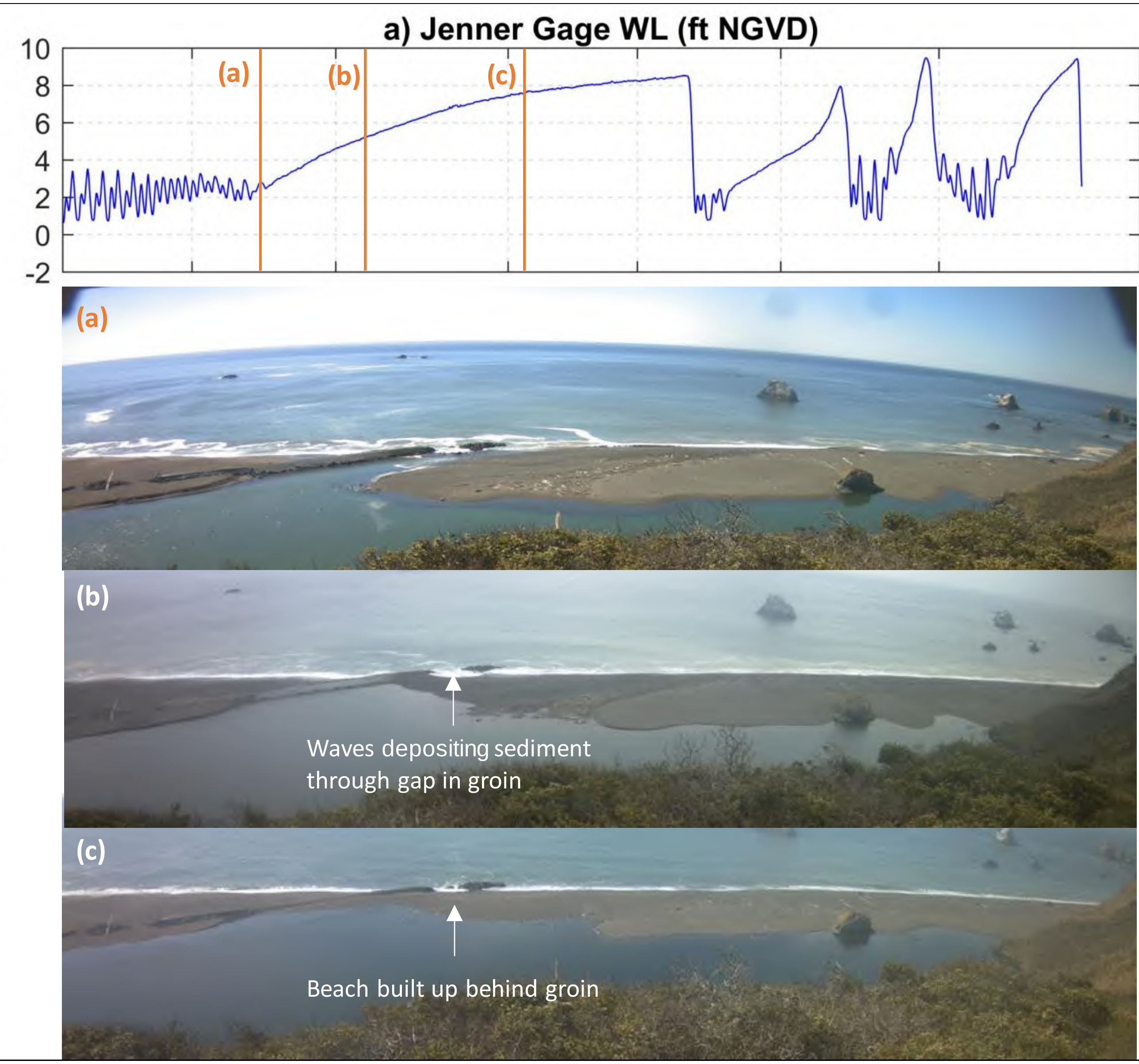
Figure 2
Estuary, Ocean, and River Conditions Compared with Closure Probability: May 2018



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 3
Estuary, Ocean, and River Conditions Compared with Closure Probability: October – December 2018



SOURCE: BML camera

Figure 4

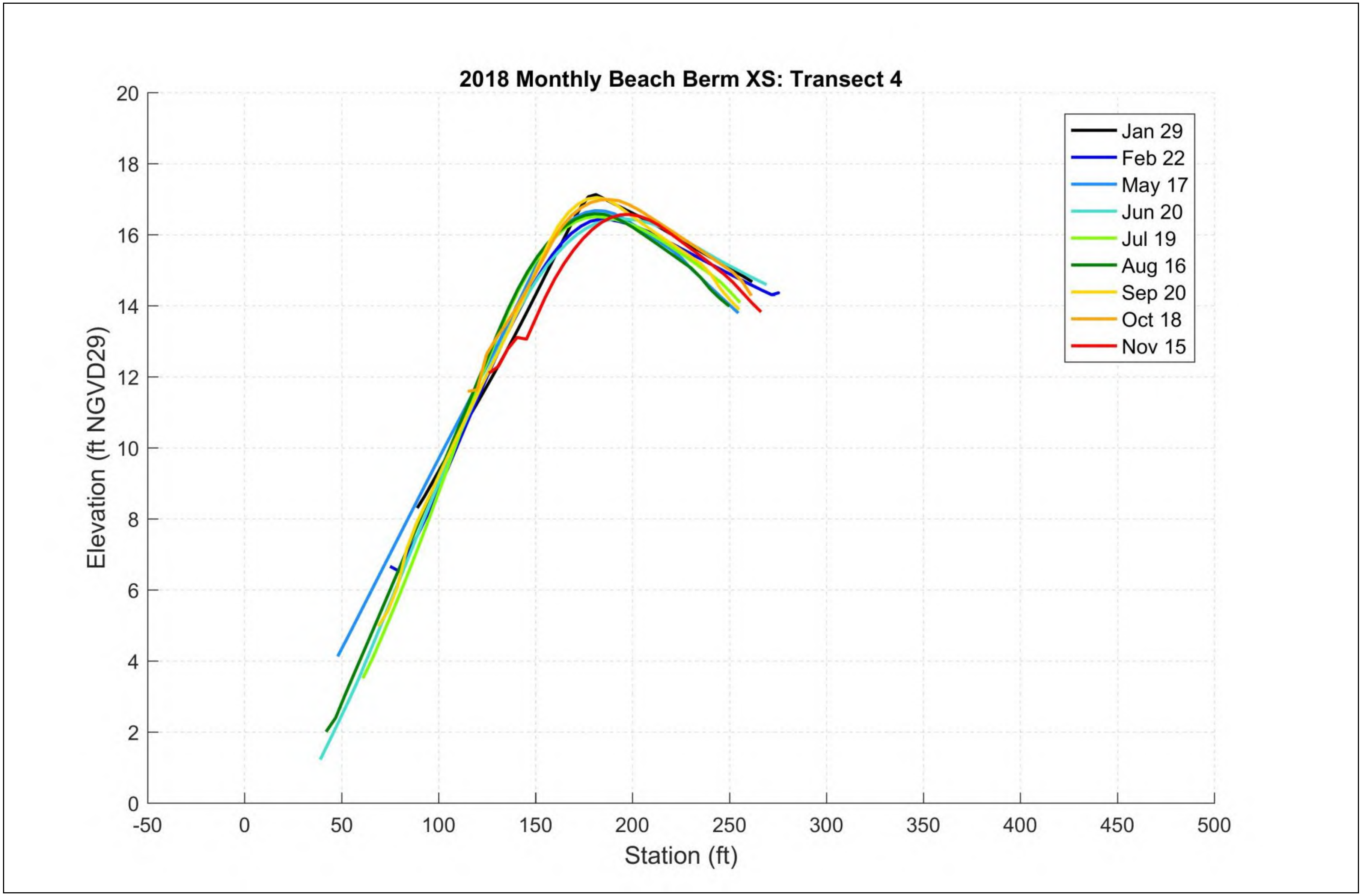
(a) Russian River prior to closure on October 15th, 2018, (b) immediately after closure, showing wave transmission through groin, and (c) after several weeks of closure.

SOURCE: image from USDA NAIP

Russian River Estuary Outlet Channel Management Plan . DW01958

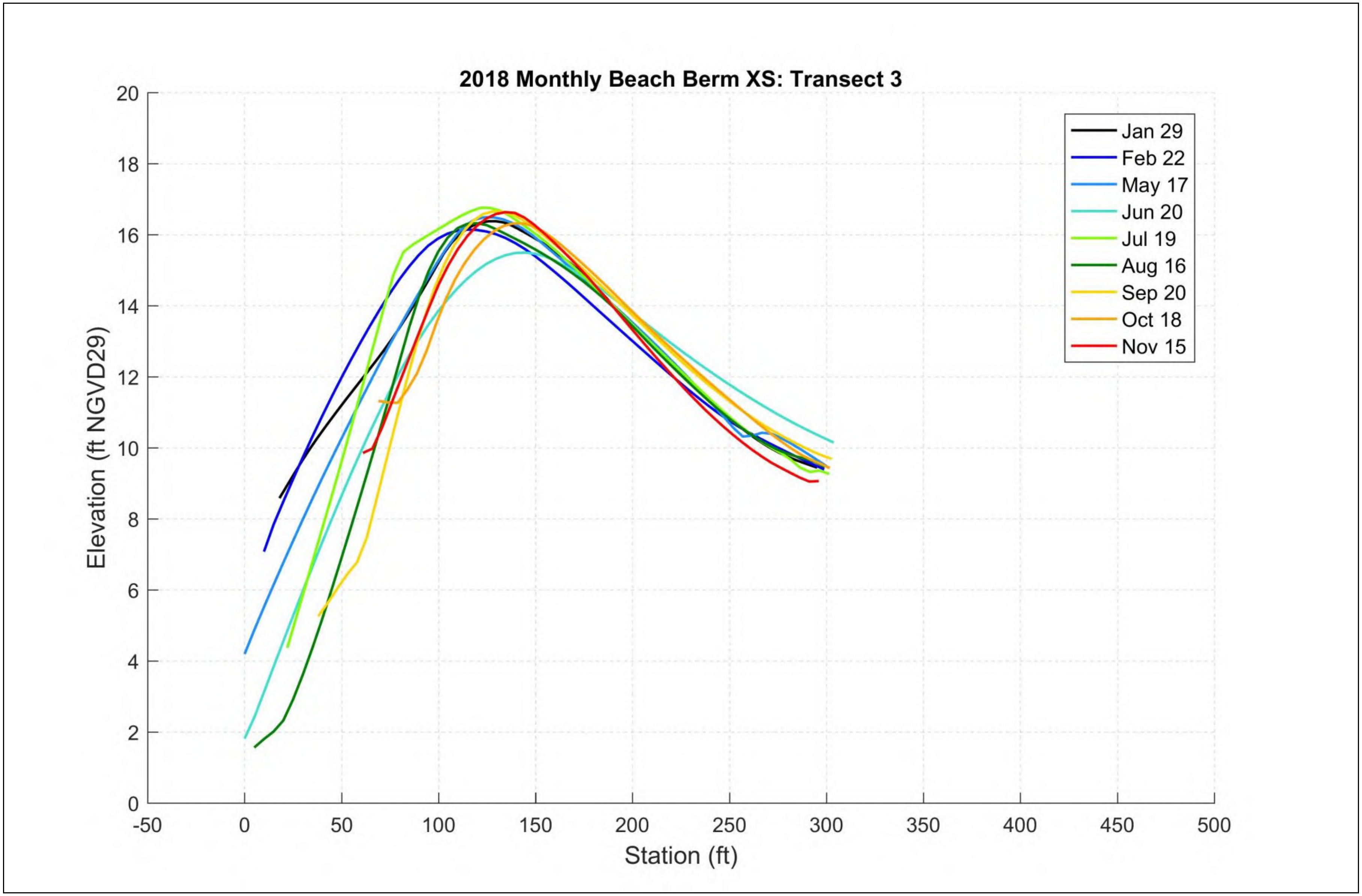
Figure 5

Beach Transect Locations



SOURCE: SCWA survey data

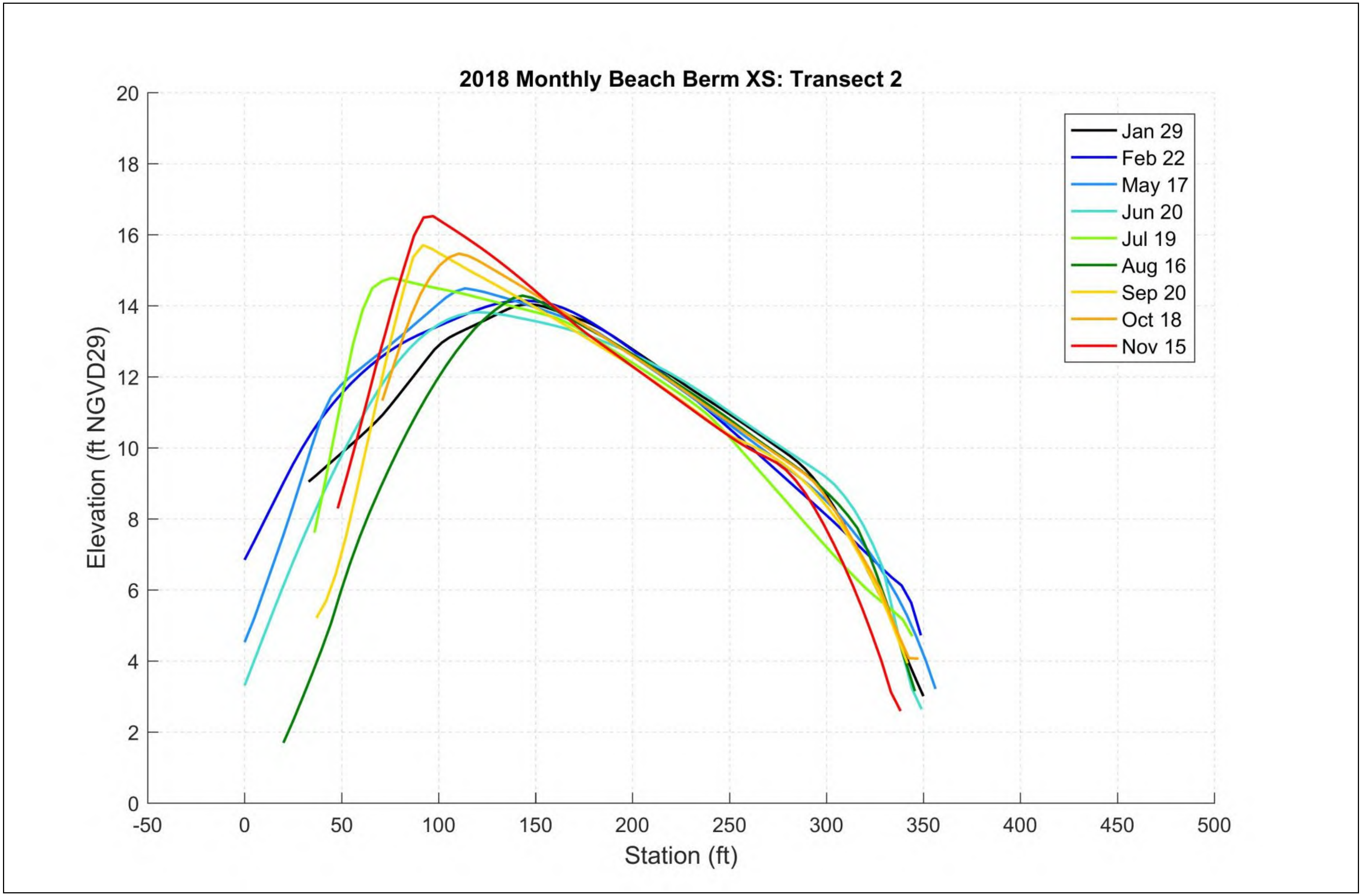
Figure 6
Beach Transect #4



SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

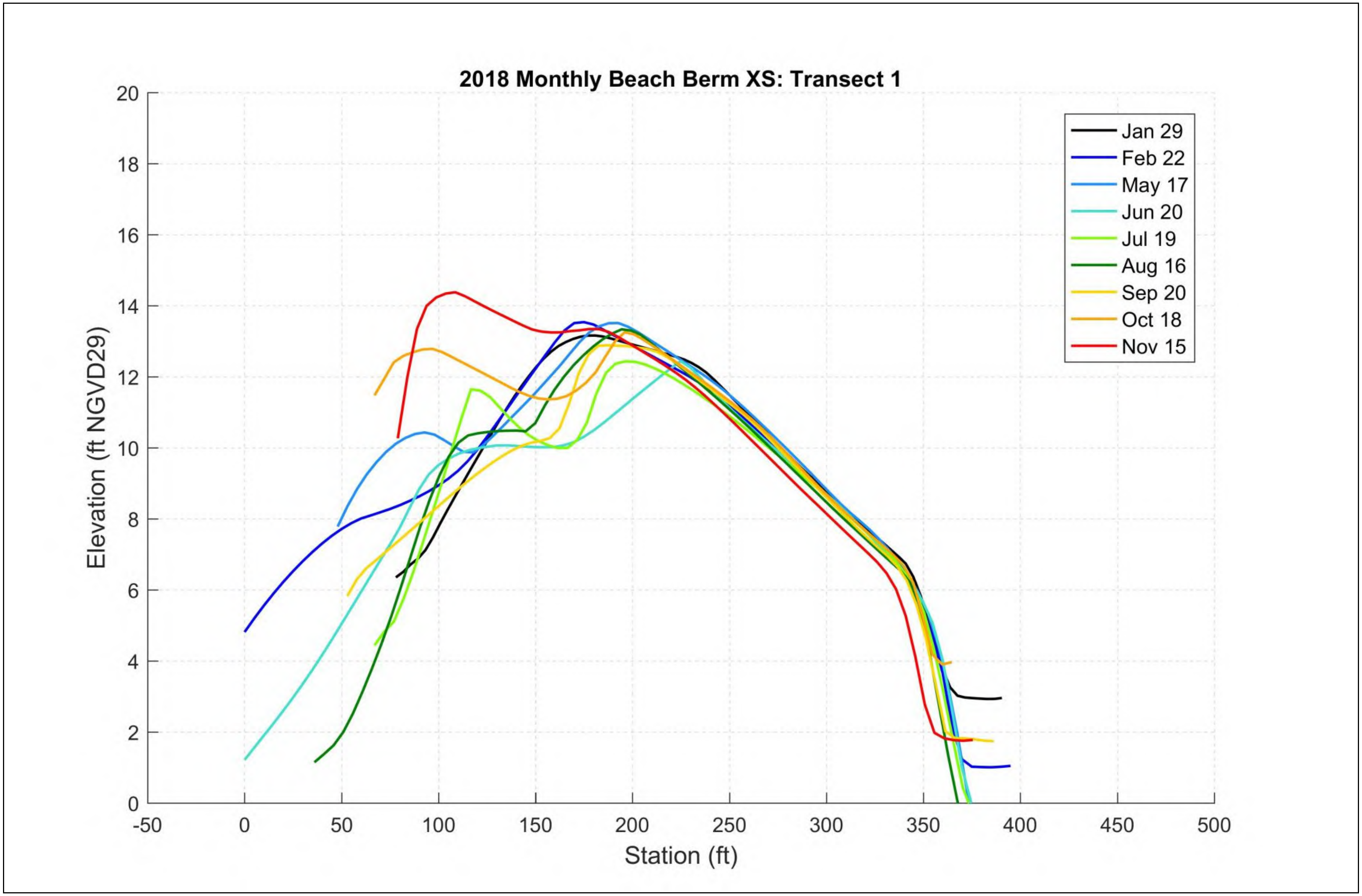
Figure 7
Beach Transect #3



SOURCE: SCWA survey data

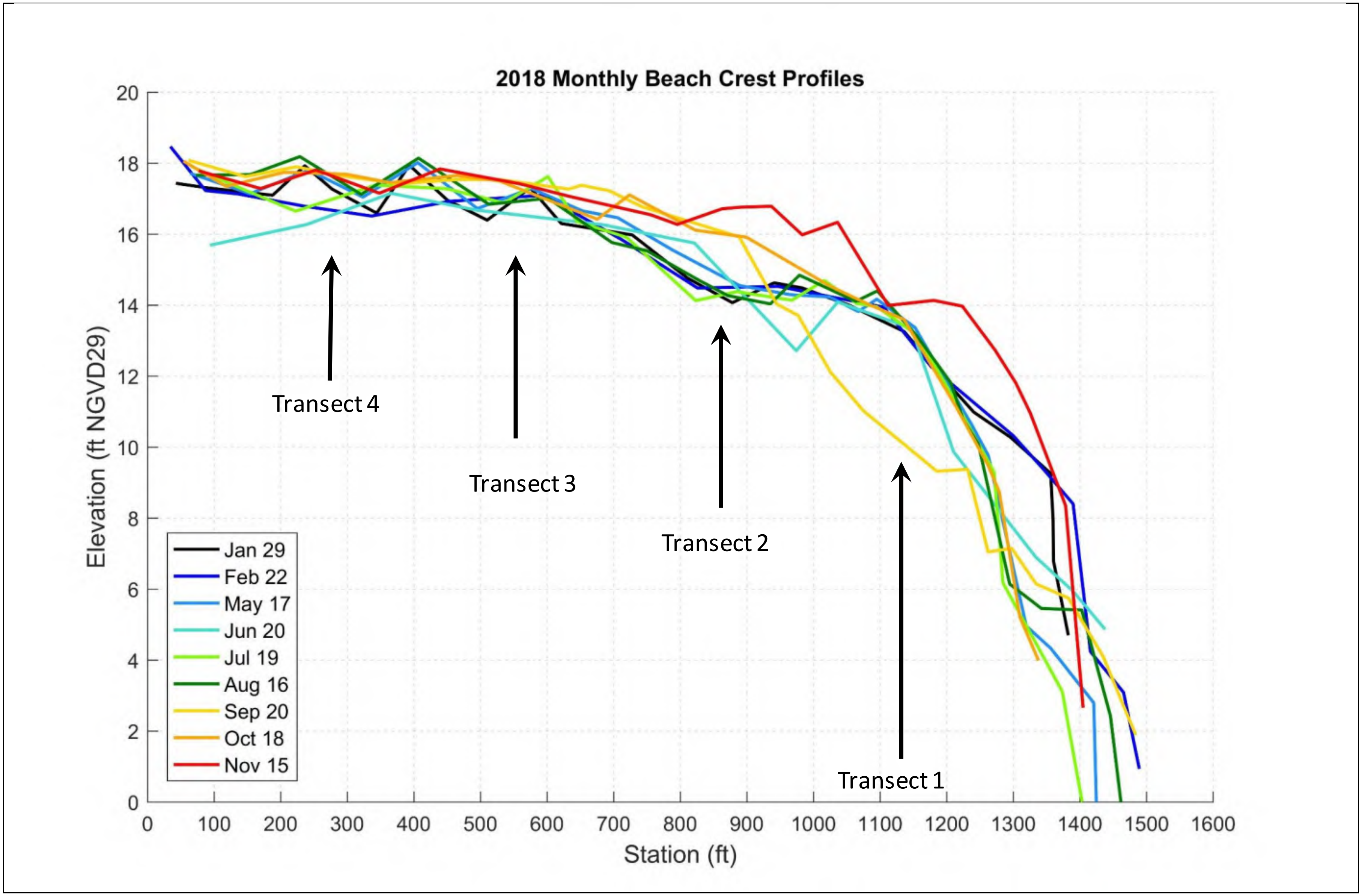
Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 8
Beach Transect #2



SOURCE: SCWA survey data

Figure 9
Beach Transect #1

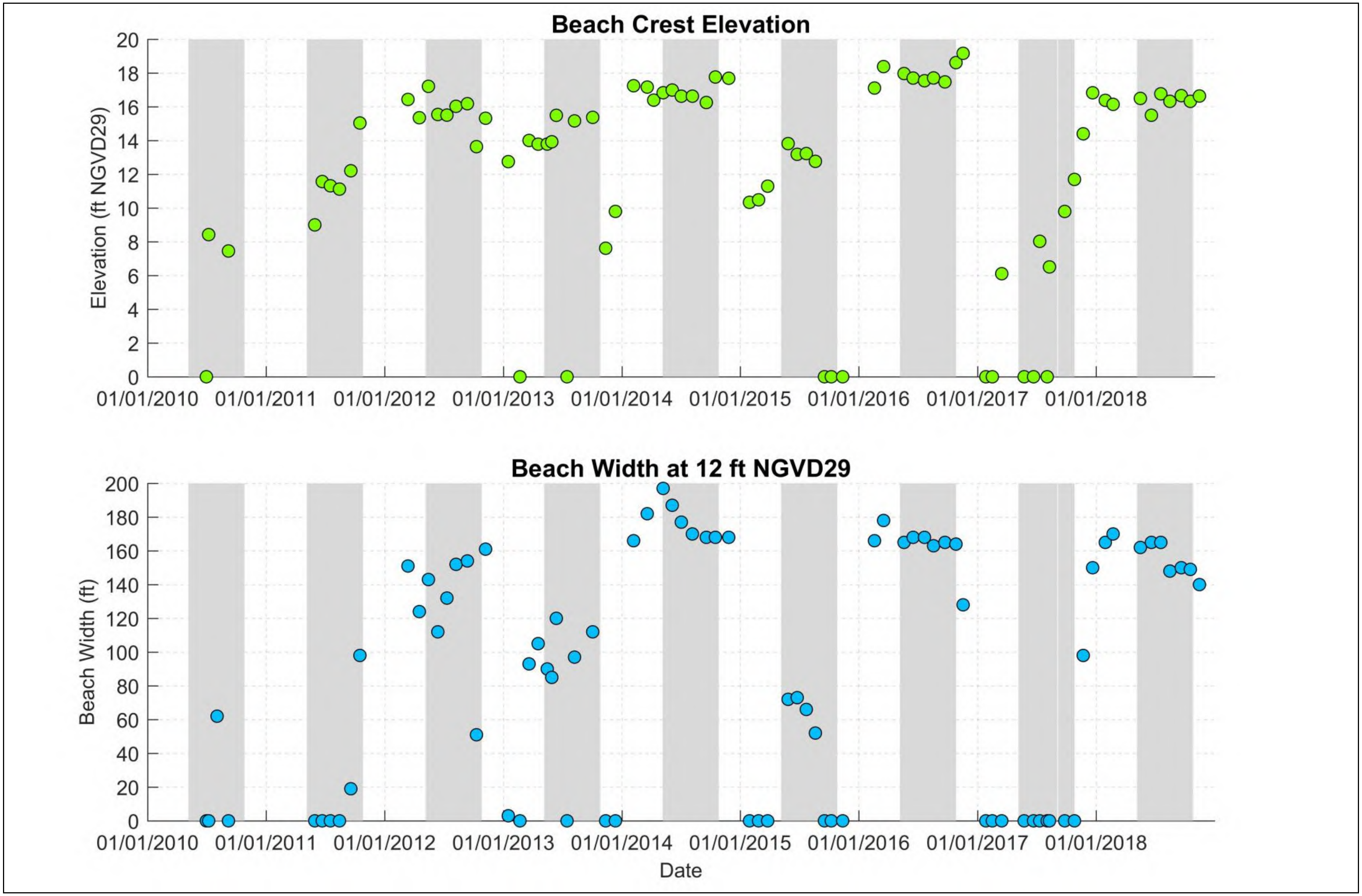


SOURCE: SCWA survey data

Note: Solid lines are from points identified as the beach crest during the monthly survey. Dashed lines are interpolated from surveyed points on the beach.

Figure 10

Beach Crest Profiles During the 2018 Management Period.

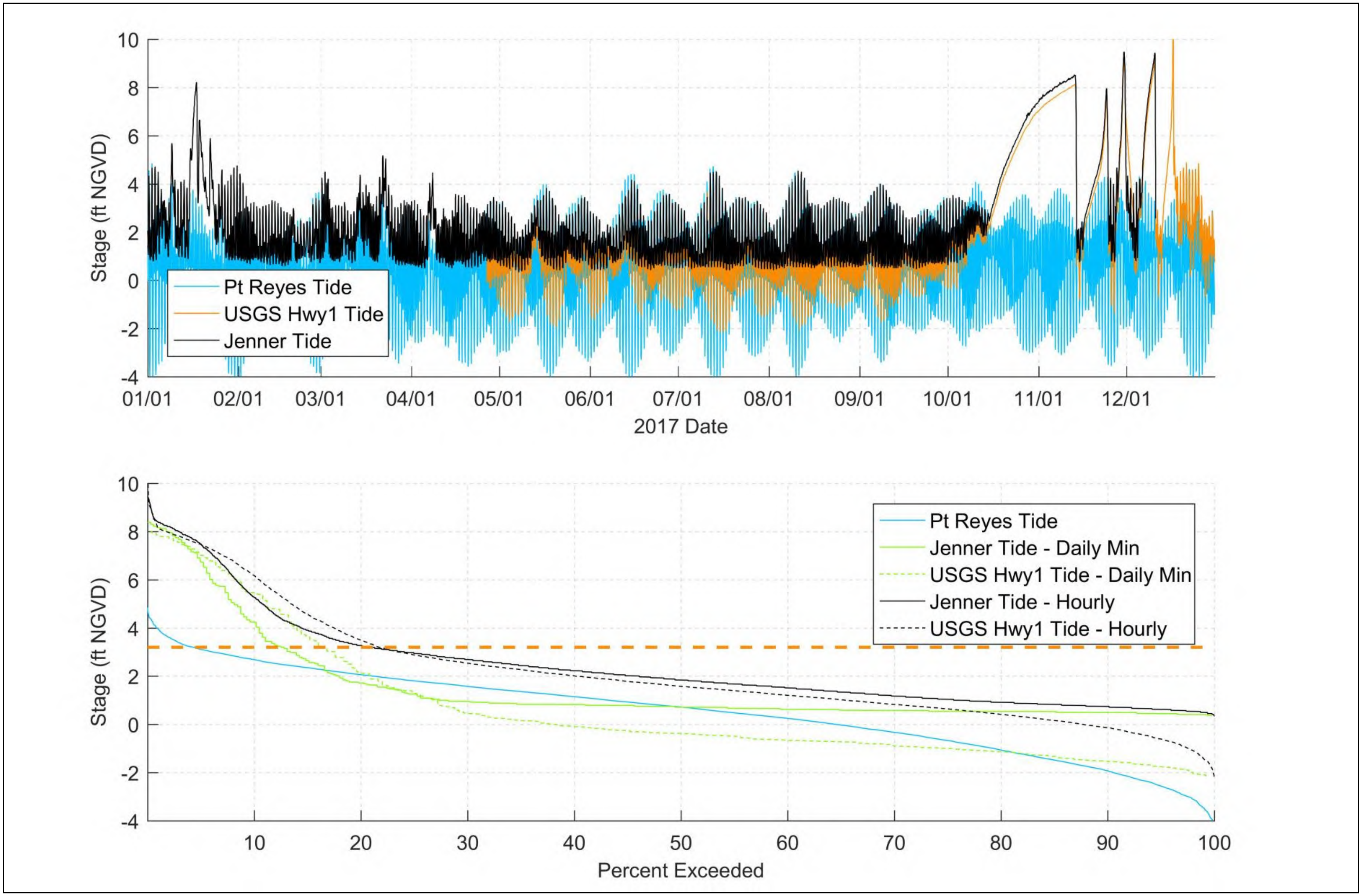


SOURCE: SCWA survey data

Note: width of zero indicates that the beach crest is below the elevation of 12 or 14 ft NGVD.

Figure 11

Transect 3 crest height and beach width (at 12ft NGVD elevation) from 2010 to 2018. Shaded areas represent management season.



SOURCE: SCWA Jenner Gage and NOAA Pt Reyes tide data

Figure 12

Russian River Estuary stage exceedance for 2018.

Attachment O. Physical Processes During the 2019 Management Period

As required by the Russian River Biological Opinion, Sonoma Water has been tasked with managing the Russian River Estuary to facilitate summer lagoon conditions to improve salmonid rearing habitat. To meet this goal, the Biological Opinion calls for decreasing marine influences in the estuary while also maintaining the current level of flood minimization for properties adjacent to the estuary (NMFS, 2008). The adaptive management plan, described in the main body of this report, was developed by the Sonoma Water with assistance from ESA and the Resource Agency Management Team in 2009 and revised annually from 2010 to 2019. Because of permit constraints, the Sonoma Water was only able to implement the plan beginning in 2010. In 2019, one mouth closure event occurred within the management season, but an outlet channel was not constructed, as the mouth self-breached before water levels reached the target elevation.

During the 2019 management season, May 15th to October 15th, Sonoma Water staff regularly monitored current and forecasted estuary water surface elevations, inlet state, river discharge, tides, and wave conditions to anticipate changes to the inlet's state. The winter of 2018/2019 was relatively wet, including two runoff events surpassing 40,000 cubic feet per second (cfs) in February alone. The peak event crested at 72,000 cfs at the USGS Hacienda Bridge gauge on February 27th. Overall, the winter had similarities to the winter of 2016/2017, and was a return to wet conditions after the relatively dry winter of 2017/2018. As a result of these high flow conditions, the beach north of the jetty groin experienced extensive erosion during the winter and was reconstructed by waves throughout the management season. The mouth closed for an extended period of time in July and August (Figure 1) as sediment discharged during the winter began to weld back onto the beach, similar to conditions observed in August of 2017. The mouth also experienced several brief periods of muted tides (less than 2 foot tide range) in May (Figure 2), and September (Figure 3), before fully closing after the end the management season in late October (Figure 1) and November. All observed closure events coincided with waves having peak periods greater than 16 seconds (Figure 1).

Owing to the large winter flows, the mouth migrated over a thousand feet northwest of the jetty by spring, which influenced its morphology throughout the management season. The prolonged summer mouth closure event occurred on July 18th, after a period of muted tides that had lasted for almost two weeks (Figure 4). The period of muted tides was notable in that it began during a spring ocean tidal phase, when the ocean tide range was almost 8 feet, which often creates currents in the mouth that cause net channel scour. River discharge at the time was also above 200 cfs. Muted conditions coincided with and were probably caused by a succession of long-period swell events (wave period greater than 16 seconds) that occurred from July 2nd to 20th. Although these wave events did not close the mouth, they caused enough deposition in the mouth to mute estuarine water levels, with water levels not falling below 3.5 feet NGVD29 for about two weeks. The mouth location on the beach may have been a contributing factor to the muted conditions, as its northward position created a more elongated (and frictional) channel than occurs when the mouth is located farther south. The vestiges of this elongated channel can be seen in Figure 5.

Muted tidal conditions were followed by a closure on July 18th during another period of long-period swell waves. By this time, the ocean tide range had diminished and flows at Hacienda bridge had dropped below 200 cfs. Estuary water level increases over the next several weeks tended to be below 0.3 feet per day. By August 1st, the mouth was still closed, water levels had increased to 8 feet NGVD29, and increases in water level were in the range of 0.1 to 0.2 feet per day. Throughout the event, Sonoma Water coordinated with NMFS and other agencies to monitor the event, with the plan of eventually creating an outlet channel as water levels neared 9 feet NGVD29. However, the mouth self-breached on August 3rd, before an outlet channel could be implemented. Peak water level was 8.56 feet NGVD29 at the Jenner Visitor Center. Although the Russian River mouth camera operated by BML was not in service at the time and could not take pictures, there were signs that a manual breach may have been performed by people on the beach.

METHODOLOGY

This review of the 2019 management period examines estuary water levels, ocean wave conditions, ocean water levels, riverine discharge, and beach topography, as well as inlet size and location. The sources for these parameters are listed in Table 1. These data were supplemented with personal observations and discussion with staff from the Sonoma Water, National Marine Fisheries Service (NMFS), California Department of Fish and Wildlife (CDFW), and BML.

Table 1. Data Sources

Parameter	Source
Estuary water level, ft NGVD (h_E)	Sonoma Water Jenner gauge USGS Highway 1 gauge #11467270
Wave height (H_s), period (T_a), and direction	CDIP Cape Mendocino buoy #094
Ocean water level (h_O)	NOAA Point Reyes #9415020
Russian River discharge (Q_f)	USGS Guerneville #11467000
Beach topography, ft NGVD	Sonoma Water monthly surveys
Inlet size and location	Sonoma Water autonomous camera (operated by BML)

INLET STABILITY PARAMETER AND CLOSURE PROBABILITY

In addition to considering individual parameters, researchers at BML have developed a combined parameter to evaluate the stability of the inlet's state. This stability parameter is then used to predict closure (Behrens et al., 2013). Note that the inlet stability parameter does not differentiate between full closure and the perched conditions with an outlet channel. When discussing this parameter, both states (closed and perched) are referred to as a 'closure' in that tides are prevented from propagating into the estuary. The inlet stability parameter presented by Behrens et al. (2013) considers the daily balance between wave-driven sediment import to the inlet and sediment export driven by tidal fluctuations. The wave-driven import is assessed using nearshore wave estimates derived from a transformation matrix and offshore buoy data (ESA PWA, 2016) and the latter is estimated from tide gauge data within the estuary and a stage-storage relation derived from the available bathymetry. Using daily-average values of the stability parameter within the period 1999-2008, Behrens et al. (2013) showed that the stability parameter correlates with the probability of the inlet closing within five days. As the percentile of the stability parameter increases, the probability of inlet closure within five days increases exponentially, from probability of roughly five percent when the parameter is at the 50th percentile to a probability of 80 percent when it is measured at the 99th percentile.

SUMMER AND FALL CONDITIONS

Time series of estuary water levels, as well as the key forcing factors (waves, tides, and riverine discharge), are shown in Figure 1 for the entire 2019 management period. The lagoon water level time series (Figure 1a) summarizes the fully-tidal conditions in the estuary throughout summer, and also shows the closure events that occurred later in the fall. During the management period, Russian River flows were higher than during the dry 2018 conditions, and similar to the wet 2017 conditions. As shown in Figure 1d, flows at Hacienda did not drop below 150 cfs at any time in 2019.

As in prior years, wave heights declined in May and June and were lowest through July, August, and September (Figure 1b). Although swell events in summer tended to have wave heights of less than 5 feet, there were almost ten events where wave periods were above 18 seconds, long-period waves are known to be more effective at moving sand onto the beach. The location of the inlet played a role in the shape of the beach and the hydrology of the estuary, similarly to 2017. As with that year, wet conditions forced the mouth to migrate north, and led to an elongated channel in spring and summer, before the mouth eventually breached near the jetty on August 3rd.

CLOSURE PROBABILITY

The 5-day closure probability, a derivative of the inlet stability parameter described above, was hindcast for 2019 according to the method described in Behrens et al. (2013). This hindcast provides an indication of the utility of the stability parameter as a prediction tool for monitoring inlet conditions and planning management action. This parameter integrates wave and ocean forcing conditions, as well as estuary water levels, to provide greater predictive skill than just waves or ocean tides on their own. The parameter (Figure 1e) indicated a high likelihood of closure events in mid-September (when the mouth became muted briefly but did not close), and prior to the observed closure events in October and November. However, the parameter did not predict the closure event in July. This may be a result of the model relying more on wave height as an indicator of sand deposition, rather than wave period. The model could be updated in light of these results to include both height and period, as was done for the Quantified Conceptual Model (QCM) that was used to inform the Goat Rock Jetty Feasibility Study.

TOPOGRAPHIC CHANGE

The Sonoma Water has conducted monthly surveys of Goat Rock State Beach that cover a region starting from the groin and extending approximately 1,500 feet to the north. The surveys do not include bathymetry within the inlet because flow conditions in the inlet prevent safe access. Also, the survey extent can be limited by the Sonoma Water's compliance with its marine mammal incidental harassment authorization, which sets guidelines for the survey crew's approach to marine mammals hauled out on the beach. Sonoma Water survey staff collect spot elevations using RTK-GPS and then assemble these elevations into a set of contour lines at 1-ft intervals, as well as profiles along the beach berm crest, the ocean wetted edge, and the estuary water line. The survey elevations are reported in the NGVD29 vertical datum.

To characterize beach berm topographic conditions, ESA assessed data from the Sonoma Water's 2019 surveys. Transects, whose location is shown in Figure 6, include two transects backed by cliff (Figure 7 and Figure 8), and two transects that extend into the estuary (Figure 9 and Figure 10). Due to wet conditions eroding most of the beach in winter, and the breaching of the mouth near the jetty in August, data were only collected at Transect 0 during two months (not shown).

Peak flows in the 2019 water year reached 72,000 cfs at Hacienda Bridge, and along with contributions from lower tributaries may have been approximately 80,000 cfs. This contrasted with 2018 and the prolonged dry period from 2011 to 2016, when low flows typically kept the beach from eroding in winter, leaving the mouth near the jetty during most months. Although 2017 experienced a greater number of high flow events above 10,000 cfs, the 2017 and 2019 management seasons experienced many similarities in beach conditions. After river flows eroded most of the beach in winter, waves gradually re-built the beach throughout the management season.

Figure 7 shows survey profiles at the northernmost location, Transect 4, from January to December 2019. The crest was initially at 13.5 feet NGVD in January prior to the major February runoff events, and the width was roughly 50 to 100 feet. After February the beach in this location eroded, but began to show a steady growth pattern beginning in June, and leading once again to a crest height of about 14 feet and width of 50 to 100 feet in December. This showed that the beach can be fully recreated within a single calendar year if the conditions are appropriate.

At Transect 3 immediately north of Haystack Rock (Figure 8), the beach crest elevation underwent a similar pattern, although the beach was eroded more completely by the February high river discharge and did not fully re-grow to its pre-flood condition by the end of the year. In January 2019, the beach crest was at 16.5 feet NGVD. After erosion, the crest elevation increased to a height of about 9 feet NGVD in July, 10.5 feet NGVD in August, 14 feet NGVD in October, and remained steady through December. After recovering from its landward position in June, the location of the crest (in the landward-seaward direction) remained stable during the regrowth period, July-December.

South of Haystack Rock, Transects 1 and 2 showed a similar growth pattern, but also showed continued seaward movement of the crest throughout the year. At Transect 2 (Figure 9), immediately after the February floods, the beach was located several hundred feet farther out to sea than its typical summer location. Between March and May the beach migrated about 300 feet landward, although it did not grow vertically. The largest periods of vertical growth occurred between May and June, and between June and July, with the crest reaching almost 9 feet NGVD29 by July 30th. After July, the beach face started to become steeper as it continued to grow, and the beach crest moved seaward again by about 100 feet. Its final crest height in December was about 12 feet NGVD. At Transect 1 (Figure 10) the trend in beach position was similar, but its growth throughout the summer and fall was more variable month-to-month, as it was closer to the inlet after it breached near the jetty groin in early August. The final crest height in December was about 12 feet NGVD.

Figure 11 illustrates some of the same patterns described above, by showing the along-beach crest profiles from January to December. At the north end of the beach (near Transect 4), there were two sets of beach 'crests', a seaward crest that experienced erosion and rebuilding as described above, and an older ridge that is located near the bluff edge. Figure 11 indicates the height of the higher landward crest, which was stable throughout the management season. Farther south, at Transects 1-3, the crest underwent a period of erosion in February and subsequent growth in spring and summer, with peak growth evident between March and May, and between May and June. A low point or 'saddle' formed in the crest between Transects 2 and 3, just north of Haystack Rock, beginning in September. This may be a result of the inlet having been located at this segment of the beach in spring, such that beach growth was limited here during spring, whereas farther south the growth of the beach had begun as early as March.

BEACH WIDTH

To provide additional information about the beach morphology, ESA assessed the beach width using the Sonoma Water survey data. Figure 12 shows the evolution of the beach width at Transect 3 from 2010 to 2019. Beach width data were added for months outside of the management period to add context for seasonal changes. In the wet winters of 2010, 2011, and 2017, the beach was often eroded at Transect 3 (north of Haystack Rock) to the point that the beach crest was below 12 ft NGVD, so that the width was effectively zero. The beach was widest in 2012, 2014, and 2018, when the mouth generally remained farthest to the south. These years also experienced the highest beach crest heights at Transect 3 (Figure 12). As already noted, the high river discharge eroded an extensive inlet in 2019, such that 2019 beach widths were similar to other wet winters.

JENNER WATER SURFACE ELEVATION EXCEEDANCE

The Biological Opinion (NMFS, 2008) sets a target for estuary water levels "a daily minimum water surface elevation of 3.2 feet [NGVD] during 70% of the year." To facilitate this target, the Biological Opinion notes "Absent river flood flows and historic mechanical breaching practices, NMFS expects cross shore transport of sand by wave action will be sufficient to maintain the bar at this elevation."

In 2019, the daily minimum water surface elevation exceeded 3.2 ft NGVD for roughly 16% of the year (Figure 13), compared with 12% in 2018, 28% in 2017, and 24% in 2016. For comparison, Figure 13 also includes hourly estuary water surface elevation (exceeded 3.2 ft NGVD for roughly 28% in 2019, compared with 20% of 2018, 41% of 2017 and 38% of 2016) and hourly Point Reyes water surface elevation (exceeded 3.2 feet NGVD for roughly 5% of the year).

Beginning in April 2018, water levels have also been available at the Highway 1 bridge, from USGS Station 11467270. Figure 13 compares the time series and exceedance curves for both water level data sets. In general, the USGS gauge shows lower water levels during tidal periods, since the USGS gauge is mounted lower than the Jenner gauge and the Jenner gauge cannot record the lowest tides.

LESSONS LEARNED AND RECOMMENDATIONS

Based on 2019 observations of the estuary, associated physical processes, and the Sonoma Water's planning for outlet channel management, we note the following lessons about implementing the outlet channel management plan.

CONCEPTUAL MODEL

- After similar conditions between the wet years of 2017 and 2019, there is more confirmation of some of the expected patterns that develop. In both years, most of the beach eroded during the peak flow events, and then remained at the north end of the beach in spring, allowing the inlet to be elongated and frictional during the management season, which contributes to behavior of both the beach and the mouth. In 2019 this contributed to the mouth to having muted tidal conditions for two weeks, prior to closing in July.
- A key finding of both the 2017 and 2019 wet years is that closure events in mid-summer may be more likely during wet years. Otherwise these events tend to be rare in summer since wave conditions are typically too weak. Evidence from these two years suggests that sediment supply to the nearshore zone during high winter discharge may cause the sediment to form sand bars, which then facilitate mid-summer closure.
- As noted in earlier reports, ocean waves with sufficient power to move sand into the inlet are needed to close the river mouth. These wave conditions occur predominantly in the early part of the management season and again in the fall at the end of the season. However, waves with low height but long periods ('long-period swell waves') can also induce inlet closure or a reduced-size inlet that causes tidal muting.

REFERENCES

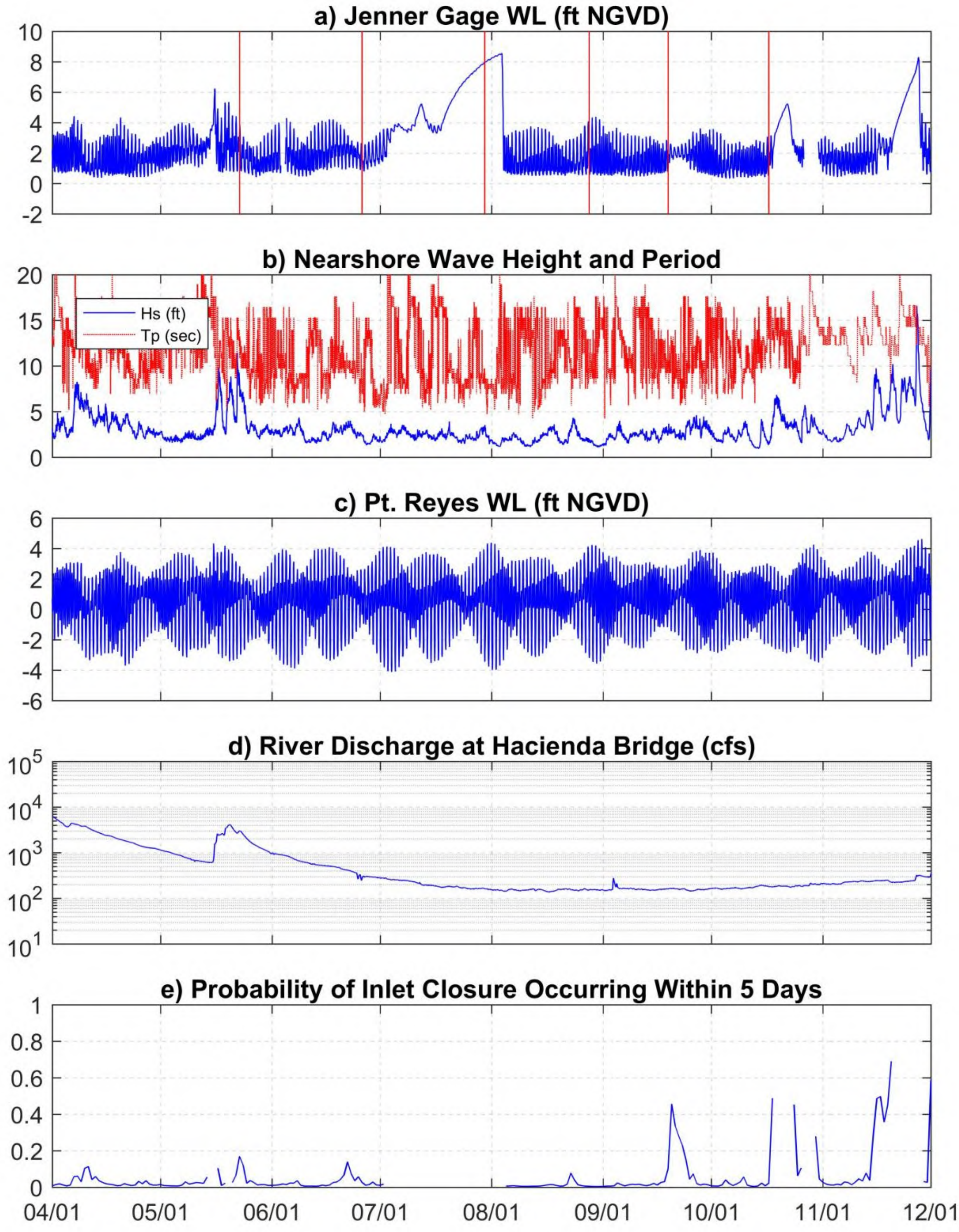
Behrens, D., Bombardelli, F., Largier, J. and E. Twohy. 2009. Characterization of time and spatial scales of a migrating rivermouth. Geophysical Research Letters. Vol. 36, L09402, doi:10.1029/2008GL037025.

Behrens, Dane K., Fabián A. Bombardelli, John L. Largier, and Elinor Twohy. 2013. "Episodic Closure of the Tidal Inlet at the Mouth of the Russian River — A Small Bar-Built Estuary in California." *Geomorphology* 189 (May): 66–80. doi:10.1016/j.geomorph.2013.01.017.

ESA PWA. 2016. Feasibility of alternatives to the Goat Rock State Beach jetty for managing lagoon water surface elevations. Prepared for the Sonoma County Water Agency.

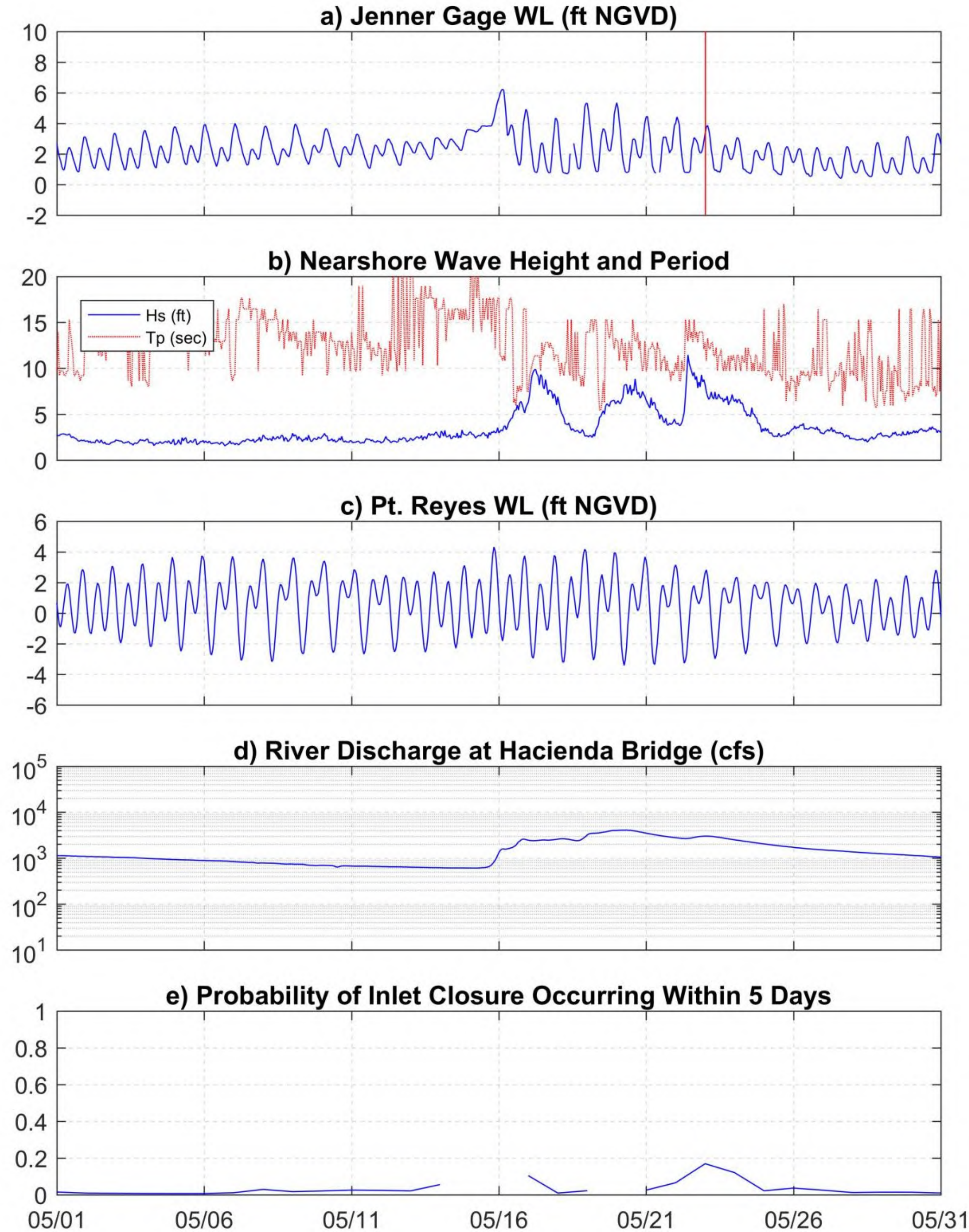
National Marine Fisheries Service (NMFS). 2008. Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers, the Sonoma County Water Agency, and the Mendocino County Russian River Flood Control and Water Conservation Improvement District in the Russian River watershed.

FIGURES



SOURCE:
a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 1
Estuary, Ocean, and River Conditions Compared with Closure Probability: April – November 2019

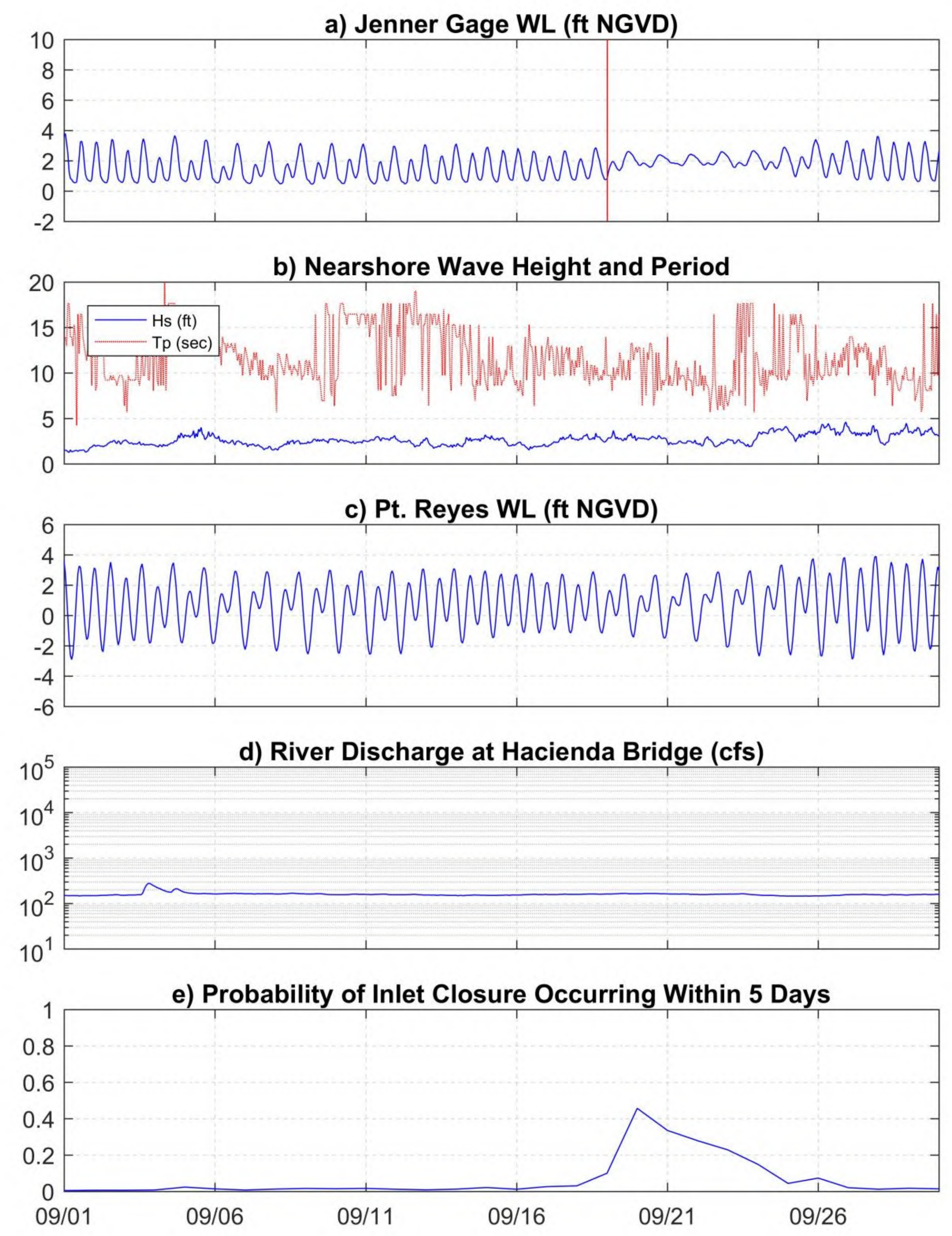


SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 2

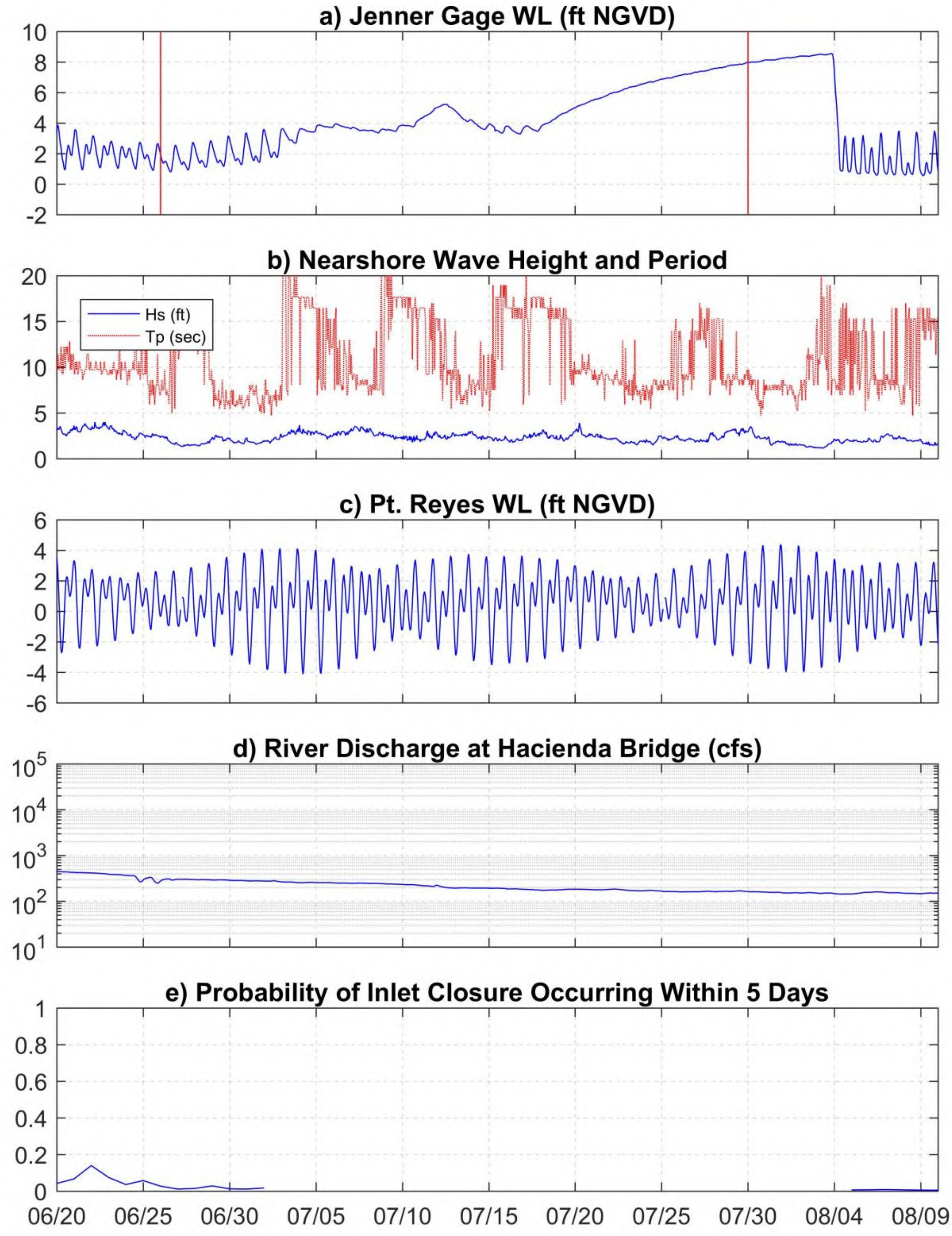
Estuary, Ocean, and River Conditions Compared with Closure Probability: May 2019



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 3
Estuary, Ocean, and River Conditions Compared with Closure Probability: September 2019



SOURCE:

a) Jenner gage water level provided by SCWA; red bar = beach survey
b) H_s = sig. wave height; Tp=peak wave period (CDIP, Pt. Reyes, #029)
c) Ocean water level provided by NOAA (Pt. Reyes #9415020)
d) River discharge provided by USGS (Guerneville #11467000)
e) Five-day closure probability provided after Behrens et al. (2013)

Figure 4
Estuary, Ocean, and River Conditions Compared with Closure Probability: June – August 2019

SOURCE: image provided by Sonoma Water

Russian River Estuary Outlet Channel Management Plan . DW01958

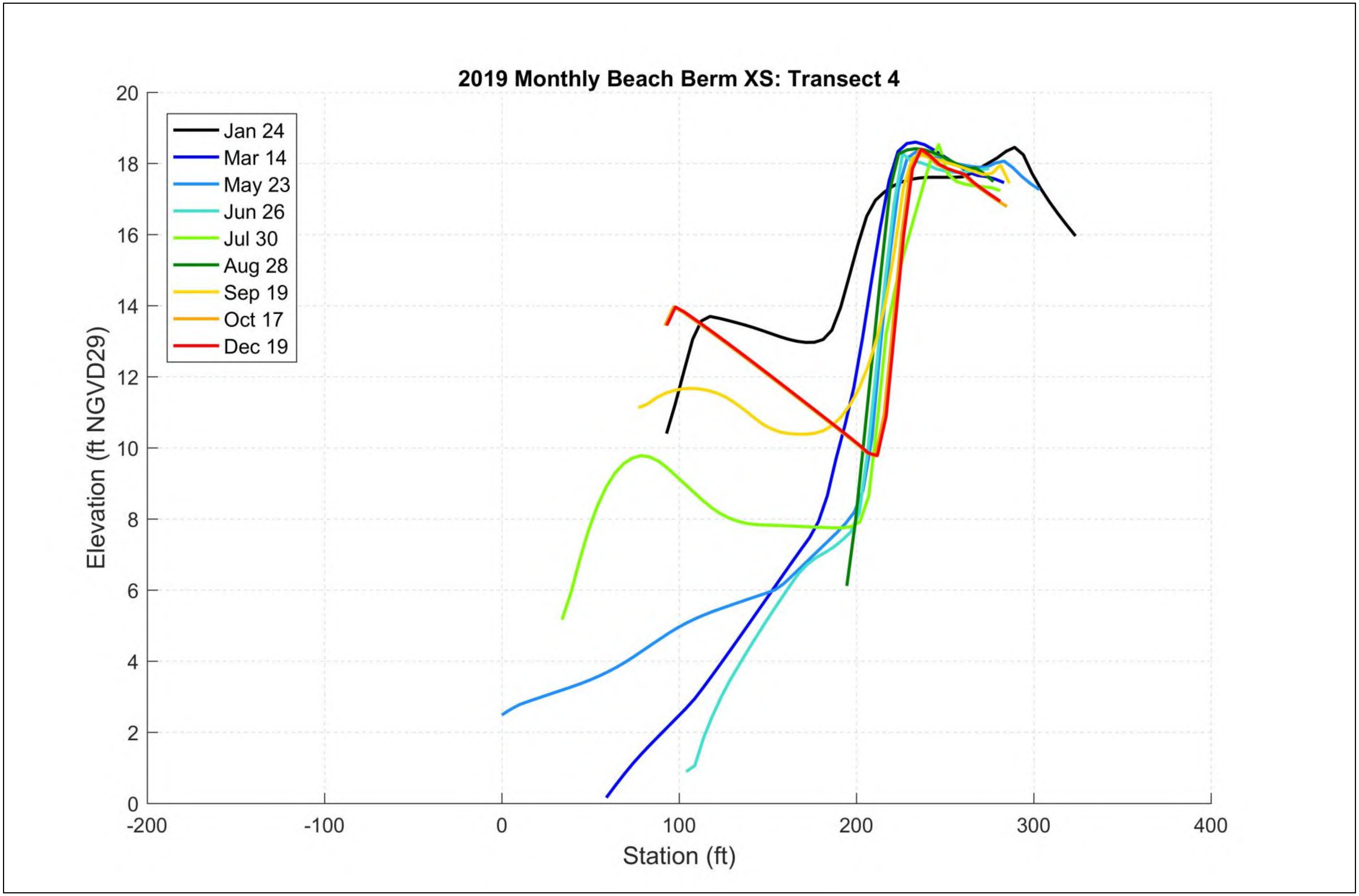
Figure 5

Condition of the beach on July 29th, 2019.

SOURCE: image from USDA NAIP

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 6
Beach Transect Locations

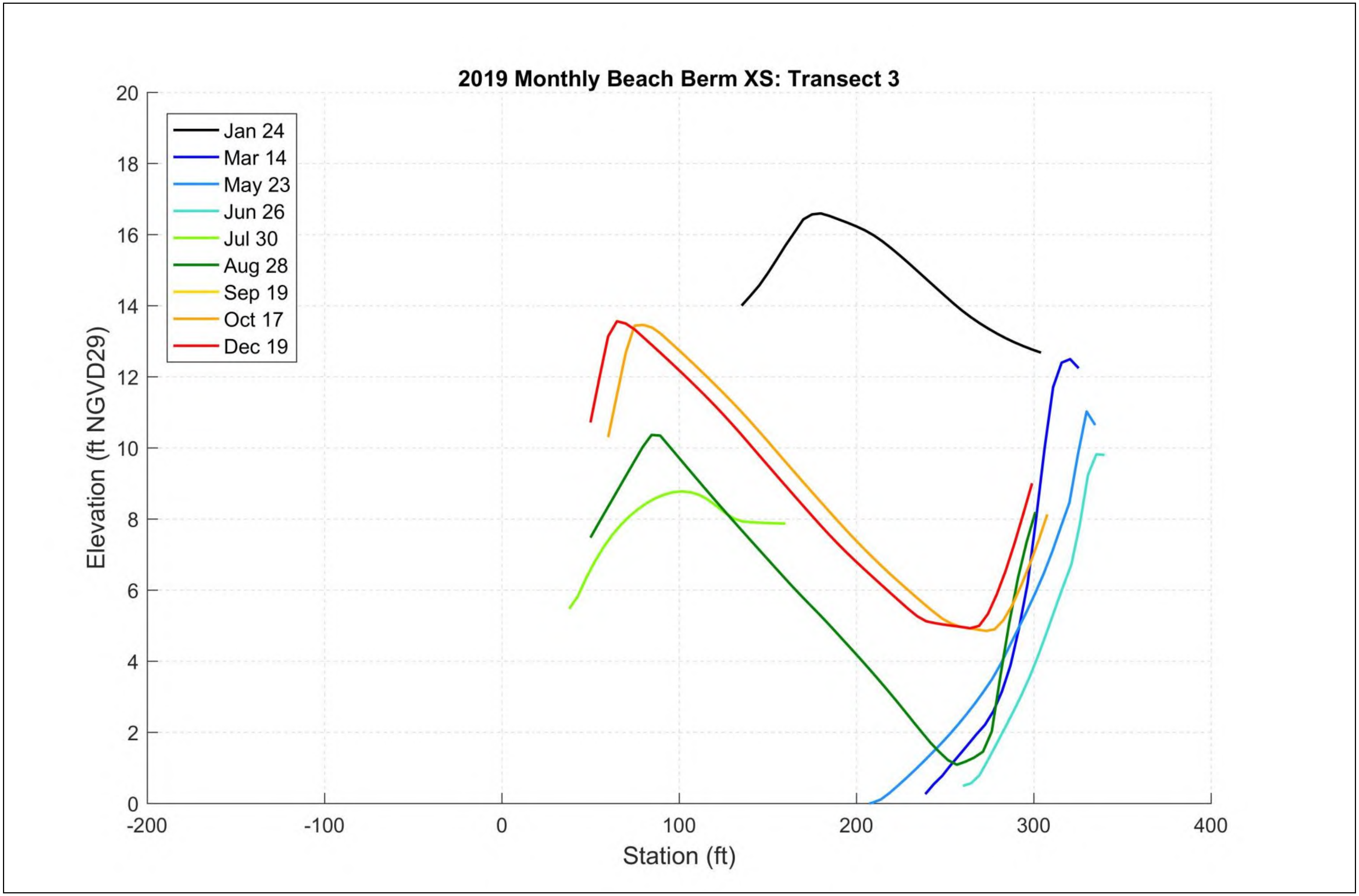


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 7

Beach Transect #4

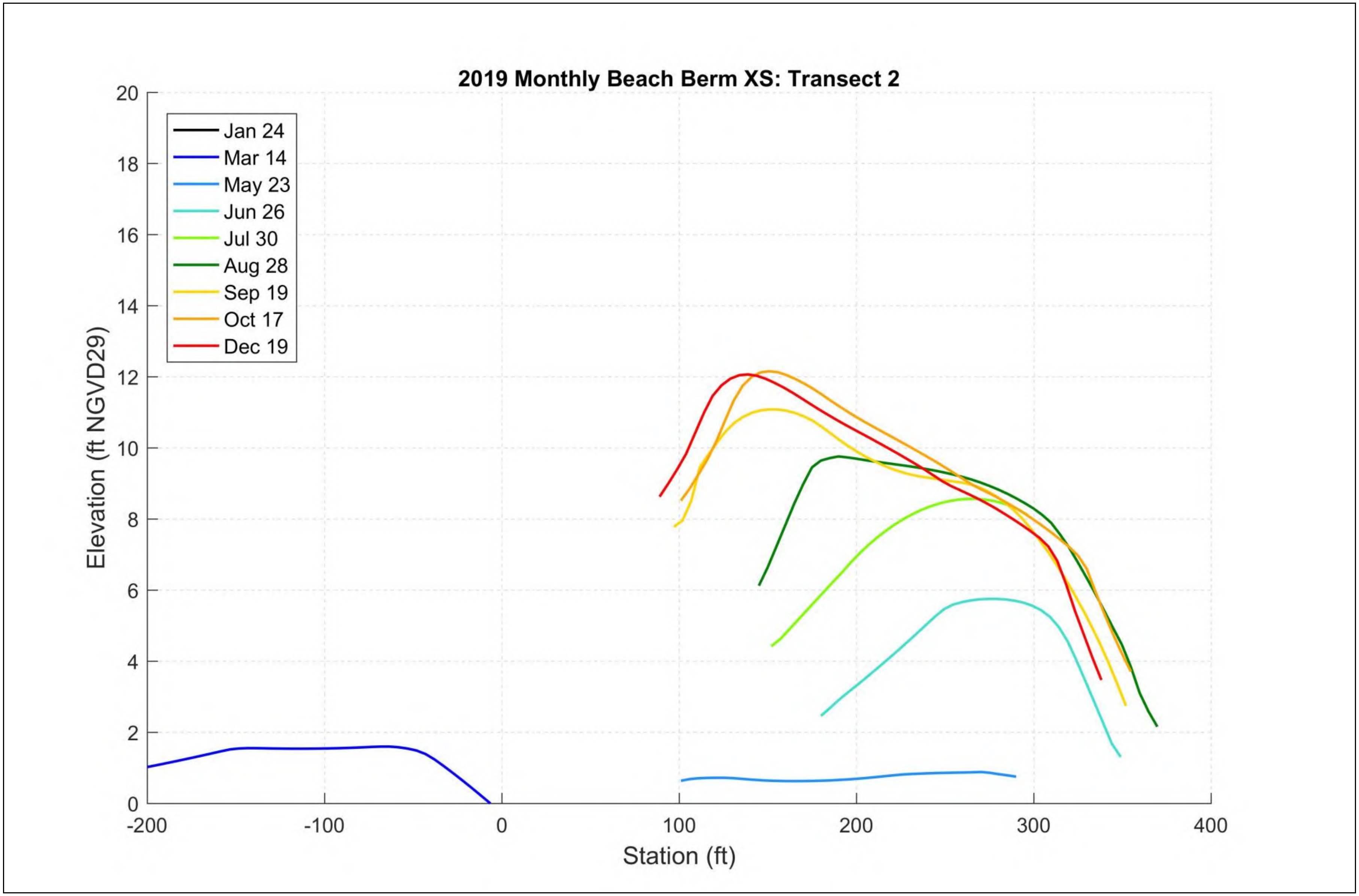


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 8

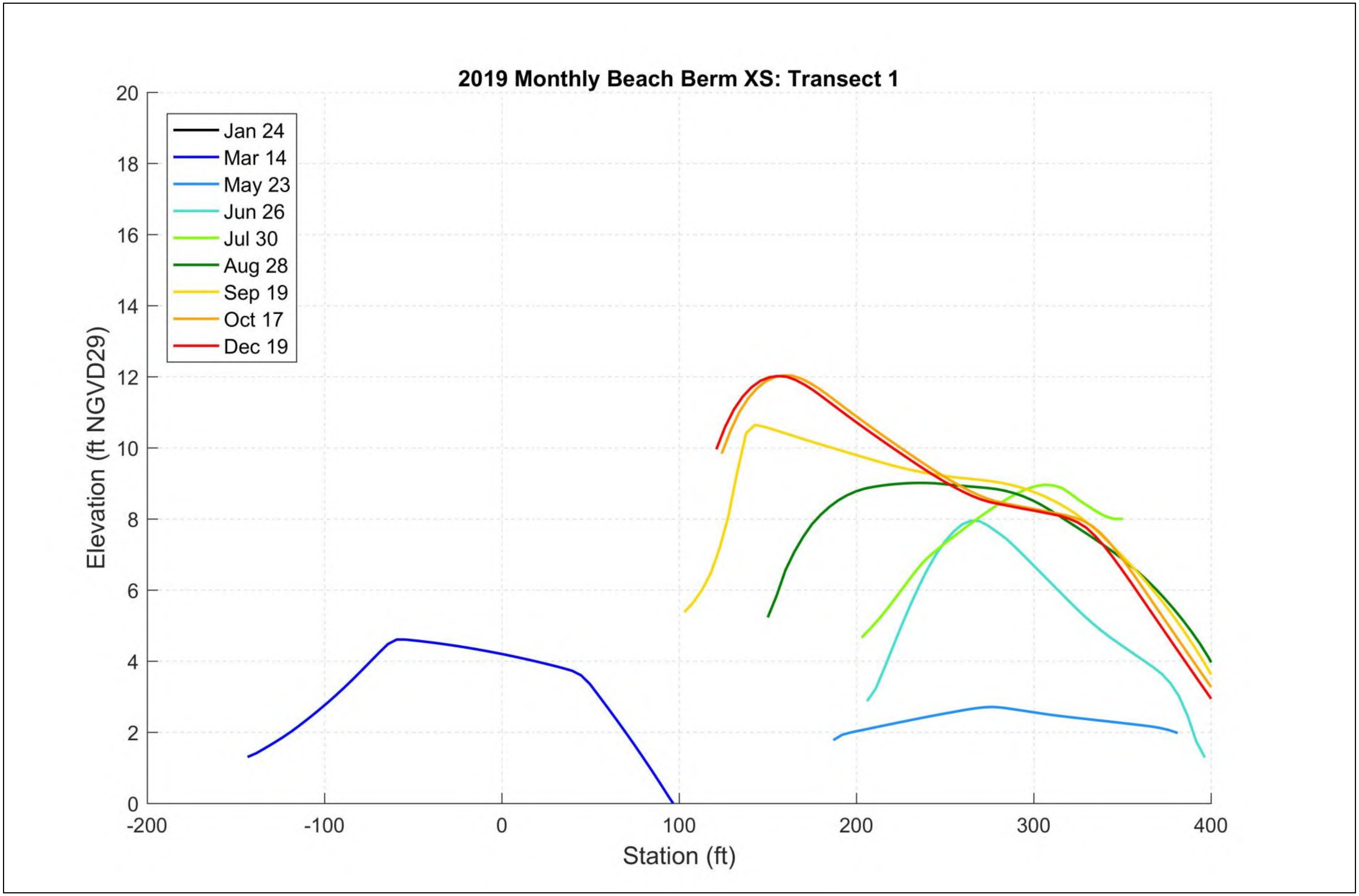
Beach Transect #3



SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 9
Beach Transect #2

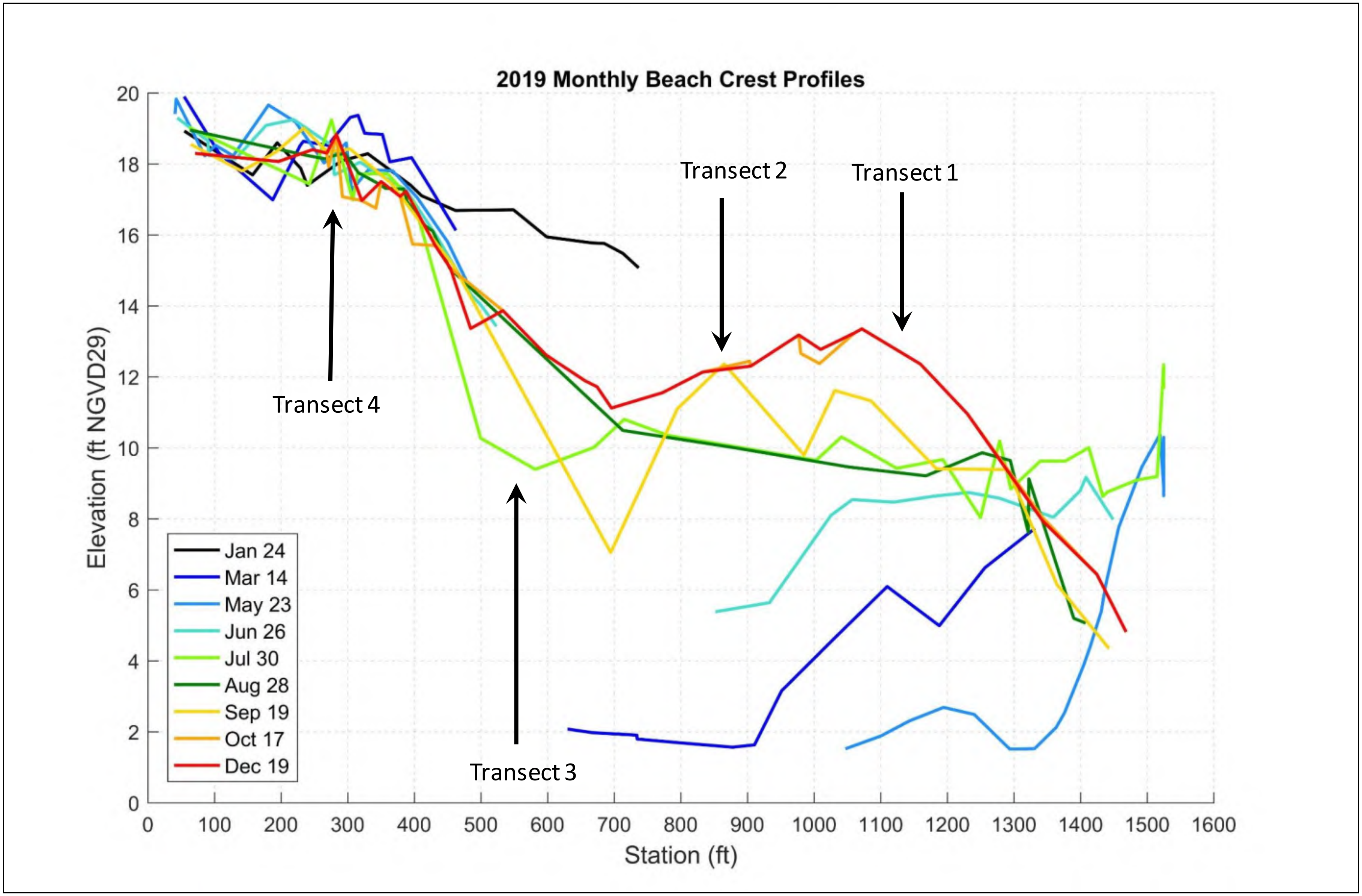


SOURCE: SCWA survey data

Russian River Estuary Outlet Channel Management Plan . DW01958

Figure 10

Beach Transect #1

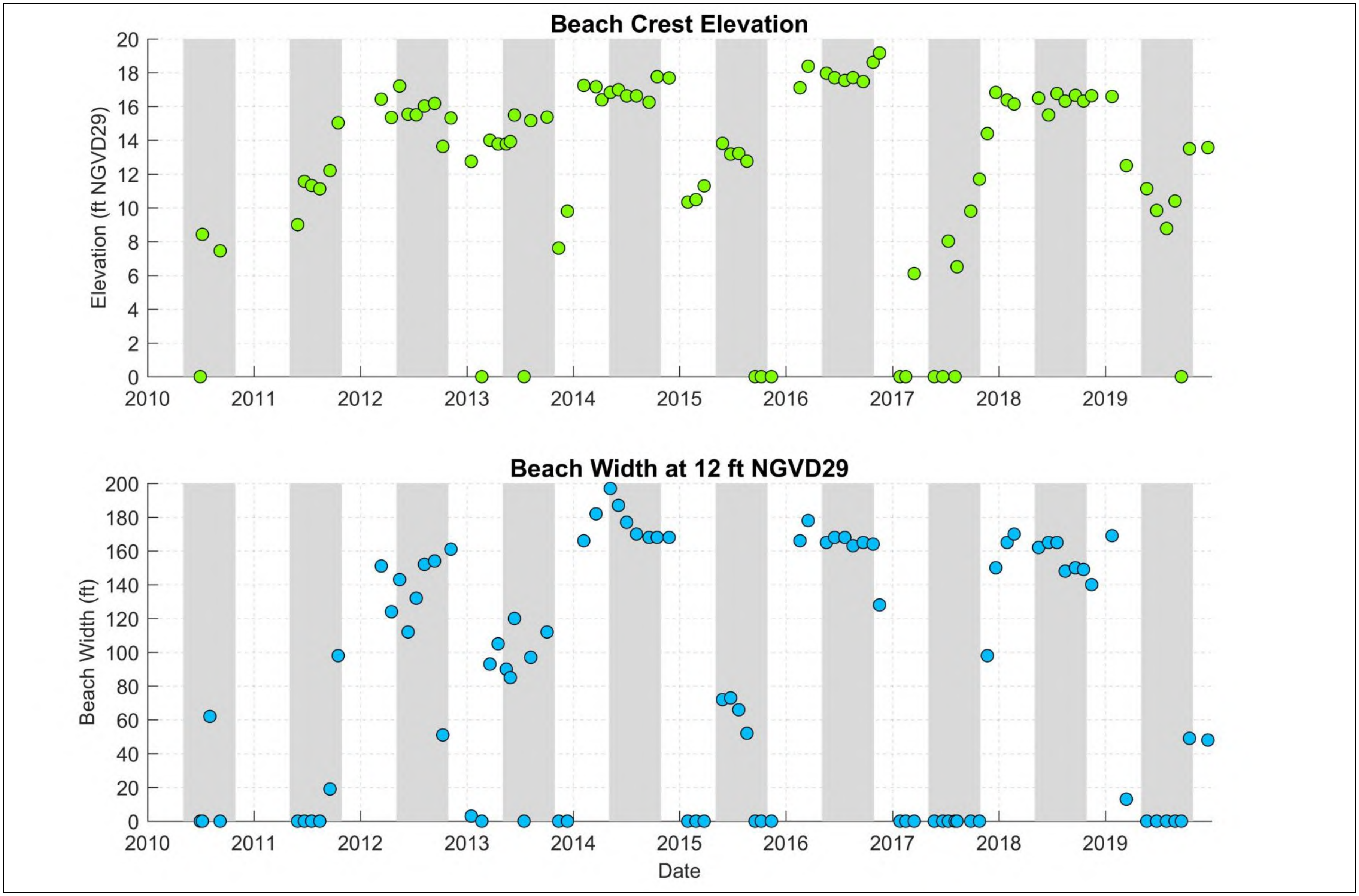


SOURCE: SCWA survey data

Note: Solid lines are from points identified as the beach crest during the monthly survey. Dashed lines are interpolated from surveyed points on the beach.

Figure 11

Beach Crest Profiles During the 2019 Management Period.

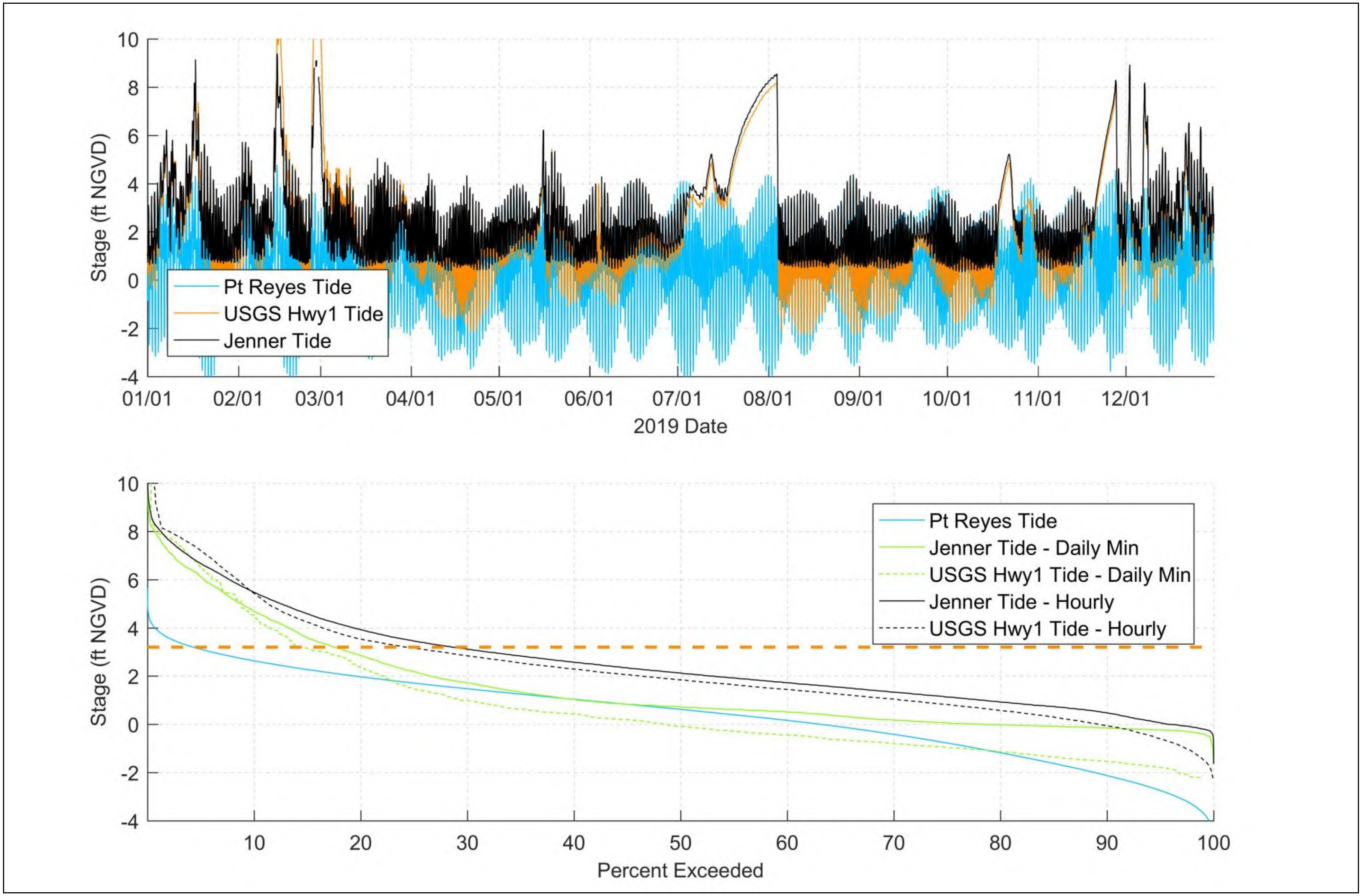


SOURCE: SCWA survey data

Note: width of zero indicates that the beach crest is below the elevation of 12 or 14 ft NGVD.

Figure 12

Transect 3 crest height and beach width (at 12ft NGVD elevation) from 2010 to 2019. Shaded areas represent management season.



SOURCE: SCWA Jenner Gage and NOAA Pt Reyes tide data

Figure 13
Russian River Estuary stage exceedance for 2019.