RUSSIAN RIVER ESTUARY OUTLET CHANNEL ADAPTIVE MANAGEMENT PLAN 2011

Prepared for

Sonoma County Water Agency

Prepared by

ESA PWA

with

Bodega Marine Laboratory, University of California at Davis

May 13, 2011

ESA PWA REF. # DW01958.02

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Sonoma County Water Agency (the Agency) is required to develop a management plan for the Russian River Estuary mouth in response to a 2008 Biological Opinion (BO) from the National Marine Fisheries Service (NMFS) designed to improve salmonid rearing habitat in the estuary (NMFS, 2008). Prior to the BO, the existing Russian River Estuary management plan focused on artificial breaching to prevent flooding. The Agency retained ESA PWA[1] to assist in developing the revised plan to address the objectives of the BO.

The BO stipulates several phases of outlet channel management over fifteen years with additional management options specified for each phase. The phases are part of an adaptive process for management actions to enhance salmonid habitat. If earlier phases are successful in meeting the performance criteria, subsequent phases will not be needed. The existing plan was first developed in 2009 to address the Phase 1 objectives in the BO and then updated in 2010. This document, the management plan for 2011, is largely based on the plan drafted in 2010. The changes between the 2010 and 2011 plan include: documented 2010 management actions (Attachment E), revised seepage and planform alignment aspects of conceptual model (Section 4), revised bed elevation guidance (Section 7.4.2), updated marine mammal permitting requirements (Sections 3.2 and 7.2; Attachment C), and revised topographic monitoring recommendations (Section 8).

Because of permitting issues, the outlet channel was not implemented in 2009. In 2010, the 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, the Agency 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 the Agency, the lagoon 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.

The approach of the 2011 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. It is recognized that the measures developed in the 2011 management plan, when implemented, may not fully meet the objective established by the RPA. The concept of this approach was developed in coordination with NMFS, Californian Department of Fish and Game (CDFG)[2], and California State Parks (CSP). The draft plan was provided to these agencies, then discussed at a meeting on April 27, 2011 that included representatives from these three agencies, as well as the Sonoma County Water Agency and ESA PWA. Comments on the draft plan from these representatives have informed the revision of the draft plan to create this final plan.

[1] Previously Philip Williams & Associates
[2] CDFG's CESA tracking number is 2080-2009-016-03 and 1600 Notification number is III-1176-96

The goal of the management plan is to reduce marine influence on the Russian River Estuary (Figure 1) during the management period, May 15th to October 15th. The management actions are intended to limit tidal exchange between the ocean and the estuary. Instead of the existing tidal estuary, the BO proposes a perched lagoon with water levels above tidal elevations. With tidal inflows limited, river inflow to the lagoon may enhance the extent of freshwater habitat for the benefit of juvenile salmonid rearing. Maintaining 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 outlet channel adaptive 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: (1) defining project performance criteria (Section 3), (2) developing a conceptual model of relevant physical processes (Section 4), and (3) conducting technical analysis to quantify target outlet channel conditions (Sections 5 and 6). The resulting operations and management plan derived from these planning steps is also documented in this report (Section 7). The adaptive management strategy will continue by actual implementation of this plan, then monitoring and evaluating the outlet channel response to refine the plan for subsequent years.

2. CONCLUSIONS AND RECOMMENDATIONS

Conclusions about the physical processes affecting outlet channel behavior and recommendations for 2011 management are summarized below.

2.1 CONCLUSIONS: PHYSICAL PROCESSES AFFECTING OUTLET CHANNEL BEHAVIOR

1. The location of the outlet channel, at the interface of the Russian River estuary and the surf zone of the Pacific Ocean, is a dynamic system influenced by river discharge, ocean waves, and sand transport. As such, the outlet channel will be subject to variable forcing at hourly, tidal, and monthly timescales. In order for the outlet channel mouth 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 its performance criteria, the outlet channel must be resilient in the face of this variable forcing. This resiliency is difficult to predict.
2. Under current management of the Russian River watershed and estuary, there has been one documented occurrence of target outlet channel conditions occurring during the proposed management season of May 15 to October 15 for the twelve year period of record (1999 to 2010). Outlet channel conditions occurred in June 2010 and persisted 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 management period) or fully closed with no exchange (12% of the time).
3. Conditions similar to target outlet channel performance criteria were observed outside the management period five times between 1999 and 2010. 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.
4. To meet the performance criteria, the outlet channel geometry must simultaneously meet two key constraints: convey sufficient discharge from the estuary to the ocean to preserve constant water levels in the estuary and 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.
5. The target 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 NMFS's goal of reducing or eliminating exposure of the estuary to tidal water levels and saline inflow. 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.

6. Based on engineering calculations, the channel 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.
7. Based on the results of hydrologic modeling, it may be difficult to convey sufficient discharge to maintain estuary water levels while simultaneously keeping the bed shear stress in the outlet channel below the threshold for scour. Even with the anticipated reduced 2011 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.
8. Discharge conditions are a significant source of hydraulic uncertainty for assessing the outlet channel. Discharge measurements are made at the USGS Guerneville gaging station[3], 21 miles upstream from the Russian River's mouth, and changes in flow (losses/gains) are known to occur between the Guerneville station and the mouth. A water balance model for the estuary indicates that net losses between the Guerneville gaging station and the mouth vary from 10% to 53% and average 37%. Limited USGS and Agency discharge measurements at other locations suggest that most losses occur in the lower 6 miles of the river; perhaps in large part due to seepage through the beach berm.

2.2 RECOMMENDATIONS: 2011 MANAGEMENT ACTIONS

1. Two channel configurations will be initially 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 minimize closure potential.

   The channel 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 outlet channel 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.
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.
4. 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.
5. A communication protocol will provide guidance between the Agency and identified points of contact representing key resource management agencies in the estuary.
6. Because of uncertainty about the system and its response to outlet channel management, the adaptive management approach specified in the BO and being pursued by the Agency is

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

critical. A year-end evaluation to assess actual channel performance and revised management for subsequent years is also recommended.

3. PERFORMANCE CRITERIA

The principal estuarine habitat goal stipulated in the Reasonable and Prudent Alternative (RPA), Alterations to Estuary Management, in the BO is to reduce marine influence in the estuary from May 15 to October 15. According to the BO, marine influence includes tidal water level oscillations and saline water. NMFS believes 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.

The performance criteria for outlet channel management are intended to assist in meeting the estuarine habitat objective of the RPA specified in the BO. This section presents performance criteria for Phase 1 of outlet channel management, and minor modifications to these criteria for 2011 management.

Performance criteria for water quality and ecological values in the lagoon are addressed separately and are not included in this document.

3.1 PHASE 1

Phase 1 of outlet channel management has the following performance criteria for the May 15 to October 15 management period:

1. **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" (BO, p. 249). Higher estuary water levels, but not exceeding flood stage of 9 ft NGVD, would be preferred by NMFS. However, water levels greater than 4 ft NGVD are expected to accompany reduced marine influence and would be likely to improve habitat.
2. **Sand channel**. The outlet channel will be a temporary feature, created only by excavating and placing beach sand. No new structures or mechanical devices, temporary or permanent, will be a part of the outlet channel implementation.
3. **Minimize artificial breaching**. Though the overall goal is to create a freshwater estuary, and therefore avoid artificial breaching, in light of natural variability of river discharge and nearshore wave conditions, several years of experience managing the estuary may be required to develop operational procedures which minimize the need for artificial breaching. As such, NMFS estimates "that SCWA 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" (BO, p. 302).
4. **Economic feasibility**. Operations and maintenance requirements will not place undue burden on the Agency in terms of cost, particularly as it relates to frequency or duration of maintenance activities.

5. **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 the Agency maintenance staff.

To meet the criterion for estuary water level (#1 above), the estuary will function as a perched lagoon with "water surface elevation above mean high tide … where freshwater flows out to the ocean over the sandbar at the lagoon's mouth" (BO, 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.

Note that each time the lagoon breaches, NMFS believes the lagoon is subject to undesirable 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" (BO p. 302). Thus the management plan seeks to minimize natural, as well as artificial breaching events.

The BO requires the Agency 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 BO also requires the Agency 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. The management plan anticipates an interim reduction in instream minimum flow requirements between the Dry Creek confluence and the mouth starting in 2010. Minimum flows would be reduced from current SWRCB Water Right Decision 1610 levels of 125 ft^3/s to 80-85 ft^3/s [4]. The expected reduction in minimum instream flow will provide more favorable conditions for outlet channel management by reducing the potential for scour-induced breaching.

For channel location, the BO 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" (BO p. 250).

3.2 2011 MODIFICATIONS

As discussed above (Section 1), the approach of the 2011 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 2011 management plan, when implemented, may not fully meet the objective established by the RPA as summarized in Section 3.1 above. The concept of this approach was developed in coordination with NMFS, CDFG, and CSP.

[4] The proposed instream flow requirement is 70 ft^3/s, but "SCWA maintains a 10 to 15 ft^3/s buffer to avoid non-compliance of the minimum standard" (BO, p. 245).

Because of the estuary's coastal location and hydrologic significance, the Agency 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 2011 outlet channel management include:

- Excavation is limited to 1,000 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 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 habor seals, sea lions, and elephant seals.

Artificial breaching may be required during 2011. With this management plan, the Agency seeks to minimize or avoid such breaches during the management period, but recognizes that they may be needed to avoid flooding of adjacent properties.

4. CONCEPTUAL MODEL

The conceptual model of the outlet channel articulates the project's working assumptions about process linkages between channel features, external conditions (e.g. river flow and ocean processes), and channel performance. These working assumptions are uncertain, and may not capture all relevant processes. However, by making these assumptions explicit, they can be documented, discussed, and tested, all of which are necessary steps in the adaptive management process. Observations of the actual outlet channel response will then enable refinement of the conceptual model. In addition, because the conceptual model is expressed in a relatively non-technical manner, it provides an avenue for public outreach and education about the outlet channel. The conceptual model is not a hydrodynamic, 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.

Development of a conceptual model for the outlet channel focuses on the essential physical processes and linkages, as well as the management parameters of the channel. Although this approach leaves out some processes which may slightly alter the channel's performance, it prevents the conceptual model from becoming so complex that it becomes unwieldy. In addition to limiting the conceptual model's scope to only the essential processes, the model also excludes impacts of the outlet channel on water quality and ecological aspects of the estuary. To further enhance model clarity, the conceptual model is presented graphically with a schematic that reflects the layout of the physical system. One caveat to simplification is that the static, schematic diagrams clearly do not encapsulate the full complexity of this dynamic system.

The conceptual model first describes target conditions for the outlet channel, in accordance with the performance criteria in Section 3. Then the model identifies the morphological processes which may lead to the two failure modes for the outlet channel: closure and breaching. Closure refers to sand transport induced by ocean waves that deposits sufficient volume of sand in the outlet channel mouth that it blocks the outlet channel. Closure prevents discharge through the outlet channel, leading to increasing estuary water levels and the threat of flooding. Breaching refers to the flows enlarging the outlet channel to the point that it becomes a tidal inlet subject to bi-directional flow. It is important to note that these "failure modes" are conditions associated with 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 native species may be adversely affected (see the BO), as well as conflicts with other man-made constraints. One of the key questions in this management plan is whether the inherently dynamic system can be "trained" to drain gradually without breaching and then closing repeatedly.

There are additional aspects of the site which may impact the outlet channel, but whose impacts are thought to be secondary or not well defined. Therefore, they are not included in the conceptual model at this time. If implementation of the outlet channel suggests these aspects are important, they will be incorporated into a revised conceptual model. These aspects include large rocks and/or bed rock within the beach berm, jetty impacts on seepage, and decadal changes to beach width.

Specifically, the jetty at the river mouth and the fill across the tombolo to the south of the site may have affected littoral processes and mouth dynamics, but are not addressed in this study.

This conceptual model is based on existing literature, knowledge of similar estuaries, professional judgment, and ongoing discussion with the Agency, NMFS, CDFG, and CSP. New data and experience adaptively managing the outlet channel will be used to revise the conceptual model in subsequent management plans.

4.1 TARGET OUTLET CHANNEL CONDITIONS

The conceptual model for target outlet conditions is shown in Figure 2. Ideally, the outlet channel conveys water from the estuary to the ocean so that estuary can be maintained in a non-tidal state during the management period. A key performance criterion of this non-tidal state is that the water levels in the estuary (h_l) fall within the range of 4 to 9 ft NGVD, with elevations above 7 ft NGVD preferred. The estuary water level will not be managed directly, e.g. by pumping. Instead, it will be managed indirectly by management actions dictated by the BO, the operation and maintenance of the outlet channel and the reduction of instream flow requirement.

The estuary water level is determined by the balance between inflowing river discharge (Q_r) and three outflows: outlet channel discharge (Q_c), evaporation (Q_e), and seepage through beach berm (Q_s). For estuary water levels to remain within the target range, the inflow 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 2, the river inflow, seepage and the outlet channel discharge are the three largest flows; evaporation is a minor factor in the water balance. As such, the sum of the seepage and outlet channel discharge capacity needs to nearly match the river discharge. If the combined outflows are too low, the estuary water level will rise to flood stage and artificial breaching will be necessary. If the outlet channel discharge is too high, the channel will scour and deepen, allowing tidal flows to enter through the channel. The outlet channel discharge is determined in part by its 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, the water level difference between the estuary and the ocean, and the ambient conditions of the regional water table (Largier and Behrens, 2010). Presently, only the water level difference is subject to management influence. In the future, modification of the jetty to increase the beach berm's hydraulic conductivity will be studied (NMFS, 2008). The river inflow is another management parameter, however, since its value is determined as part of a separate water supply determination and permitting process, its manipulation is not considered here.

Although sediment transport will be minimal within the outlet channel under target conditions, the channel's mouth will perpetually be an active transport zone. This portion of the channel, at its interface with the ocean, will be an active transport zone for two reasons. First, it lies within the surf zone and breaking waves move up and down its face in response to the tides and variations in wave direction, magnitude, and period. Second, this wave action creates a slope on the order of 10:1, which is sufficiently steep that flows of nearly any magnitude from the outlet channel will accelerate to above the scour velocity threshold. In order for the outlet channel to persist with this active transport zone at its mouth, this zone will have to experience minimal net sediment transport. In other words, tidal fluctuations in water level and variability in wave intensity will cause the locations of scour and deposition to shift at hourly timescales, but averaging across several tidal cycles, any sand lost by scour will be balanced by an equivalent amount of deposition. This active transport zone also plays a significant role in lateral migration of the existing channel mouth. This process is discussed in Section 4.4 on planform alignment.

Preserving these target conditions, particularly the discharge conveyance capacity, requires that the outlet channel maintain its cross-sectional flow area. This flow area can decrease or increase, leading to the two failure modes of the outlet channel, closure and breaching. These two failure modes are discussed in the sections below.

4.2 CHANNEL FAILURE: CLOSURE

The processes which lead to outlet channel closure are likely to originate from elevated total water levels in the ocean (z_{wave}), as shown on the right side of Figure 3. Elevated ocean water levels will move the active transport zone into the outlet channel, increasing deposition at elevations above that of the outlet channel's bed, z_{out}. Once deposition rates exceed any capacity of the outlet channel discharge to scour sediment, a berm will build at the mouth of the outlet channel, causing it to close. This process is thought to occur over one to several high tides, corresponding to one to several days. During the management season, total ocean water level is the combination of two ocean processes, the tides and ocean waves. As offshore waves interact with the coastline and nearshore, they are transformed such that the significant elevation on the beach is a function of the wave direction, magnitude, period and runup. While the tides fluctuate with a predictable schedule, ocean waves vary according to the unpredictable weather and wind patterns over the ocean. Therefore, the total water level can be best characterized as frequency distribution that is based on observed tide and wave data.

If the outlet channel closes and flow through the channel stops, the estuary water level will increase since the continuing river inflow cannot 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 seepage rates 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 flow may 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 more moderate management actions do not stop this rising water level, a full artificial breach, as is currently practiced, will be necessary to prevent flooding.

4.3 CHANNEL FAILURE: BREACHING

The breach failure considered as part of the conceptual model and shown in Figure 4 is breaching that occurs when the outlet channel is operating according to the target conditions described above. Breaching is likely to result from two processes, high discharge which scours the channel bed or seepage-induced bed mobilization. Natural or artificial breaching after a closure event are not discussed in this section because it is assumed that management actions would be enacted to return the outlet channel to target conditions prior to either of these breach mechanisms occurring. Additionally, breaching by wave overtopping or strong river discharge are not considered because these processes are associated with winter storm events, which are rare during the management period.

Because the outlet channel is an unconsolidated bed composed of relatively small particles, it is susceptible to scour by the discharge flowing through the outlet channel. Sand scoured from the channel will be lost to the ocean and there is not a significant upstream source to replace scoured sand. Extensive scour will enlarge the channel to the point of breaching and tidal inflows. To prevent scour, flow conditions within the outlet channel (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 through the management parameters of the outlet channel's width, length, and bed slope.

As noted in the description of target channel conditions, 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 target conditions, the sand scoured by this process will 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 observed by the Agency's maintenance staff when the beach berm is artificially breached under current practice. The breaching typically happens very quickly, 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 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.

In contrast to closure which can be managed with further intervention, breaching can immediately and negatively impact NMFS's habitat objectives by allowing the marine influences of tidal water levels and saline water to enter the estuary. For this reason, breaching is more detrimental to NMFS's habitat goals than closure.

4.4 PLANFORM ALIGNMENT

Because of the presence of hard barriers in the form of the southern jetty and the northern cliffs, the outlet channel is expected to occupy an alignment within the same region that the current tidal inlet occupies, as show in Figure 1. At this initial stage in the adaptive management process, the conceptual model for the outlet channel's planform alignment is indeterminate as to a target alignment most likely to facilitate outlet channel sustainability. Therefore, observations and interpretations of the existing channel are presented in this section to provide an indication of factors acting on the proposed outlet channel. Once the outlet channel is implemented and monitored, a more definitive conceptual model for target alignment will be developed.

The exiting channel's initial alignment after a closure is typically straight and set by one of three factors, depending on the breaching mechanisms. When breached by high river discharge, the channel aligns itself to the northwest, primarily in response to the direction of the river flow during these events. When the channel naturally breaches itself at water levels below flood stage, it will overflow the berm at the minimum elevation in the berm crest. For example, in April 2009, this low point was toward the north since this was where the antecedent inlet had lowered the berm crest elevation. The Agency has attempted artificial breaching in several locations; under current practice, the initial alignment is perpendicular to the beach and just to the north of the large rock ("Haystack Rock") at the northwest corner of the estuary (Agency staff, personal communication).

Once breached, the existing channel typically changes alignment because the mouth migrates laterally in response to wave and littoral transport processes (Behrens et al., 2009). Lateral migration by the mouth while the upstream channel lags behind creates a sinuous channel. The direction and magnitude of wave energy and the resultant littoral sand transport are thought to determine the migration direction and extent. For the case of a tidal inlet, the mouth typically moves in the direction of the littoral transport (Dean and Dalrymple, 2002). However, several mechanisms have been identified that enable an inlet to move updrift, opposite to the direction of the littoral transport. Aubrey and Speer (1984) demonstrate that sand bars associated with the inlet's ebb tide delta can attach to the downdrift beach, displacing the inlet in the updrift direction. Pranzini (2001) documents a mechanism whereby riverine sediments discharged to a prograding delta preferentially deposit on the downdrift side side, which translate and rotate the inlet mouth towards incoming wave energy. Aubrey and Speer (1984) also propose that flow patterns created by inlet channel bends can create erosion on the outside of the bend and deposition on the inside, much like the development of river meanders, with a net result of the inlet migrating updrift. Mechanisms similar to these may explain observations by NMFS that suggest that the direction of migration of the outlet channel may be against the direction of littoral transport (J. McKeon, personal communication).

Observations by Behrens et al. (2009) show that the existing tidal mouth typically moves both northward and southward during the management period. Their analysis correlates large changes in mouth location with rapid changes in significant wave height, indicating that the wave processes control the migration process. The bi-directional migration of the mouth suggests that wave energy also changes directions. This is further supported by the resulting shape of the channel, which can develop multiple channel bends in response to the mouth reversing directions. The temporal and spatial distribution of wave energy along the mouth is not well documented since wave observations have only been made offshore and estimates of how the offshore waves are transformed by local bathymetry have not been verified. Studies using trace elements and sand budgets along this stretch of coast indicate reversing directions of littoral transport because of varying periods of convergence and divergence of wave energy (DeGraca, 1976). The predominant direction may be sensitive to the relative contributions of northwest wind waves versus southerly swell. For instance, Behrens et al. (2009) show that mouth migration patterns are significantly different during El Niño years with the channel remaining in at the northern end of its range for the entire summer. They speculate that the decrease in northerly wind waves during El Niño events may explain this phenomenon. Another potential cause for this pattern is the more southerly approach angle of incident swell waves during El Nino years, as suggested by Allen and Komar (2006).

An additional factor which may affect the mouth location is the landward migration of the offshore bar. This bar, which is created by sand eroded off the beach during winter storms, moves landward with the low steepness summer waves. If this bar, which runs parallel to the shore, moves sufficiently close to the channel mouth, it may force the mouth to either side.

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 flow, 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 flow 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 natural breaches. Although the low number of natural 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 natural breaches within 1-2 days of closure. Including all closures, there was a correlation between Guerneville 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 the Agency 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 Guerneville[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 natural 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		**Guerneville 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. 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 BO (NMFS, 2008): to enhance the freshwater salmonid rearing habitat during summer months. Sometime in April, May, or June, once the Carmel River discharge 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 discharge to the lagoon does not taper off from 25-20 ft^3/s to 10 ft^3/s as rapidly as expected. Once river discharge falls below approximately 10 ft^3/s, evaporation and seepage export enough water from the lagoon that lagoon water levels no longer increase.

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 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

6. CHANNEL CONFIGURATION ANALYSIS

As discussed in the conceptual model for target conditions, the outlet channel geometry must simultaneously meet two key constraints: convey sufficient discharge from the estuary to the ocean to preserve constant water levels in the estuary and 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. The technical analyses described in this section 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 above in Section 5. Preventing breaching, a necessary condition for reducing marine influence on the estuary is the focus of this section.

Since the outlet channel will be located within a bed of unconsolidated beach sand, a key management objective is creating a channel which can sustain its cross section geometry instead of scouring. Breaching can occur if the discharge through the 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.

6.1 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 the 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 (Attachment A-1).

6.2 PREDICTED HYDRAULIC CONDITIONS

6.2.1 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 6 shows an example slope-versus-width stability curve for the 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 6). 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.

6.2.2 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):

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

where:

$\triangle V$	=	lagoon inflow during closure (ft^3)
$\triangle t$	=	duration of closure (days)
A	=	surface area of the lagoon (ft^2)
$\triangle h$	=	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 ($\triangle h$) – 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*, Attachment A-3).
- Berm seepage (Q_S) – estimated using Darcy's Law based on water level difference between lagoon and ocean (Attachment 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 ($\triangle h/\triangle t$) 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 ($\triangle V/\triangle t$) 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% (Attachment 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 (Attachment A-5) was used to reduce the anticipated Guerneville discharge in the unsteady hydraulic modeling discussed in Section 6.2.3 to predict downstream flow rates into the lagoon based on upstream discharge measurements.

Comparison with Discharge Measurements

A limited set of USGS and Agency discharge measurements provides estimates of river flow at other locations besides the continuous discharge measurements at Guerneville. These discharge measurements, collected at four stations[6] 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 the Agency 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 6.2.3 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

[6] 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).

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.

6.2.3 Hydraulic modeling of unsteady mean flow conditions

Using the calibrated water balance model results described in Section 6.2.2, ESA PWA developed a hydraulic model to evaluate the performance of the outlet channel for various hydrologic scenarios. This modeling is a refinement of the steady mean flow calculations described in Section 6.2.1 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 6.2.2 and Figure 7). Flow in the 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 6.2.1. Model channel geometry was revised iteratively based on subsequent hydraulic analyses and discussions with the Agency 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 (Attachment A-6).

The year 2000 discharge time series was used to generate a synthetic discharge time series to approximate anticipated 2010 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 2010 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 2010 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 7a for the simulation period.

The anticipated 2010 discharge time series at Guerneville was further reduced using the calibration curve developed in Section 6.2.2 to account for downstream losses between the gaging station and the lagoon. The resulting estuary inflow time series is shown in Figure 7a. Predicted 2010 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 the 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 6.2.2. 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. The 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. 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 the 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 6.2.2. The time series of these losses used as model input are shown in Figure 7b. Because these combined losses are less than 10% of the lagoon inflow, the modeled lagoon outflow through the outlet channel is similar to the lagoon inflow (Figure 7a). A downstream water level boundary condition was prescribed for the ocean; however, since the outlet channel 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 8a and Figure 8b, respectively. The bed shear stress values shown in Figure 8a 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 2010 hydrology are shown as the "Baseline" curve. The expected range of critical shear stress (0.4-0.7 Pa) is shown in Figure 8a 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 the channel. Lagoon water levels (Figure 8b) 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.

6.3 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 the outlet channel are somewhat uncertain because the losses between upstream observed discharges and the outlet channel are not well characterized, as described in Section 6.2.2. The baseline simulation presented in Section 6.2.3 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 the 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 6.1), 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 8a for bed shear stress and Figure 8b 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 8a as a blue band. While the predicted bed shear stress for 2010 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 2010 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 (Figure 2). In order for the outlet channel to persist, scour caused by the 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 the outlet channel, the channel is likely to breach and return to tidal conditions, as shown in Figure 4.

7. PROPOSED OUTLET CHANNEL ADAPTIVE MANAGEMENT FOR 2011

This section describes the 2011 recommended channel management practices related to the BO requirements. Existing management practices for public safety, operator safety, operational responsibility, and other practices not related to meeting the BO 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 the Agency, the resource management agencies, and ESA PWA. In addition, implementation efforts provided practical experience for adapting the plan. A detailed account of the 2010 implementation is provided in Attachment E. 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 necessitates 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 rationale supporting each of these configurations is described in more detail in Section 7.3 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 favors 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. 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 BO.

The approach may be constrained by an excavation volume limit of 1,000 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 the Agency 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 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, the Agency'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[7]. The incidental harassment authorization stipulates that management actions cannot occur for more than two consecutive days unless flooding

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

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.

Should the outlet channel close in the weeks immediately preceding the management period, the Agency, in consultation with NMFS, CDFG, 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.

7.3 CHANNEL LOCATION/PLANFORM ALIGNMENT

Two possible channel configurations within the extent of the existing alignment (Figure 1) may be pursued in 2011 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.

7.3.1 Wide and short channel alignment

Preference for a wide and short outlet channel assumes that channel failure by scour-induced breaching (Section 4.3) 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, only a relatively short channel that is nearly perpendicular to the beach berm is possible to also stay within the 1,000 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, as shown in Figure 2. 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 (Section 6.2.3), 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 Section 6.2.2, 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 (Section 6.3). 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.

7.3.2 Narrow and long channel alignment

The narrow/long approach to channel design assumes that wave-induced closure (Section 4.2) 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 (Section 6.2.3).

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.

7.4 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.

7.4.1 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 1,000 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.

7.4.2 Bed Elevation

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. 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. 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. 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 BO'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. 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 3.1). Stable conditions imply that river inflow 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 2011 because additional constraints in place during this year call for modified performance criteria.

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.

7.4.3 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.

7.4.4 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 1,000 yd^3 excavation volume limit.

7.4.5 Length

The channel length is estimated to vary within 100-400 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 1,000 yd^3. The wide/short configuration would result in channel lengths between 100-200 ft while the narrow/long configuration would result in channel lengths approaching the maximum of 400 ft.

7.5 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.

7.6 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.

7.7 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 Section 6.2.2, the two methods for estimating estuary inflow, the water balance model and limited discharge measurements, predict disparate estuary inflows. Estuary inflow 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.

8. 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 2011 is provided below in Table 5.

Table 5 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.	Field staff to collect sediment sample from the surface of the channel bed.	Monthly

	Sediment sampler used.		
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
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 the Agency 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). 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 County Water Agency, NOAA National Marine Fisheries Service, California Department of Fish and Game, and California State Parks. A list of contacts for these groups is shown in Table 6.

Table 6 Russian River Estuary Management Team

Contact	Level	Organization	Phone Number	E-mail
Chris Delaney	Primary	Sonoma County Water Agency	707-547-1946 (w) 707-975-5606 (m)	cdelaney@scwa.ca.gov
Jessica Martini Lamb	Secondary	Sonoma County Water Agency	707-547-1903 (w) 707-322-8177 (m)	jessica.martini.lamb@scwa.ca.gov
Gary Tourady	Primary	Agency Operator Sonoma County Water Agency	707-547-1065 (w) 707-975-6285 (m)	garywt@scwa.ca.gov
Jon Niehaus	Secondary	Agency Operator Sonoma County Water Agency	707-521-1845 (w) 707-975-3999 (m)	jon@scwa.ca.gov
John McKeon	Primary	National Marine Fisheries Service	707-575-6069 (w)	john.mckeon@noaa.gov
Rick Rogers	Secondary	National Marine Fisheries Service	707-578-8552 (w)	rick.rogers@noaa.gov
Bill Hearn	Secondary	National Marine Fisheries Service	707-575-6062 (w)	william.hearn@noaa.gov
Adam McKannay	Primary	CA Dept. of Fish and Game	707-944-5534 (w)	amckannay@dfg.ca.gov
Richard Fitzgerald	Secondary	CA Dept. of Fish and Game	707-944-5568 (w)	rfitzgerald@dfg.ca.gov
Eric Larson	Secondary	CA Dept. of Fish and Game	707-944-5528 (w)	elarson@dfg.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)	dajone@parks.ca.gov

9.1 IMPLEMENTATION OF OUTLET CHANNEL MANAGEMENT ACTIVITIES

A minimum of 24 hours of notice shall be provided to the Team by the Agency 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 Guerneville 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)
- For maintenance actions a general description of maintenance to be performed;
- Presence of seal pups; and
- Equipment to be used for implementation.

Team members shall provide any comments or suggestions to the approach in writing within 12 hours of the proposed implementation time. If Agency does not receive any comments before this time 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 the Agency 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 the Agency 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 Guerneville 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 the Agency to breach the estuary. The Agency shall stay in close contact with the Team on the development of any conditions which 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, the Agency 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 ouflows 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; the Agency is unable to operate equipment required for channel management activities if ocean swells are too large. In the past the Agency 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, the Agency 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, the Agency 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, the Agency shall consult with the Team on potentially changing the course of management. In cases of high bacterial levels, the Agency will additionally consult with North Coast Regional Water Quality Control Board and the Sonoma County Department of Public Health on potential management actions.

10. REFERENCES

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

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.

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, 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. 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.

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.

DeGraca, 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.

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.

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.

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.

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.

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.

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.

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.

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

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.

11. LIST OF PREPARERS

This report was prepared by the following ESA PWA staff:

Matt Brennan
Michelle Orr
Bob Battalio
Justin Vandever
Lindsey Sheehan

With Bodega Marine Laboratory, University of California at Davis:

John Largier
Dane Behrens

12. FIGURES

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

0 120 240 480
Feet

figure 1

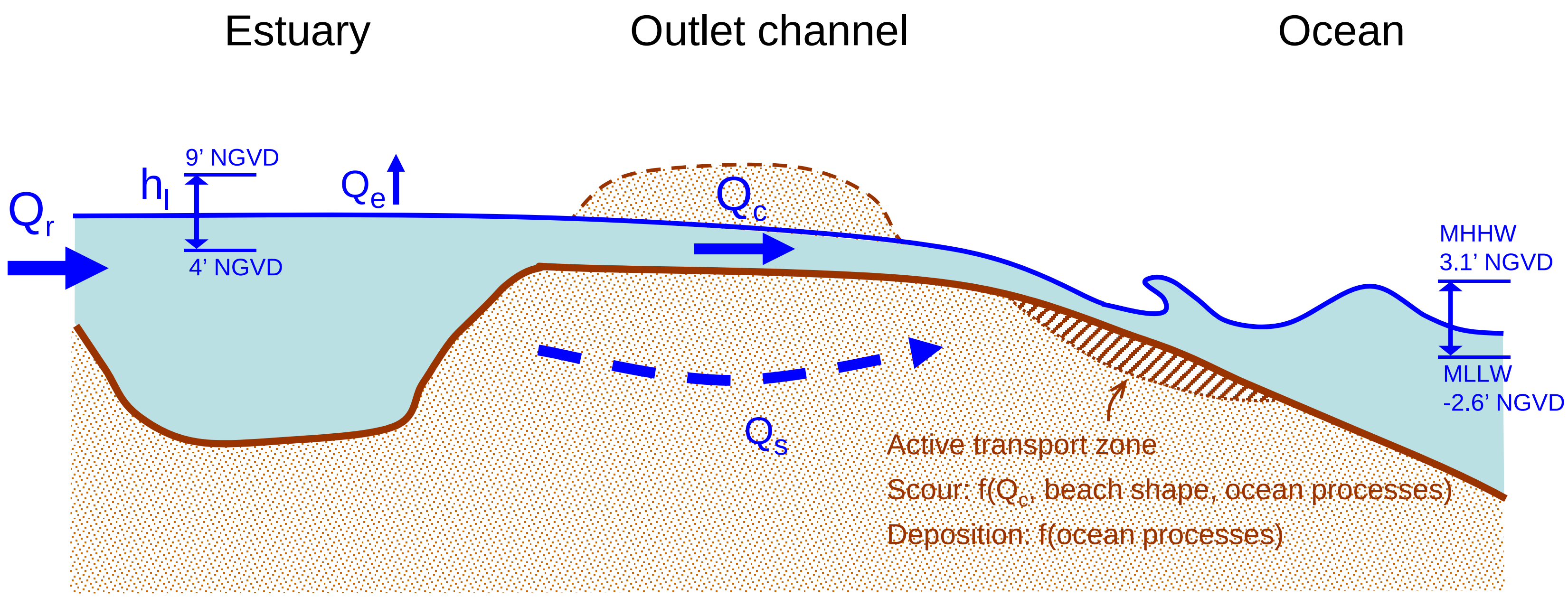
Russian River Estuary Outlet Channel Management Plan

Russian River Estuary Site Location

PWA Ref# - 1958.02

PWA

G:\1958.01_Russian_River\Projects



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

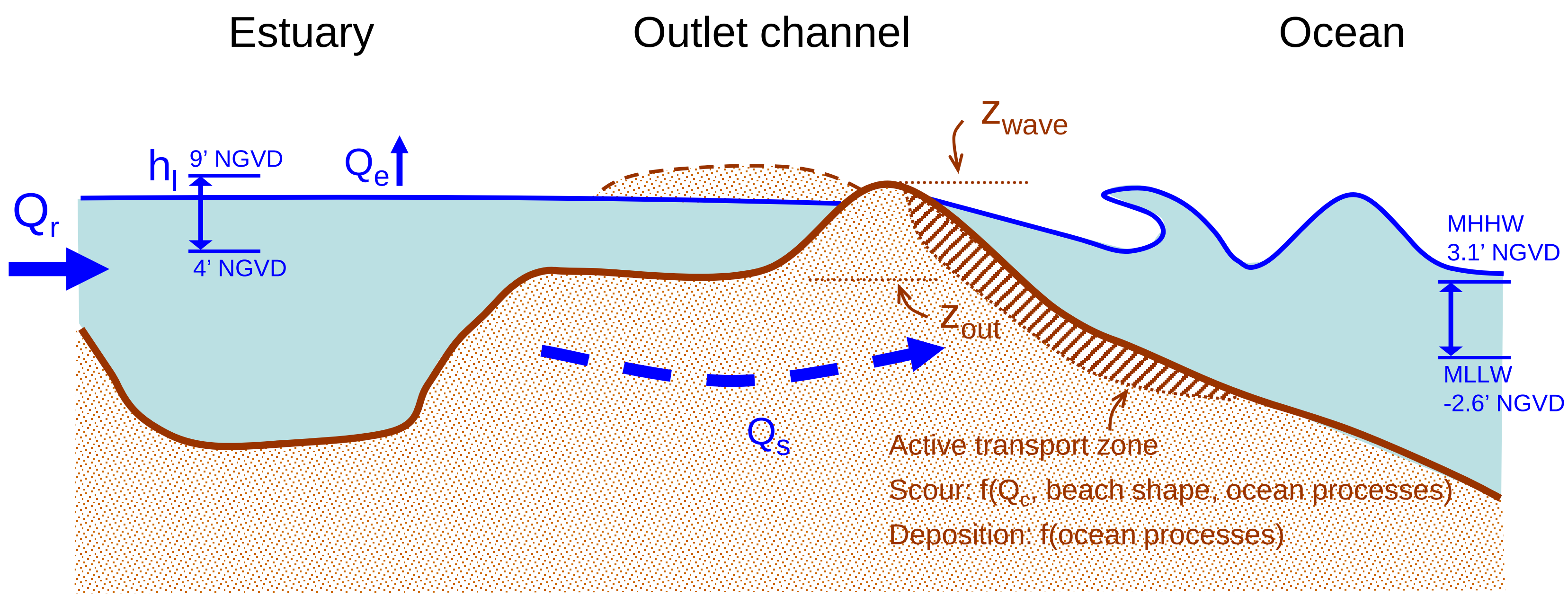
figure **2**

Russian River Estuary Outlet Channel Management Plan

Conceptual model – Target conditions

PWA Ref# 1958.01

PWA



<u>Parameters</u>

z_{out}=target channel bed elevation

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

<u>Processes</u>

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

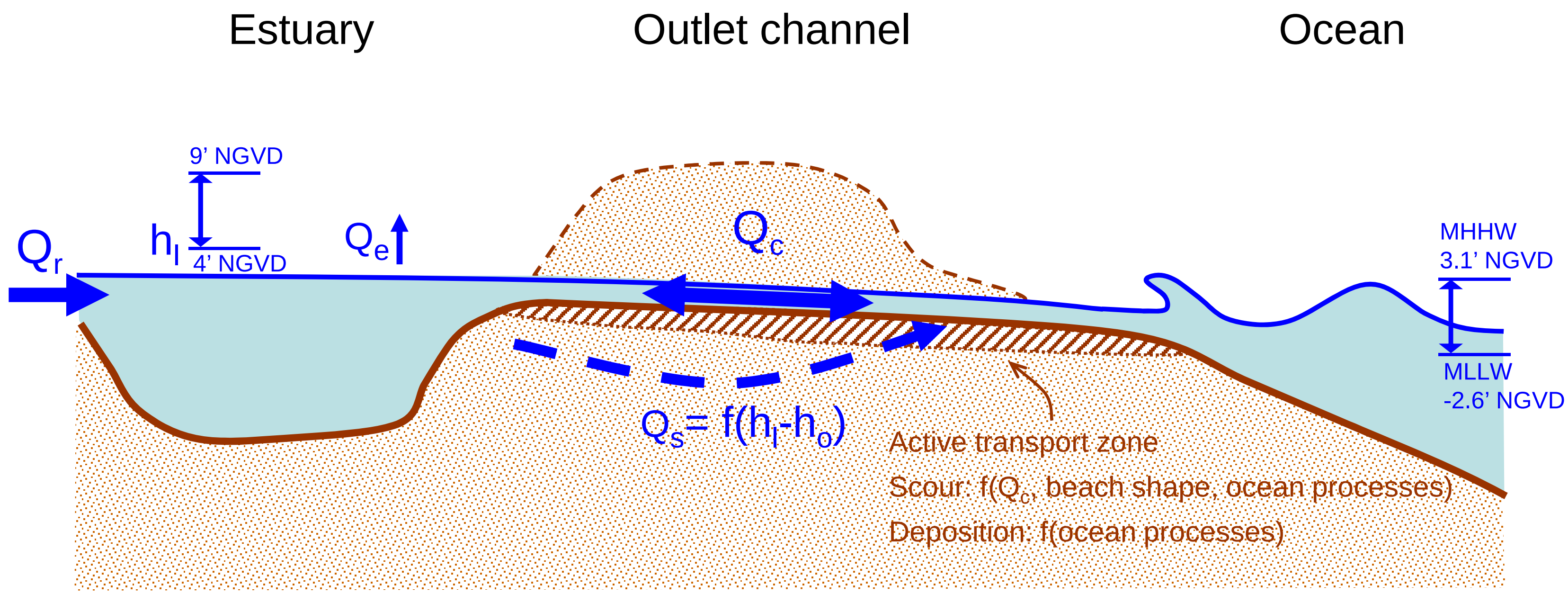
figure **3**

Russian River Estuary Outlet Channel Management Plan

Conceptual model – Closure

PWA Ref# 1958.01

K:\projects\1958.01RREAMPOutletChannel\Task 8 Year 1 eval & 2011 plan\2011 Mmgt Plan\Draft 2\figs\Figure 2-4 Conceptual model v2.doc



<u>Parameters</u>

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)

<u>Processes</u>

•$u_c > u_{crit}$; high velocities scour channel

•Q_s increases; high seepage creates groundwater piping and erosion

•sediment transport within outlet channel

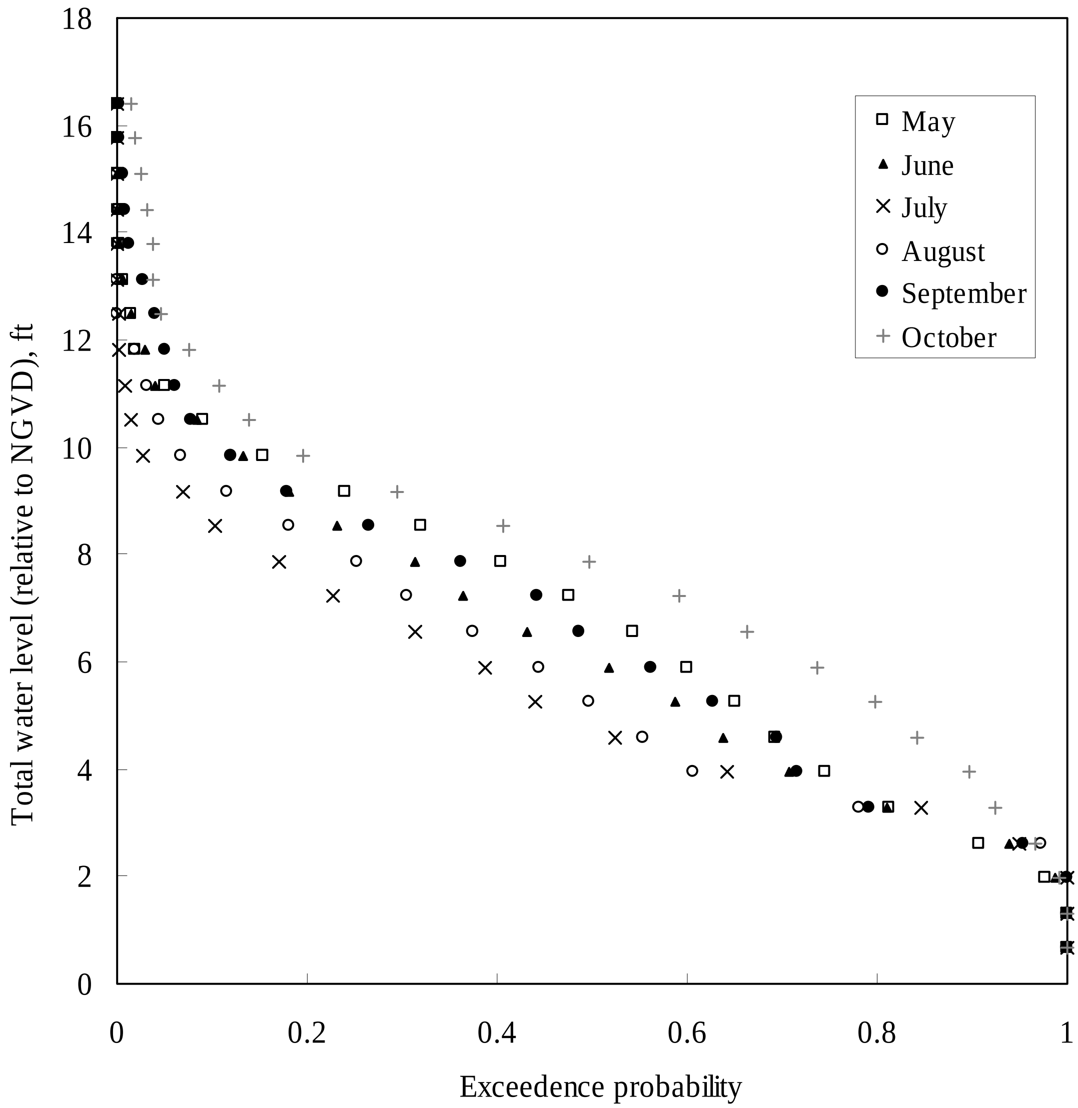
figure ***4***

Russian River Estuary Outlet Channel Management Plan

Conceptual model – Breaching

PWA Ref# 1958.01

PWA



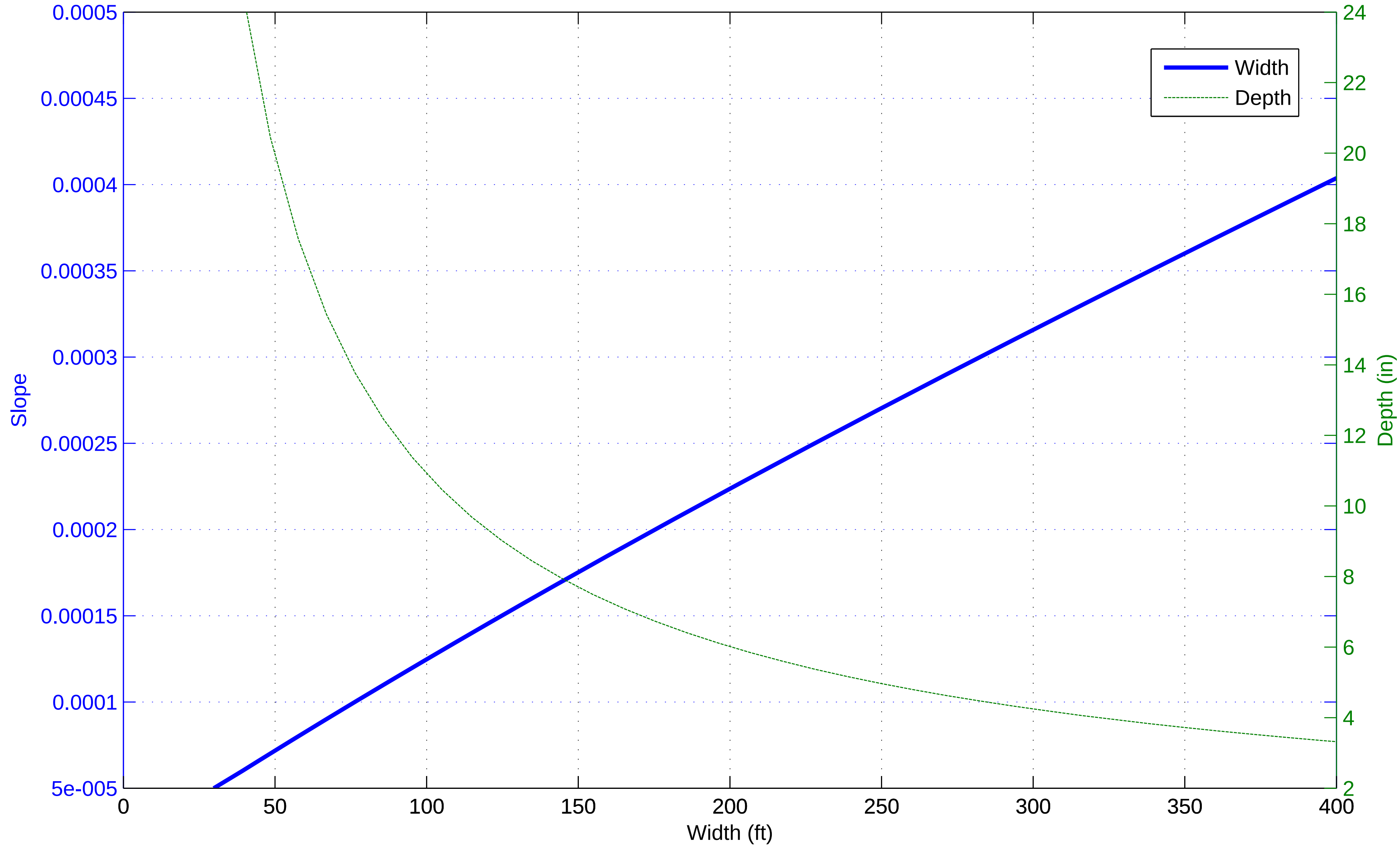
Source: D. Behrens (unpublished). Wave data from CDIP Point Reyes buoy.
Note: Total water level calculated as sum of daily higher high tide and wave runup elevation. Wave runup calculated from Stockdon et al (2006) using estimated de-shoaled deepwater equivalent wave heights.

figure **5**
Russian River Outlet Channel Management Plan

Total Water Level Exceedance, May-Oct

PWA Ref# 1958.01

PWA



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

Figure 6

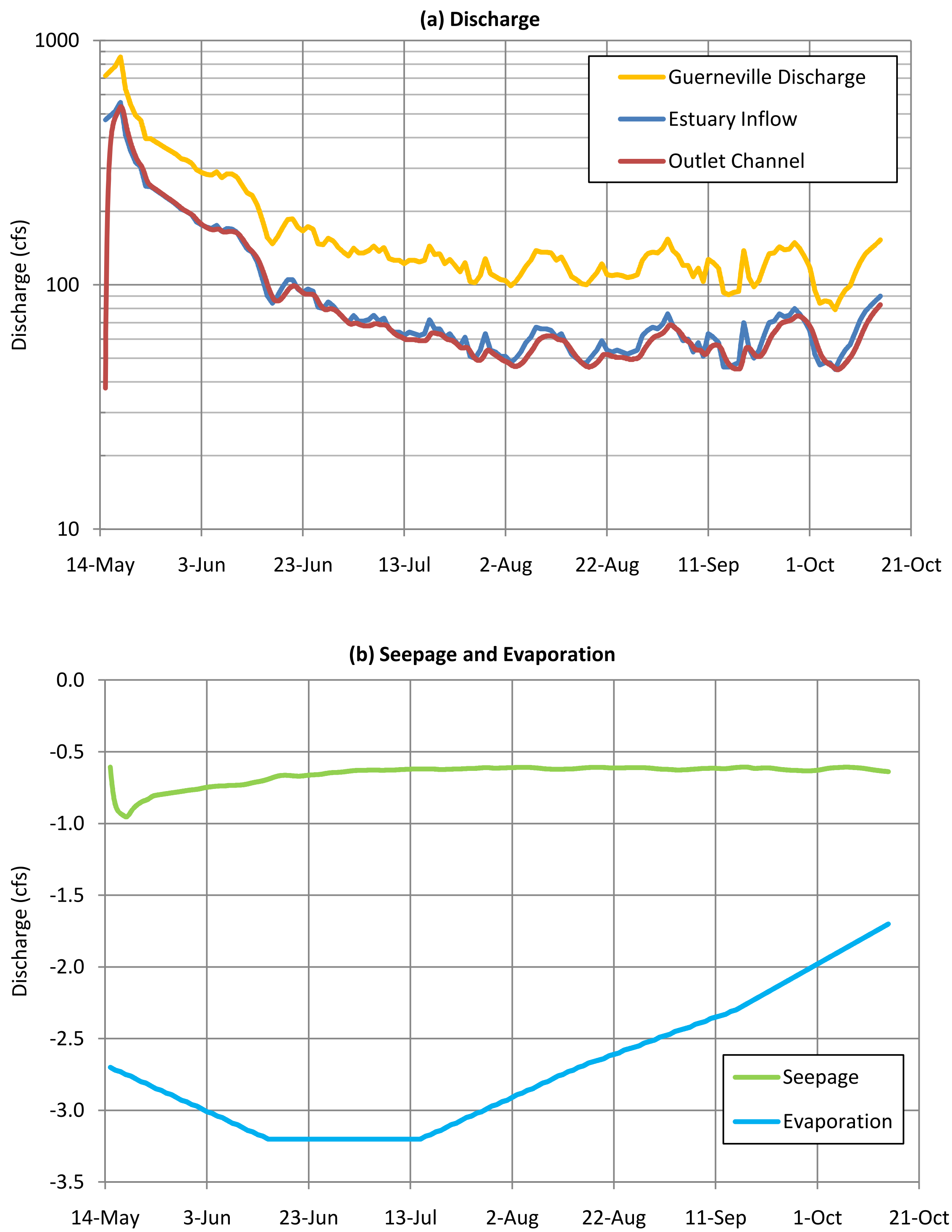
Russian River Estuary Outlet Channel Management Plan

Slope vs. Width Stability Plot

PWA Ref# 1958.01

PWA

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



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).

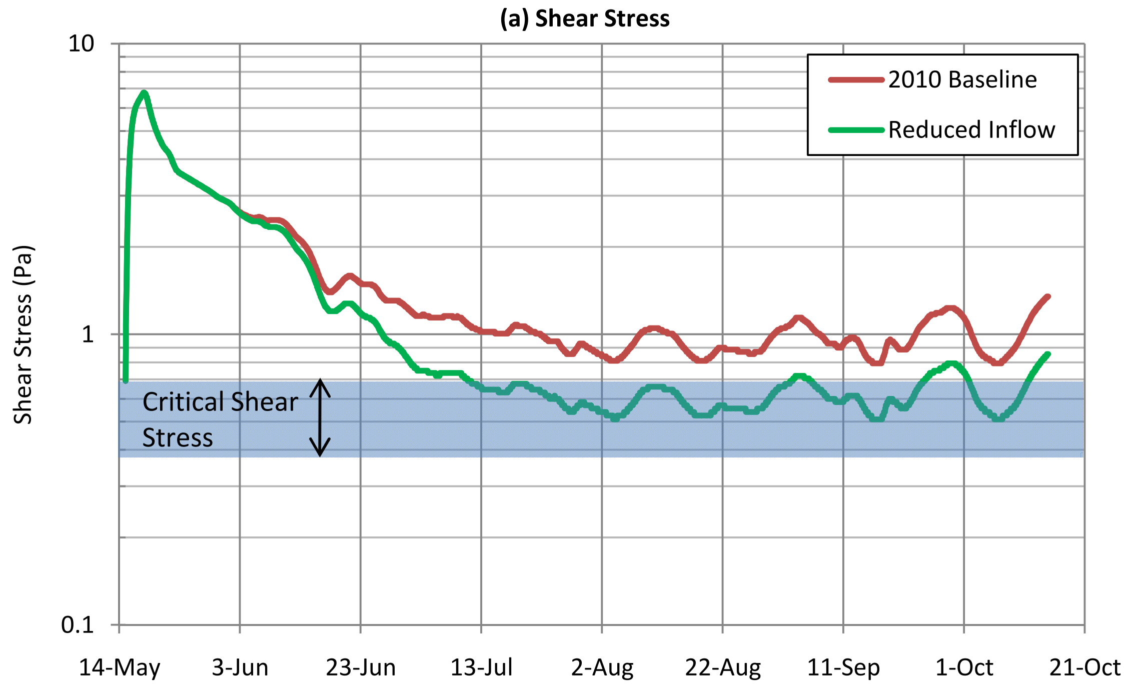
figure 7

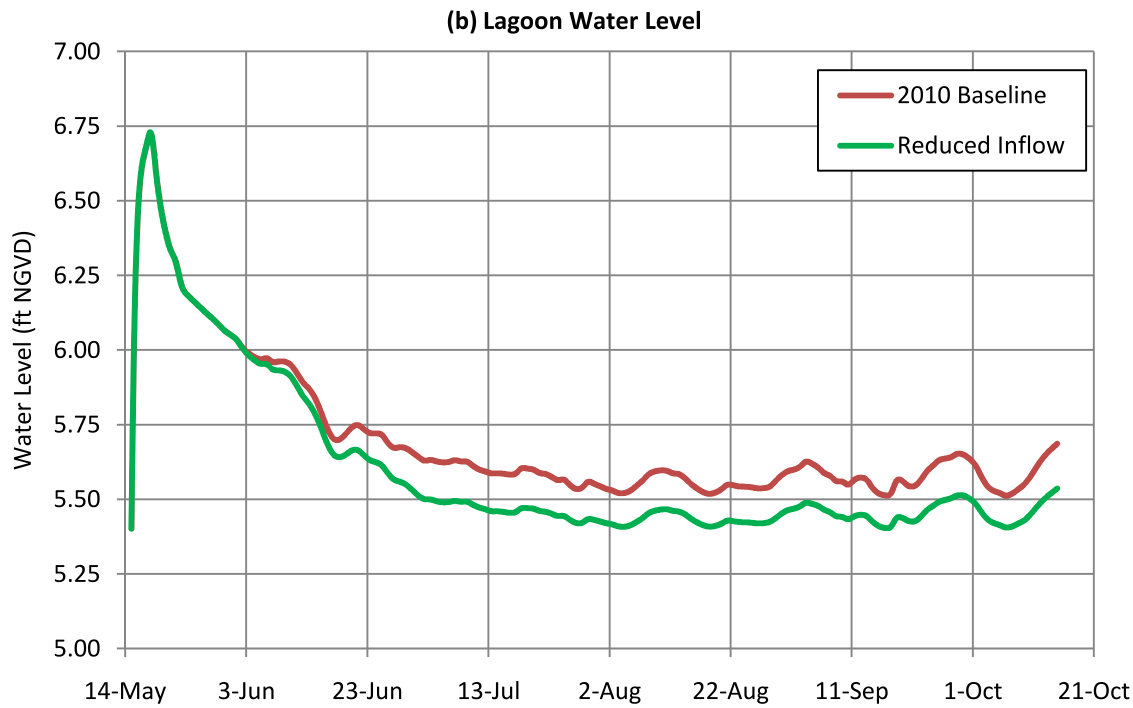
Russian River Estuary Outlet Channel Management Plan

Hydraulic Model Discharge - 2010 Anticipated Hydrology

PWA Ref#: 1958.01

PWA





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 **8**

Russian River Estuary Outlet Channel Management Plan

Hydraulic Model Results - 2010 Anticipated Hydrology

PWA Ref#: 1958.01

PWA

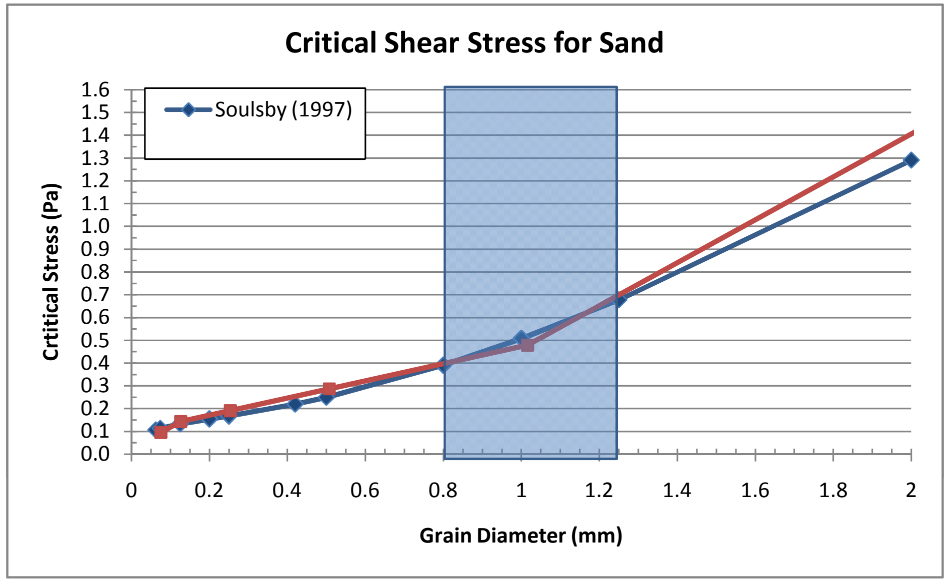
A-1. Critical shear stress for incipient motion of sand particles

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/m^2, assumes density of freshwater, quartz grained sand
Method based on Soulsby (1997) Dynamics of Marine Sand:

Note: does not account for gravitational effects on sloping bed

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

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

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

A-2. Manning's n worksheet

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

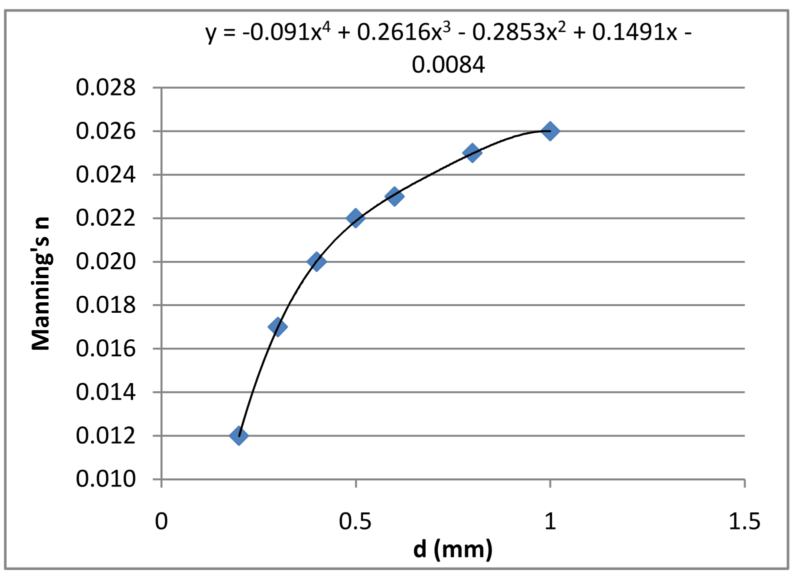
d_{50}	1	mm	0.003281 ft
D	0.84	ft	
Rh	0.83	ft	
S	0.00008	ft/ft	

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 Worksheet

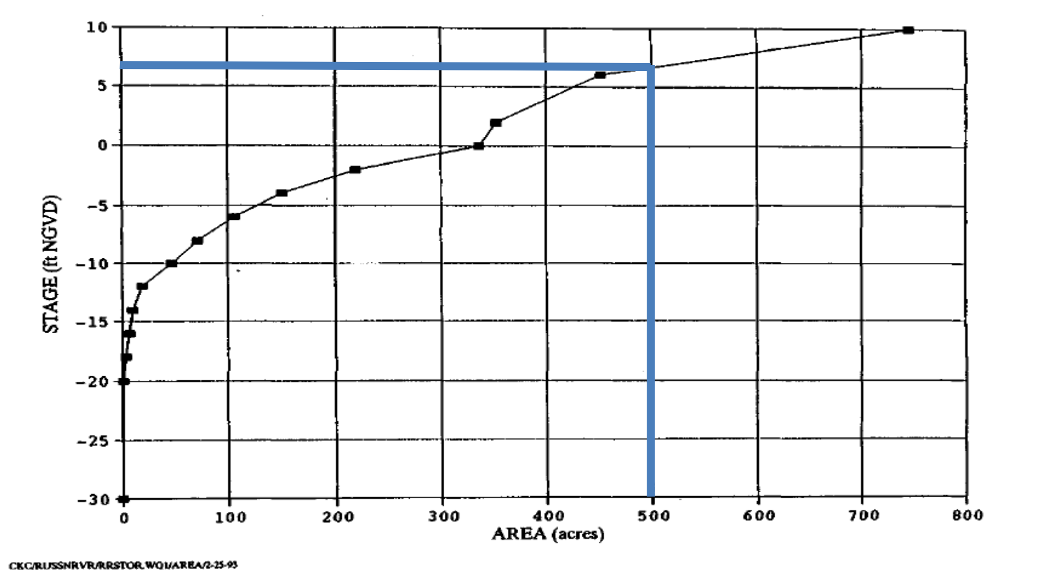
1958.01 Russian River Estuary Outlet Canal
J. Vandever (PWA)
15-Apr-09

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

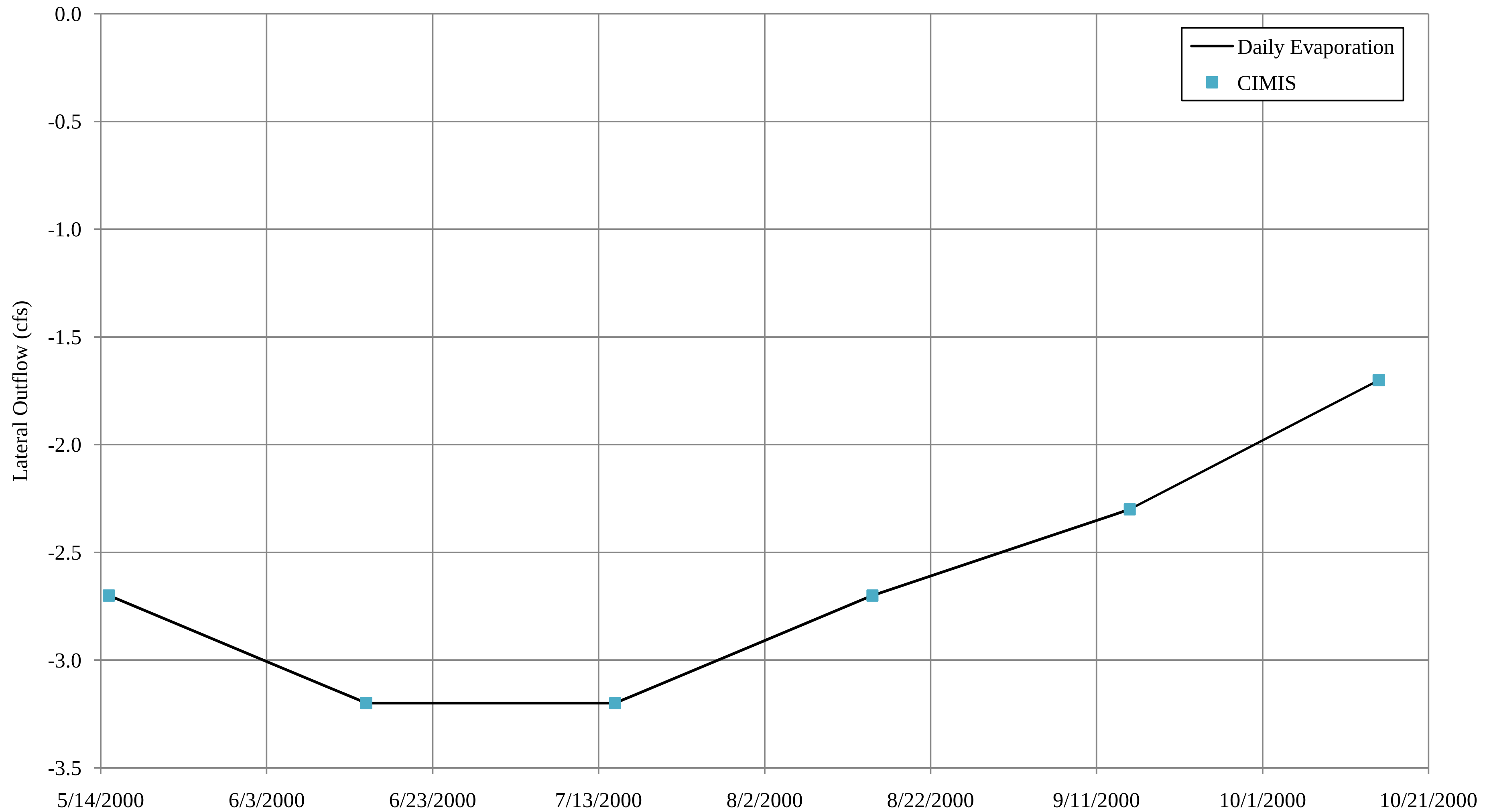
RRE Surface Area 500 acres
21,780,000 sq ft



Philip Williams & Associates, Ltd.
Consultants in Hydrology

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

Figure 5.6



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.

Appendix ***A-3***

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

A-4. Berm Seepage and Hydraulic Conductivity

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

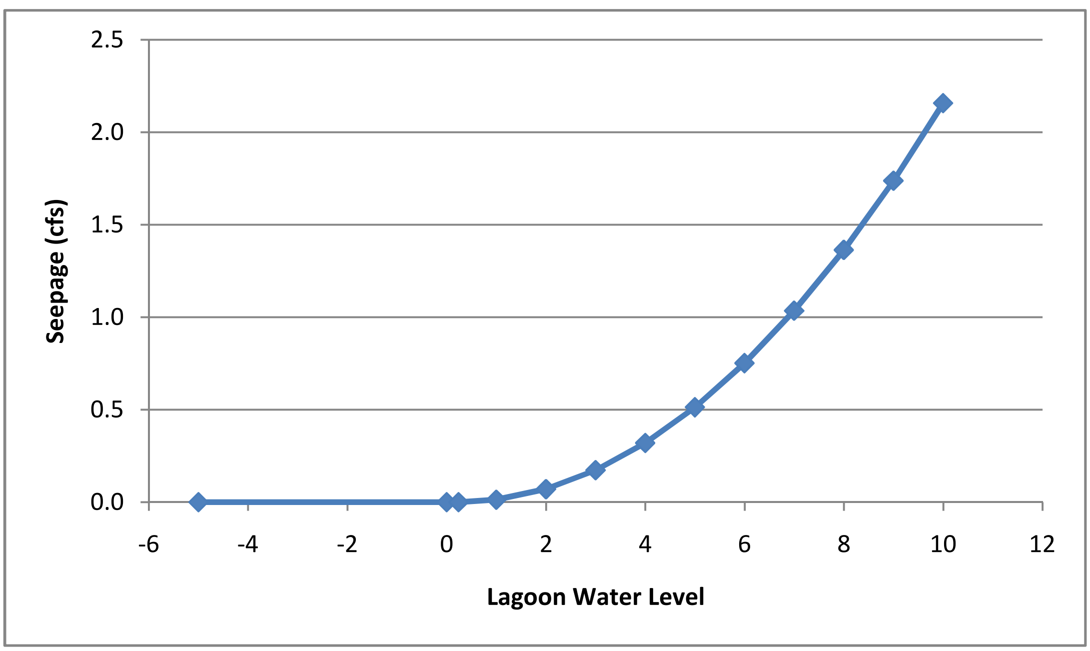
HEC-RAS Diversion Rating Curve

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



A-4. Berm Seepage and Hydraulic Conductivity

1958.01 Russian River Estuary Outlet Canal
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

A-5. Mouth Closure Calibration Worksheet

1958.01 Russian River Estuary Outlet Canal
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.

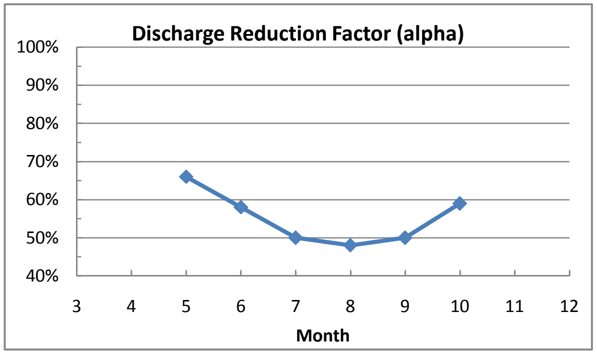
No detailed information available for the aquifer groundwater elevations or extraction rates by wells. The loss term is a calibrated variable in the model.

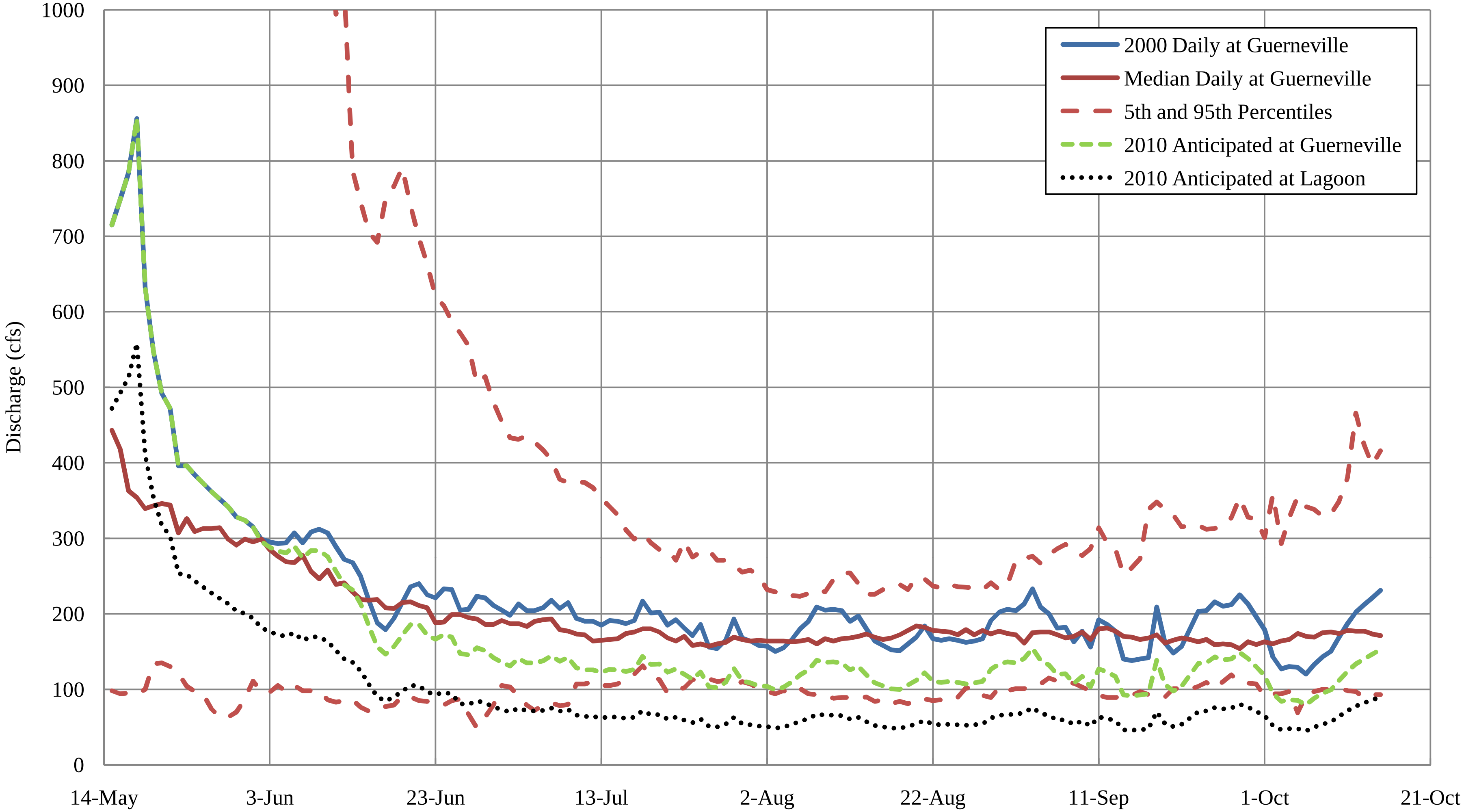
Lagoon Surface Area	400	ac
	17,424,000	sq ft
Evaporation and Seepage Losses	4	cfs

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	





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.

Appendix A-6

Russian River Estuary Outlet Channel Management Plan

Daily Russian River Discharge

PWA Ref #: 1958.01

PWA

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. The Sonoma County Water Agency 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:

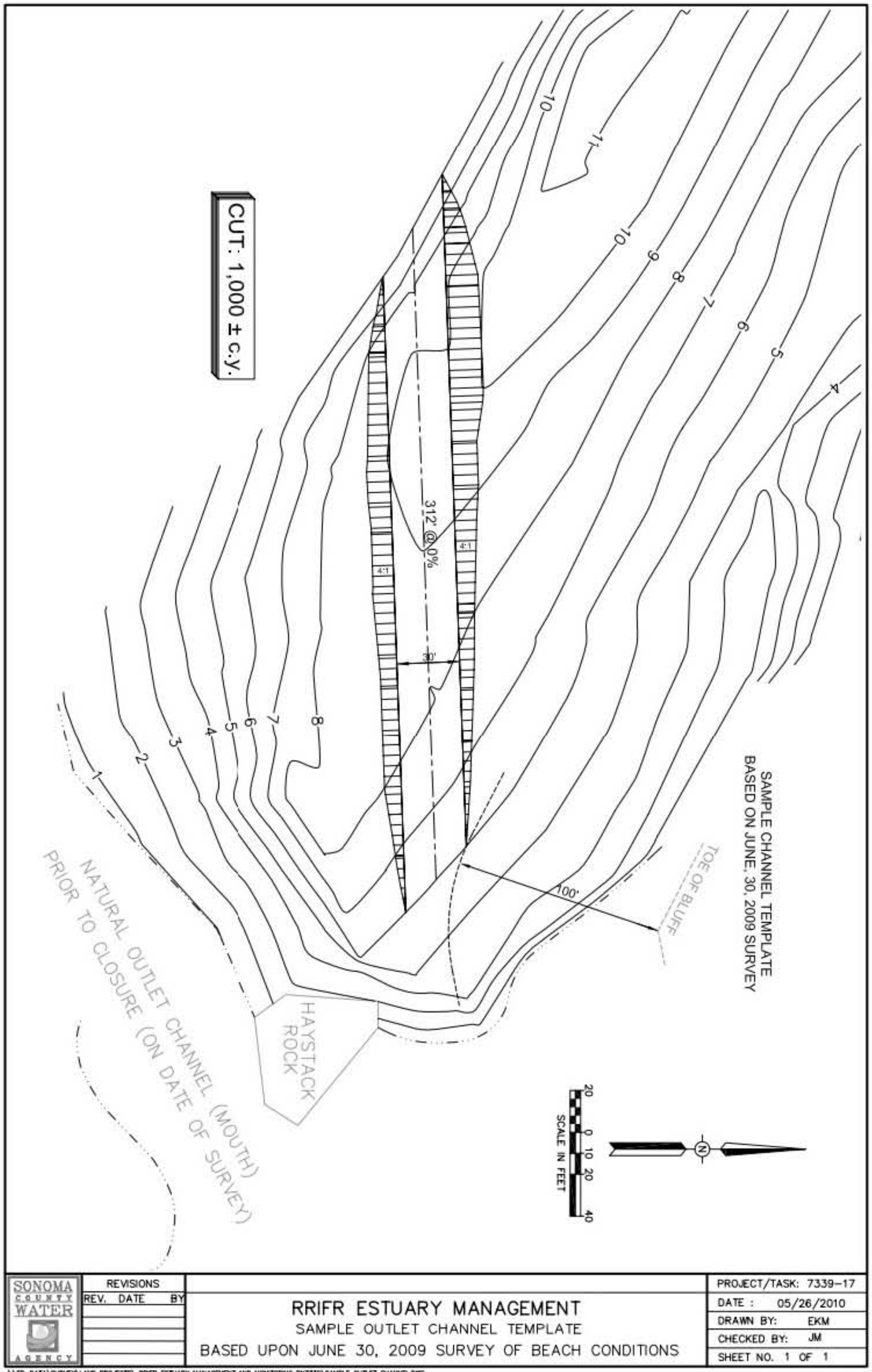
http://www.bml.ucdavis.edu/boon/russianriver

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 County Water Agency
707-547-1946 (office)
707-975-5606 (mobile)

Attachment B.2: Sample Proposed Outlet Channel Design Schematic



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. The Sonoma County Water Agency 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.

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 County Water Agency
707-547-1946 (office)
707-975-5606 (mobile)

Attachment C. Summary of Land Use Permits

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

Agency / Permit / Expiration	Special Conditions
California Department of Fish and Game 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 Expiration - December 31, 2010	[THESE ARE CONDITIONS IN THE ORIGINAL LSAA – MONITORING REQUIREMENTS HAVE BEEN REPLACED BY THOSE IN CDFG'S CONSISTENCY DETERMINATION FOR THE RUSSIAN RIVER BIOLOGICAL OPINION AND NMFS' MARINE MAMMAL PROTECTION ACT IHA] *Biological and Water Quality Monitoring for the Russian River Estuary Management Plan, dated February 13, 1996, included in original LSAA (III-1176-96)* *The following work shall be included as part of the studies:* *A. Biological Monitoring* *Seasonal otter trawl sampling and beach seine sampling, consisting' of a minimum of two (2) trawls each in spring and two (2) in fall, before and after an artificial breach, for a total of eight (8) sampling events. Sampling will be performed in the Study Area to determine the distribution and abundance of fish and macro-invertebrates.* *Seasonal deep water beach seine sampling, consisting of a minimum of two (2) samples in late spring and two (2) in early summer, before and after an artificial breach, for a total of eight (8) sampling events. Sampling will be performed in the Study Area to test for entrapment of salmonid smolts during closed estuary conditions.* *A minimum of three (3) behavioral observations of pinniped activity during artificial breaches, under restricted public access, to test the hypothesis that human activity deters pinniped landings on the beach, post-artificial breaching.* *Plankton tows, consisting of a minimum of two (2) tows per year, both at the mouth of Willow Creek, and up stream of the mouth, to monitor outflow levels of mysid shrimp and juvenile fishes. A plankton tow shall consist of one tow shortly before and one tow three hours post-artificial breaching.* *B. Water Quality Monitoring* *Monitoring of water quality, consisting of a minimum of one (1) sampling before and one (1) sampling after each artificial breach, during each season; spring, summer, and fall. Samples will be collected at four (4) sites from the mouth of the Russian River to above Willow Creek. The water quality parameters to be monitored will include temperature, salinity, and dissolved oxygen. Consultant shall also install continuous-recording salinity meters at each site during each breaching event to record salinity changes near the estuary bottom.*

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

Agency / Permit / Expiration	Special Conditions
California Regional Water Quality Control Board, North Coast Region Section 401 Water Certification (1B04001WNSO) - May 6, 2004 Amendment Extension – October 14, 2009 Expiration - December 31, 2010	Pursuant to 23 CCR3859(a), the applicant shall comply with the following additional conditions: 1. The Regional Water Board shall be notified in writing at least five working days (working days are Monday-Friday) prior to the commencement of grading work, with details regarding the construction schedule, in order to allow staff to be present on-site during construction, and to answer any public inquiries that may arise regarding the project. 2. When operations are completed, any excess material or debris shall be removed from the work area. No rubbish shall be deposited within 150 feet of the high water mark of any stream. 3. A copy of this permit must be provided to the Contractor and all subcontractors conducting the work, and must be in their possession at the work site. 4. If, at any time, a discharge to surface waters occurs, or any water quality problem arises, the project shall cease immediately and the Regional Water Board shall be notified promptly. The Regional Water Board will assess the extent of the problems and determine whether to rescind this Order. 5. The applicant shall submit an annual report, each year this Order is active, summarizing all water quality monitoring results and overall breaching activities to the Regional Water Board by December 31st. 6. This Order is not transferable. 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, 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. 7. The Applicant shall provide photos documenting the work being conducted and the completed work, to the appropriate Regional Water Board staff person, in order to document compliance.

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

Agency / Permit / Expiration	Special Conditions
California Coastal Commission Coastal Development Permit (2-01-033) – May 15, 2002 Amendment Requested – November 18, 2009 No expiration date	The Commission grants this permit subject to the following special conditions: Assumption of Risk, Waiver of Liability and Indemnity. 1. By acceptance of this permit, the applicant acknowledges and agrees (i) that the site may be subject to hazards from flooding and surf or wave conditions; (ii) to assume the risks to the applicant and the property that is the subject of this permit of injury and damage from such hazards in connection with this permitted development; (iii) to unconditionally waive any claim of damage or liability against the Commission, its officers, agents, and employees for injury or damage from such hazards; and (iv) to indemnify and hold harmless the 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 claims), expenses, and amounts paid in settlement arising from any injury or damage due to such hazards. B. PRIOR TO ISSUANCE OF THE COASTAL DEVELOPMENT PERMIT, the applicant shall submit a written agreement, in a form and content acceptable to the Executive Director, incorporating all of the above terms of this condition. 2. Schedule**.** Except under emergency conditions requiring immediate action to prevent or mitigate loss or damage to life, health, property, or essential public services, the breaching activities authorized herein shall not be initiated on or within 36 hours prior to any weekend or holiday. 3. Management Plan Changes. Within 90 days of final action by the National Marine Fisheries Service on a Biological Opinion addressing the threatened populations of chinook salmon, coho salmon, and steelhead in the Russian River, the permittee shall submit an application for an amendment to this coastal development permit requesting Commission authorization for any changes to the breaching program that are either required or recommended in the Biological Opinion. Such changes shall not be incorporated into the project until the permittee obtains a Commission amendment to this coastal development permit, unless the executive director determines that no amendment is legally required. 4. Period of Time Development is Authorized. Development is authorized by this permit only until December 31, 2002, except that the executive director may extend this authorization for any additional period authorized by the California State Lands Commission.

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

Agency / Permit / Expiration	Special Conditions
US Army Corps of Engineers, San Francisco District Section 404 & Section 10, Individual Permit (285610N) - July 22, 2005 Permit Modification - October 5, 2009 Expiration - December 31, 2010	<u>Individual Permit Dated July 22, 2005</u> Special Conditions: To ensure compliance with this Department of the Army permit and to further minimize adverse impacts to water quality and aquatic-dependent biological resources, including federally listed threatened salmonid fish species, designated critical habitat, and designated essential fish habitat, the project is subject to the following Special Conditions: 1. To remain exempt from the prohibitions of Section 9 of the Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 *et seq.),* SCWA shall fully implement the non- discretionary terms and conditions for incidental take of Central California Coast threatened coho salmon *(Oncorhynchus kisutch),* Central California Coast threatened steelhead *(Oncorhynchus mykiss),* and California Coastal threatened chinook salmon (*Oncorhynchus tshawytscha)* In the manner stipulated in the Biological and Conference pinion (Pages 33-35) entitled, "Clean Water Act Section 404 Permit for the Russian River Estuary Breaching Activities Conducted 2005-2010" (File No. 151422SWR04SR9206), issued by the National Marine Fisheries Service (NMFS), Southwest Region, on 20 May 2005 (Attachment 3). SCWA shall notify both NMFS and USACE bye-mail or by phone of any known violation of incidental take within twenty-four (24) hours of the occurrence. 2. SCWA shall provide USACE a copy of the approved Estuary Monitoring Plan and all subsequent Annual Monitoring Reports required by the Biological Opinion. 3. All breaching events shall occur only after the estuary water level reaches between 4.5 feet and 7.0 feet NGVD under current flow regimes, as measured by the stage gage at the Jenner Visitor Center. 4. To facilitate adequate inspection of work, SCWA shall notify USACE by e-mail or by phone of the proposed breaching date at least five (5) days prior to the commencement of work. 5. 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. 6. To ensure public safety while minimizing disturbance of harbor seals and other marine mammals during each breaching event, SCWA shall implement a Beach Closure Plan that restricts public access to all areas within 750 feet of the breaching location for a period of 24 hours before and after completion of work. 7. SCWA shall provide USACE a Breaching Activities Report by 31 March for each year of the five-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

Agency / Permit / Expiration	Special Conditions
	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. 8. The current Coastal Development Permit (CDP 2-01-033) issued by the California Coastal Commission expires on 31 December 2005. The current Section 401 water quality certification (WDID No. IB04001WNSO) issued by the Regional Water Quality Control Board expires on 15 October 2009. 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 five-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. <u>Letter of Modification dated October 5, 2009</u> Under the provisions of33 CFR 325.7(b), Department of Anny Permit No. 285610N is hereby modified to incorporate the following Special Conditions to reflect the recommendations of NMFS and incidental take requirements specified in the Russian River BO (issued September 24,2008): 1. To remain exempt from the prohibitions of Section 9 of the Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 *et seq.),* the non-discretionary Terms and Conditions for incidental take of Central California Coast endangered coho salmon *(Oncorhynchus kisutch),* Central California Coast threatened steelhead *(Oncorhynchus mykiss),* and California Coastal threatened chinook salmon *(Oncorhynchus tshawytscha)* shall be fully implemented in the manner stipulated in the Biological Opinion entitled, "Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Anny 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" (File No. 151422SWR2000SRI50) issued by National Marine Fisheries Service on September 24, 2008. 2. All work shall be done in general accordance with SCWA's adaptive management plan for the estuary outlet channel at the mouth of the Russian River, as mandated by NMFS in the Reasonable and Prudent Alternative section of the Russian River BO for alterations to estuary management (pp. 249-50), entitled, "Russian River Estuary Outlet Channel Adaptive Management Plan Year 1" dated July 30, 2009 (Enclosure 1).

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

Agency / Permit / Expiration	Special Conditions
California Environmental Quality Act Notice of Exemption	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	1. Lessee shall maintain and comply with all regulatory permits during the term of the lease. 2. Lessee shall supply CSLC with updated copies of renewed leases or permits as needed. 3. Lessee shall provide to the CSLC, yearly summaries of the breaching activities preformed for each calendar year under lease, please reference to existing Lease No. PRC 7018.9.
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	This permit is issued subject to the following conditions: 1. The exercise of any of the privileges granted by this permit constitutes acceptance of all of the conditions of this permit. 2. The real property subject to this permit is more particularly -described and shown on attached Exhibit "A". 3. This permit is issued for the purpose of gaining access to and breaching the sand barrier which periodically forms at the mouth of the Russian River. 4. The premises are to be used only for the purpose specified above. 5. The term of this permit begins on the date of approval by STATE and ends five (5) years thereafter. 6. PERMITTEE, in the exercise of the privileges herein granted, shall at all times comply with all applicable laws, rules, and regulations including, but not limited to, rules and regulations for the State Park System now in effect or hereinafter adopted. 7. That no tree or plant shall be cut, injured, or disturbed by PERMITTEE without approval of STATE. Any tree or slash so cut or removed shall be disposed of in a manner satisfactory to STATE. 8. This permission is subject to all valid and existing contracts, leases, licenses, encumbrances, and claims of title which may affect said property, and the use of the word "grant" herein shall not be construed as a covenant against the existence of any thereof. 9. PERMITTEE hereby waives all claims and recourse against STATE for loss or damage to persons or property arising from, growing out of, or in any way connected with or incident to this permit. PERMITTEE agrees to indemnify, save harmless, and defend STATE, its officers, agents, and employees against any and all claims, demands, or causes of action that may be brought against STATE, its officers, agents, and employees arising out of or in any way connected with or incident to this permit excepting such claims, demands or causes of action resulting from the sole negligence or willful misconduct of the

Agency / Permit / Expiration	Special Conditions
	STATE, its officers, agents, and employees. 10. That upon termination of this permit, PERMITTEE shall remove all property and equipment placed by or for PERMITTEE upon said premises and restore said premises as nearly as possible to the same state and condition they were in prior to PERMITTEE's entry upon said premises; but if PERMITTEE shall fail to do so and in the event PERMITTEE shall not correct such breach within ten (10) days after being requested in writing to do so by STATE, then STATE may do so all at PERMITTEE's cost and expense, to be paid by PERMITTEE on demand. 11. The route of ingress, egress, and access by PERMITTEE for the purposes herein shall be reasonably designated and redesignated by STATE. 12. In its use of the area, PERMITTEE shall comply with all STATE requirements including, but not limited to; parking control and the uses set forth herein. 13. This permit shall terminate at the end of the period as hereinabove provided except that STATE reserves the right to terminate at any time during said period upon giving ten (10) days written notice to PERMITTEE of STATE's intention to terminate. Upon breach by PERMITTEE of any of the conditions set forth herein, STATE may terminate the permit immediately by written notice to PERMITTEE. 14. This permit shall not, nor shall any interest therein or there under, be assigned, mortgaged, hypothecated, or transferred by PERMITTEE, whether voluntary or involuntary or by operation of law, nor shall PERMITTEE let or sublet or grant any license or permit with respect to the use and occupancy of the premises, or any portion thereof, without the written consent of STATE being first had and obtained. 15. PERMITTEE shall, at all times during the term of this permit, maintain in full force and effect, with respect to this permit, a policy or policies of public liability and property damage insurance. The policy or policies shall be in an amount not less than the following: Public Liability - $1,000,000 each person, $1,000,000 each accident; Property Damage Liability (and Products Damage Liability) $1,000,000. OR Combined Single Limit (CSL) - $1,000,000 each occurrence. and shall be underwritten to the satisfaction of STATE in a form satisfactory to STATE, and a complete and signed Certificate of Insurance thereof shall be submitted to STATE concurrently with the execution of this permit. The PERMITTEE's self-insurance program as described in attached Exhibit “B” may be substituted for above-required coverage. The certificate of insurance will provide:

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

Agency / Permit / Expiration	Special Conditions
	1. The insurer will not cancel the insured's coverage without 30 days prior written notice to STATE. 2. STATE OF CALIFORNIA, its officers, agents, employees, and servants are included as additional insured, but only insofar as the operations under this agreement are concerned. PERMITTEE agrees that the bodily injury liability insurance herein provided for shall be in effect at all times during the term of this permit. In the event said insurance coverage expires at .any time or times during the term of this permit, PERMITTEE agrees to provide at least thirty (30) days prior to said expiration date, a new certificate of insurance evidencing insurance coverage as provided for herein for not less than the remainder of the term of the permit, or for a period of not less than one (1) year. New certificates of insurance are subject to the approval of the Department of Parks and Recreation and PERMITTEE agrees that no work or services shall be performed prior to the giving of such approval. In the event PERMITTEE fails to keep in effect at all times insurance coverage as herein provided, STATE may, in addition to any other remedies it may have, terminate this permit and all privileges PERMITTEE may have hereunder. This cancellation provision shall not be construed in derogation of the duty of PERMITTEE to furnish insurance during the entire term of the permit. 16. STATE prefers methods of breaching which place highest value on public and worker safety, which are the least damaging to State Park lands, facilities and resources, and which are the least intrusive or disruptive to the resident population of harbor seals. The workers and equipment shall access the site from the Goat Rock parking lot south of the mouth of the river. To minimize damage to paving, track-laying and other heavy equipment shall be off and on loaded on the beach / dune sand. 17. PERMITTEE is responsible for public safety during and after the breaching operation until such time that water velocities and standing waves recede, and the sandbar banks stabilize and cease to erode, cave and wash away. In the interest of public and Park visitor safety, STATE reserves the right to require PERMITTEE to provide Peace Officers and/or Lifeguards, at no cost to STATE, to monitor and close the beach to the public for a distance of 750' on each side of the breach as recommended in the Russian River Estuary Study. 18. In the interest of public safety, the preferred days for sandbar breaching are from Monday to Thursday when Park visitation is usually at a minimum. Breaching should not be attempted within 36 hours prior to, or during, a holiday or weekend as sandbar bank erosion and instability may continue for several days after breaching and thus endanger or inconvenience the visiting public during periods of peak attendance. In the event of emergency situations, breaching may proceed immediately after notifying the State Park District Superintendent. 19. Prior to any, except emergency, breaching activity, PERMITTEE shall notify State Park District Superintendent 24 hours or more in advance of the breaching. During the notification process PERMITTEE and STATE shall confer and make a determination regarding the methods and equipment to

Agency / Permit / Expiration	Special Conditions
	be employed access routes, timing and other details of the breaching. In the event consensus cannot be reached the final determination regarding methods and equipment will be made by PERMITTEE and the final determination regarding access routes, timing and requirements for public safety shall be made by STATE. 20. Within sixty (60) days after approval of this permit, PERMITTEE shall arrange for a meeting with STATE to discuss and develop a detailed Operations Plan for breaching. The Operations Plan shall describe, in step-by-step fashion, the protocol and details that need to occur prior to, during, and following a breaching operation. 21. Before commencement of any repair or maintenance work on State Park lands, other than sandbar breaching, PERMITTEE shall obtain from STATE prior review and written approval of plans, specifications, material samples and/or submittals for said work. No work shall be undertaken, nor shall materials be placed by PERMITTEE except in accordance with such approved plans, specifications, and submittals. PERMITTEE shall provide STATE with plans, specifications, and submittals at least 30 days prior to the start of any project work or maintenance operation. 22. Approval of plans, specifications, and submittals by STATE does not relieve PERMITTEE of responsibility for the safety, effectiveness, adverse consequences or environmental damage caused by the design or execution of the work. PERWTTEE is responsible for any damage caused by PERMITTEE's use of State Park lands. In the event of damage to State Park lands or resources caused by PERMITTEE's use or other activities, PERMITTEE shall repair damage, remove undesirable materials, and/or restore the area to its previous condition as directed by and to the satisfaction of STATE. 23. All project work and activities shall be designed and executed in a manner which will cause the least damage to Park resources, minimum alteration to the land, and minimum interference with the use and enjoyment of the PARK by the public. All project work shall be designed and constructed to be attractive, cause minimal intrusion, and be visually compatible with the natural Park setting. 24. At least sixty (60) days prior to the expiration of this permit, PERMITTEE shall arrange for a meeting with STATE to review and, if necessary; modify the terms and conditions for renewal of this Permit. Such a meeting may be called for at any time, however, by written request from either party, and shall occur within 60 days of such request. 25. All project activities shall be coordinated with and subject to the approval of the State Park Sector Superintendent. The State Park Sector Superintendent may be contacted at: Russian River Sector Office 25381 Steelhead Boulevard, P.G. Box 123 Duncans Mills, California 95430 (707) 865-2391

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

Agency / Permit / Expiration	Special Conditions
US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service Incidental Harassment Authorization April 21, 2011 Expiration – April 20, 2012	This Authorization is valid only for water level management and monitoring activities, as described in the Agency's MMPA application. These activities include mechanical breaching, mechanical lagoon outlet channel creation and maintenance, and physical and biological monitoring of the Russian River Estuary. This Authorization allows the incidental taking, by Level B harassment only, of the following number of marine mammals, by species: 2,735 harbor seals (Phoca vitulina richardii) , 19 California sea lions (Zalophus californianus), and 15 northern elephant seals (Mirounga angustirostris). The taking by Level A (injurious) harassment, serious injury or death of any of the species listed in Condition 3 above or the taking of any species of marine mammal not listed in 3 above is prohibited and may result in the modification, suspension or revocation of this Authorization. The taking of any marine mammal in a manner not allowed for under this Authorization must be reported immediately to the Southwest Region (NMFS) 501 West Ocean Blvd., Suite 4200, Long Beach, CA 90802; phone (562) 980-4000; fax (562) 980-4027, and the Chief, Permits, Conservation, and Education Division, Office of Protected Resources (NMFS); 1315 East-West Hwy, Silver Spring, MD 20910; phone (301) 713-2289; fax (301) 713-0376. A copy of this Authorization must be in the possession of the lead contractor and marine mammal observer operating under the authority of this Incidental Harassment Authorization. The holder of this Authorization is required to cooperate with NMFS and any other federal, state, or local agency authorized to monitor the impacts of the activity on marine mammals <u>Mitigation Measures</u> In order to ensure the least practicable impact on the species listed in condition 3(b), 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 to minimize the potential for sudden flushes, which may result in a stampede – a particular concern during pupping 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 appearing suddenly at the top of the sandbar, again preventing sudden flushes. (d) 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.

Agency / Permit / Expiration	Special Conditions
	(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, to minimize disturbance of seals at the haul-out. (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 to minimize flushing seals. In addition, 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) to allow for an adequate disturbance recovery period. During the no-work period, equipment must be removed from the beach. (j) 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 CDFG to determine the appropriate course of action. SCWA shall coordinate with the locally established seal monitoring program (Stewards' Seal Watch) to determine if pups less than one week old are on the beach prior to a breaching event. (k) 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. <u>Monitoring Measures</u> The holder of this Authorization is required to conduct baseline monitoring and shall conduct additional monitoring as required during estuary management activities: (a) Baseline monitoring shall be conducted twice-monthly for the term of the IHA. These censuses shall begin at dawn and continue for eight 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 thirty 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) In addition, peripheral haul-outs shall be visited for ten minute counts twice during each baseline monitoring day. (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

Agency / Permit / Expiration	Special Conditions
	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) Monitoring of peripheral haul-outs shall occur concurrently with event monitoring, when possible. (e) For all monitoring, the following information shall be recorded in thirty 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. (f) All monitoring during pupping season shall include records of any neonate pup observations. SCWA shall coordinate with the Seal Watch monitoring program to determine if pups less than one week old are on the beach prior to a water level management event. Reporting The holder of this Authorization is required to: (a) Submit a report on all activities and marine mammal monitoring results to the Office of Protected Resources, NMFS, and the Southwest Regional Administrator, NMFS, 90 days prior to the expiration of the IHA if a renewal is sought, or within 90 days of the expiration of the permit otherwise. This 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 SCWA's Pinniped Monitoring Plan, if possible.

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. The estimated volume of excavated sand was 230 yd^3. 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 naturally 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.

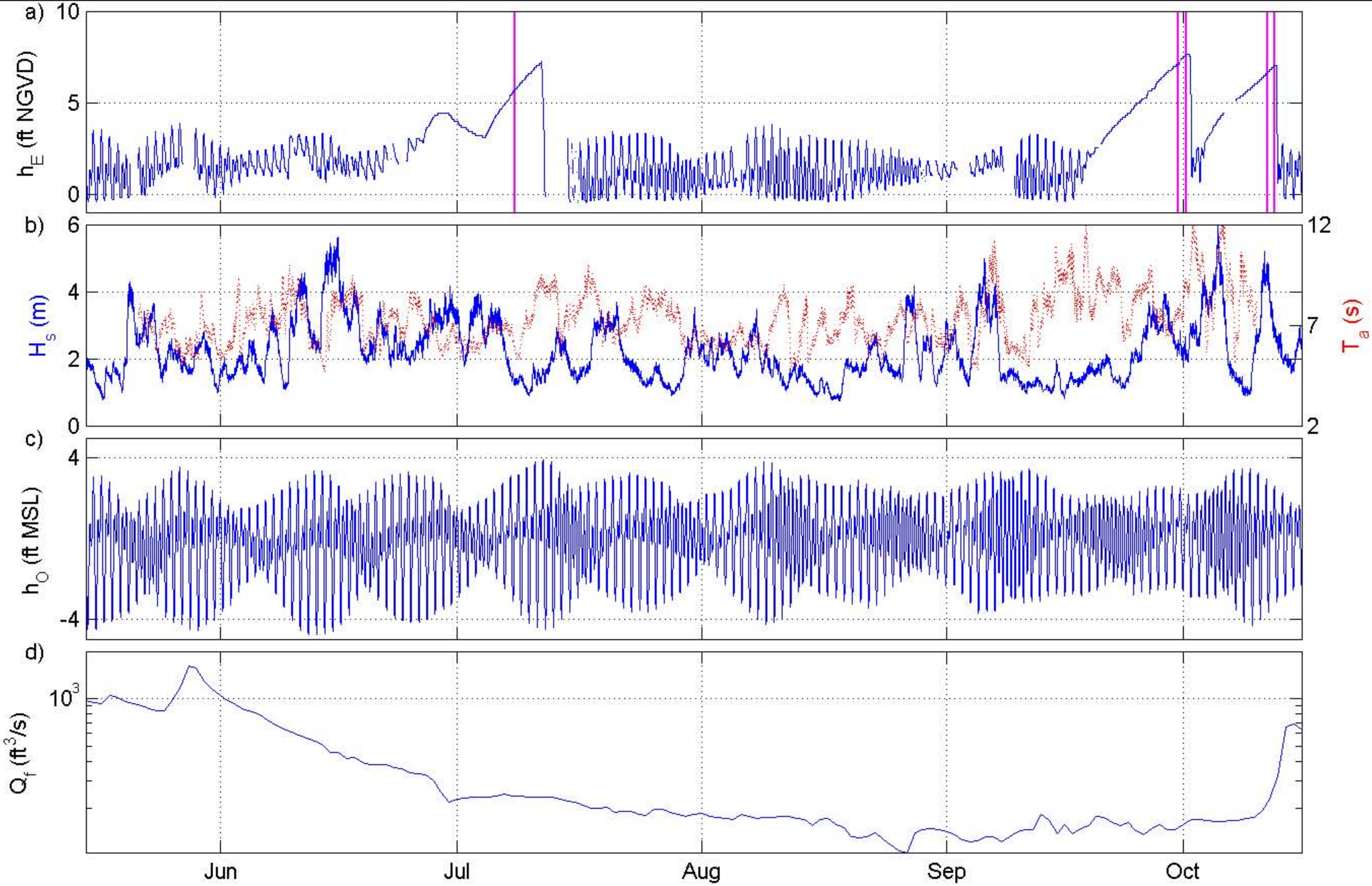
MONITORING

- 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

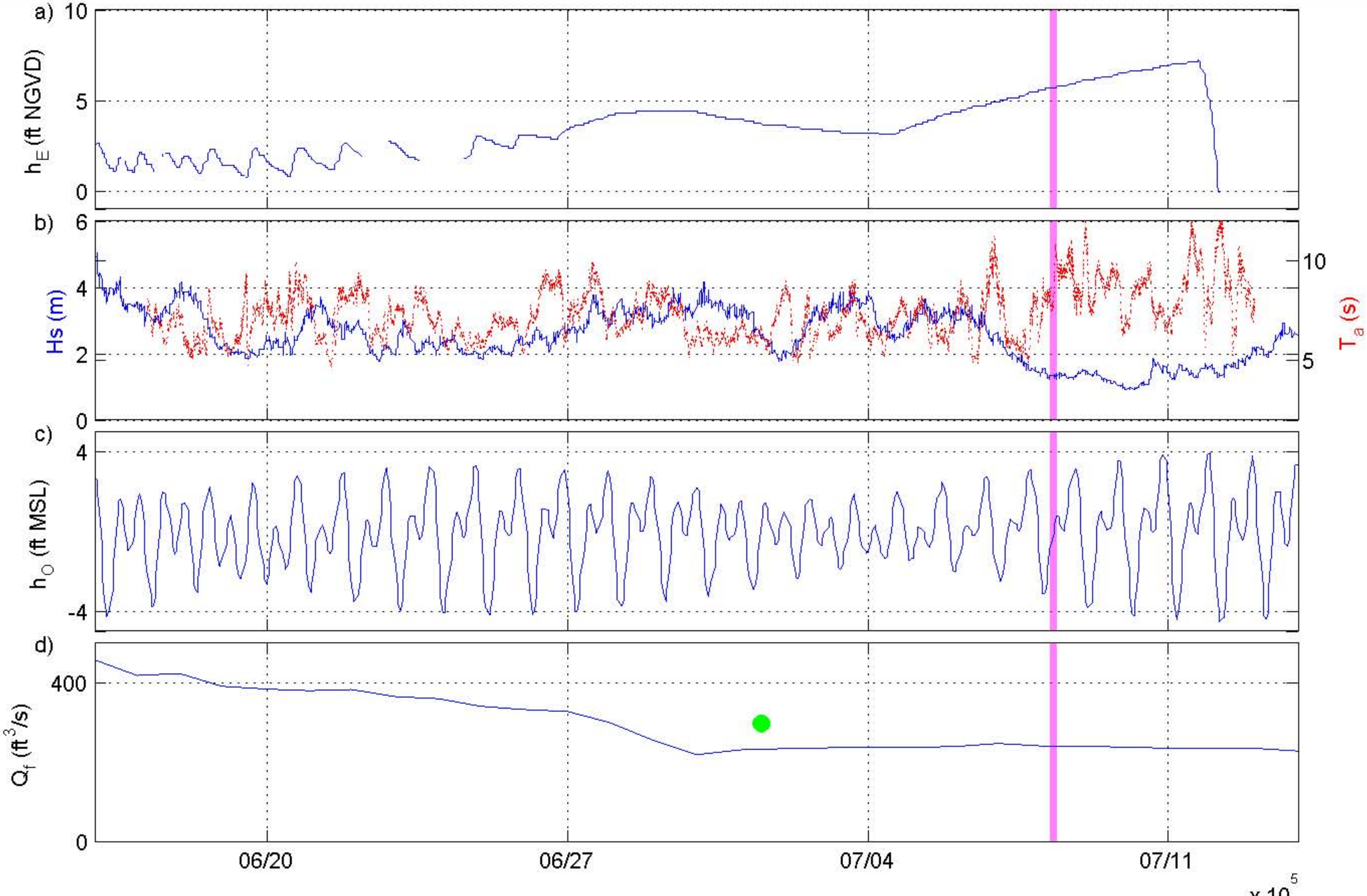
Russian River Estuary Outlet Channel Management Plan

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 = 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 2

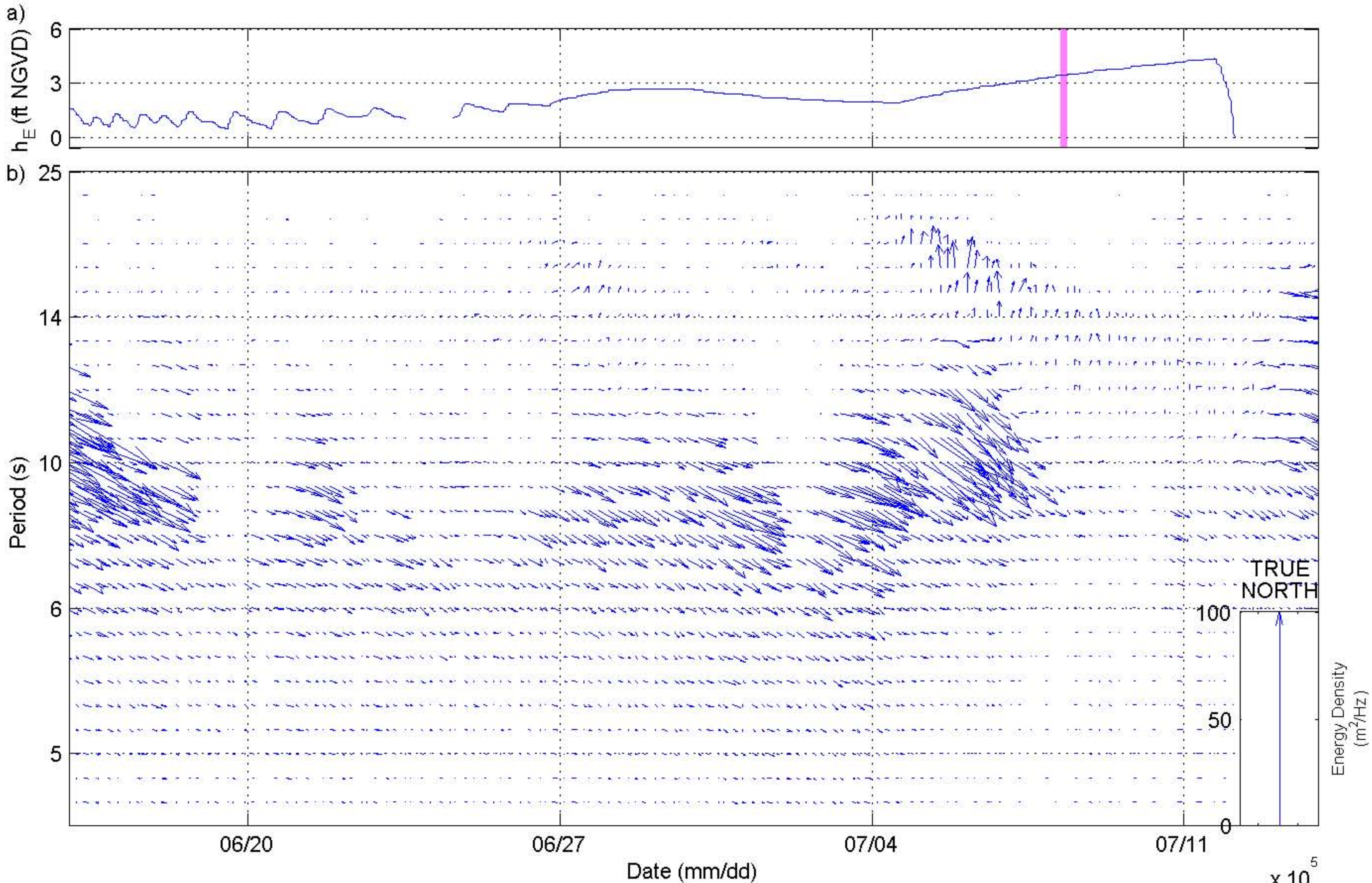
Russian River Estuary Outlet Channel Management Plan

Estuary and Ocean Conditions, 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\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

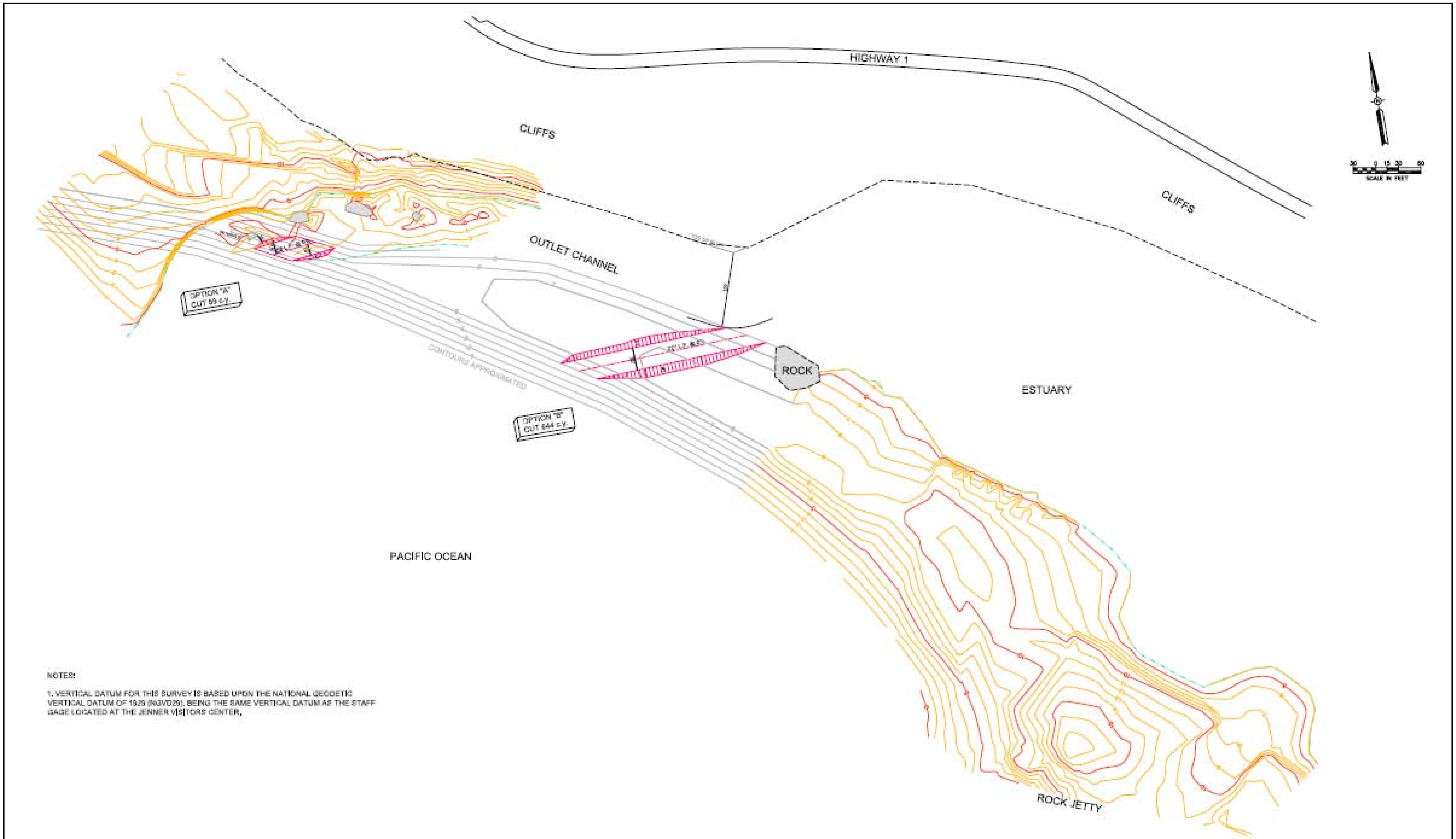
Russian River Estuary Outlet Channel Management Plan

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

a)

b)

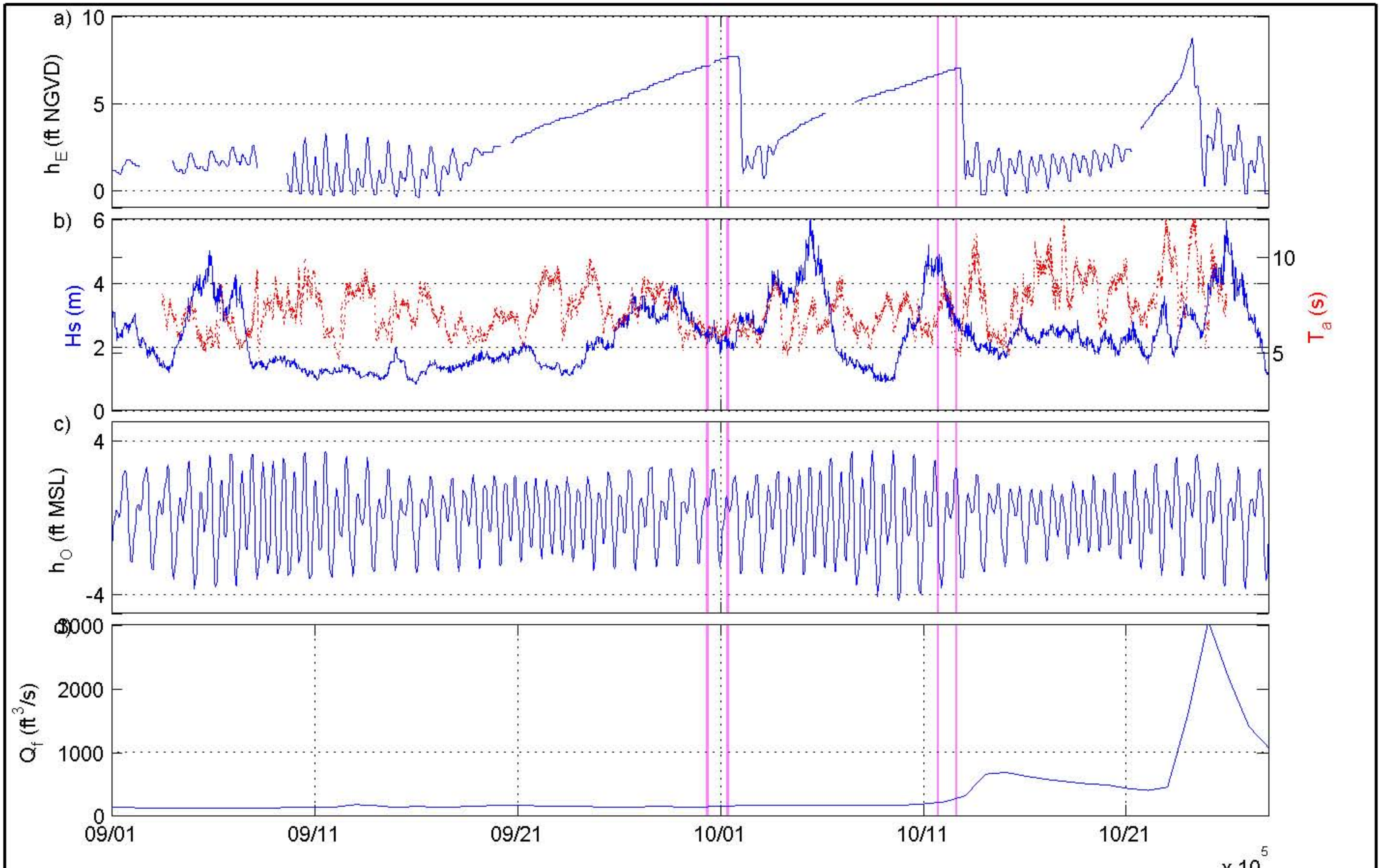
Source: C. Delaney, SCWA

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

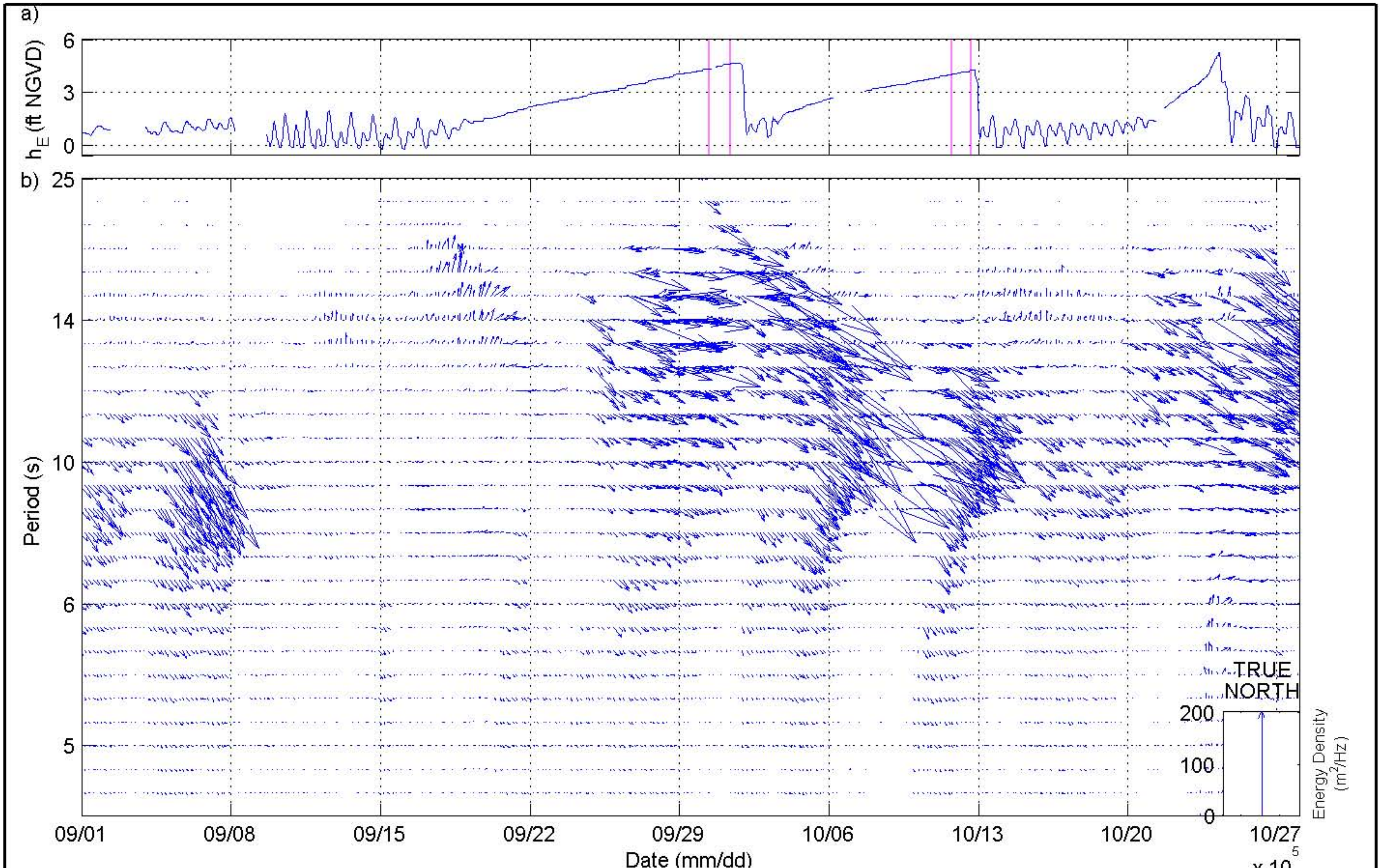
Russian River Estuary Outlet Channel Management Plan

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

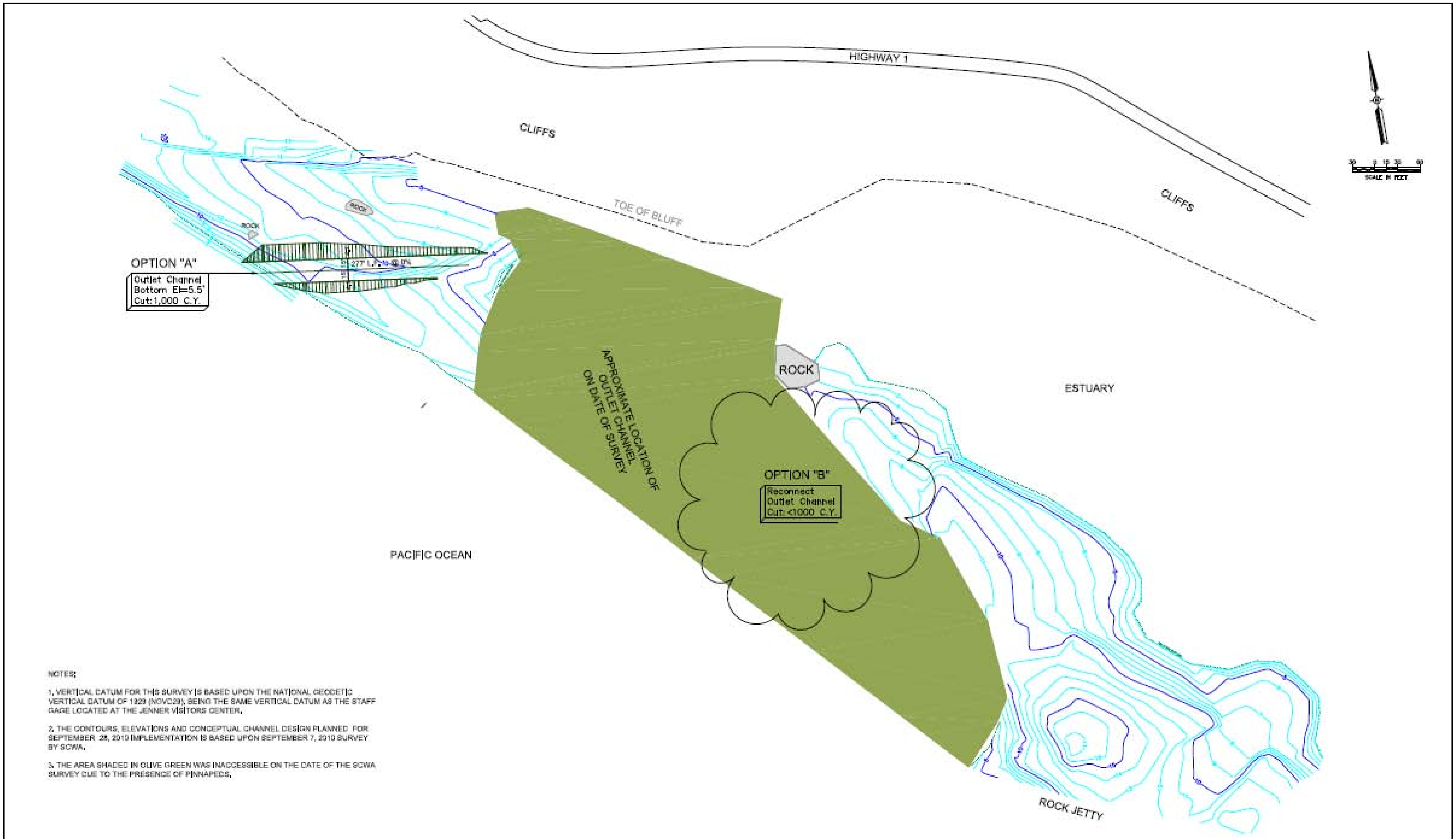
Russian River Estuary Outlet Channel Management Plan

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