5. THE QUANTIFIED CONCEPTUAL MODEL

The conceptual model described above was quantified using field data collected at the site in order to develop a tool to predict closure and breaching of the inlet at Crissy Field. This Quantified Conceptual Model (QCM) is based upon a stability index to estimate the likelihood for closure and a breach criterion based upon water levels in the bay. The paragraphs below describe the details of the QCM, as well as its calibration and limitations. Conventional inlet stability criteria are also summarized.

5.1 INLET STABILITY CRITERIA

The dynamics of tidal inlets vary greatly, from sites which are continually open with relatively small changes in location and shape, to inlets that are ephemeral or subject to intermittent opening and closing. Inlet stability is primarily a function of the opposing forces of waves that move sediment into the mouth of the inlet and tidal action that scours deposited material from the channel, and stability criteria that directly or indirectly incorporate these processes. Stream discharge can significantly augment or replace tidal power as the scouring force, but creek flow into Crissy Field from Tennessee Hollow is relatively weak and therefore neglected in the following discussion. Proposed stream restoration activities in the Tennessee Hollow watershed should not significantly change this.

The paragraphs below summarize criteria that have been used by others to determine the stability of tidal inlets. Along with the summary of each criteria, its applicability to the present study is qualitatively addressed.

5.1.1 Tidal Prism Relationships

Hydraulic geometry relationships between tidal prism and the cross-sectional area of the inlet channel are perhaps the most common criteria applied to predict the stability of tidal inlets. These are empirical relationships based on surveys of stable inlets, and take the form:

$$A_e = C\,\Sigma^n$$

where A_e is the minimum cross-sectional area, Σ is the tidal prism, and C and n are empirically derived parameters. Jarrett (1976) examined earlier work by O'Brien (1931) for Pacific Coast inlets, and established relationships for sites along the Gulf and Atlantic coasts. His results were further divided among inlets that had one, two, or no jetties. Although the expressions established by Jarrett are considered the best available predictors for equilibrium cross-sectional areas, small inlets tend to exhibit equilibrium area much larger than predicted by these tidal prism relationships.

Considerable scatter in the data suggest that not all of the relevant processes are included in these simple relationships. Therefore, they should only be used as a first approximation and interpreted as representative of long-term average conditions. Significant variations can occur over the spring-neap tide

cycle, during storms when wave attack is more intense, or following large flood events. This is especially true for small dynamic systems such as the Crissy Field inlet. A process-based tidal prism relationship developed by Hughes (2002) shows better agreement between small and large tidal inlets, and more promise for application to the Crissy Field inlet.

5.1.2 Wave Power versus Tidal Prism

Tidal inlets reach an equilibrium configuration when the sediment transported towards the mouth of the inlet by wave and currents is balanced by the scouring effect of currents in the channel. Based on this understanding and physical model tests, O'Brien (1971) proposed the following closure criteria:

$$S = P_W/P_{T,}$$

where, P_W is the wave power and P_T is the tidal power per tidal cycle. O'Brien postulated that the inlet would close if the stability parameter, S, exceeded some critical value, S_{CRIT}.

Although tidal currents complicate the movement of sand, O'Brien speculated that wave power could still be used as a reasonable surrogate for littoral transport. It was also noted that not all of the tidal energy is available for maintenance of the flow area since some is dissipated by friction along the channel and head losses in the ocean (bay) and basin (lagoon).

Despite its limitations, the O'Brien stability criterion explicitly accounts for the opposing forces of waves and tides and is capable of predicting stability over the short-term due to time-varying conditions. Therefore, it can be used to simulate discrete inlet closure events based on a time series of wave and tide data. Application to the present study relies upon selection of S_{CRIT} and the availability of input data.

5.1.3 Johnson's Wave Power – Tidal Prism Criterion

Johnson (1973) noted that nearshore wave data needed to apply O'Brien's closure criterion is lacking for most sites, and instead proposed a simplified approach of comparing the estimated average annual deep-water wave power with the potential tidal prism. Johnson concluded that for a given wave power, there appears to be a tidal prism that must be exceeded if the inlet is to remain open.

After graphically presenting his results, Johnson identified a line that separates inlets that have closed or are usually closed and those that stay open. Like the tidal prism relationships, this criterion gives a general indication of the long-term stability of the inlet, but cannot provide more than a qualitative indication of the frequency of closure. PWA (1999) noted corrections to the data from Johnson (1973) that affect the wave power values reported but not the validity of the approach.

5.1.4 Littoral Drift versus Tidal Prism

Bruun (1966, 1978) examined the delivery of sediments into the mouth of the inlet by littoral transport and compared this to the neap tidal prism. From these studies, he developed stability criteria based on total annual littoral drift (M) and neap tidal prism (Σ_N). The stability of an inlet is rated as good, fair or poor according to the ratios:

$\Sigma_N / M > 150$	good
$100 > \Sigma_N / M < 150$	fair
$50 > \Sigma_N / M < 100$	fair to poor
$\Sigma_N / M < 50$	poor

Longshore transport during storms is assumed to contribute most of the sediment, however cross-shore transport may be significant under certain conditions. The usefulness of the Bruun stability criteria is limited by the ability to accurately predict the longshore transport.

5.1.5 Peak Tidal Current

Escoffier (1940) proposed a semi-analytic method for developing stability criteria based on the peak tidal velocity (U_{MAX}) and the cross-sectional area (A_C). Peak velocities are based on numerical models or analytic methods. Escoffier curves (U_{MAX} versus A_C) suggest three possible scenarios:

1. *Inlet normally closed*. If U_{MAX} is less than the velocity required to remove sediment from the previous tidal cycle (U_{CRIT}) the inlet will close.
2. *Unstable Inlet*. If U_{CRIT} intersects the curve, there are two possible solutions. The first solution (the lower value of A_C) is unstable since initial change in flow area is accentuated and the inlet will continuously shoal until closure or, scour until critical flow area is attained.
3. *Stable Inlet*. The second intersect of U_{MAX} and U_{CRIT} (the larger value of A_C) indicates a stable inlet since any induced changes in the cross-sectional area of a stable inlet will result in a change of velocity that returns the inlet to its original size by deposition or scour.

Implicit in this analysis is that the inlet dimensions will change in time, in response to the spring neap cycle as well as seasonal and other trends in the forcing parameters. Seasonal changes are associated with storms and are characterized by changes in cross-sectional area about an average value. It should also be noted that even stable inlets may be subject to perturbations under extreme conditions that result in the inlet area changing to unstable values. The joint probability of these conditions (high wave, tides, and freshwater runoff) affects the expected frequency of closure.

5.2 DETAILS OF THE QCM

The conceptual model described in Section 4.2 was extended to a computer program that uses time series of wave and tidal levels to estimate the potential for inlet closure and breaching at Crissy Field. The

output of this FORTRAN program is a corresponding time series of a stability parameter, with a time history of closure and breach events. The QCM uses a modified O'Brien stability criterion to quantify the time-varying potential for closure (Williams and Cuffe, 1994; PWA, 1993) and a simple breach criterion based upon the elevation of tides in the bay and the beach barrier.

5.2.1 Closure Potential

Closure potential is estimated by applying a time-varying O'Brien stability index based on the changing environmental conditions at Crissy Field. This stability index is simply the ratio of wave to tidal power, and can be defined as:

$$S = P_W/P_T$$

where, P_W is a moving 6.5-hour average of the wave power at Crissy Field, and P_T is the tidal power of the marsh. The inlet will close if the stability index exceeds some critical value (S_{CRIT}).

Wave power is the rate of energy flux, and is defined as:

$$P_W = ½ \Delta g H^2 Cg$$

In this expression, Δ is the density of seawater, H is the wave height at Crissy Field, Cg is the group velocity (i.e., the speed at which wave energy travels). Since the group velocity depends on the wave frequency, contributions from individual wavelets must be computed separately and then summed to provide the total wave power. Therefore,

$$P_W = ½ \Delta g \Sigma_i H_i^2 Cg_i$$

where the subscript *i* represents various frequency bands in the wave spectrum. This expression can be similarly extended to sum contributions from different wave directions. In the present application, directionality is implicitly included in the wave transformation matrix.

Tidal power represents the rate at which the potential energy of the water flushed through the inlet is spent, and is defined as:

$$P_T = (\gamma \Omega R) / (b T)$$

where, γ is the unit weight of water, Ω is the effective diurnal tidal prism, R is the effective diurnal tide range in the lagoon, b is the width of the inlet, and T is the period over which the water level in the lagoon varies. It is important to note that in its present morphological condition, the effective tidal prism at Crissy Field is significantly less than its potential tidal prism. As discussed in Section 4.1 is due to the relatively high elevation of the inlet channel thalweg which limits tide range in the lagoon. Due to this tidal muting, the expected tide range in the lagoon is determined by the higher high (HH) water level in

the bay and the low water (LW) elevation set by the maximum thalweg elevation. Since the majority of the effective tidal prism is drained during the first ebb cycle in the bay, tidal power at Crissy Field is computed by setting T to 6.25 hours and taking the difference between HH and LW as the effective tidal range in the marsh. This formulation remains applicable as the effective tidal range increases to a larger percentage of the potential (bay) tide range.

Using input time series of wave and tide data, and setting the low water drainage elevation based on monitoring data, a time-varying stability index was computed. An example of this is shown in Figure 5–1, which plots the wave and tidal conditions as well as stability index computed by the QCM for the period of 06/04/2001 to 06/20/01. According to the O'Brien criterion, closure occurs when the stability index exceeds some critical value, S_{CRIT}.

5.2.2 Breaching

As described in Section 4.2, natural re-opening of the tidal inlet at Crissy Field is usually driven by the difference in elevation between the high tides in the bay and the beach barrier. Therefore, the following criterion was used to determine if a closed inlet would naturally re-open,

$$\text{if } \eta_{BAY} > \eta_{CRIT}, \quad \text{the inlet naturally breaches}$$
$$\text{if } \eta_{BAY} < \eta_{CRIT}, \quad \text{the inlet stays closed}$$

where, η_{BAY} is the observed water level in the bay and therefore includes the meteorological and hydrological effects as well as the tides. η_{CRIT} is the critical value the bay water level must exceed in order to breach the beach barrier. Observations of natural breaching events indicate that the closed inlet tends to re-open near the remnant mouth, where the crest of the barrier is minimum. Since closure occurs when sedimentation near the mouth creates a barrier sufficient to block tidal inundation during flood currents, η_{CRIT} is initially set slightly higher than the coincident high tide in the bay. This value is subsequently increased as a function of wave power incident on the closed inlet to account for beach processes that tend to increase the beach berm elevation. The critical bay water level required to induce natural re-opening, therefore, is modeled in the QCM with the following expression,

$$\eta_{CRIT} = [HW_O + a] + [b \times \int P_W \, dt] + [\Sigma \, (c \times P_{W\text{-}Peak})].$$

HW_O is the diurnal high tide in the bay at the time of closure, $P_{W\text{-}Peak}$ is the peak incident wave power above a critical value, t is time since closure, and a, b, and c are calibration coefficients. The first term in brackets represent the initial elevation of the beach berm immediately following closure. The second and third terms represent increases in the berm elevation due to, respectively, the cumulative and peak wave power incident upon the beach during closure. Based on survey data η_{CRIT} is limited to 5 ft NGVD, the highest expected elevation of the beach barrier. This elevation relates to the typical beach morphology at Crissy Field, as defined by wave run-up at high tides.

Since water levels in the bay may not reach the critical elevation required to naturally re-open a closed inlet if the beach barrier is sufficiently large, the QCM assumes that intervention (mechanical breaching) will take place once the duration of closure reaches 14 days. This ensures at least one spring tide cycle has passed without bay tides high enough to naturally re-open the inlet.

5.2.3 Channel Alignment

As described in Section 4.1, the inlet channel responds to changing wave conditions by migrating between one of two natural positions, which in turn affects the low water drainage elevation. The low water drainage elevation is an important parameter and strongly affects tidal power and hence the stability index. Since wave conditions along California generally exhibit the seasonality of strong winter storms and relatively low-energy summer waves, the low water drainage elevation is prescribed in the QCM based on the calendar month.

After examining the monitoring data shown in Figure 4-2, the following values were selected for low water drainage elevations in the marsh. Note that the low water elevation is slightly higher than the maximum thalweg elevation due to frictional losses along the channel length.

LW = + 1.75 ft NGVD	From June to September
LW = +1.50 ft NGVD	October to April
LW varies from +1.75 to +1.5 ft NGVD	October
LW varies from +1.5 to +1.75 ft NGVD	May

Low water elevations in the marsh are lower following mechanical breaching, and persist for several months. Following the mechanical intervention of mid-January 2002 the low water dropped from its initial elevation of +1.5 ft NGVD to approximately +0.3 ft NGVD by mid-to-late March 2002 as the inlet channel slowly downcut. Sedimentation in the channel then returned, and by mid-June 2002 the low water elevation was again +1.5 ft NGVD.

5.3 INPUT DATA

Time series of tide and wave data were collected from readily available sources and used as input to the QCM. Historical tide data were collected from verified water surface elevations observed at the Presidio tide gage[1]. The daily high and low water surface elevations and times of these events were used to compute the tidal power at the Crissy Field marsh. Samples of these data are shown in Table 5-1.

[1] NOAA station 9414290. Data available from http://www.co-ops.nos.noaa.gov

Table 5-1. Sample Tide Data from Presidio Gage

```
Data are in Feet above MLLW
Times are on UTC (GMT)
9414290 SAN FRANCISCO, SAN FRANCISCO BAY, CA  from  20011201 to 20021101
Click HERE for further station information.
-------------------------------------------------------------------------------
Station Date       Time      WL  TY

9414290 2001/12/01 01:18   -0.67 LL
9414290 2001/12/01 08:30    4.98 H
9414290 2001/12/01 12:42    3.16 L
9414290 2001/12/01 18:54    7.25 HH
9414290 2001/12/02 01:54   -0.55 LL
9414290 2001/12/02 09:18    5.61 H
9414290 2001/12/02 13:42    4.31 L
9414290 2001/12/02 19:36    7.62 HH
9414290 2001/12/03 02:48   -0.33 LL
```

Offshore wave data collected by the California Data Information Program (CDIP) of the Scripps Institute of Oceanography were transformed to construct a time series of nearshore wave conditions at Crissy Field using methods established by PWA as part of previous studies (PWA, 2001a). CDIP collects directional wave data from its buoy located approximately 21 miles offshore of Point Reyes[2] (see Figure 5–2 for a location map). Due to the limitations of saving and transmitting time-varying directional wave spectra, data from this buoy are summarized into nine period bands. Each band contains the energy content for a range of wave frequencies and is assigned a dominant wave direction. Tables 5-2 and 5-3 show sample data from the Pt. Reyes buoy, and illustrate how the energy content and directionality of each period band is summarized from offshore measurements.

Table 5-2. Sample Directional Data from CDIP Buoy

		ANGULAR DISTRIBUTION IN PERIOD BANDS (ANGLES IN DEGREES)								
UTC	Dp	BAND PERIOD LIMITS (SECS)								
YYYYMMDDHHMM	(DEG)	+22	22-18	18-16	16-14	14-12	12-10	10-8	8-6	6-2
199612060136	304	302	306	309	303	303	304	293	283	265
199612060206	302	304	308	310	303	306	302	294	283	265
199612060236	306	314	306	308	309	311	305	299	286	264
199612060306	310	317	308	309	309	309	310	298	285	262

[2] CDIP Pt. Reyes Buoy (station ID 029). Data available from www.cdip.ucsd.edu

Table 5-3. Sample Wave Energy Data from CDIP Buoy

			ENERGY (CM^2)								
UTC	Hs	Tp	BAND PERIOD LIMITS (SECS)								
YYYYMMDDHHMM	(CM)	(SEC)	+22	22-18	18-16	16-14	14-12	12-10	10-8	8-6	6-2
199612060136	389	11	196	2064	417	574	1072	2190	1382	800	725
199612060206	382	11	274	1261	449	493	1244	2661	1283	827	658
199612060236	413	20	155	2918	1353	467	1415	1950	933	952	533
199612060306	408	11	196	1754	1028	689	1931	2230	1246	714	607

Offshore wave energy was transferred to nearshore values based on methods established in previous studies (PWA, 2001a). The approach uses a transformation matrix derived by comparing directional wave data measured offshore at Point Reyes and at Crissy Field, about 300 yards to the east of the inlet and in a water depth of 10 meters. Coefficients from the transformation matrix are used to estimate nearshore wave heights from offshore conditions. Implicit in this analysis is the assumption of linear wave theory and the simplified representation of very complex transformations into a single ratio of wave heights. Details and limitations of this methodology are discussed in PWA (2001a).

5.4 CALIBRATING THE QCM

Calibration of the QCM program consisted of selecting the critical values for closure (S_{CRIT}) and breaching ($>_{CRIT}$), and comparison of predicted closure and breaching events to those observed and listed in Table 4-2. Although instrument malfunction and maintenance prohibited a continuous record of water levels, the available data show several closure and breaching events since May 2001. Due to the strong influence of mechanical breach on January 16, 2002 on the hydraulics of the inlet, this event was hard-wired into the QCM program for calibration purposes. This assured that the model reflected the subsequent increase in tidal power due to improved low water, and that it would not predict closure events that might have otherwise occurred immediately following the intervention.

Examination of the stability index during these observed closure events reveals a minimum critical value of approximately 12. An example of this calibration data is shown in Figure 5–3, which plots the measured water levels and estimated wave and tidal power at Crissy Field for the period of 4/21/2001 to 6/15/2001 and included two closures and breach events. Note that during the closure of 5/12/2001 the effective tidal power in the marsh is reduced not just by the low water drainage elevation, but also by incomplete filling during the flood cycle. Variability in tidal power is more typically associated with the spring neap cycle and storm surges generated by low-pressure systems that pass the San Francisco Bay Area. The observed high tides recorded by the Presidio gage include both of these astronomical and meteorological effects, and can be used with reasonable confidence as a surrogate for high water levels in the lagoon.

The QCM was calibrated by simulating the stability index for the period from January 2001 through November 2002, and adjusting the values for closure (S_{CRIT}) and calibration parameters determining

natural breaching ($>_{CRIT}$). Time series of the stability index, tides, and significant wave height for the period of 4/21/2001 to 6/15/2001 are plotted in Figure 5–4. Most of the intermittent closures and natural re-opening events over the entire calibration period are captured by the calibrated QCM, as summarized in Table 5-4. The QCM did less well at predicting the details of the closures from November 2001 through January 2002, when a series of large wave events dramatically affected the hydraulic efficiency of the inlet, and ultimately lead to the unplanned mechanical breach on January 16, 2002 by non-NPS staff. However, the model did predict a series of closure events (simulated closures #5 through #7) in response to these winter storms, with one event requiring intervention (simulated closure #7).

Table 5-4. Simulated Closure Events During Calibration Period

Closure	Dates		Days	Index	Wave Power	Tidal Power	HH-1	HH-2	Berm	Breach
1	4/30/2001	5/5/2001	5.2	12.7	482.6	38.1	2.00	3.46	3.35	Nat
2	5/15/2001	5/20/2001	4.9	12.4	72.3	5.8	1.99	3.53	3.30	Nat
3	6/13/2001	6/18/2001	5.1	45.6	179.0	3.9	2.13	3.54	3.39	Nat
4	10/24/2001	11/5/2001	11.9	46.7	333.2	7.1	1.98	3.27	3.56	no data
5	11/20/2001	12/1/2001	11.4	29.5	1596.3	54.1	2.34	4.77	4.65	Nat
6	12/6/2001	12/9/2001	2.7	14.2	367.8	25.9	2.12	3.40	3.37	Nat
7	12/20/2001	1/3/2002	14.0	12.2	737.0	60.5	2.67	3.09	5.32	Mech
8	6/1/2002	6/10/2002	9.1	12.5	801.5	64.2	2.14	3.75	3.69	Nat
9	6/30/2002	7/8/2002	8.9	50.8	274.9	5.4	2.14	3.61	3.47	Nat
10	8/26/2002	9/3/2002	7.3	18.9	124.7	6.6	2.16	3.50	3.44	Nat

Wave Power = Estimated wave power at Crissy Field at time of closure [lbf-ft/sec].
Tidal Power = Tidal power at time of closure [lbf-ft/sec].
HH-1 and HH-2 = Observed diurnal high water in bay day of closure and breach, respectively [ft NGVD].
Berm = Estimated berm elevation [ft NGVD].
Breach = Natural (Nat) or mechanical (Mech) breach. No data = data gap during closure, therefore inlet reset to open.

Closures during the storms of November 2001 – January 2002 were used to calibrate the simulated evolution of the beach barrier. As described earlier, the simulated beach barrier elevation is determined by the bay water levels at time of closure and increases if large wave activity continues while the inlet remains closed. Figure 5–5 plots the bay tides, wave power at Crissy Field, and the simulated berm elevation during closure events #5 through #7. Calibration of $>_{CRIT}$ produced a berm elevation that allowed for natural re-opening of closures #5 and #6, but mechanical intervention of closure #7. This is generally consistent observation shown in Figure 4–9. Monitoring data from the marsh tide gage reveal that the inlet was significantly restricted (low water drainage to only +3.0 ft NGVD) before the inlet was completely blocked by a high and wide barrier (marsh water level constant at +4.0 ft NGVD) by mid-January 2003. This general, but not precise, agreement between predicted and observed closures should not be surprising given the simplicity of the QCM and complexity of the natural system.

5.5 LIMITATIONS

Although the QCM predicts the frequency of closure and natural re-opening to the level of accuracy appropriate for a management tool, uncertainties associated with its simplified structure and the variability of the natural system should be considered when interpreting the results. The model is reasonably successful at simulating the intermittent closures at Crissy Field since the joint probability of high wave power and low tidal power can be well predicted from the observed data, and a calibrated value of the stability index has been determined. The utility of the QCM is enhanced by its simplicity – only the bay tide and offshore wave data are needed as input for a given lagoon size (effective tidal prism and range). However, uncertainties remain and include:

1. Directionality of the Offshore Wave Spectra
   Directional wave data collected at the Point Reyes buoy is condensed in order to minimize the load in storing and transmitting the information to shore. Therefore, the directionality of the offshore waves are condensed by assigning one predominant direction to each of the nine period bands. Actual wave conditions along the California coast typically include multiple wave trains that are more accurately represented by directional wave spectra, and the wave transformation coefficients used in the present study could be improved by using the full directional spectra. Such a description of wave data is available in the F291 format of data collected by the National Oceanographic Data Center (NODC), but not for the CDIP buoy at Point Reyes.

2. Limited Frequency Content of Offshore Waves
   The nine period bands used to summarize the offshore wave energy impose a fixed discretization on the wave data. Better resolution of the distribution of wave energy across the frequency spectrum could be achieved with more bands (not equally spaced) or other methods could be used to more accurately summarize the true frequency content of the sea.

3. Linear Wave Transfer Matrix
   The wave transformation matrix developed previously (PWA, 2001) and used in the present study does not account for wave breaking over the San Francisco Bar, although this occurs during high storm events, including a dependence on the magnitude of the wave heights, which is not accounted for in this approach.

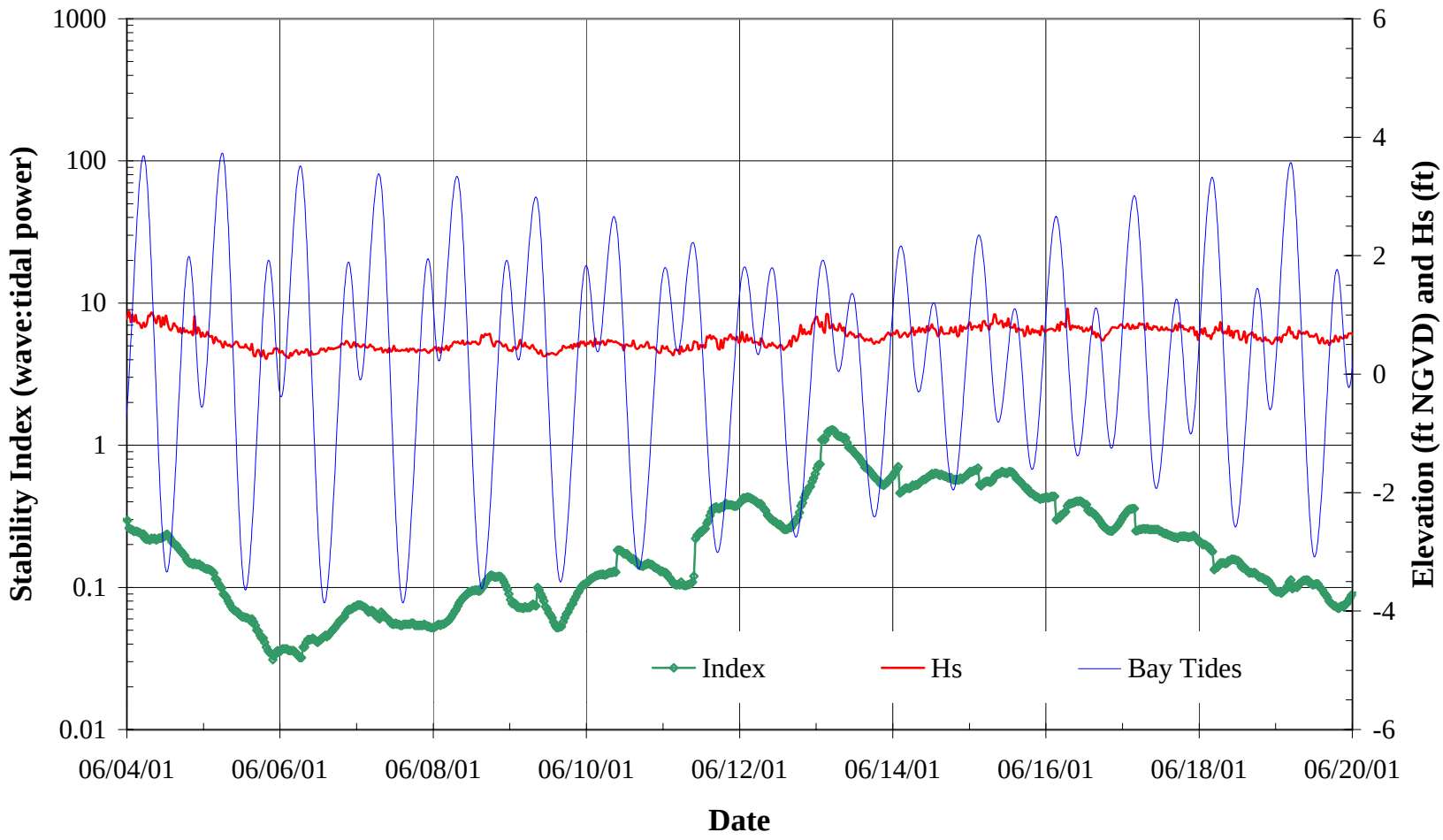
4. No Wind-Wave Generation over San Francisco Bay
   Since the nearshore waves are derived by transforming wave data collected offshore of Point Reyes, local seas (waves generated by wind blowing over the bay) are not accounted for in the present method.

5. Wind Driven Transport not Explicitly Accounted for in QCM
   Wave power has been used as a surrogate for total sand transport into the inlet channel and onto the beach barrier, and wind driven processes have been neglected in the QCM. However, the strong and steady winds at Crissy Field also drive sediment to the east.

This Aeolian transport is probably more important in building the expansive beach barrier during periods of prolonged closure.

6. Partial Closure
   The effective tidal prism is computed assuming the lagoon high tides match the high water levels in the bay, although reduced conveyance of a partially-closed inlet may mute the high tide. Typically, high tides in the lagoon match bay levels, but in some cases strong wave action deposit enough sand in the entrance channel to preclude complete filling of the lagoon during the flood tide.

The QCM could be improved by including one or more of the above processes. However, the results obtained with the presently calibrated model appear adequate for planning purposes without these refinements.



Source: Tides from NOAA Presidio Gauge. Significant wave height (Hs) at Crissy Field from transformed

Notes:
Tide, wave, and stability index for exisiting conditions.

figure 5-1

Crissy Field Marsh Expansion Study
Representitive Output from QCM

PWA #:1623

PWA

figure 5-2

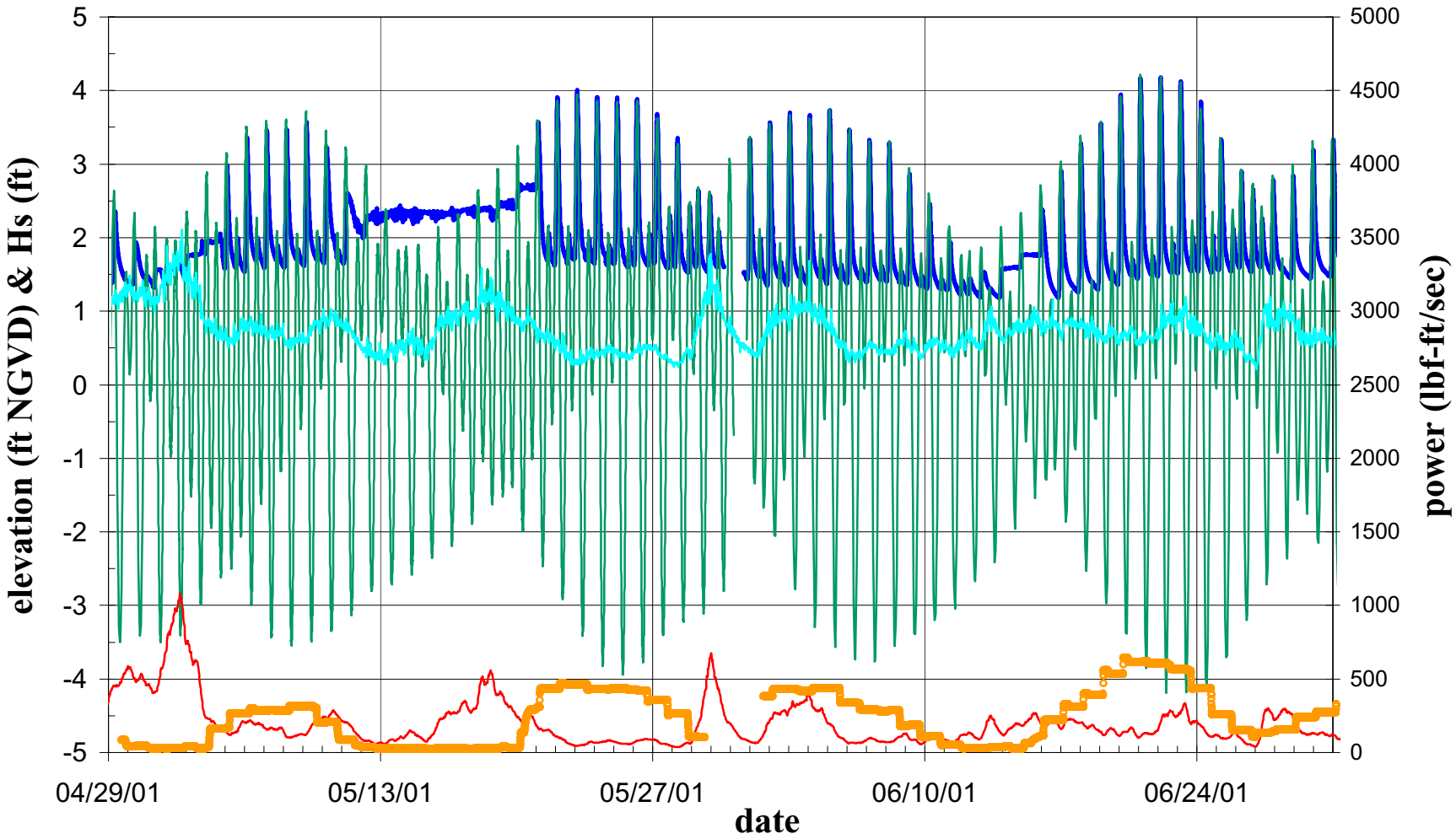
Crissy Field Marsh Expansion Study

Tide & Wave Gage Locations

PWA#: 1623

PWA

Projects\1623-00_CrissyField_Expansion_Study\Task10_Reporting\Figs\Sec5\ Fig5-x_TideWveGageLoc.cdr



Notes: Wave power is 6.25-hr moving average.
Tides from NOAA (Presidio gauge), and waves from Pt Reyes Buoy (transformed).
Hs = Significant wave height

Source: PWA, CDIP, NOAA.

- Crissy Tides
- Bay Tides
- Crissy Hs
- Crissy Wave Power
- Tidal Power

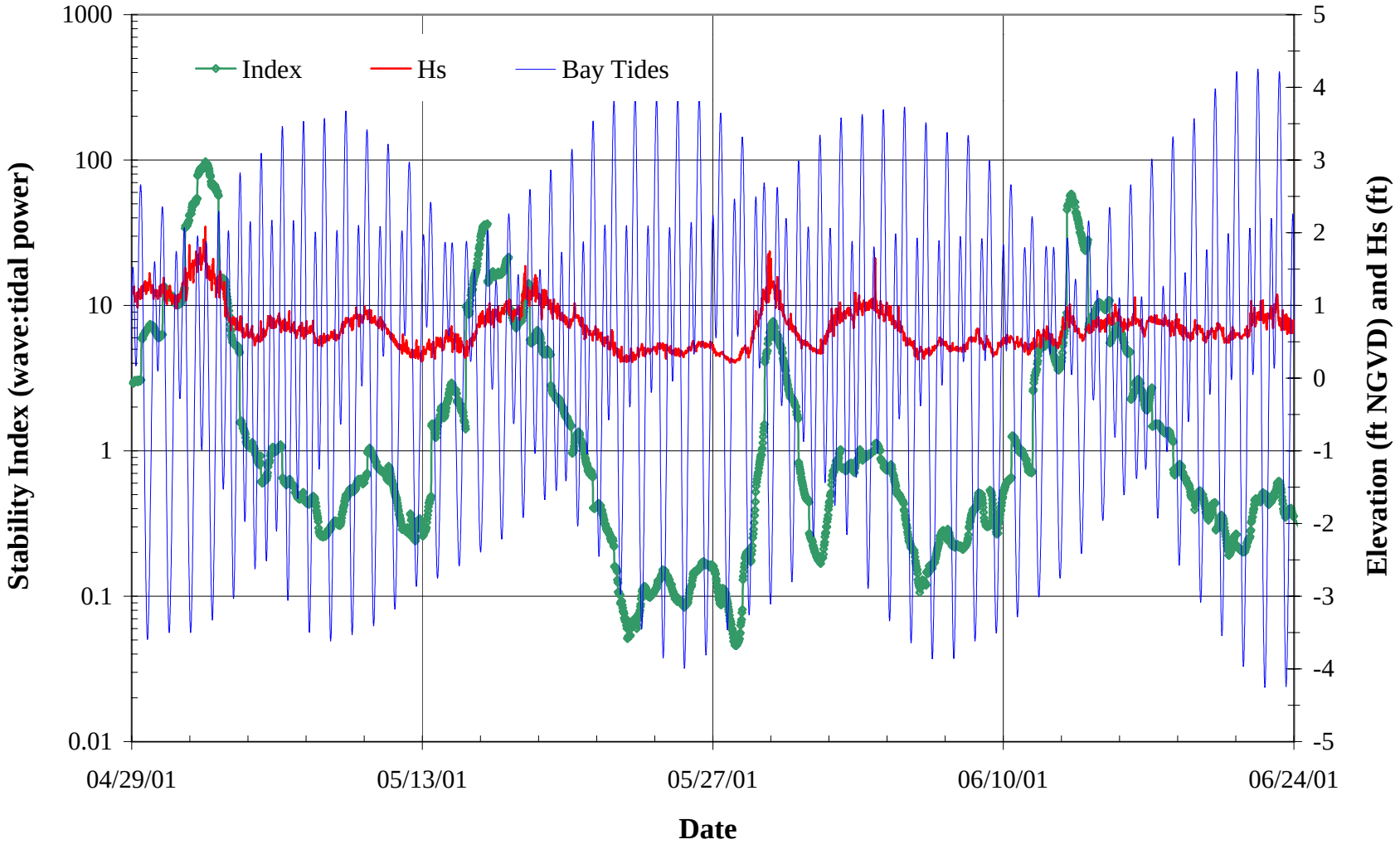
figure 5-3

Crissy Field Marsh Expansion Study

Calibration Data - May and June 2001

PWA#: 1623

PWA



Source: Quantified Conceptual Model (QCM)

Notes:
Calibrated QCM results from existing marsh.

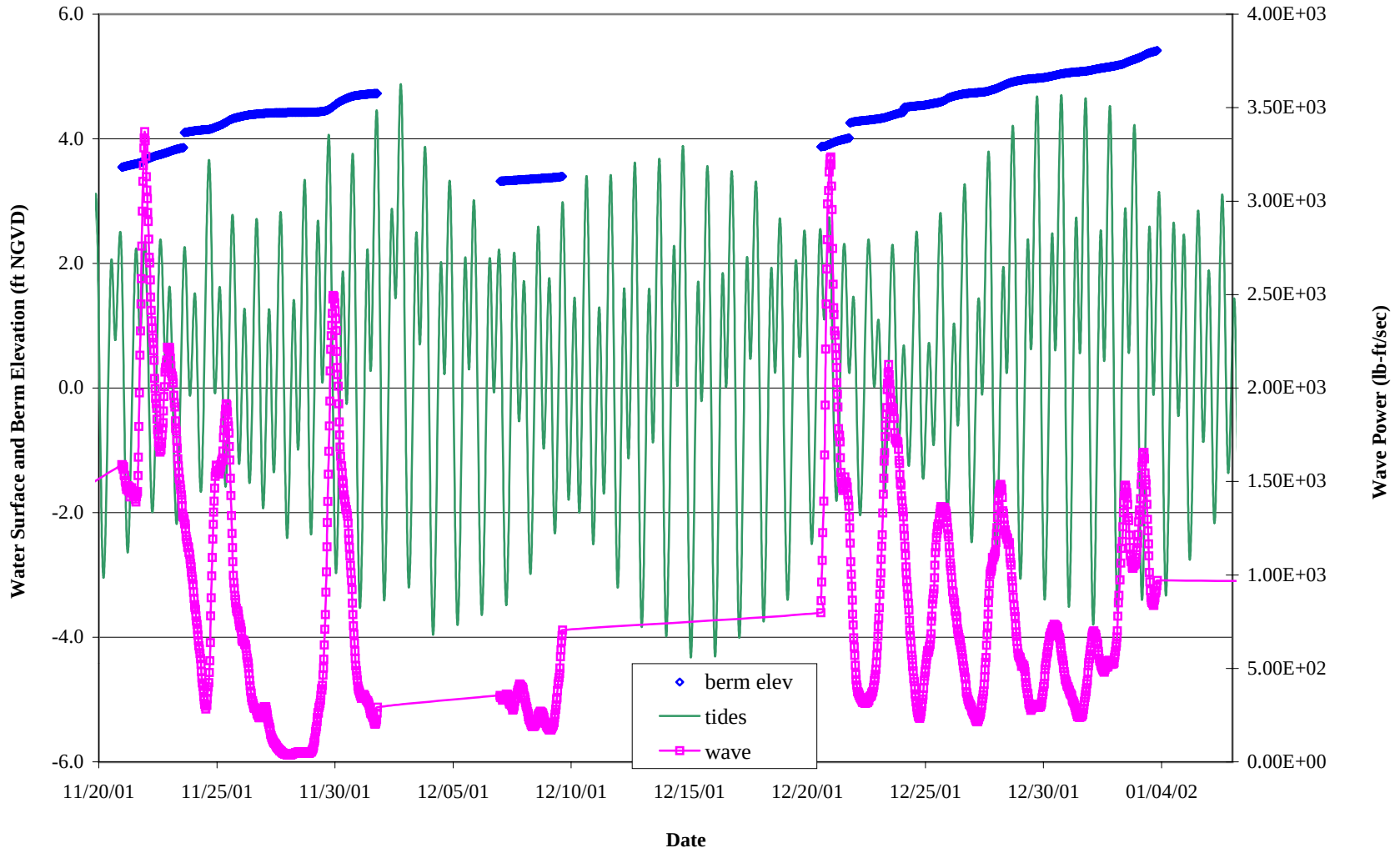
figure 5-4

Crissy Field Marsh Expansion Study

QCM Output for Calibration Period - May and June 2001

PWA #:1623

PWA



Source: Quantified Conceptual Model

Notes:
Critical elevation to induce natural breaching, as simulated by the QCM, is plotted for the winter storms of 2001-2002.

figure 5-5

Crissy Field Marsh Expansion Study

Simulated Berm Elevation During Closures of Nov. and Dec. 2001

PWA#: 1623

PWA