FLETCHER COVE REEF CONCEPTUAL DESIGN
Solana Beach, California
Final Report

Image: Everest International Consultants, Inc.

Prepared for
U.S. Army Corps of Engineers, Los Angeles District

and
City of Solana Beach, California

Prepared by
Everest International Consultants, Inc.

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FINAL REPORT

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Executive Summary

A coastal engineering study was performed to develop a conceptual design for a sand retention reef at Fletcher Cove, Solana Beach, California. The sand retention reef could be used in conjunction with ongoing and planned beach replenishment projects to improve their effectiveness. The study has been conducted by the Los Angeles District of the U.S. Army Corps of Engineers (USACE) under the Regional Sediment Management (RSM) Program. The primary goal of the study was to (a) develop a concept-level reef design that would create a wider beach in the lee of the reef and (b) estimate resulting shoreline changes upcoast and downcoast from the reef. A set of design criteria were developed by the USACE, City of Solana Beach and Everest International Consultants, Inc. to achieve these goals, including:

1. The reef should provide an approximate 30 meter wide beach at mean sea level (MSL).
2. Any reef induced beach width (salient) should be pre-filled to avoid potential downcoast effects.
3. The reef should not be shore connected.
4. The reef should not have adverse effects on surfing, hard bottom habitat, or aesthetics.

An initial reef design was provided by the USACE based on the proposed Oil Piers Reef in Ventura County, California. Additional reef designs were developed by the team with the goal of achieving the design criteria listed above. The reef and salient dimensions were calculated with a method based on measurements of existing reefs and breakwaters in southern California. Results were checked against two other independent methods. The reef design that satisfied the design criteria was one that had a crest height at MSL. Due to budget constraints, the surfing criterion was not investigated in great detail, however the MSL Crest Reef was designed such that it could be modified in the next study phases to better achieve the surfing criterion.

Potential upcoast and downcoast shoreline changes from the MSL Crest Reef were estimated using a method based on measured beach changes near groins in southern California. The results indicate no significant long-term upcoast or downcoast shoreline changes would be expected from this reef and the associated salient. Consequently, the MSL Crest Reef was deemed the preferred reef design within the current study and should be the focus of the next phases of study.

It is expected that the next phases of the study would consider surfing enhancement, sea level rise, environmental impacts, construction issues, costs (construction, maintenance, removal), economics, and funding.

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1. INTRODUCTION

1.1 BACKGROUND

Fletcher Cove is located along the coast of the City of Solana Beach, approximately 35 miles north of San Diego, California. The vicinity and location are shown in Figure 1.1. Fletcher Cove is the highest use public beach in Solana Beach. The entire City shoreline experiences damage due to wave attack from coastal storms. These storms have caused significant recreational beach loss, threatening the stability of surrounding public and private structures and the safety of the public.

A stabilization structure, such as a multi-purpose reef could be used to retain sediment, attenuate beach loss, provide storm damage reduction, and maximize benefits of ongoing and future beach nourishment projects. This type of structure could also mitigate for recreational impacts while avoiding potential impacts to adjacent natural habitats. Early on, traditional exposed breakwaters were eliminated from consideration due to their unpopularity with the public and difficulty in permitting.

An Initial Appraisal Report (IAR) was initiated by the U.S. Army Corps of Engineers (USACE) in 2004 under the Continuing Authorities Program (CAP). The intent of the IAR was to investigate concepts for innovative shoreline stabilization measures that potentially could be implemented at Fletcher Cove. The IAR document was used as a starting point for the initial reef design. In 2007, the USACE converted the CAP study to the Regional Sediment Management (RSM) Program.

The RSM Program is a USACE program managed by Engineering Research and Development Center (ERDC). The RSM Program began in October 1999 with a demonstration program in the Northern Gulf of Mexico and expanded to include five additional demonstration sites in November 2000. RSM was implemented for the purpose of beneficially managing sediment from a regional perspective. RSM is the integrated management of littoral, estuarine, and riverine sediments to achieve balanced and sustainable solutions to sediment-related needs. From a coastal management perspective, RSM focuses on the factors that affect the transport, erosion, removal, and deposition of sediment.

The USACE, Los Angeles District has been given the task to implement the California component of the National RSM Program, and to specifically look at the Solana Beach area of southern California for implementation of a potential RSM project. Everest International Consultants, Inc. (Everest) was hired to study a reef at Fletcher Cove as a potential RSM project for Solana Beach.

1.2 Purpose and Objectives

The purpose of this study was to develop a conceptual sand retention reef design for Fletcher Cove and estimate the upcoast and downcoast shoreline impacts resulting from that reef.

The primary objectives of this study included:

- Establish a list of design criteria, including a target salient size. A salient is the outwardly projecting beach retained by a reef;
- Estimate salient size for an initial reef design provided by the USACE and compare that to the design criteria;
- Optimize a reef design to achieve the target design criteria; and
- Estimate potential shoreline changes caused by the optimized reef.

Secondary objectives that may or may not be addressed in the study included the need to develop a design that is efficient, enhances surfing, and enhances offshore habitat.

1.3 Reef and Salient Definitions

A definition sketch is provided in Figure 1.2 to aid understanding of reef and salient features. A generalized reef is shown in the plan view (upper) and a cross section view is shown below. In the figure, the reef material is hatched with diagonal lines, while the salient and the existing ground are shown in light and dark shades, respectively.

Figure 1.1 Project Location and Vicinity

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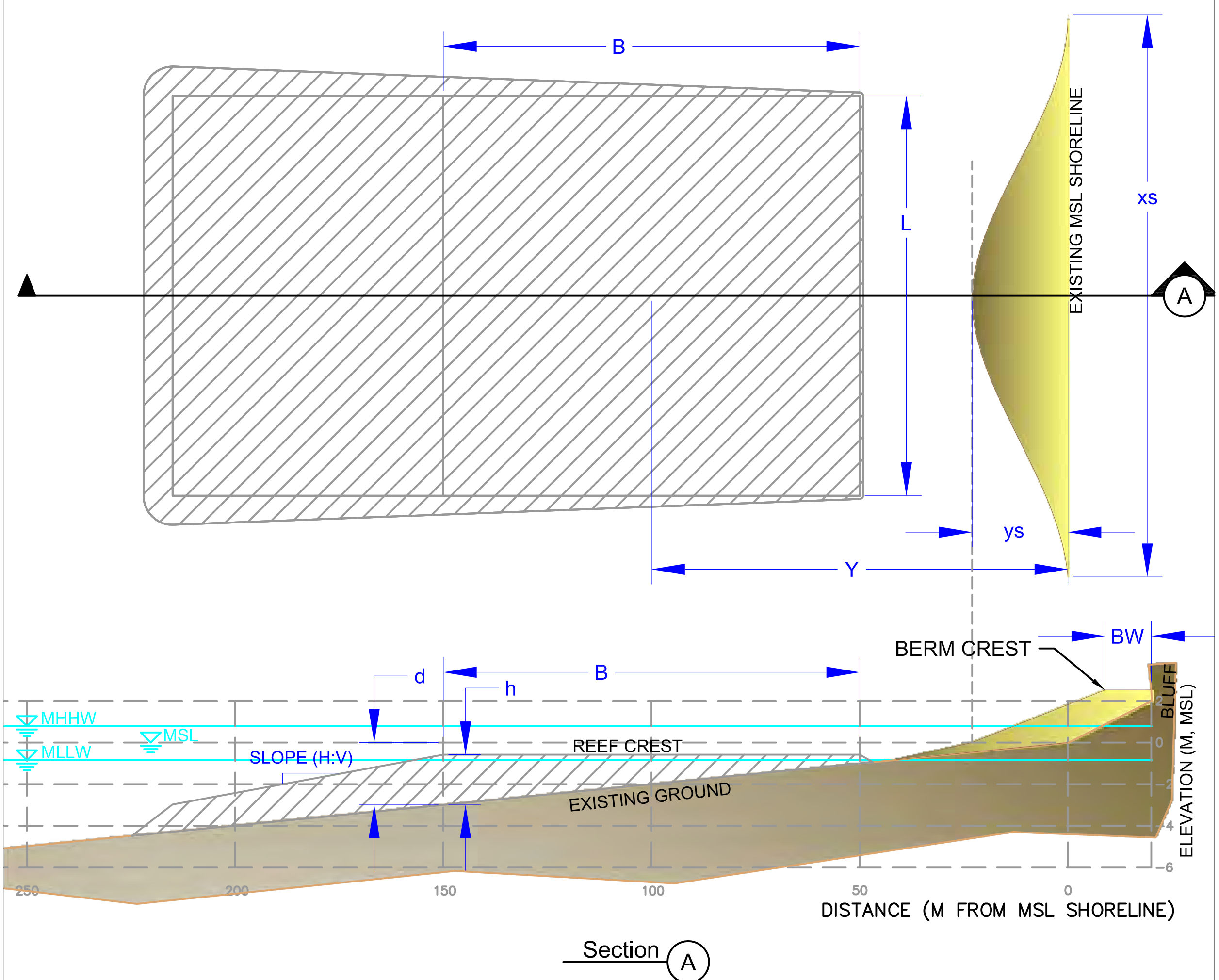

Definitions:

B = Reef crest cross shore dimension
BW = Berm width covers the backshore (distance between the berm crest and bluff)
L = Reef crest longshore dimension
Y = Distance from shoreline to crest centroid for reefs, distance to widest point for breakwaters
y_s = Salient projection distance
x_s = Salient longshore dimension
h = Reef height
d = Water depth
H:V = Slope (horizontal to vertical)
MHHW = Mean higher high water
MSL = Mean sea level
MLLW = Mean lower low water

Figure 1.2 Reef and Salient Definition Sketch

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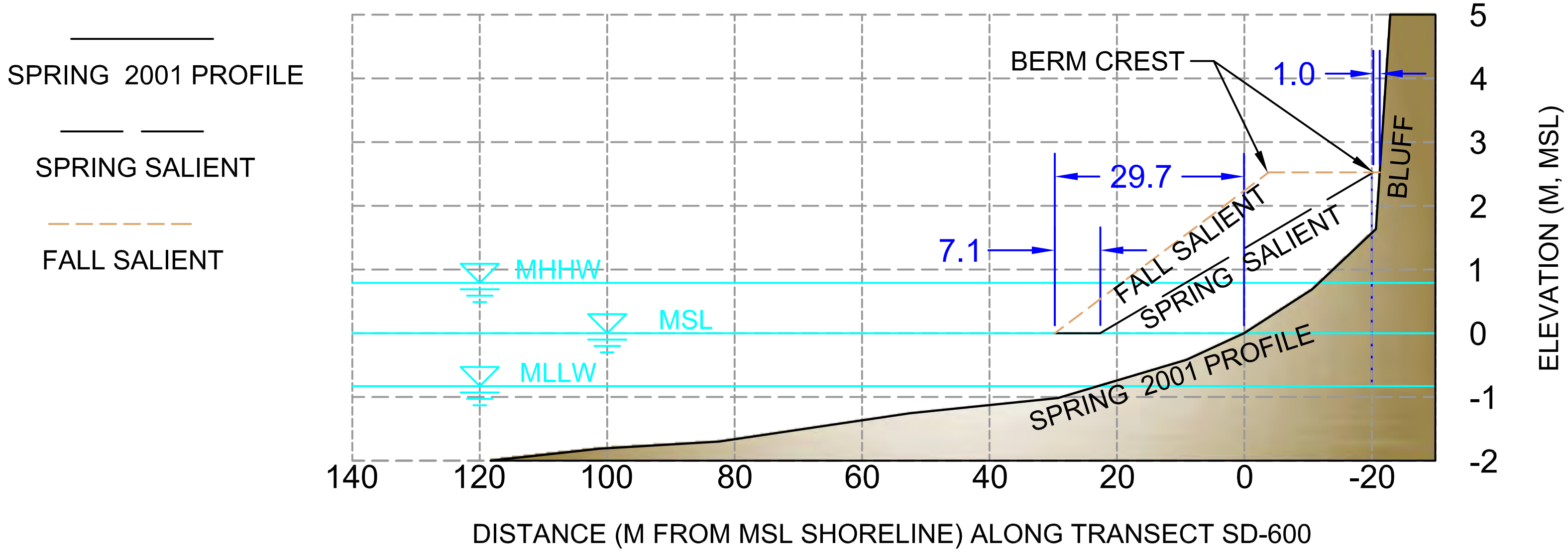
2. DESIGN CRITERIA

The range of conceptual designs was bound by a set of design criteria established by the USACE, City of Solana Beach, and Everest. The major design criteria that were developed for the study include:

1. The reef should provide a dry beach berm at Fletcher Cove during typical fall and spring conditions. With the beach berm width as a starting point, a salient projection distance of 30 meter (M) was calculated as detailed in Figure 2.1.
2. Any salient retained by the reef would be pre-filled to minimize sand loss to adjacent beaches.
3. The reef should be permittable. To achieve this it was assumed that the reef should **not**:
   a. directly cover existing hard substrate habitat;
   b. negatively impact aesthetics;
   c. be shore connected (i.e. it should be detached from the beach); and
   d. negatively impact surfing.

The surfing design criterion (3d) is not addressed in detail in the current study due to funding limitations. It should however be addressed in later studies. It was assumed that the base shoreline condition for these analyses was represented by the Spring, 2001, pre SANDAG Regional Beach Sand Project (RBSP) shoreline. This is the narrowest the beach has been in the last decade, and the currently eroding shoreline is trending towards this sand-starved position (Coastal Frontiers Corp., 2009).



Calculate Salient Projection Distance Design Criteria

1) Assume a minimum spring beach berm width of 1 M. The narrowest beach widths occur in the spring of each year.
2) Assume a beach berm elevation of +2.5 M, MSL as measured from the fall 2001 profile at SD-600 (this was the only date with a measured beach berm).
3) Apply 1 M beach berm width to the most eroded profile (Spring 2001, SD-600) which occurred prior to the SANDAG RBSP.
4) Slope down @ 17:1 (H:V) to MSL. This is average of spring 2003 and spring 2004 slope between MSL and beach berm, at DM-580, during years with enough sand to have a berm in the spring.
5) To find the average fall MSL shoreline position, add the average difference between the spring and fall MSL shoreline positions. The average of all the absolute differences at SD-600 between 1996 to 2006 was 7.1 meters.
6) The salient projection distance of 30 M is the distance between the spring 2001 MSL shoreline and the average fall MSL shoreline position. This is a conservative distance representing the maximum amount of pre-fill required to achieve the 1 M beach berm assumption.
Profile data source: Coastal Frontiers Corp., 2008

Figure 2.1 Salient Criteria

3. Optimize Reef and Salient Design

The reef shape, size, and location were varied through different alternatives with the goal of satisfying the design criteria. Analytical methods were used to estimate both the salient size resulting from an initial reef provided by the USACE, and conversely, these methods were used to estimate reef dimensions and locations that best satisfy the design criteria. The different reef alternatives, their associated salients, and the calculation methods are described in this section.

3.1 Reef Alternatives

Initial Reef

An initial reef design was provided by the USACE. The Initial Reef was loosely based on a similar project known as the Oil Piers Reef, which has not yet been constructed, also located in southern California (ASR Ltd, 2004). Figure 3.1 shows plan and cross sectional views of the Initial Reef and the estimated salient resulting from this reef. Methods used to estimate the salient are described in the next section (Section 3.2) of this report. The reef crest was set at -1.3 M, relative to mean sea level (MSL) and the cross shore dimension of the crest was set at 10 M. The center of the structure was located at the -3.8 M, MSL elevation contour, about 200 M from the MSL shoreline.

This reef alternative would rarely change the existing aesthetics since it would be exposed less than 0.1 percent of the time (i.e., less than 5 hours per year). During a negative tide (i.e., very low), this alternative would look similar to the nearby Tabletops Reef during a negative tide as shown in Figure 3.2. Tabletops Reef has a higher crest elevation and is exposed approximately sixteen percent of the time (i.e., 1,390 hours per year).

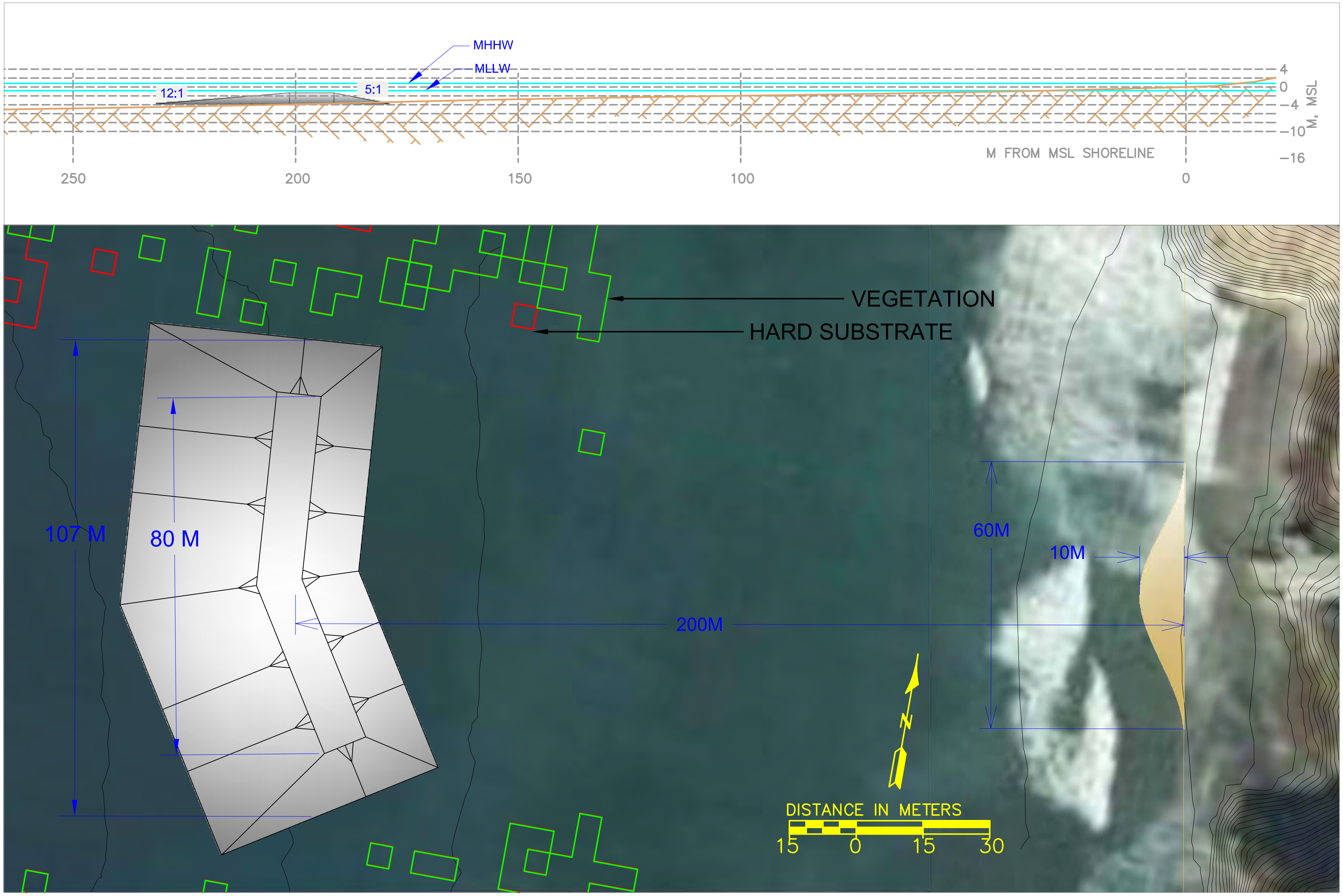


Figure 3.1 Initial Reef and Salient

Figure 3.2 Tabletops Reef Exposed During a Negative Tide

MLLW Crest Reef

A reef alternative was proposed with a crest elevation at or below mean lower low water (MLLW). The impetus behind this alternative was to have a reef that is higher than the Initial Reef, but would remain submerged for most tides. The benefits of this are three-fold: 1) a higher reef would block more wave energy, 2) maintaining the crest below MLLW would not significantly change the existing aesthetics, and 3) there would be minimal opportunity for surfers to impact the reef, since it would be covered with water most of the time. The resulting MLLW Crest Reef and estimated salient are shown in Figure 3.3. This reef alternative would rarely change the existing aesthetics since it would be exposed approximately six percent of the time (i.e., 560 hours per year) at which time it too would look similar to Tabletops Reef during a negative tide.

While the offshore slope of the Initial Reef was set at 12:1 (horizontal to vertical), the offshore slope of the MLLW Crest Reef was set at 30:1 to better satisfy the surfing design criterion (3d). This milder slope was recommended as the steepest allowable offshore slope in the authoritative text on surf reef design “Recreational Surf Parameters” (Walker, 1974). To save on construction costs, steeper slopes have been recently implemented, but with mixed results.

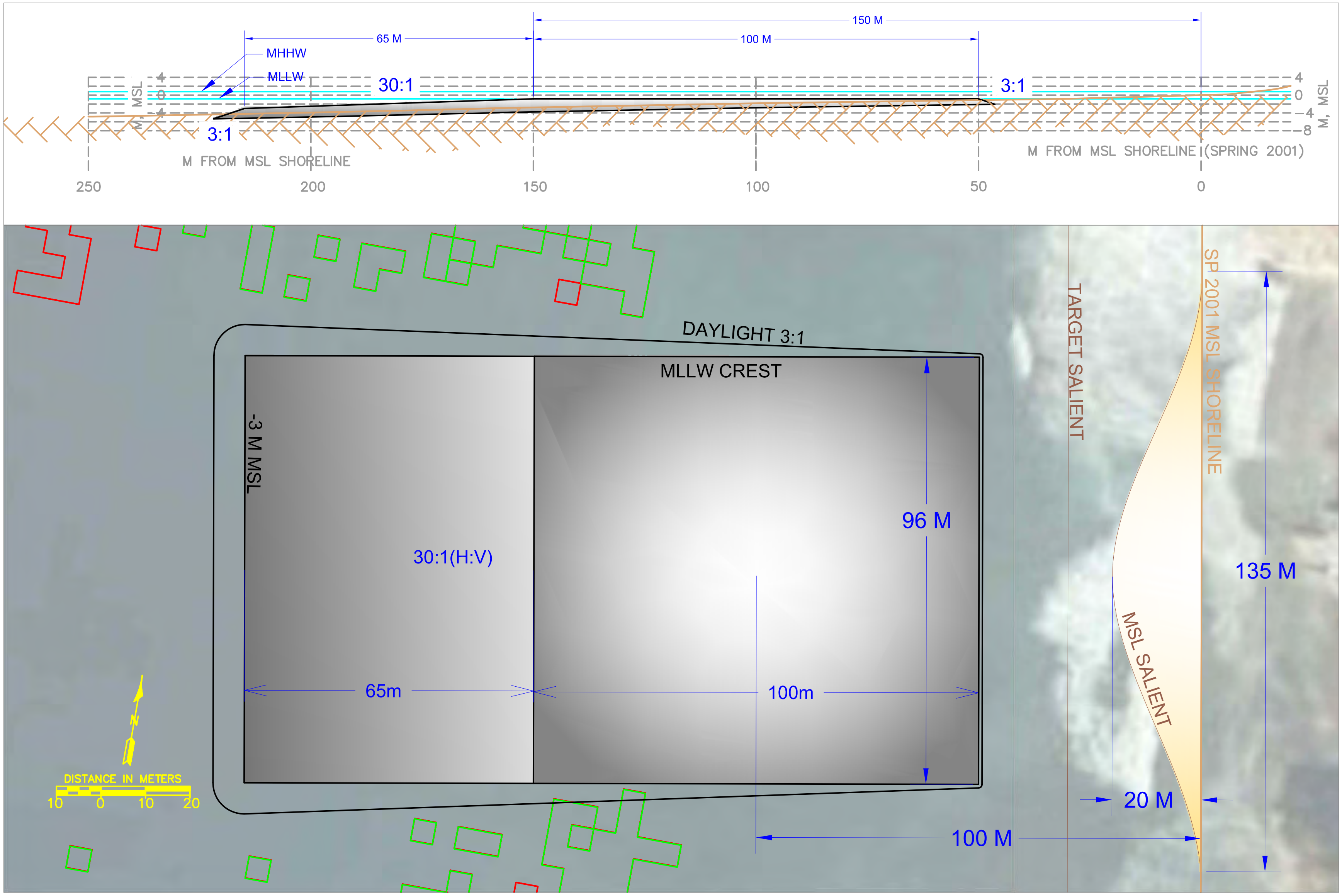


Figure 3.3 MLLW Crest Reef and Salient

MSL Crest Reef

Another reef alternative was proposed with a crest elevation at MSL. While this would be exposed more often than the other alternatives, this higher reef could block more wave energy, thus increasing the probable salient size. The resulting MSL Crest Reef and estimated salient are shown in Figure 3.4. This reef also has a mild offshore slope of 30:1.

This alternative would significantly change the aesthetics since it would be exposed approximately 50 percent of the time during which it too would look similar to Tabletops Reef during a low tide.

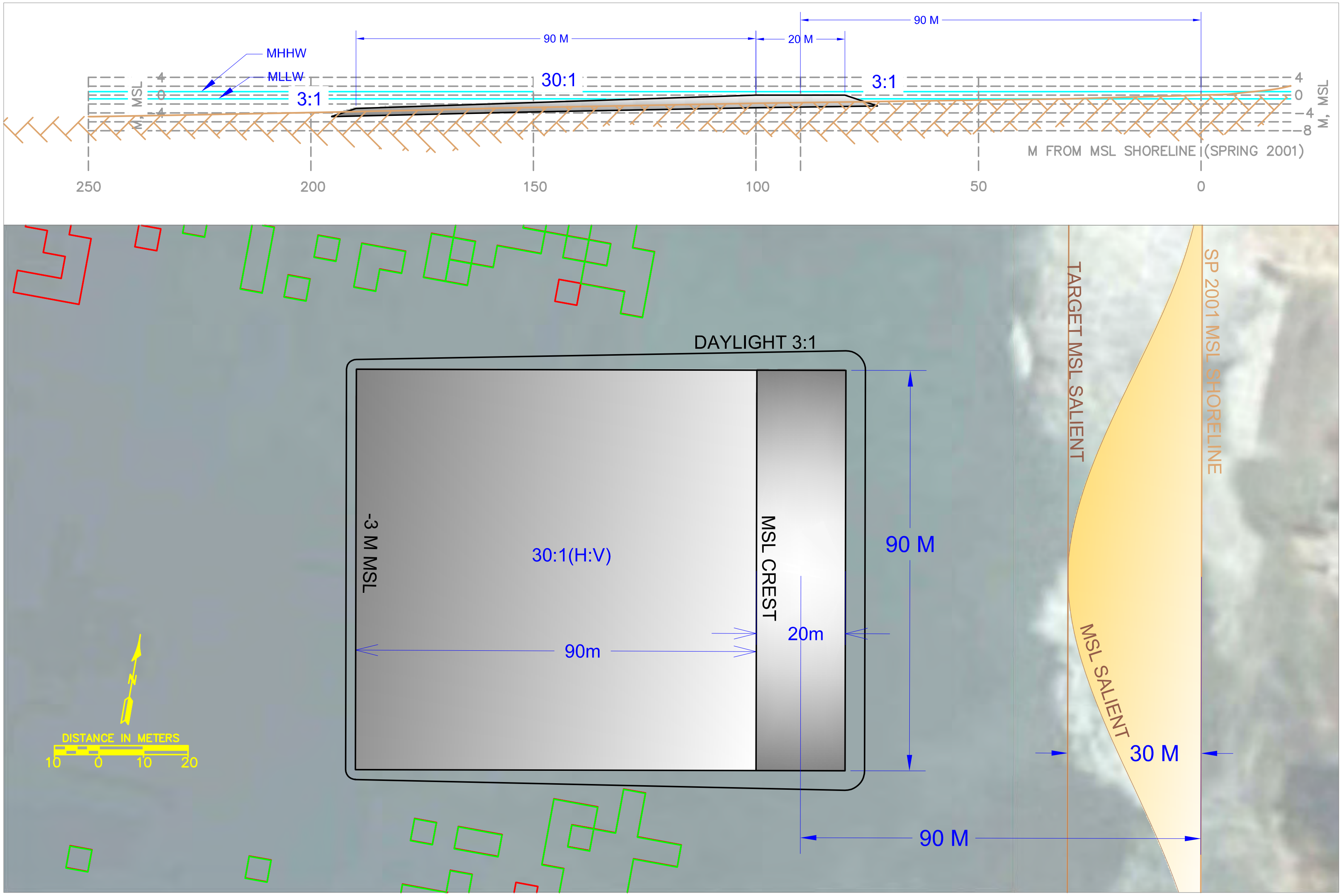


Figure 3.4 MSL Crest Reef and Salient

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3.2 METHODS

For the Initial Reef, salient dimensions were calculated using a method based on the wave height transmission coefficient (Kt Method) and results were compared to the design criteria. For the MLLW Crest Reef and MSL Crest Reef, the design criteria and Kt Method were used to develop the reef dimensions. Since the Kt Method is somewhat new (2001), the results were checked against two other equally experimental methods.

Kt Method

The salient sizes were analytically estimated using a three-step process. The first step was to estimate the wave height transmission coefficient, Kt, for a proposed reef. This transmission coefficient and other reef dimensions were then used in an empirically-based graph to determine the salient projection distance (y_s). The third step was to calculate the longshore salient dimension (x_s) using an empirical multiplication factor. These steps are briefly described in this section and covered in detail in Appendix A.

A transmission coefficient is the ratio of the transmitted wave height divided by the incident wave height. For a reef or breakwater, this is the wave height on the landward side of the reef divided by the incident wave height on the seaward side. Up to seven different empirical methods were used to estimate the transmission coefficient. Typical input parameters included: reef height, water depth, cross shore crest dimension, offshore slope, reef porosity, significant wave height, and peak wave period. The calculation goal was to determine the typical salient size, as opposed to a maximum or minimum salient size. To achieve this, the average water elevation (MSL), average significant wave height (CDIP, 2009a) and average peak wave periods (CDIP, 2009b) were used as input to these calculations.

The transmission coefficient, in combination with the longshore crest dimension (L) and distance to the reef centroid (Y), were applied to the empirically-based graph of Figure 3.5 to find the salient projection distance (y_s). The original version of this graph was based on southern California breakwater and salient dimensions measured from aerial photographs (Moffatt & Nichol Engineers, 2001). It included data for non-transmissive breakwaters (Kt=0), with a straight line forced through the origin. It assumed a line for completely transmissive structures (Kt=1) running vertically along the L/Y axis. This is logical, since a structure that allows all of the wave height to pass (Kt=1) would develop no salient (y_s=0) regardless of how wide that structure is relative to its distance offshore (L/Y). The straight lines for Kt=0.8 and Kt=0.4 were assumed by Moffatt & Nichol Engineers. Southern California semi-transmissive reefs (0.2<Kt<0.3) and the resultant salient dimensions were added to the graph as part of the current study (blue dots). A straight line was fit through these data with the y-intercept forced through zero. The original graph and modifications from the current study are available in Appendix A.

This method uses the water level over the reefs as they would exist today. It does not consider changes to conditions that would result from sea level rise. Those changes should be considered in future analyses, when more time-sensitive details are available.

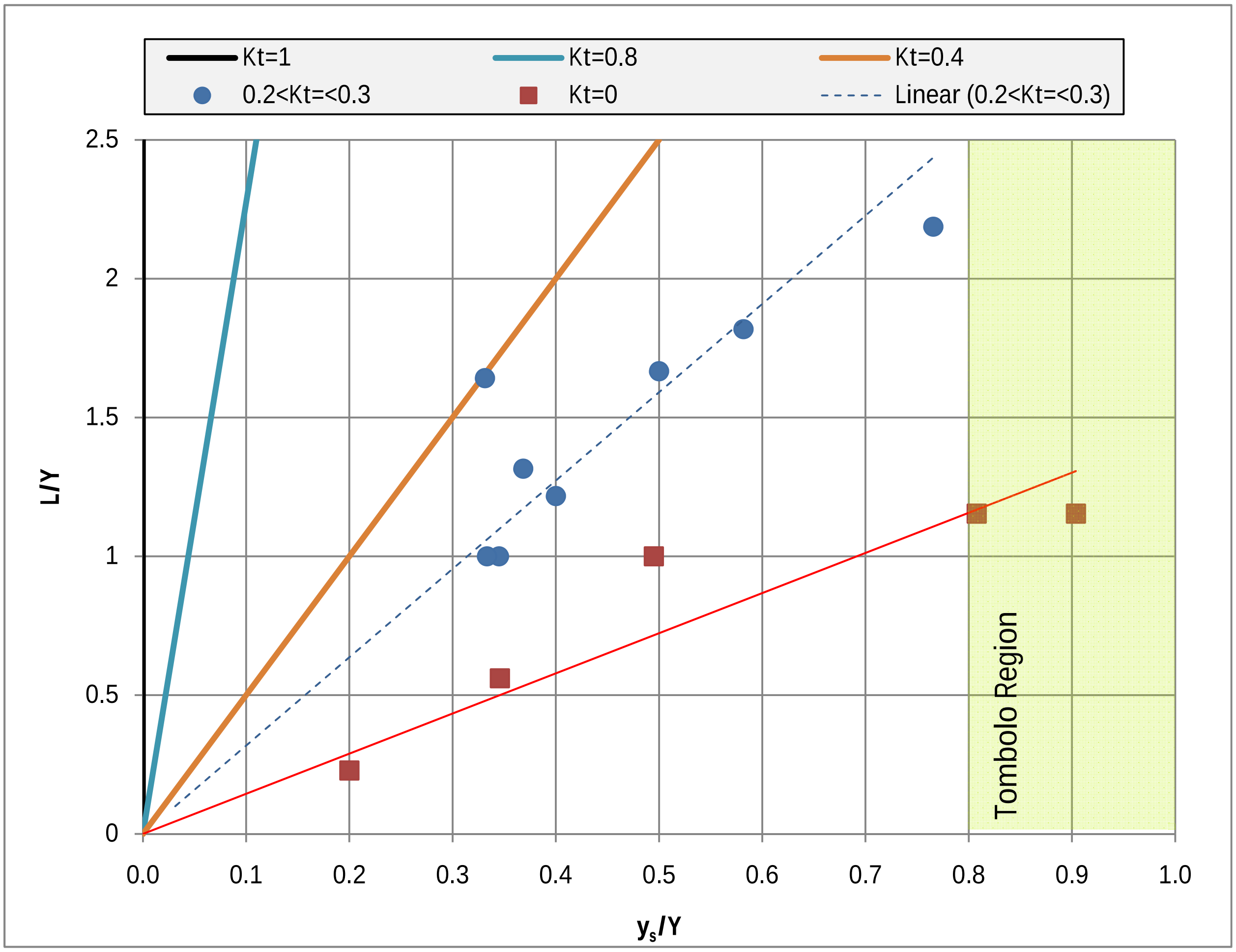

Figure 3.5 L/Y Versus y_s/Y for Southern California Reefs and Breakwaters

The average southern California ratio between the longshore salient dimension (defined in Figure 1.2) and the salient projection distance has been calculated as 6 to 1 (Moffatt & Nichol Engineers, 2001). This ratio was verified with measurements of reefs in Orange and San Diego Counties (see Appendix A). Consequently, longshore salient dimensions in the current study were found by multiplying the calculated salient projection distance by a factor of 6.

The Kt Method was applied to the Initial Reef resulting in a salient projection distance that was significantly smaller than the 30 M design criterion. Given this, the USACE requested development of new alternatives to better satisfy the design criteria. The MLLW Crest Reef and MSL Crest Reef, described earlier, are those new alternatives. With assumed crest elevations

(MLLW and MSL) and the known design criteria, the calculation steps (using the Kt Method) were reversed to find the remaining dimensions and locations of the reefs.

Calculated reef and salient dimensions using the Kt method are summarized in Table 3.1. Results in English units are shown in Appendix B. The calculated reef volumes are conservatively large, with an assumed quantity of material added to allow for one meter of reef settling below the existing ground surface. This settling assumption should be verified in subsequent studies. The given salient dimensions are only predicted averages (i.e., typical) of what are expected to be dynamic and variable salient size, location, and shapes.

Table 3.1 Reef and Salient Results Summary

Parameter	Units	Initial Reef	MLLW Crest Reef	MSL Crest Reef
Reef Crest Elevation	M, MSL	-1.33	-0.83	0.00
B, Reef Cross Shore Crest Dimension	M	10	100	20
Y, Distance To Crest Centroid	M	200	100	90
Reef Offshore Slope	(H:V)	12	30	30
L, Reef Longshore Dimension	M	80	96	90
Reef Volume	M^3	7,000	38,000	25,000
Kt, Transmission Coefficient		0.6	0.4	0.1
y_s, Salient Projection Distance	M	10	20	30
x_s, Salient Long Shore Dimension	M	59	120	180
Salient MSL Area	M^2	300	1,200	2,700
Salient Volume	M^3	600	2,400	5,400

As mentioned earlier, the Initial Reef did not satisfy the 30 M salient projection distance. Various reef designs with crest elevations at MLLW were analyzed, but none achieved the target salient projection distance of 30 M. For example, MLLW crest reefs with cross shore crest dimensions (B) of 20, 50, 80, and 100 M were attempted, with little improvement of the resultant transmission coefficient (Kt) and salient projection distance. A limit of B=100 M was chosen as it became apparent that this crest elevation was not amenable to design efficiency. The best of these reef designs was the MLLW Crest Reef shown in Table 3.1, which achieved a salient projection distance of 20 M. Of the reef designs analyzed, only the MSL Crest Reef satisfied all of the analyzed design criteria, including the 30 M salient projection distance.

Reef/Island Check

An analytical method (Reef/Island Method) was used to check the results based on the Kt Method. For this method, two empirical equations were developed to estimate salient dimensions based on reef, island, and salient measurements made in New Zealand and Australia (Black and Andrews, 2001). A review of this method is available in Appendix C. This method resulted in larger salient projection distances than those calculated by the Kt method as shown in Table 3.2. This difference implies that the Kt method is relatively conservative and does not over-predict salient dimensions. In general, the Reef/Island Method was found to be overly optimistic for application in southern California and hence was only used as a check to support results of the Kt Method.

Table 3.2 Salient Projection Distance from Two Methods

METHOD	INITIAL REEF	MLLW CREST REEF	MSL CREST REEF
Kt Method	10 M	20 M	30 M
Reef/Island Method	72 M	49 M	45-54 M

For example, the Reef/Island Method finds that greater salient projection distances can be achieved if the reef or island is moved farther offshore than the proposed alternatives. This concept is graphically shown in Figure 3.6 where the proposed reef alternatives are graphed with the reef equation (dashed curves) and the island equation (solid curve). In this graph, the salient projection distance (y_s) increases with distance offshore (Y) until an apex is reached, at which point the trend reverses. This method finds that the proposed Initial Reef, for example, can achieve an optimal 90 M salient projection distance if it is moved to 400 M from shore. These results are somewhat counter intuitive and likely reflect greater complexity in the natural systems as described in the next section of this report.

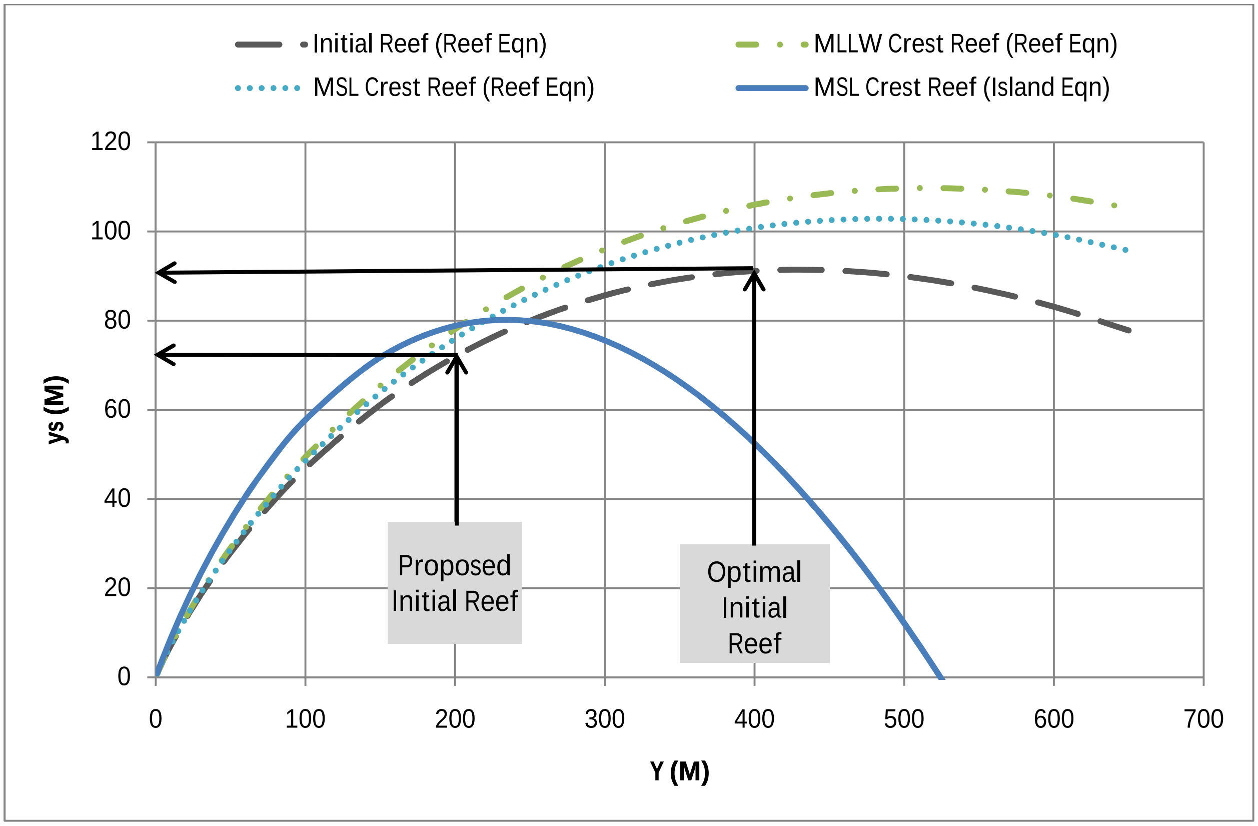

Figure 3.6 Optimal Salient Projection Distance as Calculated with the Reef/Island Method

Scour Check

When evaluating the proposed reefs, it is important to guard against the possibility of increasing shoreline erosion as a result of the reef structure. In the past, some submerged structures, have resulted in net shoreline erosion in the lee of the structure. This erosion likely occurred as a result of wave mass flux (i.e., ponding) over the structure, resulting in hydrodynamic circulation patterns that scour away sediment as this elevated water drains in the lee of the reef. One study found seven out of ten submerged structures constructed for beach protection resulted in net erosion of the shoreline in their lee (Ranasinghe and Turner, 2006). Prominent examples of submerged structures that caused shoreline erosion were the PEP Reef in Florida (Martin and Smith, 1997) and a perched beach in Slaughter Beach, Delaware (Douglass and Weggel, 1987).

The mechanisms by which submerged reefs induce shoreline erosion have been researched through numerical and physical model studies (Ranashinge et. al., 2006). It has been found that when a submerged reef is located too close to shore for the wave environment, a two-cell hydrodynamic circulation pattern develops resulting in currents scouring the shoreline in the lee of the reef. The left panel of Figure 3.7 shows the erosive two-cell circulation pattern and the right panel shows a four-cell pattern which results in shoreline accretion.

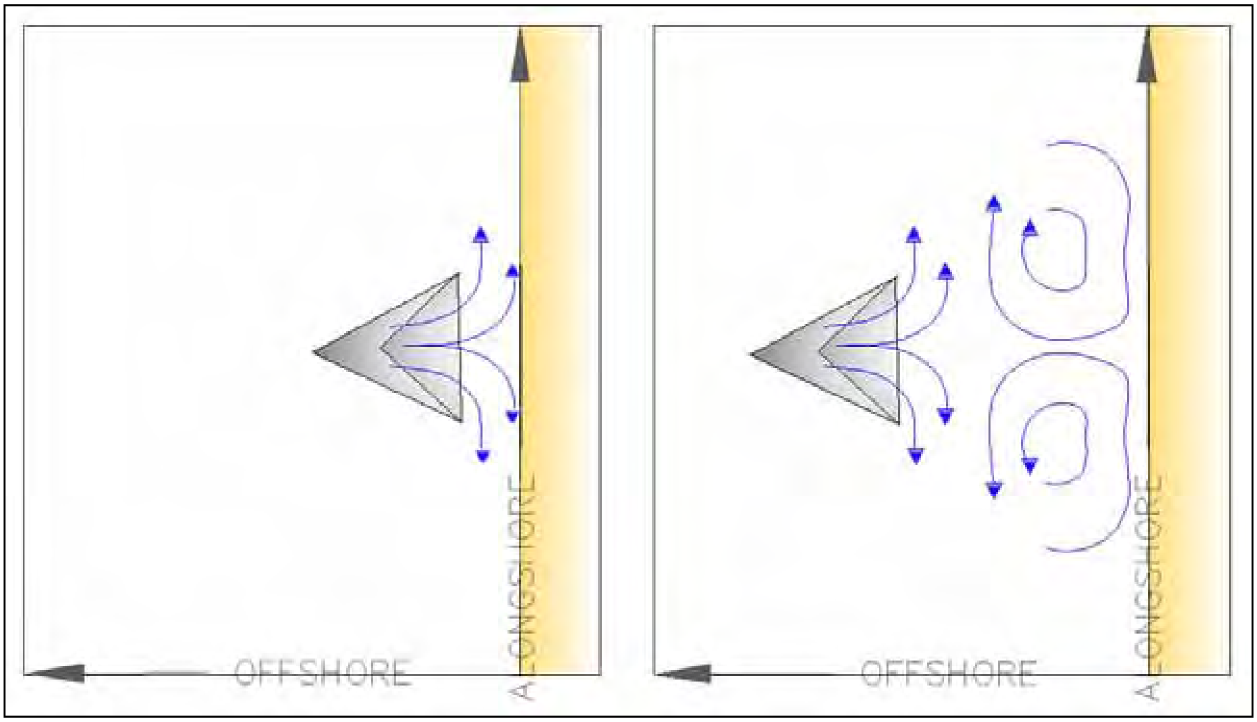

Figure 3.7 Erosive Two-Cell Circulation Pattern (left) and Accretive Four-Cell Circulation Pattern (right)

These model results tend to support the initially counter-intuitive results for submerged reefs indicated by the Reef/Island Method above in which salient projection distance increases with reef distance offshore, up to an optimal distance. However, these results are limited to fully submerged reefs, and do not apply to emergent structures as suggested by the solid blue curve of Figure 3.6 and explained below.

A similar numerical model study was performed illustrating the different circulation patterns found between emergent and submerged structures (Cáceres et. al, 2006). The circulation pattern for a typical emergent structure is shown in Figure 3.8, where the structure crest was at the water level. The circulation pattern for a submerged structure was similar to the four-cell circulation pattern shown at the right of Figure 3.7. For the emergent structure, the hydrodynamic circulation is a result of wave diffraction and refraction in the lee of the structure and wave breaking at the shoreline. No ponding occurs over the structure. The resulting circulation pattern allowed suspended sediment to be deposited in the lee of the structure, resulting in a salient. Moving emergent structures closer to shore, brings the calm region in the lee of the reef even closer to shore, resulting in even greater sedimentation, until a tombolo is formed. This pattern is consistent with other observations (Chasten et. al., 1993).

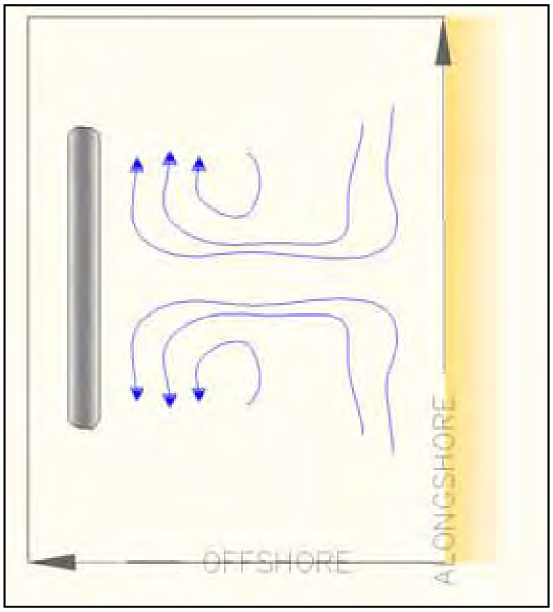

Figure 3.8 Circulation Pattern for an Emergent Structure

A rule of thumb derived from the Ranasinghe et. al. study is that if the distance between the shoreline and landward edge of a submerged structure crest is greater than 1.5 times the distance from the shoreline through the surf zone, then net accretion can be expected. Conversely, if the submerged reef is closer, erosion can be expected. Using this rule, the Initial Reef would be expected to cause accretion and the MLLW Crest Reef would be expected to cause erosion. The MSL Crest Reef behaves like an emergent structure in this regard, so the rule of thumb would not apply, and accretion would still be expected. A rule of thumb is not however considered adequate for final design. If a submerged reef should be required, additional alternatives beyond the MLLW Crest Reef should be considered and analyses should be performed to verify that these new alternatives would not result in shoreline erosion.

3.3 RESULTS

The MSL Crest Reef satisfies all the design criteria while the other reef designs did not. The MSL Crest Reef also passes both the Reef/Island Check and Scour Check. Use of fully submerged reefs requires extensive modeling to achieve the delicate balance required to ensure a four-cell circulation system in the lee of the reef so as to not cause undue shoreline erosion. Even then, achieving the salient design criterion with a submerged reef would not be possible at Fletcher Cove, unless a very large reef was placed much farther from shore, beyond the sensitive habitat resources. This very large size would then violate the secondary objective of achieving efficiency in the design. Use of fully emergent breakwaters is relatively straightforward with great probability of salient development, but with extensive public opposition. The MSL Crest Reef is put forward as a compromise between a submerged reef and a fully emergent breakwater, while providing a high likelihood of success.

The current study scope does not include assessment of project costs. In lieu of costs, a simple comparison of man-made reef volumes is provided in Table 3.3. This shows that the preferred MSL Crest Reef is larger than man-made surfing reefs and within the volume envelope of proposed and man-made sand retention reefs.

Table 3.3 Comparison of Reef Volumes

REEF NAME	VOLUME (M^3)	PRIMARY PURPOSE	STATUS	SOURCE
Pratte's, El Segundo	1,400	Surfing	Built	Innes, 2003
Cables, Australia	5,500	Surfing	Built	Jackson and Corbett, 2007
Mount Manganui, New Zealand	6,000	Surfing	Built	Borrero, 2009
Bascombe, England	11,900	Surfing	Built	Elwany, 2007
Oil Piers, Ventura	17,000	Sand retention	Proposed	ASR Ltd, 2004
MSL Crest Reef, Fletcher Cove	**25,000**	**Sand retention**	**Proposed**	**Current study**
Narrowneck, Australia	70,000	Sand retention	Built	Jackson and Corbett, 2007

The preferred MSL Crest Reef was carried forward to the next phase of the study for estimation of the upcoast and downcoast shoreline changes caused by the reef.

4. ESTIMATE POTENTIAL SHORELINE CHANGE

The purpose of this task was to estimate the potential for upcoast and downcoast shoreline changes resulting from the preferred reef.

4.1 METHOD

An empirical method to calculate the upcoast and downcoast shoreline changes was developed by Everts Coastal (2002b). This method assumes that a reef induced salient would perform similar to a shore normal groin in its tendency to trap sand in an upcoast fillet. This approach was verified by Everts Coastal for the salient behind the Santa Monica Breakwater. A fillet is a deposit of sand that is wider than the natural condition caused by a longshore transport blocking structure. A schematic diagram of a shore normal groin with a fillet on the upcoast side and downcoast erosion is shown in Figure 4.1.

This method relies on the concept of blocking distance, which is the minimum shore normal distance a structure (e.g. groin) must be before a fillet starts to form. Structures that extend beyond that blocking distance result in a measureable fillet as sketched in Figure 4.1. The blocking distance is a function of the ratio of net longshore sediment transport rate to gross longshore sediment transport rate. In southern California, this ratio is closely correlated to the bearing of the existing shore normal, relative to true north. The closer that bearing is to 180°, the higher the net/gross longshore sediment transport ratio is and the shorter the required blocking distance is. As the bearing of the existing shore normal increases the net/gross longshore sediment transport ratio decreases and the required blocking distance increases. In the project region, this shore normal bearing ranges from 250°, encompassing all of Solana Beach, to 290°, for Fletcher Cove.

The empirical relation, developed for beaches in southern California, is shown in Figure 4.2 with the shore normal bearings for Solana Beach and Fletcher Cove marked on the x-axis. The resulting range of blocking distance is marked on the y-axis.

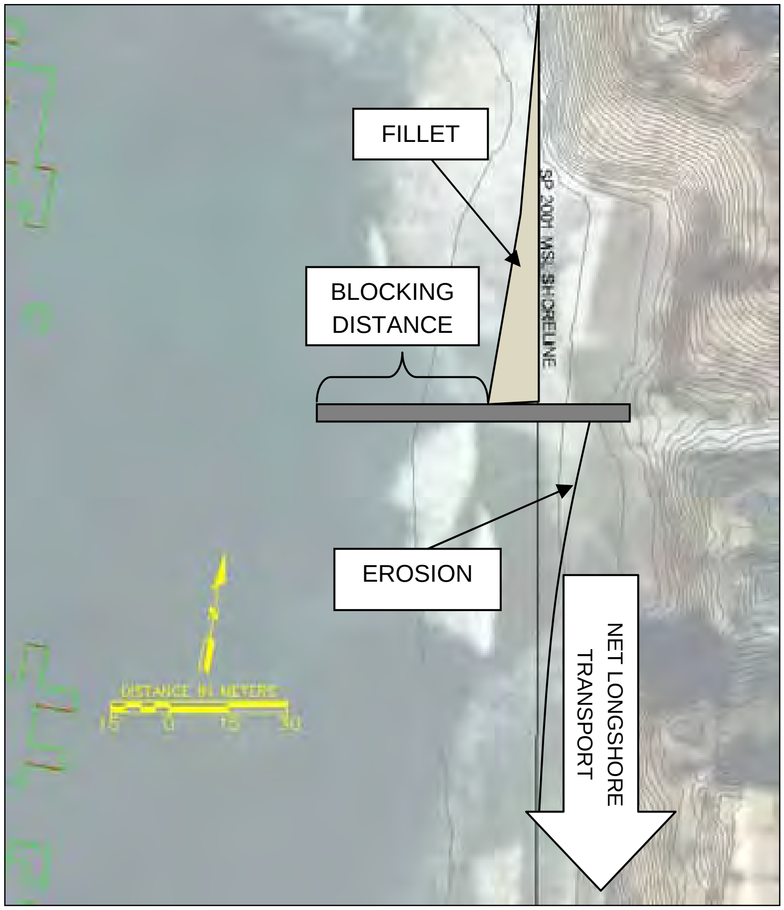

Figure 4.1 Schematic of Groin and Fillet

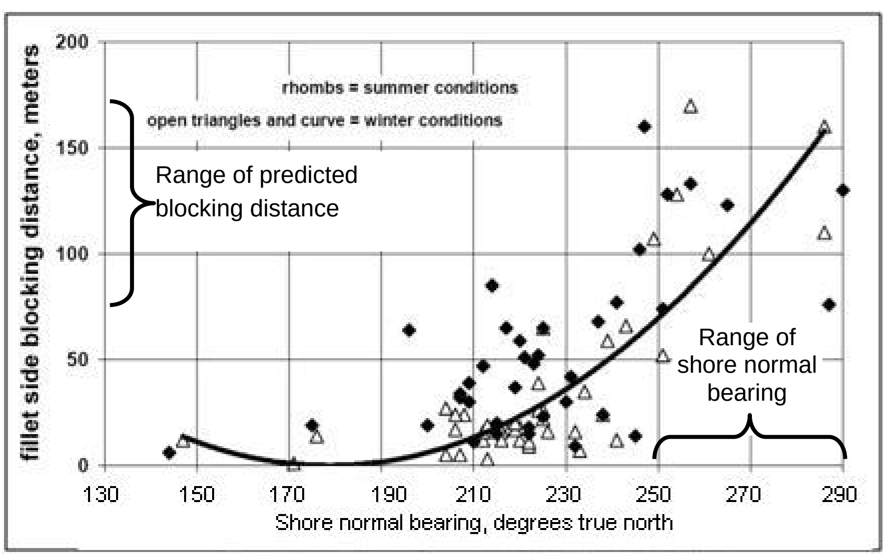

Figure 4.2 Structure Blocking Distance versus Bearing of the Shoreline

In addition to the empirical method described above, a numerical model was used to estimate the upcoast and downcoast shoreline changes. The numerical model approach was deemed unsuccessful hence the results were not relied upon. The numerical model approach is described in Appendix D.

4.2 RESULTS

As shown in Figure 4.2, the predicted blocking distance in the study area ranges from 70 to 170 M. Since the target salient projection distance is much less than the range of predicted blocking distances, the salient at Fletcher Cove is not likely to develop a fillet. Since the salient projection distance is too small to produce a fillet, and since the downcoast beach is very narrow, no attendant downcoast erosion would be expected.

A nearby natural feature was used as a qualitative check on the above results. A 27 M longshore transport blocking projection at the nearby Seascape Surf Park is shown in Figure 4.3. There is no noticeable development of an upcoast fillet or downcoast erosion near the projection. This lack of fillet or erosion is in close agreement with the above calculations.

Based on this analysis, it was found that the preferred MSL Crest Reef and salient at Fletcher Cove would not be expected to result in significant long-term upcoast or downcoast changes to the shoreline.

Image Source: Google Earth Pro

Figure 4.3 Longshore Transport Blocking Projection with no Fillet or Downcoast Erosion

5. SUMMARY, RECOMMENDATIONS AND FUTURE DIRECTION

5.1 SUMMARY

The purpose of this study was to develop a conceptual sand retention reef design for Fletcher Cove that would create a wider beach and then estimate the potential for upcoast and downcoast impacts to the shoreline resulting from that reef. To achieve the former, a set of design criteria were developed which include:

1. The reef should provide a 30 M, MSL salient projection distance.
2. The salient should be pre-filled.
3. The reef should be permittable. To achieve this it was assumed that the reef should **not**:
    a. directly cover existing hard substrate habitat;
    b. negatively impact aesthetics;
    c. be shore connected (i.e. it should be detached from the beach); and
    d. negatively impact surfing.

The initial reef design was provided by the USACE based on the proposed Oil Piers Reef in Ventura County, California. The reef and salient dimensions were calculated with an analytical method based on wave height transmission coefficients (Kt Method). Results were checked against two other independent methods (Reef/Island Check and Scour Check). The resulting 10 M salient projection distance was significantly less than the target 30 M salient projection distance, so additional reef designs were developed.

The driving parameter behind these two additional reef designs was the crest elevation. One was set at MLLW and the other at MSL. With these set crest elevations, the reef design goal was to achieve the design criteria and the project objectives. Reversing the calculation process, the Kt Method was used to develop the remaining reef dimensions that best achieved the design criteria. Once again, the reef designs were reviewed against the Reef/Island Check and Scour Check.

It was found that only the MSL Crest Reef satisfied all the analyzed design criteria. While the surfing design criterion was not addressed in detail, it is expected that the general dimensions of the MSL Crest Reef could be modified for surfing while maintaining the sand retention capabilities.

Upcoast and downcoast shoreline changes from the preferred MSL Crest Reef were estimated using an empirical method. The results indicate no significant long-term upcoast or downcoast shoreline changes would be expected from the MSL Crest Reef and associated salient.

5.2 RECOMMENDATIONS AND FUTURE DIRECTION

Future analyses for this project should include estimating project costs as well as the other design criteria in the optimization. When reef volume and surfing characteristics are considered, the optimal reef crest elevation and distance from shore may change from the MSL Crest Reef. If a lower reef crest elevation is desired, the new design should be tested with two or three-dimensional numerical hydrodynamic modeling and sediment transport modeling to verify that the reef would not cause shoreline erosion.

Additional criteria that should be considered in future analyses for this project include, but are not limited to:

- the effect of sea level rise on the reef and salient,
- surfing characteristics (peel angle, breaker type, frequency of breaking, surfer capacity, wave quality, and skill level),
- settling and stability,
- reef volume and materials,
- constructability and construction schedules,
- construction and maintenance costs,
- project lifetime,
- long-term management,
- economic benefits,
- habitat mitigation costs or benefits,
- liability,
- funding sources, and
- possible teaming partners.

The recommendation for the future course of action for the final design and implementation of a multi-purpose reef at Fletcher Cove is to proceed under the Section 2038 Authority of the Water Resources and Development Act (WRDA) of 2007. This Authority, formally the Section 227 Program from WRDA 1996, includes provisions for:

> *''(i) projects consisting of planning, design, construction, and monitoring of prototype engineered and native and naturalized vegetative shoreline erosion control devices and methods;*
> *(ii) monitoring of the applicable prototypes;*
> *(iii) detailed engineering and environmental reports on the results of each project carried out under the demonstration program; and*
> *(iv) technology transfers, as appropriate, to private property owners, State and local entities, nonprofit educational institutions, and nongovernmental organizations."*

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APPENDIX A – KT METHOD FOR CALCULATING REEF AND SALIENT SIZE

Estimating the salient size for a proposed reef using the method developed by Dr. Craig Everts (Moffatt & Nichol Engineers, 2001) was a three-step process.

STEP 1: TRANSMISSION COEFFICIENT

Step 1 was to estimate the transmission coefficient for a proposed reef. A transmission coefficient is the ratio of the transmitted wave height divided by the incident wave height. For a reef or breakwater, this is the wave height on the landward side of the reef divided by the incident wave height on the seaward side.

Up to seven different methods were used to calculate the transmission coefficient (Buccino and Calabrese, 2007; d'Angremond, et. al., 1996; Davies and Kriebel, 1992; DELOS. 2002; van der Meer and Daemen, 1994; CEDEX, 1993; Yoshioka et. al. 1993). The methods used for each reef depended on how that method matched the physical features of each reef.

Typical input parameters included: reef height, water depth, cross shore crest dimension, offshore slope, reef porosity, significant wave height, and peak wave period. The calculation goal was to determine the typical salient size as opposed to the maximum or minimum salient size. To achieve this, the average water elevation (MSL), average significant wave height (CDIP, 2009a) and average peak wave period (CDIP, 2009b) were used as input to these calculations. Where called for, a deep water wave height of 1.0 M (CDIP, 2009a) was used to calculate the transmission coefficient. This is the average of all available yearly average deep water wave heights for the Torrey Pines wave gage. Where called for, a linearly shoaled incident wave height of 1.3 M was used at a water depth of 3.0 M. The input peak wave period was 12 seconds, which is the average of all data from the nearby Del Mar wave gage. It was assumed that the wave approach angle was shore normal.

STEP 2: SALIENT PROJECTION DISTANCE

For the second step, the transmission coefficient, in combination with the longshore crest dimension (L) and distance to the reef centroid (Y), were applied to an empirically-based graph to find the salient projection distance (y_s). The original version of this graph, as seen in Figure A.1, was based on southern California breakwater and salient dimensions measured from aerial photographs (Moffatt & Nichol Engineers, 2001). It included data for non-transmissive breakwaters (Kt=0) with a straight line forced through the origin. It assumed a line for completely transmissive structures (Kt=1) running vertically along the L/Y axis. This is logical, since a structure that allows all of the wave height to pass (Kt=1) would develop no salient (y_s=0) regardless of how wide that structure is relative to its distance offshore (L/Y). The data points shown in Figure A.1 indicate the degree of uncertainty in the measurement, with points being relatively certain and bars covering a range of measured conditions.

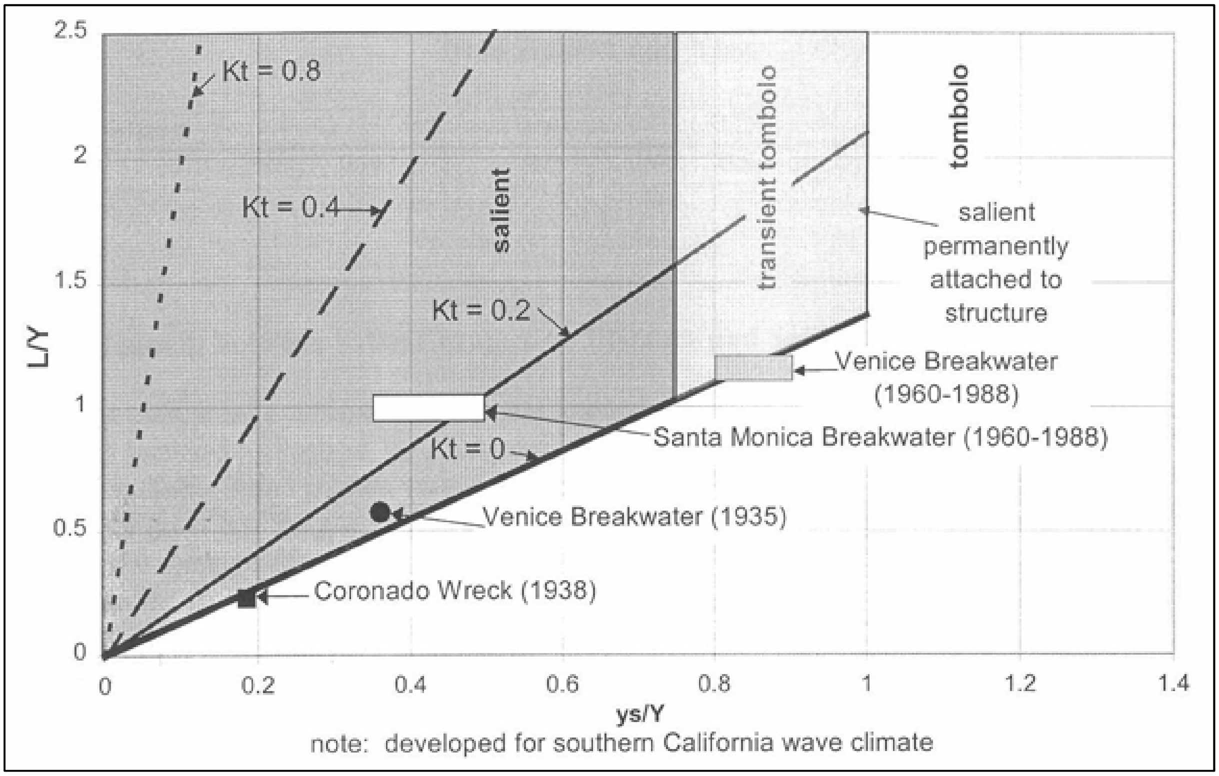

Figure A.1 L/Y Versus y_s/Y for Southern California Breakwaters

Southern California semi-transmissive (0.2<Kt<0.3) reef dimensions and the resultant salient dimensions were added to the graph as part of the current study. Example measurements are shown for a reef at Crystal Cove Beach in Figure A.2. The Moffatt & Nichol Engineers data as well as the new data are shown in

Table A.1 and graphed in Figure A.3. A straight line was fit through these data with the y-intercept forced through zero as shown in Figure A. 4. Where no new prototype data was available (1.0<Kt<0.4), the original lines were copied into the updated version. This updated version was the basis for the Kt method of calculating salient projection distance.

Image Source: Google Earth Pro

Figure A.2 Example Reef Measurements at Crystal Cove N

Table A.1 Measured Southern California Reef and Breakwater Dimensions

Reef Name	L (M)	Y (M)	Y_S (M)	B (M)	X_S (M)	L/Y	Y_S/Y	X_S/Y_S	Source
Coronado Wreck	49	213	43	9	213	0.2	0.2	5	Moffatt & Nichol, 2001
Venice Bkwtr 1935	183	326	113	9	1219	0.6	0.3	11	Moffatt & Nichol, 2001
Santa Monica Bkwtr 1960	610	610	302	9	1524	1.0	0.5	5	Moffatt & Nichol, 2001
Venice Bkwtr 1988	183	158	128	9	610	1.2	0.8	5	Moffatt & Nichol, 2001
Venice Bkwtr 1960	183	158	143	9	610	1.2	0.9	4	Moffatt & Nichol, 2001
Sta Monica Bkwtr 1988	610	610	210	9	1524	1.0	0.3	7	Moffatt & Nichol, 2001
Crystal Cove S	85	70	28	46	146	1.2	0.4	0	Google Earth Pro
Table Top Reef	152	116	43	79	457	1.3	0.4	11	Google Earth Pro
Crystal Cove N	55	55	19	45	82	1.0	0.3	5	Google Earth Pro
Lowers	152	91	46	122	213	1.7	0.5	5	Google Earth Pro
Uppers	305	168	98	137	610	1.8	0.6	6	Google Earth Pro
Topanga Creek	427	195	149	85	671	2.2	0.8	4	Google Earth Pro
Churches	168	102	34	119	305	1.6	0.3	9	Google Earth Pro
El Segundo	18	305	0	0	30	0.1	0.0	-	Google Earth Pro

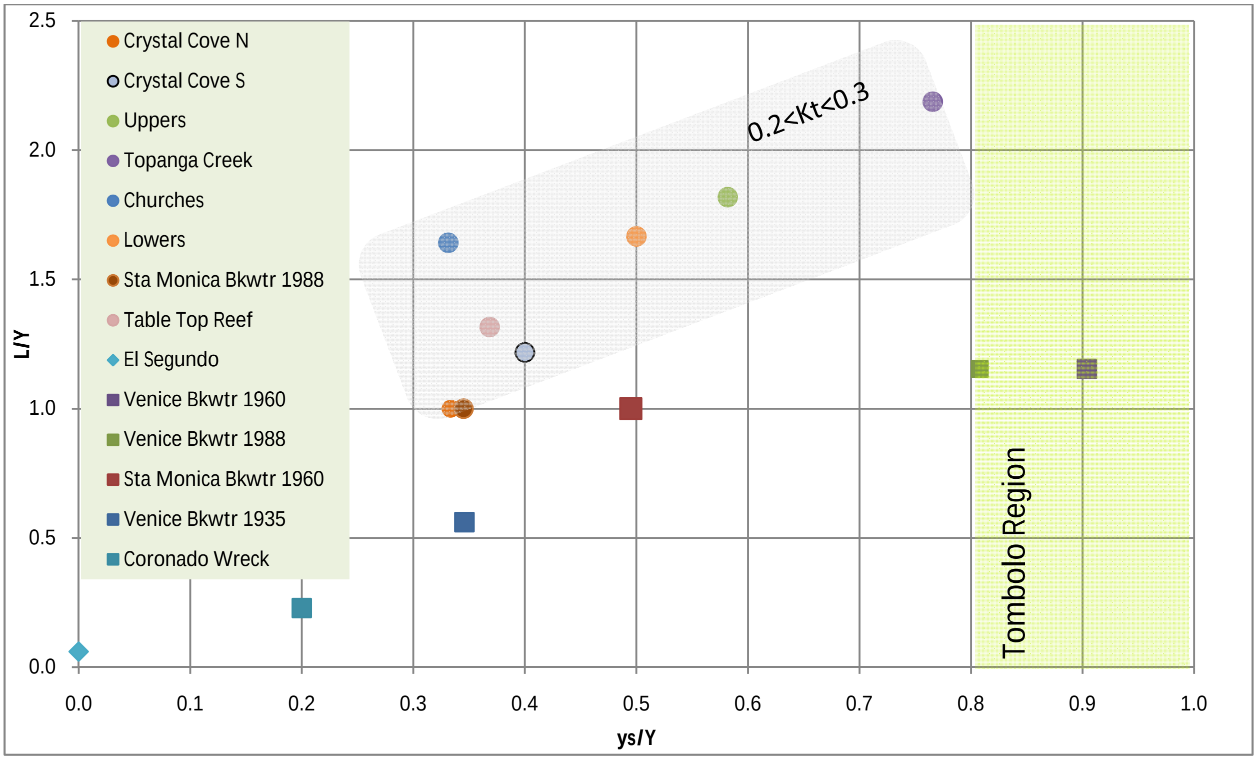

Figure A.3 Measured L/Y Versus y_s/Y for Southern California Reefs and Breakwaters

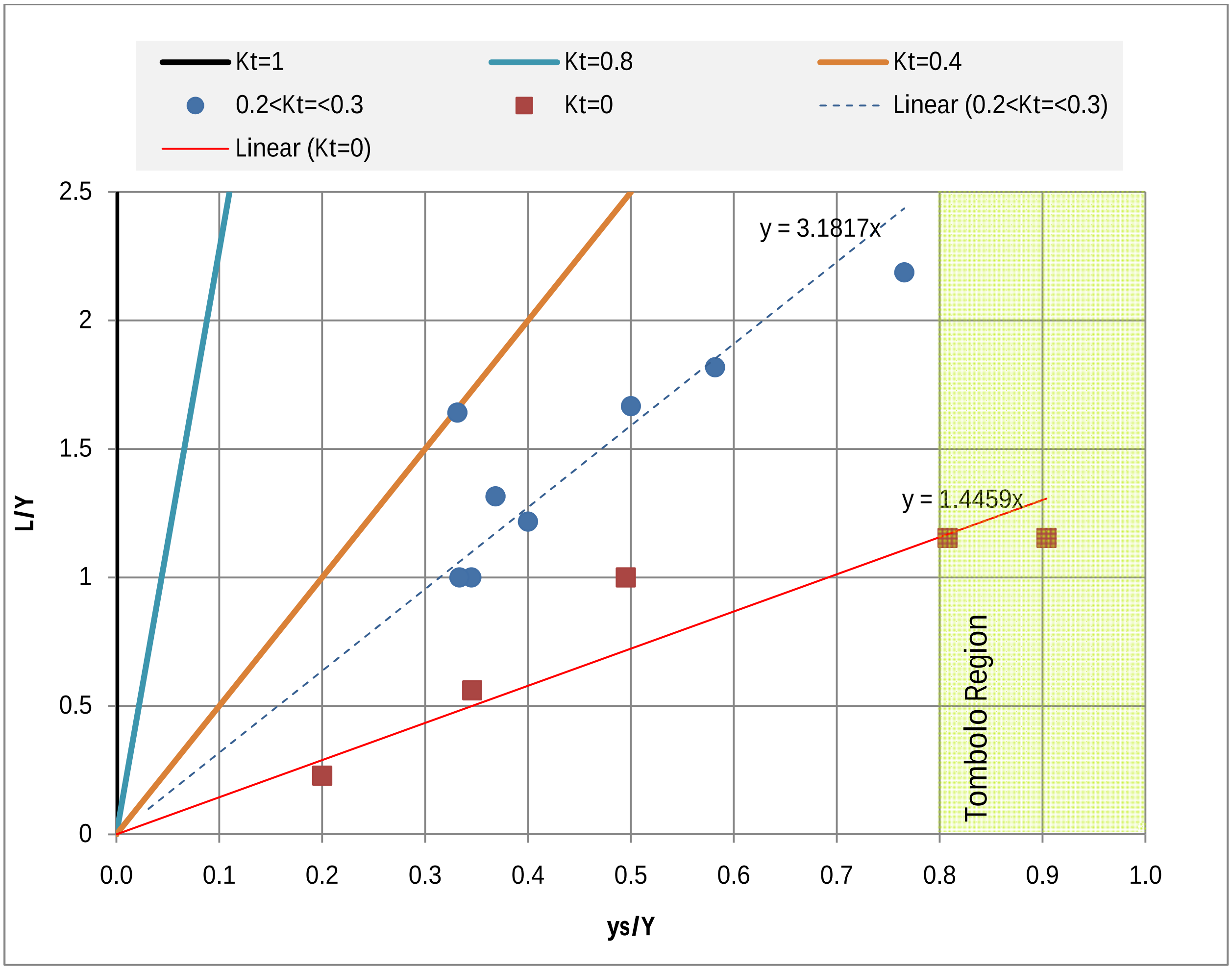

Figure A. 4 Updated L/Y Versus y_s/Y for Southern California Reefs and Breakwaters

STEP 3: SALIENT SHAPE

The third step used other empirical relationships to determine the remaining shape of the salient. Estimates for the longshore salient dimension vary from 5 (Everts Coastal, 2002b) to 8 (Black & Andrews, 2001) times the salient projection distance. A multiplier of 6.0 (Moffatt & Nichol Engineers, 2001) was used for the current study. This value was verified with measurements of southern California salients as shown in the column titled x_s/y_s in

Table A.1. The average of these x_s/y_s values is 6.0.

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APPENDIX B – STUDY RESULTS IN ENGLISH UNITS

PARAMETER	UNITS	INITIAL REEF	MLLW CREST REEF	MSL CREST REEF
Reef Crest Elev	Feet, MSL	-4.4	-2.7	0.0
B, Reef Cross Shore Crest Dimension	Feet	33	328	66
Y, Dist. To Crest Centroid	Feet	660	330	300
Reef Offshore Slope	(H:V)	12	30	30
Kt, Transmission Coefficient		0.6	0.4	0.1
L, Reef Longshore Dimension	Feet	262	315	295
Reef Volume	Cubic yards	10,000	50,000	33,000
y_s, Salient Projection Distance	Feet	32	66	98
x_s, Salient Long Shore Dimension	Feet	192	394	591
Salient MSL Area	Square feet	3,229	12,916	29,062
Salient Volume	Cubic yards	392	1,570	3,532

APPENDIX C – REEF/ISLAND METHOD FOR CALCULATING REEF AND SALIENT SIZE

Black and Andrews (2001) developed two equations for calculating salient projection distances based on measurements made from aerial photographs in New Zealand and Australia. The equation for islands (or non-transmissive breakwaters) is:

$$y_s = Y - 0.4\,L\,(L/Y)^{-1.52.}$$

The equation for submerged reefs is:

$$y_s = Y - 0.5\,L\,(L/Y)^{-1.27}$$

where variables are as defined in Section 1.3 of the current study report. The actual data as it was presented is re-copied in Figure C.1 (Moffatt & Nichol Engineers, 2001).

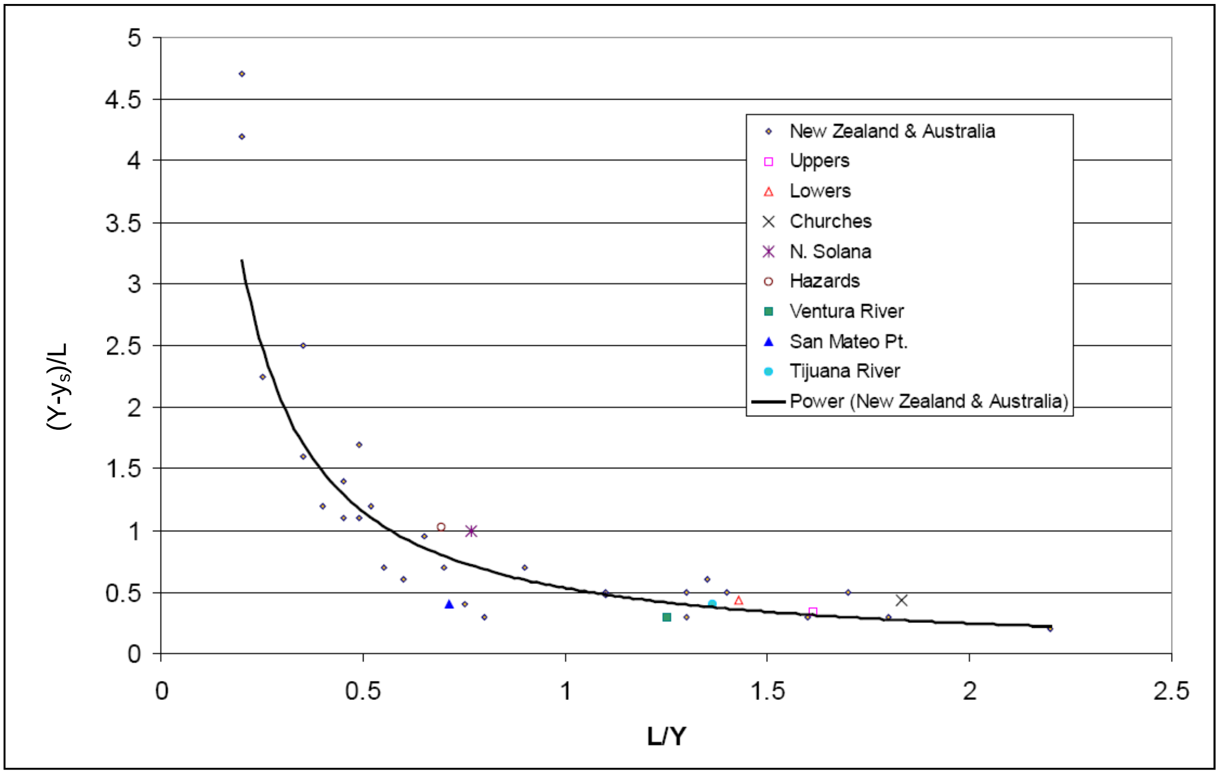

Figure C.1 Reef/Island Method for Calculating Reef Induced Salients

Calculated salient dimensions using the Reef/Island Method applied to the proposed reef alternatives are summarized in Table C.1. Salient projection distance predictions are greater using this method than those calculated with the Kt Method.

Table C.1 Reef and Salient Results Using Reef/Island Method

PARAMETER (UNITS)	INITIAL REEF	MLLW CREST REEF	MSL CREST REEF	MSL CREST ISLAND
Reef Crest Elevation (M, MSL)	-1.33	-0.83	0.00	0.00
Y, Distance to Centroid of Reef Crest (M)	200	100	90	90
L, Reef Longshore Dimension (M)	80	96	90	90
y_s, Salient Projection Distance (M)	72	49	45	54

This method was tested for applicability in southern California by applying the reef/island equations to various salients associated with southern California breakwaters (as reported by Moffatt & Nichol Engineers, 2001) as shown in

Table C.2.

Table C.2 Reef/Island Method Applied to Southern California Breakwaters

STRUCTURE	KT	SALIENT PROJECTION DISTANCE, Y_S (M)		
		MEASURED	ISLAND EQUATION	REEF EQUATION
Santa Monica Breakwater 1960-1988	0.2	210 - 302	366	305
Venice Breakwater 1935	0	113	150	136
Coronado Shipwreck 1938	0	37 - 46	30	54

The reef equation over predicts salient projection distance, even when the structure is a breakwater (or shipwreck) with less wave transmission than a reef. Theoretically, reefs should create smaller salients than breakwaters. While these equations are in the proper range, they generally tend to over predict salient projection distances in southern California.

When plotted against measured prototype reef and breakwater data from southern California (Figure C.2), it can be seen that the Reef/Island Method is not representative for the southern

California coastal environment. The squares and circles are the same breakwater and reef data points described in Appendix B.

Based on these results, the Reef/Island Method of calculating salient projection distance was only relied upon as a secondary supporting source.

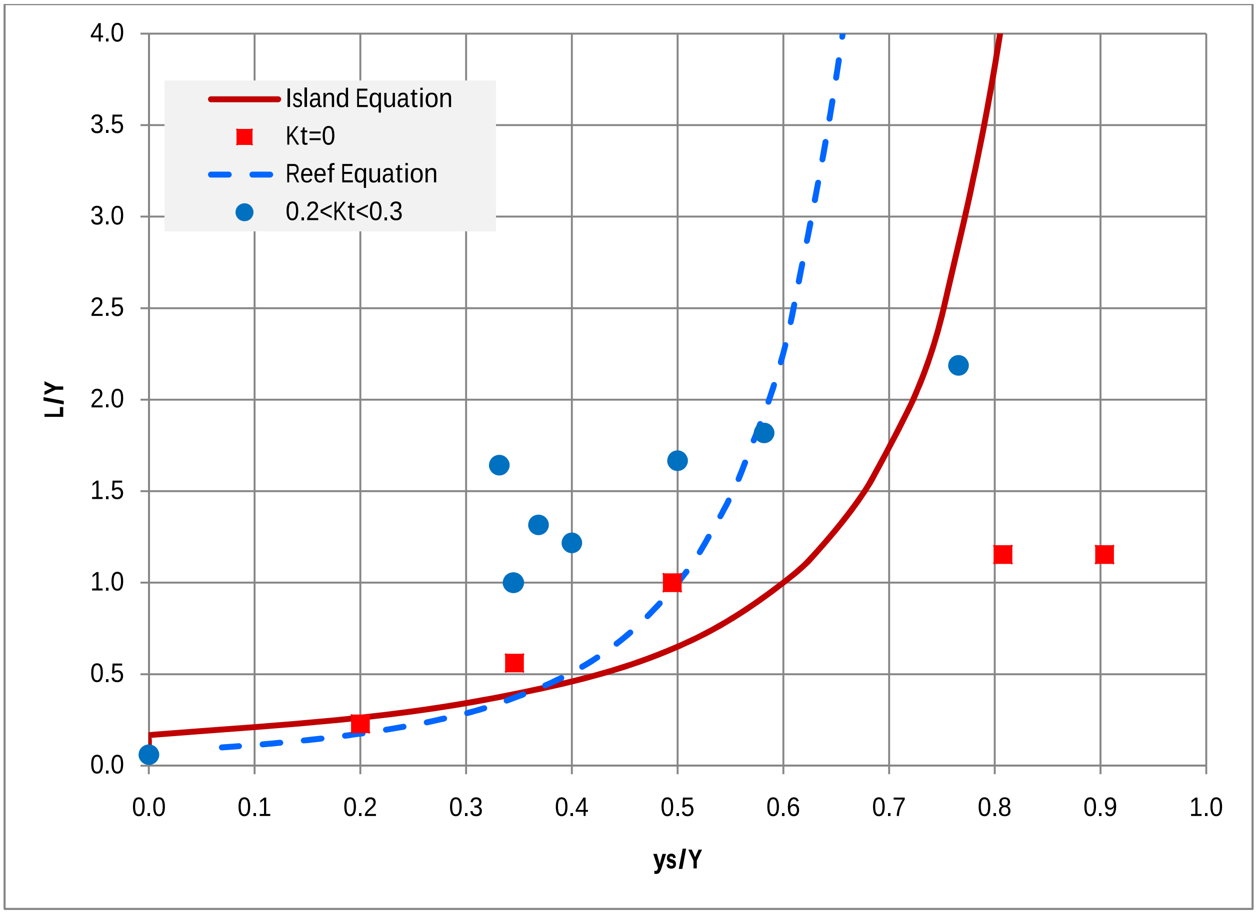

Figure C.2 Reef/Island Method Plotted With Prototype Southern California Data

REFERENCES

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APPENDIX D – NUMERICAL ESTIMATE OF SHORELINE CHANGES (GENESIS MODELING)

PURPOSE

The purpose of calculating upcoast and downcoast shoreline impacts caused by the reef and a pre-filled salient is to understand the environmental impacts of such a project and for use in estimating mitigation costs. The normal net longshore sediment transport direction in the project area is from north to south. With a large enough net transport it may be possible for a reef induced salient to cause upcoast deposition and downcoast erosion in a manner similar to that seen near of groins and other shoreline obstructions. The numerical modeling approach was thought to be useful for accounting for the many longshore transport parameters occurring in the project area.

METHODS

Numerical modeling is a common engineering tool that is capable of calculating shoreline changes that incorporate the numerous temporal and spatial varying parameters required for analysis of structural features on the coastline. Of the numerical models available, GENESIS is preferred due to its capability to handle a varying wave climate, multiple and different shaped structures, and its successful application on the southern California coast. The current task was scoped and funded based on the assumption that a previously developed GENESIS model configuration (USACE, 2005) could be adapted for use at this location without the need for extensive offshore wave analysis and transformation. The following section describes the numerical model, how it was configured, and how it was applied for the current task.

Model Description

GENESIS is one module of a larger suite of computer programs called the Nearshore Evolution Modeling System (NEMOS), which itself is a sub-component of the larger Coastal Engineering Design & Analysis System (CEDAS), developed by the USACE and distributed by Veri-Tech, Inc. The current study used CEDAS version 4.0 and NEMOS version 4.03. NEMOS, originally developed by the U.S. Army Coastal Engineering Research Center at the Waterways Experiment Station, is a set of model modules that simulate the temporal and spatial shoreline evolution of a subject beach in response to imposed wave conditions, presence of coastal structures, and other engineering activities such as beach nourishment. The only NEMOS module that was applied in this analysis was the GENEralized model for SImulating Shoreline change (GENESIS) (Gravens & Kraus, 1991, Hanson & Kraus, 1989). The STeady state irregular WAVE model (STWAVE) (Smith et. Al., 2001) module in the NEMOS suite was used for wave transformation in another project in the same area (USACE, 2005), and results from that wave analysis and transformation were used in the current study.

GENESIS was developed to simulate long-term shoreline changes on an open coast as induced by spatial and temporal differences in alongshore sand transport. The GENESIS model, equipped with an internal wave transformation sub-model, is generalized in that a wide variety of offshore wave inputs, initial beach planform configurations, coastal structures and beach fills can be included in the simulation. The main utility of GENESIS lies in simulating shoreline response to an artificial beach fill with or without the presence of coastal structures such as detached breakwaters, groins, jetties, and seawalls. Extensive testing and field verification for GENESIS have been conducted by the USACE before its release for public use. The model has continuously been updated and improved based on recent technical research and field applications. It has been successfully applied to simulate shoreline changes for several proposed projects (USACE, 2005) and completed projects (Moffatt & Nichol Engineers, 2000; Chambers Group, 2001) in southern California.

It should be noted that GENESIS can only predict the long-term shoreline evolution induced by alongshore sediment transport under the assumption that the cross-shore sand transport occurs mainly seasonally without any long-term net gain or loss across the beach profile. The short-term shoreline change that is significantly dependent on the cross-shore sand transport cannot be obtained from GENESIS model prediction.

In the GENESIS simulations, the alongshore sand transport rate is computed based on the alongshore wave energy flux method with an additional contribution resulting from a variation of breaking wave height alongshore. The additive component is relatively significant only in the vicinity of coastal structures. Either the internal wave transformation model or an external wave model can be optionally used to deduce nearshore wave information for computing the alongshore sand transport rate. To account for the irregular bathymetry of the study area, STWAVE was used as the external wave model in the previous referenced study, and the results were re-used in the current study. The STWAVE model calculates wave transformation from offshore deep water to a nearshore reference line, from which the internal wave model of GENESIS further propagates the waves to the breaking point so that the alongshore sand transport rate can be estimated.

Wave Data

As the shoreline positions are changed in response to impinging waves over one incremental time step, the new shoreline formation would affect the surfzone wave hydrodynamics and, consequently, alter the shoreline response induced by the subsequent wave events. Therefore, the sequential order of incoming waves is required to accurately simulate any historical time period. The sequential series of an offshore hindcasted wave data set of 22 years was reassembled into 5 groups of 8 year simulations, representing a range of different wave climates. The groups covered the following time periods: 1979 to 1986, 1983 to 1990, 1987 to 1994, 1991 to 1998 and 1993 to 2000. By having a range of wave groups, the behavior of a beach fill can be analyzed under various wave climates so as to estimate the broad spectrum of beach evolution after project construction. Refer to the Encinitas-Solana Beach Shoreline Feasibility Study (USACE, 2005) for further details on the wave climate.

After the model was configured in various ways, it was found that the long-term shoreline evolution was relatively insensitive to which wave group was used. It was much more sensitive to the other calibration parameters. The relatively average 1983 to 1990 wave group (see Figure D.1) was used for the model runs.

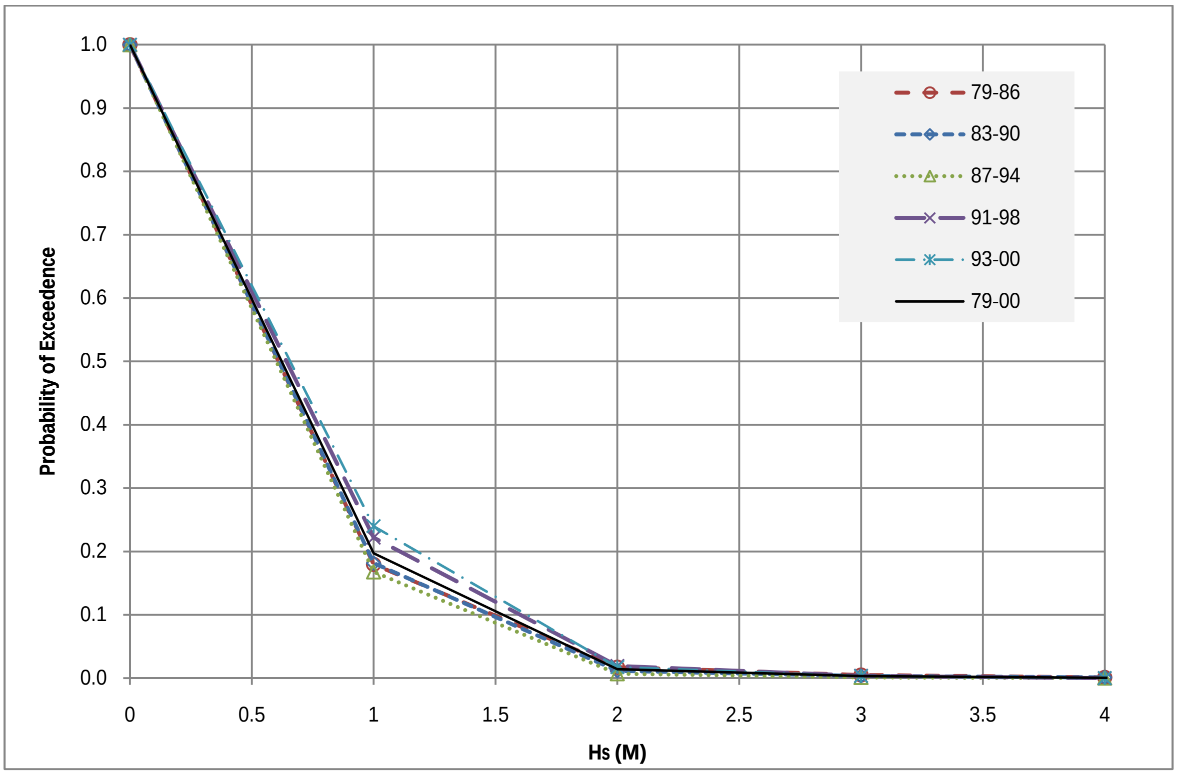

Figure D.1 Significant Wave Height Probability of Exceedence for the 5 Wave Groups and All Wave Data

Model Parameters & Setup

For a complete description of the model configuration, calibration, and input parameters, see the Encinitas and Solana Beach Shoreline Feasibility Study (USACE, 2005). Since this previous project used the same model in the same area, some of the input parameters from that project were re-used in the current study. Table D.1 lists the basic input parameters used, changes made in the model configuration, and the reasons for changing them.

Table D.1 GENESIS Model Parameters

Parameter	USACE, 2005 Configuration	Current Model Configuration	Reason for change
dx, Cell length	40 m	5 m	At least 8 cells required behind detached 50 M long breakwater
Domain Length	25 km	3 km	Lateral boundaries reduced to 1.5 km on either side of Fletcher Cove.
dt, time step	3 hr	0.25 hr	Reduce time step to improve model stability
N, number of cells	626	601	Smaller model domain was used covering well beyond project impacts
Kt	Not used	0.3	Constant transmission coefficient used to model reef at Fletcher Cove
K1	0.55	Same	This was a base parameter that was varied throughout the process
K2	0.40	Same	This was a base parameter that was varied throughout the process
Gross Transport	986,000 m^3/yr	Varies	Attempted to calibrate to shoreline position, not gross transport. Therefore this parameter was not investigated.
Net Transport	191,000 m^3/yr South	Varies	Attempted to calibrate to shoreline position, not net transport. Therefore this parameter was not investigated.
Grain size	0.34 mm	Same	No change
Depth of Closure	-7.2 M, MLLW	Same	No change
Berm Height	+3.8 M, MLLW	Same	No change
Lateral Boundary	Pinned beach with impermeable groin	Varies	Calibration variable
Pre-filled Salient	none	Yes	Initial size equal to equilibrium salient size
Seawall	Entire model domain	Same	No change

GENESIS does not consider the complex 3-D hydrodynamic processes which can occur around submerged nearshore structures such as reefs and breakwaters. These complex processes are described in the Scour Check part of Section 3.2 of the current study. GENESIS can only reduce the transmitted wave height through the use of either fixed or variable transmission coefficients. In many cases the resulting GENESIS-predicted salient prediction can be far from accurate and in some cases this approach can predict a salient where erosion would actually occur. For these reasons, GENESIS was not used to predict salient development. Salient prediction was limited to the methods provided in Section 3.2 of the current study. Then the breakwater dimensions and transmission coefficients in GENESIS were tuned so that the resulting salient dimensions matched these analytical predictions of Section 3.2.

While it was possible to simulate the salient size calculated analytically, it was not possible to simultaneously simulate a reasonable upcoast & downcoast shoreline with the same settings. Therefore, it was decided to use a breakwater with a fixed transmission coefficient that developed a salient in the proper order of magnitude, and focus the majority of the calibration effort on producing realistic upcoast and downcoast shorelines.

RESULTS

During the attempt to find a representative and useful model configuration, more than 50 model runs were developed. Of these runs, a handful of results are reproduced below, encompassing the range of configurations and results. The run number given is simply an accounting tool to track configurations and not indicative of any order.

Run 45

Results of an early GENESIS model configuration are shown in Figure D.2. For this configuration, the MSL Crest Reef was simulated by placing a detached breakwater in the model at the same location as the proposed MSL Crest Reef and adjusting the transmission coefficient (Kt) and breakwater longshore length (L) until a reasonable salient size was predicted by the model. The lateral boundaries were simulated as pinned beaches.

The background (without project) condition is shown as the solid black line in Figure D.2. The model predicted average, summer, and winter shoreline positions are shown with solid lines and their net differences relative to the background shoreline are shown with dashed lines.

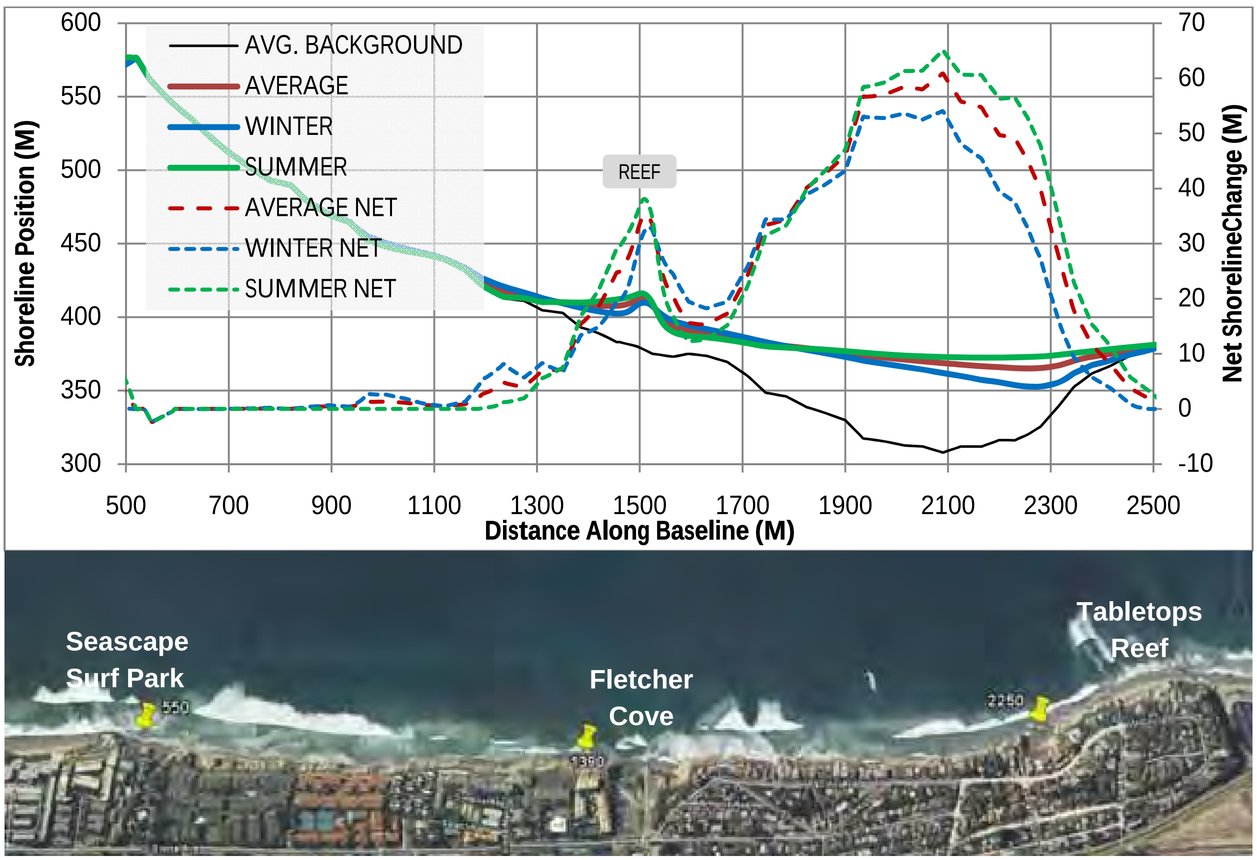

Figure D.2 GENESIS Shoreline Predictions for Run 45 Configuration

As shown, the model successfully predicted a salient in the lee of the MSL Crest Reef. In addition, a net accretion of between 50 and 65 M was predicted between the salient and Tabletops Reef. The model perceives this region as a pocket beach bound by these two features. The accuracy of this prediction is questionable. Similar accretion was predicted by previous modeling efforts in the same area (Moffatt & Nichol Engineers, 2000 and USACE,

2005) but has not been observed to occur in either the SANDAG monitoring (Coastal Frontiers Corp., 2009, Plate 5) or the 2004 LiDAR[1] survey (Scripps).

Additional model configurations were developed to attempt to alleviate the erroneous accretion found between the salient and Tabletops Reef.

Run 46

Results of the most successful GENESIS model configuration are shown in Figure D.3. This configuration is similar to Run 45, with the addition of impermeable groins at the lateral boundaries which were used to limit the sand supply. Once again, the model predicted a net accretion between the salient and Tabletops Reef, but of smaller magnitude than Run 45. These results are questionable for the same reasons as for Run 45.

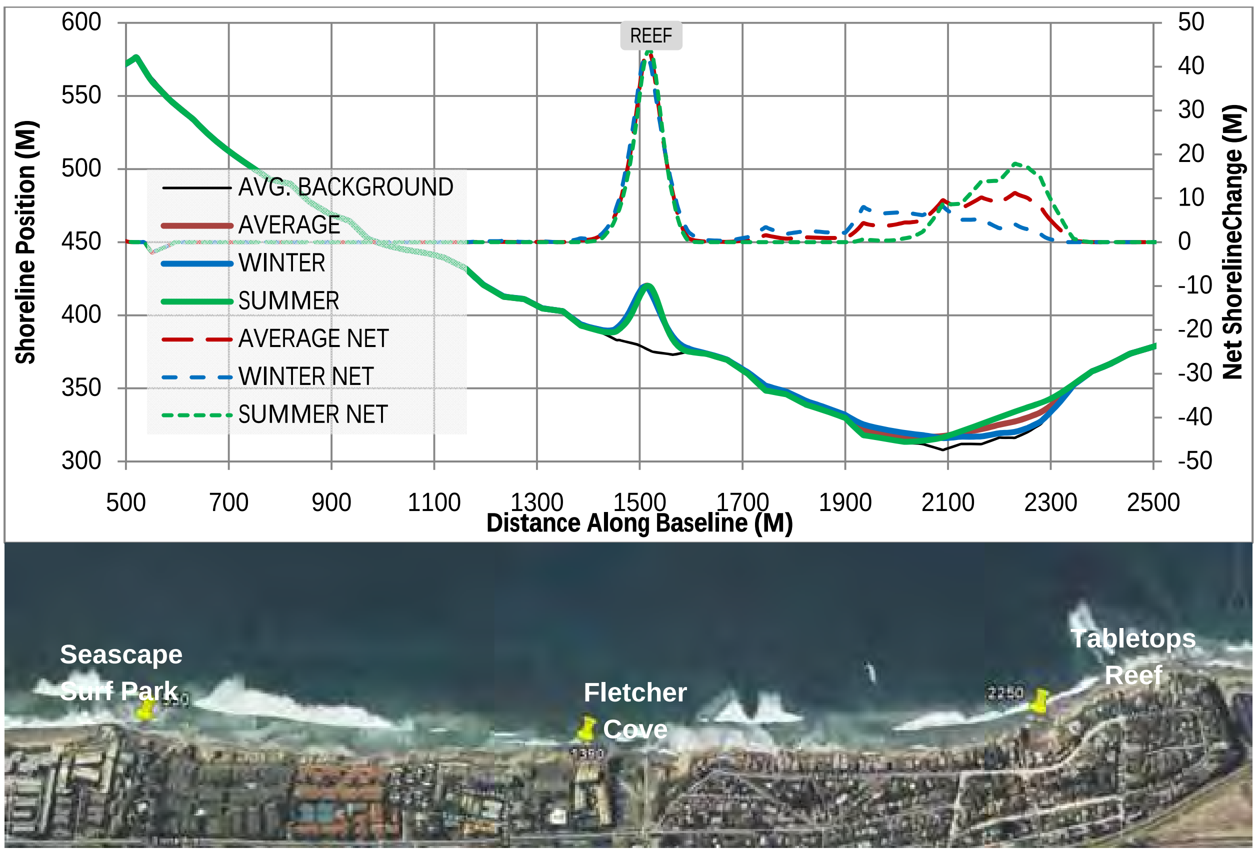

Figure D.3 GENESIS Shoreline Predictions for Run 46 Configuration

[1] High resolution bathymetry and topography were collected in April 2004 by the CHARTS 1000 LIDAR system. These data were collected by Fugro NV with funding from the USACE Southern California Beach Processes Study being conducted by Scripps Institute of Oceanography.

Run 42

If the problem was that GENESIS perceived the region between the salient and Tabletops Reef as a pocket beach (where sand could accrete), a possible solution would be to flatten the shoreline, thus eliminating the pocket. Therefore, the shoreline was modeled as a straight seawall as shown in Figure D.4. Lateral boundaries were once again simulated as pinned beaches.

For this configuration, the model predicted large areas of accretion on both upcoast and downcoast sides of the reef. The model perceives the salient as an impediment to longshore transport, behaving much like a groin. This groin effect creates a fillet on the left (south or downcoast) side of the salient in the model. It is likely that the groin effect of the salient, in combination with transformed waves, creates the accretionary area shown between the salient and Tabletops Reef. These results are also questionable as discussed for Run 45.

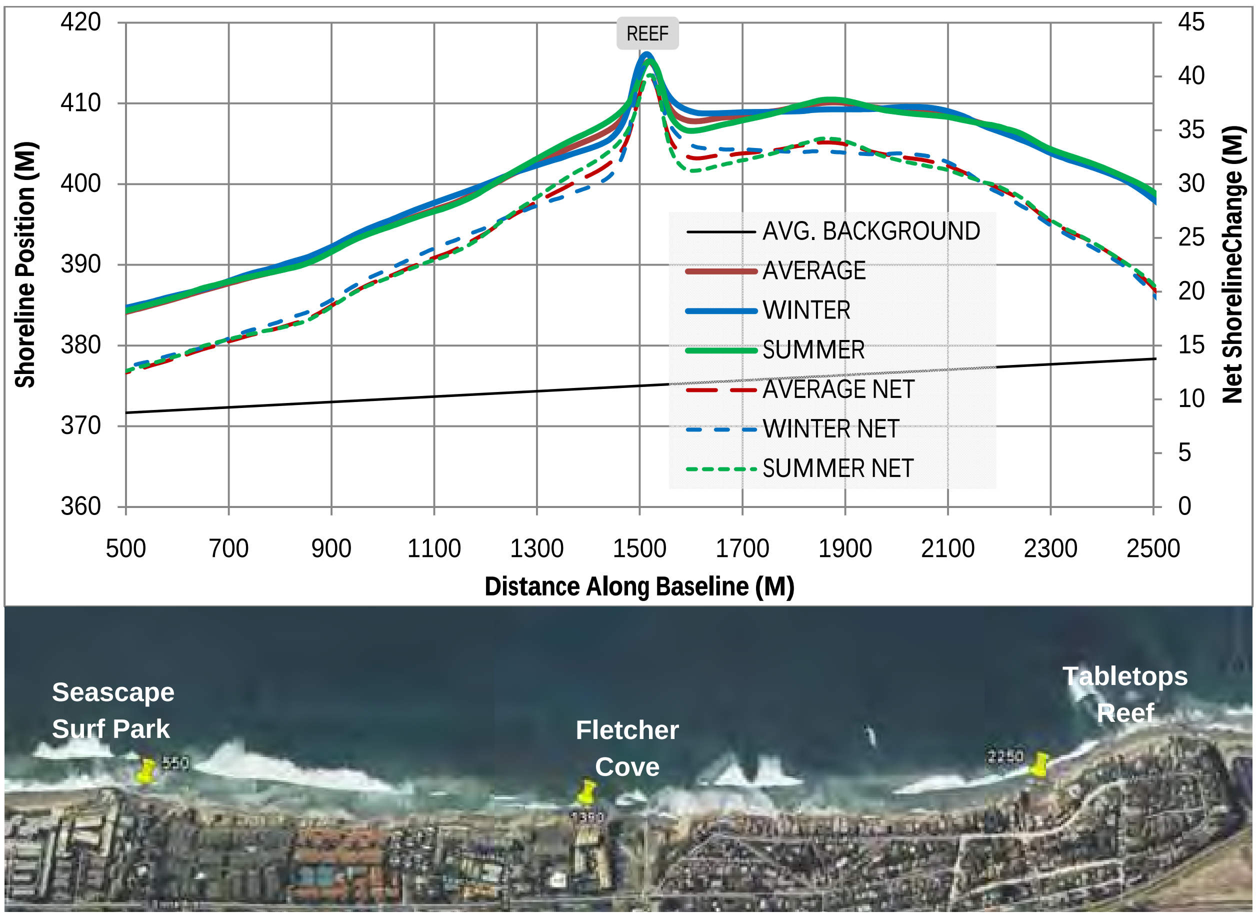

Figure D.4 GENESIS Shoreline Predictions for Run 42 Configuration

Run 49

The model configuration for Run 49 was similar to that of Run 42, but with the addition of impermeable groins at the lateral boundaries to limit the amount of sand entering the model domain. While this generally results in less accretion, the large accretion between the salient and Tabletops Reef, shown in Figure D.5, is still questionable. In the figure, the net shoreline changes (dashed lines) lie directly under the shoreline positions (solid lines).

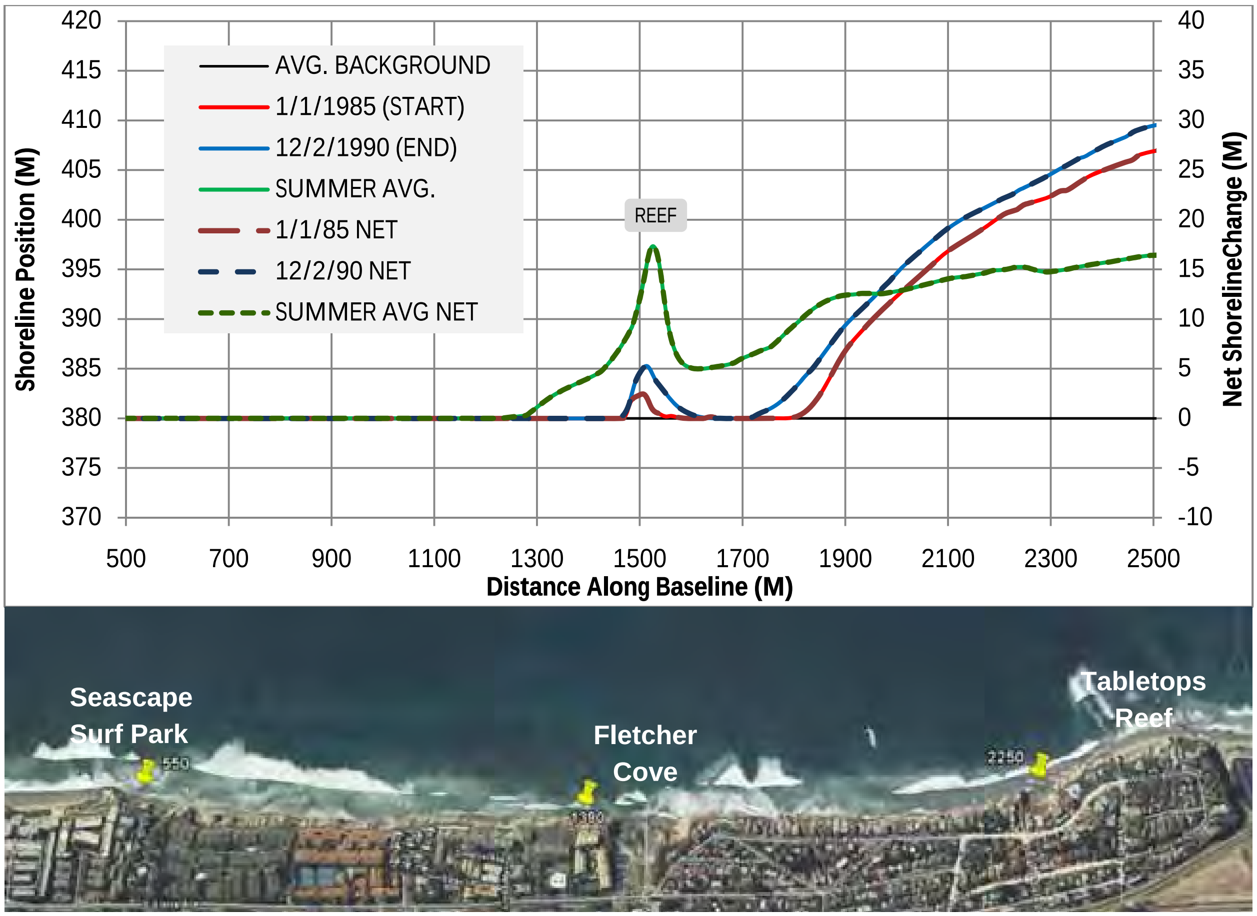

Figure D.5 GENESIS Shoreline Predictions for Run 49 Configuration

SUMMARY

The shoreline extending 1.5 kilometers upcoast and 1.5 kilometers downcoast from Fletcher Cove was modeled using the GENESIS shoreline evolution numerical model. The detached breakwater feature was used to simulate the MSL Crest Reef and resulting salient at Fletcher Cove. Due to limitations in the model configuration, no reasonable results were produced.

DISCUSSION

It was found that in the absence of obstructing elements along the coast, GENESIS will gradually evolve towards a straight line. GENESIS also has a tendency to unduly cause accretions in perceived pockets, and unduly cause accretions due to improper nearshore wave transformation.

These problems are avoided in another numerical shoreline simulation model called DNR because the model assumes a straight shoreline and straight and parallel offshore contours to begin with (Dean, 2001). However, the DNR model cannot be used for reef or breakwater modeling because it does not simulate those types of structures.

It would likely be possible to model a variable shoreline with a reef by assigning straight and parallel offshore contours and a straight initial shoreline in the GENESIS model in combination with the detached breakwater feature found in GENESIS. This would eliminate the tendency of GENESIS to: 1) flatten the shoreline, 2) unduly cause accretion in perceived pockets, and 3) unduly cause accretion due to improper wave transformation. At the same time this would allow the robust detached breakwater modeling capabilities available within GENESIS.

RECOMMENDATION

Since GENESIS does not model the complex hydrodynamic processes occurring around submerged nearshore structures, it is recommended that GENESIS not be used as the primary salient predictive too for these types of structures.

It was beyond the study scope and budget to modify the offshore wave transformation and bathymetry contours to accurately model the project. However, if any future modeling of similar shoreline and structure features should occur, GENESIS can be used, but with assumed straight and parallel shoreline and nearshore contours. This would likely eliminate the GENESIS shortcomings that were encountered, while effectively simulating the upcoast and downcoast shoreline features associated with the reef induced salient.

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