Review of ASR and EIC reports *re* Fletcher Cove Reef Design

Prepared for

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Terminology

Throughout this report, *ASR* and *EIC* will always refer to the reports under review and not to the companies. *Cove* will always refer to the Fletcher Cove area. *City* will always refer to the City of Solana Beach.

Stated Goals

Both EIC and ASR restate the goal that the reef should "provide an approximate 30 m wide beach at mean sea level." The remaining three goals are of lesser pertinence to this review.

Deficiencies Common to Both Reports

Both reports appeared to treat this beach width feature (salient) as an attribute that once-built would remain constant under the effects of the *average waves*. [See General Comments in this review]

There was no evident consideration for extreme El Nino events, like the winter of 1981-82 with storms that completely stripped the beach of sand and exposing cobbles and country rock in this area, as well as causing an increase in the elevation of MSL of more than 50 cm for almost a full year.

No consideration was evident of seasonal changes in either wave height or direction.

Although avoiding destruction of valuable bottom habitat was a stated objective, no information was provided on where this habitat was located (areas? depths?) or how the location recommended related to these areas.

No evaluation was made of the potential for the constructed reef to increase valuable habitat.

The effects of reef volume, site depth or distance from shore on the cost of the project were not discussed.

Although there are there are massive data sets on waves and beach profiles for this area available on the Internet, as well as historical profiles archived by the USACE (accessible, presumably through that client), the only use appears to be the determination of average wave height and period.

Although the Tabletops Reef was within about a kilometer of the proposed site for the desired salient, and therefore experienced essentially the same wave climate and certainly is involved in the same alongshore sediment transport regime, there was no evidence that the performance of this reef was investigated through the data sources discussed above. [See General Comments in this review]

Evaluation of EIC

1) The rejection of the "initial design" reef concept was based on unsupportable arguments. The results depicted in Figure C.1 clearly show reasonable agreement for the Black and Andrews curve with reef data in Southern California (eight locations) and there is no discernable bias towards either over or under prediction. However, EIC chooses to compare measured and modeled salient distance on three breakwaters, which have transmission coefficients far smaller than any Southern California reefs in Fig. C.1. The predicted values using the reef equation range from 1.01 to 1.46 times the measured, which would appear to be reasonable considering that the none of the sites selected were in fact reefs. Based upon the EIC interpretation of these results, however, the use of the reef formula appears to be considered unreliable in the remainder of the report. A further mystery is Figure C.2 which the accompanying text says are "the same …… data points described in Appendix B". In the review copy of EIC, Appendix B contains only 3 reef configurations. Perhaps they were the unidentified "Southern California" reefs and breakwaters from Figure 3.5. The lack of specific identification made evaluation of these curves questionable.
2) However, since Figure 3.5 is a necessary step in the Kt method it will be treated generically. The approach using average values of water level and wave height and period , although less labor intensive than looking at the possible effect of extremes, could mask important performance differences. In the real situation, Kt would always have a substantial range. The Kt with MLLW and tiny waves could be zero for an assumed reef design and the transmitted wave, reformed beyond the reef, could contain nearly 100% of its entering energy during an energetic winter storm and high water elevations. The assumption that each of those low values of Kt has equal value to a huge storm in determining the "average" impact on salient size is clearly very unrealistic. This problem is treated in more detail in the General Comments later in this review.
3) The Appendix A treatment of establishing the relationships between Kt, reef dimensions and salient size as depicted in Figure A.1 suffers from the same defects as the previous discussions. There are no data plotted for reefs – only breakwaters.
4) Close inspection of the dimensions assigned to the Crystal Cove reef in Figure A.2 shows that the ys of 19m is measured from a point about 2.5m into the cliff. As stated in paragraph 3) in the General Comments that follow, multiple realizations of the underwater and onshore profiles at this site are readily available on the Web.

5) Based upon the Tabletops and Crystal Cove observations, a shallow water reef similar to the MSL design, but closer to the beach, would maintain a substantial salient – probably greater than 30m in width – and would be relatively resilient in a regime of rising sea level. Since the available survey data includes a very energetic El Nino storm wave season, the design could be tested using real world observations not hampered by the assumptions of based-on-averages models.
6) The 10 pages of non-results from GENESIS analyses ends with a recommendation that this program not be used. This certainly would have been known beforehand by any coastal engineer who had ever attempted to use this program to provide real world answers.

Evaluation of ARS

1) Since the present evaluation is, in effect, a review of a review, much of the content in ARS is devoted to the deficiencies in EIC which have already been discussed here in the preceding section. In general, this information will not be further reviewed here.
2) As a general comment, ARS was comprehensive in its review and substantiated its arguments using detailed and fully explained references.
3) Beginning with section 4.3 and through the end of page 28, there are repeated assertions that submerged or semi-emergent structures inside the active surf zone **must** cause erosion (hereafter referred to as "the Rule"). The principal defense for this assertion appears to be Ranasinghe et al. (2006). This work involves a computational model arranged to match a 1:50 scale physical (wave tank) model in which a submerged surfing reef is placed at varying distances from the beach.
   The wave tank model results presented were limited to photographs of dye streaks in the zone between the reef and the beach which seemed to reproduce similar patterns in the numerically modeled flows. The smooth edges of the dye streaks indicate that there is no significant cross-shore-directed wave energy penetrating this zone, so that the numerically modeled results are not duplicated in the wave tank tests.
   In particular, Figure 11(b) in Ranasinghe, reproduced below, shows the numerical model predicting significant erosion of the bed (order 1m) between the reef face and the beach 50 m away. Also it predicts large accretionary lobes on either side of the reef that are not found in real reef contours. As a contrast to this model result, which is the basis for the

"The Rule", the measured contours of an existing reef close to the Cove are plotted adjacent to this model result. Tabletops Reef with a leading edge distance from the beach line of about 50 m, clearly inside the active surf zone, obviously breaks The Rule in a convincing fashion.

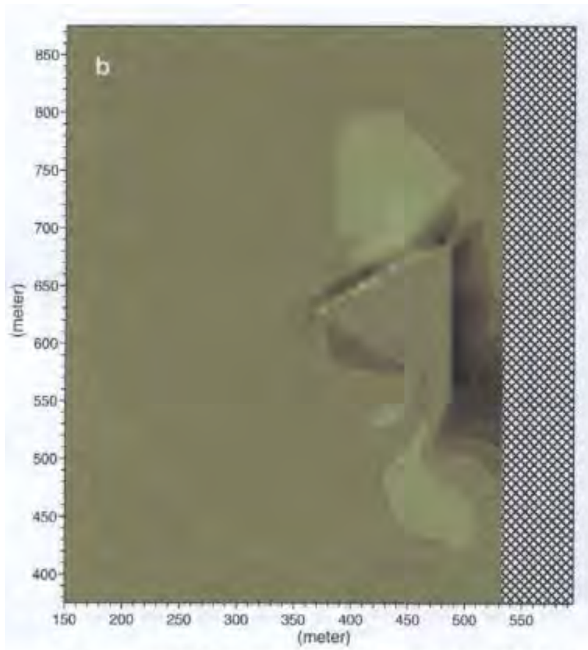
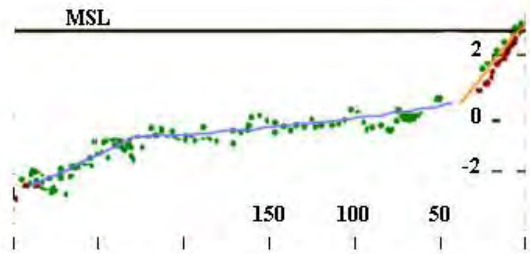


Figure 11(b) in Ranasinghe et al. (2006)



Tabletops Reef profile

Ranasinghe also ignores the strange situation presented in his Table 1 list of site characteristics in which Lido di Ostia #1 with a distance from the shore of 100m *erodes* and Lido di Ostia #2 which is only 50m away *accretes*. They appear to share the same wave climate and differ principally in their submerged depth – with the one that erodes the beach being submerged 1m deeper (inverse of what Ranasinghe claims). There are obviously serious problems with The Rule and based upon this evidence the multiple claims in ARS that the MSL and MLLW reefs defined in EIC should be rejected (on the basis that they will cause erosion) should be ignored.

4) In paragraph 4.3.1 ARS compounds the problem of using average wave conditions by justifying the average as "the most common wave condition." It is ridiculously easy to mentally construct time series in which the most common is far from the average. Unfortunately, this kind of name substitution tends to justify assumptions which are not statistically robust.
5) Given Japan's incredible record for constructing shore protection schemes that are failures (a subject well-known to this reviewer), the use

of Figure 4.1 depicting a dominant headland with an enormous shore-attached natural reef in its lee and a quite normal looking down-coast fillet (and also some obvious constructed reefs whose gaps show no signature in the coastline) is not a very convincing example of salient formation by offshore reefs.

6) The reference to surfing values in paragraph 4.2 is an interesting point. There was no consideration of this in the goals set for EIC. Given the realities of the powerful objections to any modification to the beach from the Surfrider Foundation, it is my opinion that even calling this a beach protection project would greatly decrease the chances of success for the City. On the other hand, construction of a functional surfing reef in this wave environment, which would certainly draw support from Surfrider (and lots of unsolicited design advice), has been shown to be a very expensive proposition. This is a result of the long wave lengths (forget the average wave), the destructive force of huge winter storms and wide range of deep water approach directions. Natural surfing reefs along this coast come in two basic types – beds of huge boulders (most are larger than 1m in diameter) at what were once river mouths, and uplifted ridges of hard native rock. Dayton et al. (1989) documents the fracture and overturn of huge sections of ridges weighing many tons at a depth of more than 30m from a single storm. This is probably not the ocean for fabric bag reefs.

7) The paper on the Boscombe Reef was quite informative. The narrow range of wave directions would seem to simplify the design for surfing performance (compared to the Cove) but post construction modification was necessary because of long waves, described as “beyond design specifications” (the average wave concept strikes again!) The existence of a very substantial groin field complicates the analysis of changes. In the first aerial view (Figure 3(c)) the groin cells have a pronounced underfill. There is no date on this record. In the top view of Figure 9, dated just a few weeks after the completion of the reef, there is no evidence of the groin cell structure and the area under the pier (which was a salient in the earlier undated picture) is now a depression. It suggests that a nourishment project may have been part of the redevelopment program and if so, would make evaluation of the salient formation possible only with information along a much greater coastal extent and over a much broader time span.

General Comments

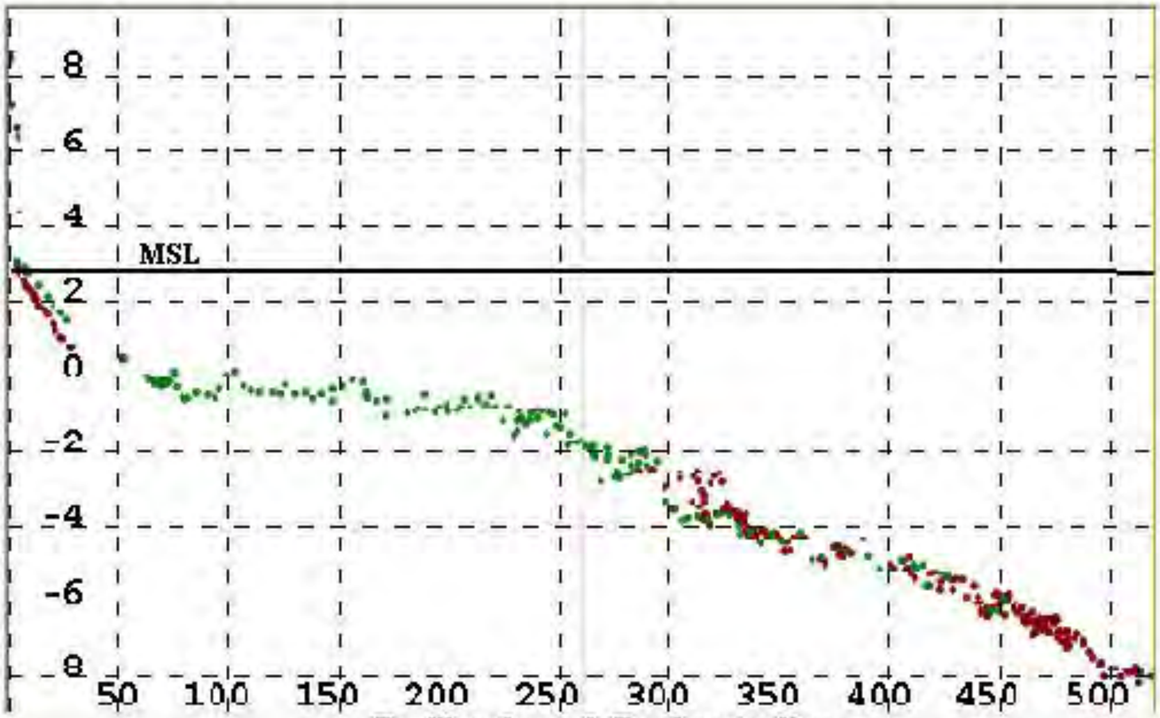
1) *Non-linearity of Sediment Transport*. Throughout both EIC and ARS, designs, predictions or estimates of salients of beach sand are proposed or predicted based upon an assumption of a locally reduced rate of alongshore transport. This process has been assumed to be amenable to modeling using some form of quasi-linear model involving a factor relating sediment suspension concentration to breaking wave energy and an alongshore velocity model that is also a function of a wave directionality parameter. The results of the GENESIS studies reported in EIC show that this relatively simple transport concept doesn't predict nature. On the other hand, this alongshore transport is infinitely simpler than the problem of predicting transport in the cross-shore direction. We are lulled into thinking that the salient we measure from the aerial photograph or the LIDAR map is a constant bump on the River of Sand. The wealth of data on beach profiles made possible by technology improvements like LIDAR, ATVs, GPS, JetSkis, etc. has done little to improve our ability to predict why a wave spectrum that rips out most of the sand on a beach in September will actually restore some sand to that same beach in March. Because alongshore currents are almost never fast enough to mobilize beach sand, cross-shore flows typically control the alongshore transport of sand. Therefore, diagrams showing neat patterns of assumed or modeled alongshore currents behind offshore reefs or breakwaters can tell very little of value if it is not possible to reliably estimate how much sand (if any) is mobilized by bed load or suspension from the cross-shore directed flows. Phenomena related to cross-shore transport are observed in the field that cannot be duplicated in the model basin, most probably largely caused by the inability to scale the sediment. Reversing the locations in that statement is equally true. Therefore, the safest and most reliable approach is to observe in nature what you want to duplicate and observe it as close as possible to your site so that the subtleties of sand size distributions and wave seasonality are duplicated to the highest possible degree. Nature has provided a MSL reef less than a mile away from the Cove. If it were somehow plunked down there today it would be something greater than 30m from the shoreline that would have existed without it. If the City would be happy to have another Tabletops at the Cove, it is already designed and time-tested. Otherwise, any different solution involves a measure of risk that is difficult to predict.

2) *Use of average values for wave characteristics*. Because a stable salient obviously depends upon the accumulative effects of alongshore sediment transport, it is important to understand the importance of a few extreme events in this process. Castel and Seymour (1986) using slope array data at Oceanside, a nearby site, found that 50% of the modeled annual gross

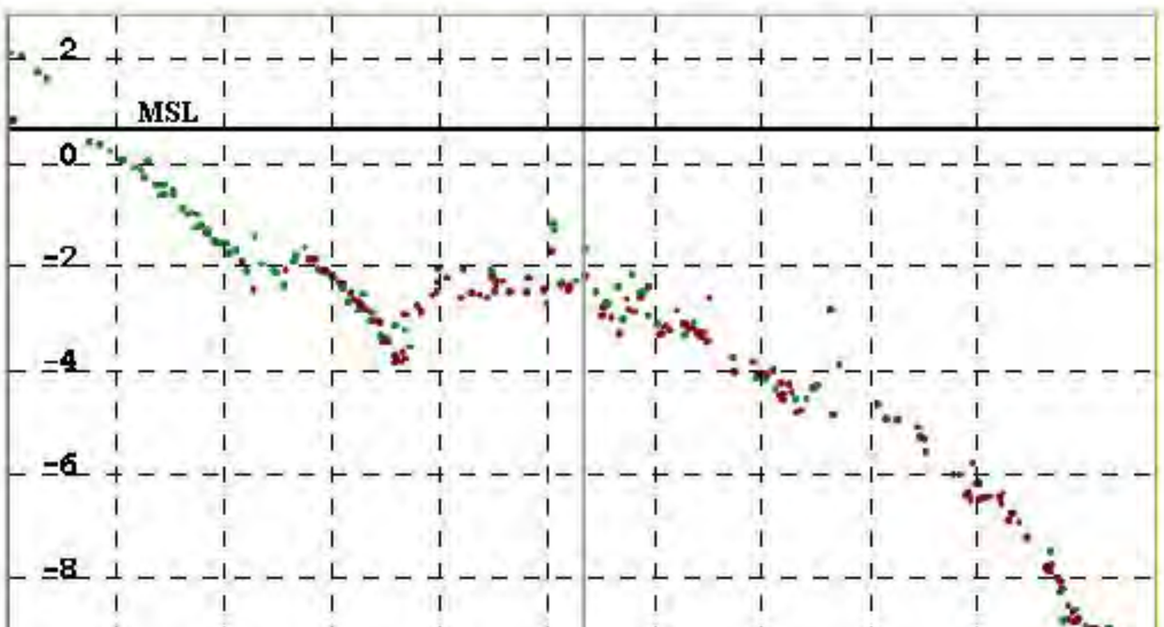
transport occurred in only 10% of the time in both 1979 and 1980. Even more significant, the seasonal net transport was a very small fraction of the gross transport throughout the year. This suggests that salients on this coastline (Tabletops, Crystal Cove, etc.) having no downcoast erosion are a product of the wave climate rather than reef configuration.

3) *Neglect of Tabletops Reef*. As part of this review, an assessment of the available information on this feature, which matches very closely the attributes of the MSL Crest Reef in EIC, appeared to be worth a few mouse clicks. First, the reef profile along its centerline (see Figure 1) was determined using the LIDAR bathymetry from two surveys, 2004 and 2009 (see Figure 2) [see http://cdip.ucsd.edu/SCBPS/?nav=data)] From the same web site, a number of beach profile difference plots were randomly selected (see Figure 3) comparing profiles in the Spring and the Fall of 2002. Figure 3A shows the maintenance of a 30m salient along the profile of the line depicted in Figure 2. Figure 3B, shows that, only 100m south of this line, significant differences between the fall and spring beach widths is evidenced. Figures 3C and 3D indicate similar seasonal changes in the vicinity of the reef location at the Cove considered for establishing a salient. This brief study was not intended to provide design information. It was intended only to indicate that valuable data are available here to support design approaches for a salient at the Cove. Figure 3B shows that, only 100m south of this line, significant differences between the fall and spring beach widths is evidenced. Figures 3C and 3D indicate similar seasonal changes in the vicinity of the reef location at the Cove considered for establishing a salient.

Figure 1 Selected Reef Centerline (CDIP MOP D0664)

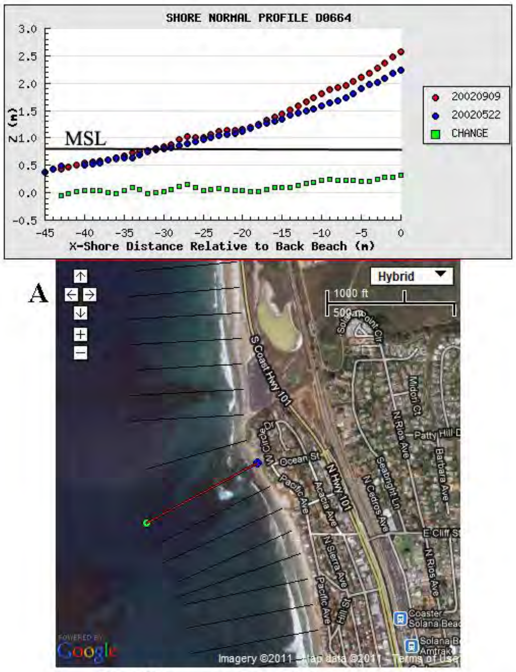


Profiles through Reef centerline

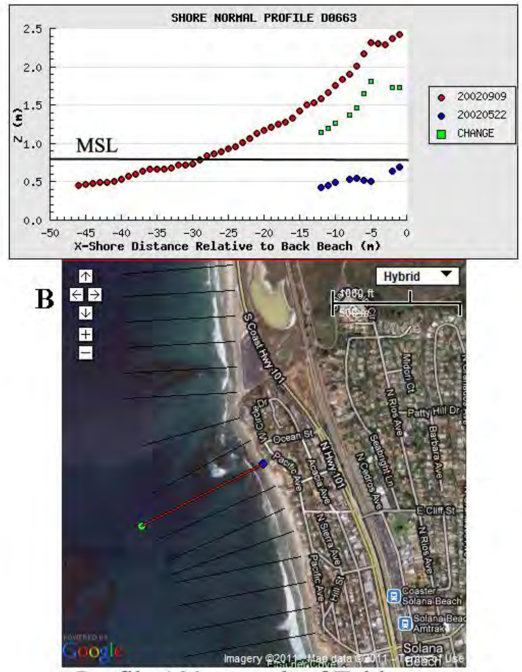


Profiles 100m south of Reef centerline

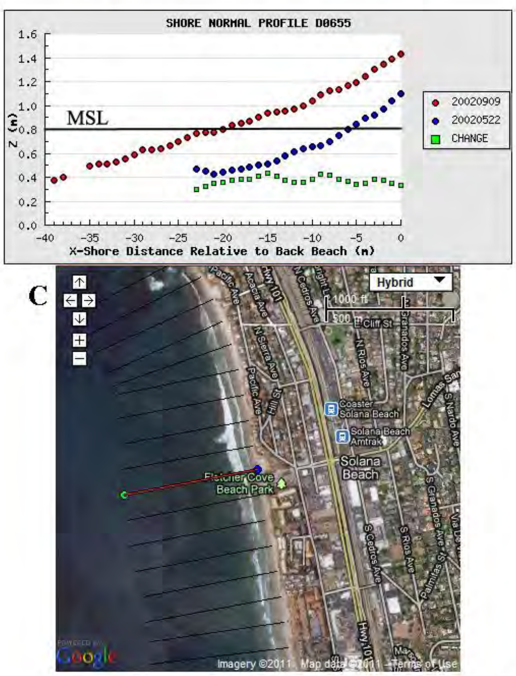
Figure 2 LIDAR profiles of Tabletops Reef 2004 & 2009

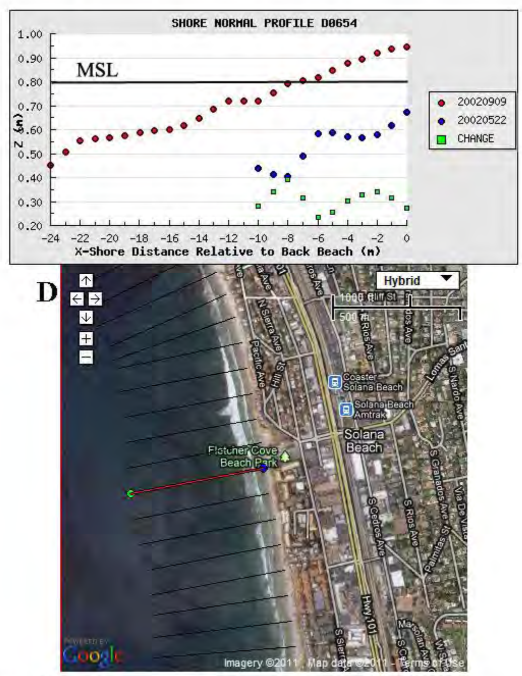


Profile across Tabletops Reef



Profile 100m south of Tabletops





Fletcher Cove Profiles

Figure 3 Fall (red) and Spring (blue) Profiles 2002

References

Castel, D., and R.J. Seymour. (Reprinted March 1986) Coastal data information program. Longshore sand transport report. IMR, U.S. Army Corps of Engineers, and California Department of Boating and Waterways. February 1978 - December 1981. IMR Ref. No. 86-2. 216 pp. (1982)

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