

CSBPA PRESENTATION

by WALTER F. CRAMPTON

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Being the last speaker of this session, I would like to start my presentation with a quick overview on coastal erosion to provide some perspective for the seawall debate. I would also like to take a moment and thank Professors Gary Griggs and Doug Sherman, along with their graduate students, for yesterday afternoon's session on increasing sand supply to Southern California's littoral cells. Possibly most important to this morning's discussions was Kiki Runyan's observations regarding both the Santa Barbara and Oceanside littoral cells. To quote from Kiki's abstract, "Overall, bluff erosion plays an insignificant role as a source of sand for the Santa Barbara littoral cell in particular. The total amount of sand supplied to the beaches by bluff erosion, whether under natural or actual conditions, is less than 1 percent of the total littoral budget for this cell. This is due in large part to the low percentage of sand in most of the bluff materials and the relatively low historic rates of bluff retreat. Removing riprap or seawalls as a mechanism for increasing the natural sand supply to the shoreline is not a worthwhile approach in this area; the potential sand augmentation is insignificant in the overall littoral budget and the associated impacts of removing armor far outweigh the very minor benefits that would be achieved. While there are impacts of coastal armoring (visual, access, etc.), none include significant impacts on the littoral budget of this cell." Kiki went on to discuss the Oceanside littoral cell and although she noted that bluff erosion contributes approximately 11.6 percent of the sand to the overall littoral budget within the Oceanside cell, the primary source area is northerly of Oceanside Harbor; including both San Onofre State Park and the Camp Pendleton area and within the Torrey Pines State Park area. Again, within the developed portion of the Oceanside littoral cell, as with the Santa Barbara cell, sediment contribution from the central more urbanized coastal bluffs amounts to approximately 2½ percent of the total littoral budget for the Oceanside cell, and the removal of seawalls as a mechanism for increasing the natural sand supply is again not a worthwhile approach within the Oceanside cell. These comments are particularly important coming from Dr. Griggs and his students, as I view Dr. Griggs as the environmental conscience of the coastal engineering community. This morning's presentation -

A Geomorphic Perspective on Sand Beaches vs. Seawalls



[Tulum](#)

Man's fascination with, and need to live adjacent to, the coast dates back well before biblical times. The Mayans, almost 2,000 years ago, considered Tulum one of their most important trading centers and built this lighthouse and other structures atop the coastal bluff. As capable coastal engineers, they recognized that coastal erosion is a function of the abrasion resistance of the cliff-forming material and undoubtedly chose Tulum because they knew that the limestone cliffs had very high unconfined compressive strengths, well in excess of that necessary to resist the onslaught of the occasional Caribbean hurricanes. In the last 2,000 years, sea level has risen 2 to 3 feet and I strongly believe that the appearance of this sea cliff has changed very little in the last 2,000 years. The sand, of course, is calcium carbonate, in essence broken up skeletal remains of marine organisms, as opposed to the crystalline silica that comprise California's beaches. Unlike most equatorial sands, primarily the calcium carbonates, the silicates originate from quartz, or the granitics from the upland watersheds of California's coastal ranges.



[Swami's 1939](#)

In San Diego's North County, although coastal development was fairly limited at the time, the Self Realization Fellowship temple constructed in 1939 was a testament to the special qualities of the coastal environment.



[Swami's 1941](#)

However, unlike their Mayan ancestors, they did not realize that our Eocene-age cliff-forming sediments do not possess the strengths of the Yucatan limestones, or even San Diego's older Cretaceous cliff-forming sediments. The coastal bluff failed only two years after the temple was built, but in fairness to the Self Realization Fellowship engineers, subaerial processes played a significant role in the early demise of this structure.



[D.C. Collier, 1905](#)

This photograph, taken in 1905 at the foot of Santa Cruz Avenue in San Diego's Ocean Beach area, shows one of Point Loma's original residences atop the coastal bluff where the sea cliff, the lower portion of the coastal bluff, is comprised of the Cretaceous-age, 120-million year old Point Loma Formation, possibly 5 to 10 times as strong as North County's Eocene sediments. Even in Ocean Beach, the cliff-forming sediments are overlain by the same terrace deposits, which extend from the Mexican Border up into Orange County.



[Santa Cruz Avenue, 1979](#)

Again, the same area in 1980, same offshore wave environment as San Diego's North County, and literally no erosion in 80 years. I should probably point out that the cove you see in the foreground resulted from differential erosion associated with a fault along the axis of the cove, allowing more accelerated coastal erosion to form the cove area. And yet, 100 feet to the south, the cliff-forming bedrock is so hard that literally no erosion has occurred in 80 years.



[Tide Beach Park, Aug. 1989](#)

Having illustrated the importance of rock strength on coastal erosion, which we will discuss again in more detail a little later in the talk, I would now like to focus on the real theme of today's presentations ... that of sand beaches and seawalls, and I'll focus on Solana Beach, one of our field trip stops, where we've seen literally no coastal erosion in almost a century, and in the last 4 years, Solana Beach has locally experienced upwards of 15 feet of sea-cliff retreat with some spectacular upper-bluff failures, all in the absence of seawalls. This photograph of Tide Beach Park in August 1989 nicely illustrates what Solana Beach was famous for ... beautiful sand beaches backed by natural and attractive, sloping coastal bluffs.



[Tide Beach Park, Jan. 31, 1999](#)

This is the same site in January 1999 during a tidal low of -1.5 feet, MLLW, with absolutely no sand beach and an exposed shore platform, which in this vicinity is about 2 feet below mean sea level, or, for talking purposes, $+1$ MLLW.



[1997 -98 El Niño Storm Surf](#)

About 6 hours after every low tide comes a high tide, and in the absence of a protective sand beach, add a little storm surf, as during the 1997-98 El Niño storm season, actually Christmas Day.



[Solana Beach Sea Cliff Collapse](#)

This is December 27, 1997, the El Niño storms, assailing the coastline in the absence of sand beaches, brutalized the Solana Beach coastal bluffs.



[Colton Seawall Under Construction](#)

The scourge of the seawall opponents. A 35-foot-high seawall under construction in Solana Beach where massive upper-bluff failures threatened bluff-top residences.



[Colton Seawall](#)

Although I am a coastal engineer and design seawalls, I am not a strong advocate of seawalls. I think everyone in this room will agree that healthy sand beaches, in addition to being a multi-billion-dollar recreational resource, protect our coastal bluffs and those private properties atop the coastal bluffs. With the loss of our sand beaches, we see accelerated coastal erosion and we find ourselves in an interesting and complex philosophical dilemma. And although the seawall debate pits sand beaches against seawalls, I can promise you that even in the total absence of seawalls within the 52-mile-long Oceanside littoral cell, it was man's urbanization of the coastal watershed and the resulting wholesale loss of sand that beget the seawalls. This seawall represents the last line of defense when insufficient sand is available to protect the coastal bluffs, much less provide a recreational resource. This seawall is 35 feet high and in essence replicates the vertical sea cliff, with a reconstructed sloping upper bluff that does look natural.



[Colton Seawall Edge](#)

This is the southern edge of the same seawall, and when people say that seawalls accelerate erosion, I can promise you that a wave cannot distinguish between the seawall and the coastal bluff. Actually, you will notice in this photograph the small notch adjacent the seawall that pre-dated the seawall. Just to the south, you can see the upper lip of the notch that has since failed from the vertical jet after the waves slam against the bluff, and on the right margin of the photo, you can see where the overhang has completely collapsed, creating a flat slab more planar than that of the seawall. Waves cannot distinguish between linear seawalls and linear coastal bluffs.



[Lake Hodges Dam](#)
[Feb. 22, 1980](#)

It has been said that seawalls deprive the beaches of sand. There is no question that San Diego's North County beaches' loss of sand is the result of extensive urbanization of the coastal watershed. The construction of dams and flood control facilities, the relatively effective elimination of sediment production within the watershed, and the extensive mining of the alluvial sands from the lower reaches of the County's rivers has effectively severed the natural supply of historical sediment to the littoral zone. These conflicting societal interests, presumably for the benefit of the citizens of this county, have clearly been to the detriment of the County's coastal resources. This is Lake Hodges Dam on the San Dieguito River along the southerly border of Solana Beach during the February 1980 storms, the second time this dam spilled since its construction in 1941. This dam also severs 93% of the San Dieguito River's 327 square mile watershed from the littoral zone. More troublesome is man's exhaustive sand mining activities in the lower reaches of this county's major rivers to enable the many construction activities that we, as a county, embrace. In the Oceanside littoral cell today, there is a 30 million cubic yard sand deficit. Yet in the last 60 years, just sand mining alone in San Diego County almost exclusively downstream of the county's dams and reservoirs, has removed over 100 million cubic yards of beach quality sand originally destined for the beach. There has been much discussion of the cumulative impacts of seawall construction, but I would ask you, What of the cumulative impacts of development within the upland watershed? The wholesale elimination of littoral sands reaching this county's beaches has had a significant cumulative environmental impact on this coastal resource.



[Tide Beach Park](#)
[looking south,](#)
[Dec. 12, 1997](#)

This is again at the foot of Tide Beach Park on December 12, 1997, still early into the El Niño storm season, looking south at a totally sand-barren bedrock shore platform at an extreme tidal low. Again, the platform/sea cliff junction elevation is around -1 foot, MSL.



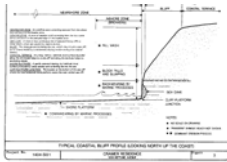
[Tide Beach](#)
[Close-Up](#)
[with Dave Skelly](#)

And in this close-up with Dave Skelly for scale, you can imagine that the elevation of a healthy sand beach would be about +12 feet, fully protecting this entire sea cliff. However, in the absence of a sand beach, the sea cliff is now subjected to wave activity and cobble abrasion on a daily basis.



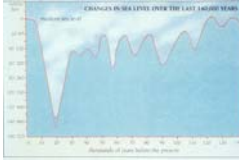
[Dec. 1997,
Blackburn
Slope Failure](#)

The current lack of protective beach sands has resulted in a dramatic increase in the rate of marine erosion not previously observed in San Diego's North County. It is this loss of sand and the resulting coastal erosion that has necessitated structural fortification of coastal bluffs and low-lying river valleys to protect adjacent coastal improvements. Even considering this background, many people blame the construction of seawalls for the accelerated loss of sand beaches and the associated loss of public access. There are some that would have you believe that by not allowing seawalls, the sandy beaches that once existed along Southern California would return. As a coastal engineer, I can unequivocally guarantee you that the millions of people that now live along the Southern California coastal watershed, extending from the coastal ranges often 50 miles inland and extending out to the coast, have eliminated that possibility.

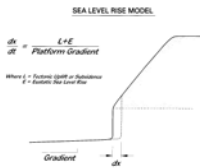


[Geologic
Profile](#)

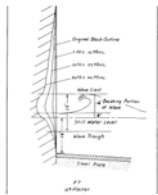
To understand the geomorphology, or the evolution of San Diego's North County coastal bluffs, we must first look at the geology comprising these coastal bluffs. The coastal geology fronting the entire San Diego County coastline is comprised of a lower cliff-forming Tertiary or Cretaceous-age sediment, in all cases overlain by Quaternary-age terrace deposits. The Rose Canyon fault, which defines the headland of the La Jolla Submarine Canyon and crosses the coast a short distance northerly of La Jolla, has offset the geologic section, resulting in 120 million year old Cretaceous cliff-forming sediments southerly of the Rose Canyon fault, extending continuously down to the tip of Point Loma ... remember D.C. Collier's house in Ocean Beach ... then we find the younger 50 million year old, and generally weaker, Tertiary cliff-forming sediments extending northerly, well into Orange County. Remember the Self Realization Fellowship temple collapse in 1941. This conceptual coastal bluff profile is important in that it illustrates the top of the coastal bluff, which coincides with the seaward edge of the coastal terrace, the geologic contact between the lower cliff-forming sediments, and the upper terrace deposits and the contemporary shore platform, which has been created by relatively recent, in geologic terms, relatively recent marine erosion. The contact between the cliff-forming sediments and the upper terrace deposits is important also, in that this geologic contact itself represents an abrasion platform, which formed about 125,000 years ago when sea level was about 25 feet higher than it is today. Obviously, the buried coastline would be off to the right of this picture; actually, in Solana Beach, it's about 1,200 feet to the right of this picture along Cedros Boulevard. When sea level dropped some 120,000 years ago, the terrace deposits formed on this old abrasion surface. The relic abrasion surface and the contemporary shore platform have the same geomorphic origins and represent the abraded surface of the sea floor, as marine erosion advances the coastal bluff landward. Recognize also that the transient sand beach resides on top of this bedrock shore platform surface, with a healthy back beach berm at around elevation +12 feet, and throughout Solana Beach and Encinitas, this cliff/platform junction elevation is around -1 foot MSL. Thus, when compared to the healthy backbeach of a decade ago, today we have lost upwards of 13 to 14 feet of a protective barrier that in the past has protected this coastline from marine erosion.



Changes in sea level drive coastline changes. I want to draw your attention to this high still stand, 125,000 years ago, which was responsible for the configuration of our contemporary coastline. It was at that point in time that the relic abrasion surface was formed. That surface we see in our coastal bluffs, below which we have relatively old cliff-forming sediments, and the terrace deposits above. This slide is also important in that it shows the last ice age, roughly 19,000 years ago, when the eustatic water level was almost 400 feet below today's sea level. This coincides with the edge of our continental shelf about a mile and a half offshore and represents the location of the coastline 19,000 years ago. In the ensuing 19,000 years, as sea level rose, if we were around for that entire period of time, we would have observed essentially 8,000 feet of sea cliff retreat.



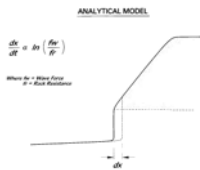
Although I'm not going to dwell on this, this represents the sea level rise erosion model, which, in geologic time scales, nicely represents the big geologic picture on coastal erosion, driven by sea level rise. This basically says that, at least on a geologic time scale, the rate of sea cliff retreat equals sea level rise divided by the shore platform slope. I only include this to acknowledge the impact of sea level rise, which is significant.



But what I would like to focus on is the actual erosion mechanism of the coastal bluff, and here I've copied this from Sunamura's work, where the assailing waves most efficiently impact the coastal bluff around mean high tide, slowly scouring out a notch at the base of the sea cliff using both hydrodynamic wave force and cobble abrasion to enlarge the notch until the overhang collapses.



This photo of the sea cliff in Encinitas clearly shows the development of the basal notch in the background and the collapse of the overhang in the foreground. This sea cliff collapse then undermines the upper terrace deposits and propagates failures up to the top of the bluff. As the sea cliff in this photograph and in Solana Beach is comprised of a cemented sand, this sand then contributes to the littoral system.



This mathematical model developed by Sunamura really distills the whole coastal erosion process into one simple equation ... and I promise, this is the last equation ... but it basically says the erosion rate is proportional to the natural logarithm of the wave force divided by the rock resistance. A couple of things are implicit to this equation. First off, it is important to recognize that there is a threshold wave force below which no additional erosion can occur, and obviously the wave force that we are interested in is what actually impacts upon the coastal bluff, and this is a function of the presence or absence of the protective sand beach. In other words, a healthy sand beach pushes f_w below its threshold, and there's no coastal erosion. Of course, the other obvious thing is that by increasing the rock's resistance, or actually its unconfined compressive strength, it increases the threshold wave energy necessary to cause erosion.



Let's for a moment go down to the Point Loma Peninsula. Again, if you recall D.C. Collier's house, along this section of coastline, we have fault-controlled irregularities along the coast, where sea caves form along fault traces, where the rock resistance is somewhat weaker, eventually forming coves and occasionally small pocket beaches. But the headlands themselves, where you have intact, unfractured rock with unconfined compressive strengths often well over 1,000 psi, the rock is so resistant that essentially no recognizable marine erosion is occurring over literally several thousand years, allowing sea level to rise against an essentially vertical sea cliff, drowning out the shore platform, leaving a deep-water sea cliff void of a sand beach, void of lateral access, void of passive erosion, and exposed to progressively higher wave energy.



This is roughly the same latitude, again in Point Loma, about a mile offshore in 100 feet of water where we have a submerged sea cliff. There is a notch at the base of the sea cliff and, as sea level rose, the bedrock was so hard that sea level continued to rise without eroding the cliff, essentially drowning out the lower portion of the cliff. But as sea level at that time rose 20 feet, and think of the wave energy that you could propagate into this sea cliff at 20 foot water depth. But at this point, I believe the lithology changed, allowing significant erosion, with the sea cliff retreating and leaving this now submerged relic very hard and erosion resistant shoreline.



A decade ago, Solana Beach had a relatively healthy back beach, and photographs back to the 1920s confirm that this coastline has had virtually no erosion. In spite of the 1982-83 El Niño storm season, which I would propose withdrew sand offshore to create an offshore bar that tripped storm surf to minimize the erosive wave energy impacting the coastal bluffs. A decade ago, the Solana Beach coastal bluffs contributed nothing to the Oceanside Littoral Cell.



The same location a decade later is now missing upwards of 14 feet, +12 to -2, 14 feet of protective sand beach, exposing this sea cliff to potentially erosive wave energy day in and day out, and although significantly weaker than the Point Loma Formation, these sea cliffs are still tough enough to not yield much of any sand under normal wave conditions, even with a totally scoured beach face.



It is true that during the 1997-98 El Niño storm season, locally significant sea cliff failures occurred, possibly averaging 6 to 10 feet in sea cliff retreat. This time without the offshore bar. But this retreat occurred during a period of violent storms, with all of that sea cliff sediment immediately swept away.



And yet two years later at Fletcher Cove, a little over 1,000 feet downcoast, two years of constant wave attack has still not failed significant sections of the coastline, still in the absence of any sand. Yes, a notch is forming. But after two years, there is still no collapse of the sea cliff, no sediment production from the sea cliff, and no contribution to the littoral system. And again, that sea cliff, whether it's a seawall or a sea cliff, the waves cannot distinguish between the two. And the sediment release from the sea cliff is many orders of magnitude less than the available littoral transport capacity that the offshore wave environment provides. And that's averaged over the entire 1.4 mile Solana Beach coastline.



If we go a short distance downcoast, and again this is the entire Solana Beach coastline photographed two weeks ago during a tidal low of 0.8 feet, MLLW, with some residual SANDAG sand still remaining – Fletcher Cove is here in the middle. But what I draw your attention to is a very minor erosion-resistant headland just northerly of the southerly City limits that's created a small sand fillet quite small, yet enough to reduce the available wave energy actually impacting the sea cliffs.



Along this section of coastline along one project, there was a total of 18 sea caves filled in 1986. Remember, all of these sea caves originated on old micro faulting lineaments, with relatively intact rock literally 5 feet from the fault axis. And we have the same Solana Beach coastline, the same cliff-forming materials, the same Solana Beach geology, the same unconfined compressive strengths, and the same offshore wave environment. And yet, 4,000 feet southerly of where we saw upwards of 6 to 10 feet of erosion during the 3-month 1997-98 El Niño storm season, we have had possibly 2 to 3 inches of sea cliff retreat over 15 years. Why? Because this small protective sand fillet has reduced the wave energy below the threshold necessary to cause erosion. So actually, along the southerly third of the Solana Beach coastline, there is virtually no erosion at all occurring, again in the absence of any significant sand beach, with again no sediment production.



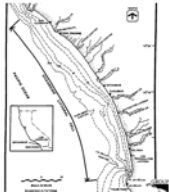
Still in Solana Beach, and in Encinitas, slope failures are still occurring, putting both the public and bluff-top structures at risk. More importantly, and using north Solana Beach as an example, there has been no protective sand beach to reduce the wave energy and, hence, this localized erosion. Important also is that the volume of erosion is many orders of magnitude smaller than the available transport capacity and the sand is immediately gone. In other words, the sea cliffs ... think again of Sunamura's model ... the sea cliffs are strong enough to not release enough sand to materially affect the littoral system and it will not get better in Solana Beach unless we artificially renourish the beach and consider sand retention structures. By not allowing seawalls, we will not fix the problem. The public will continue to be at risk and I would submit to you that there is absolutely no benefit to the quality of life that we associate with the coastal experience if we do nothing to ameliorate the societal impacts from the upland watershed on this coastal beach.



In closing, I want to show two final slides and speak for a moment about the currently available sediment within the Oceanside Littoral Cell, and I give Dr. Flick, an Oceanographer, credit for this admittedly geomorphic perspective on the littoral budget within the 52-mile-long Oceanside Littoral Cell. This is San Onofre State Beach --- probably the biggest sediment producer within the Oceanside Cell, and in the northern end of the cell. And the cliffs at San Onofre and Camp Pendleton, both north of Oceanside Harbor, are the big sediment producers to the north.



Along the southern end of the Oceanside Cell, Torrey Pines State Beach and the landslides here are the other big sediment producers. But this is along the southern end of the cell, with both sediment sources a fairly significant distance from Solana Beach and Encinitas. Conservatively, these three areas produce about 350 cubic yards of sand per year. However, by contrast, erosion of the unprotected cliffs in Solana Beach may contribute, at most, 5,000 to 10,000 cubic yards of sand per year, and this is post 1997-98 El Niño storm season with a scoured beach profile.



If we address, for a moment, the longshore transport within the entire cell, and again using Dr. Flick's numbers, estimates of long-term transport potential average about 750,000 cubic yards per year to the south, and 550,000 cubic yards per year to the north. This means that a total of about 1.3 million cubic yards of gross transport per year are capable of being mobilized, with a net southward rate of about 200,000 cubic yards per year. The problem, of course, is the sediment producers are at the extreme northern and southern end of the cell, and there is in essence a small shadow in the middle where sand is trapped north of Oceanside, deflected offshore south of Oceanside, and lost in the La Jolla Submarine Canyon from the southerly margins of the cell, with a net significant and persistent deficit within the central portion of the cell, specifically Solana Beach and Encinitas, or, worst case, 10,000 yards of sediment may be released by the coastal bluffs where we've got a 1.3 million cubic yard transport capacity to remove it out of the small Solana Beach Subcell. It is not lost to the littoral system within the Oceanside Cell. It's just lost to Solana Beach and seawalls have no impact on this coastal and geomorphic process.



Much has been said about passive erosion during the course of this conference. And from a geomorphic perspective, and we will again use Solana Beach as the example, the total lack of any transient sand beach is necessary to cause the small amount of erosion or sediment production from the sea cliffs to occur. In other words, if you add even a small amount of sand, the erosion stops, and that small amount of sand is insufficient for any recreational value in Solana Beach. If we don't renourish the beach, the erosion that does occur will advance the profile easterly, never improving lateral access. The rate of downwearing is equal to the shoreline retreat divided by the shore platform slope, or at this location about 1/60 of the sea-cliff retreat rate. If we add a seawall as a last resort to protect bluff-top improvements, the effect of passive erosion, and really its impact on lateral access, is gradually deepening water from sea level rise and downwearing, both of which over the next century would be less than a foot. Now compare that with the 14 feet of sand loss here in the last decade, clearly a cumulative impact, and the 14 feet that we should put back if we are to fully renourish the beach and reacquire the recreational benefits that existed here not that long ago.

Thank you.