PROJECT MEMORANDUM

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JN 1151-01
County of Santa Barbara Parks Division
Goleta Beach Shoreline Management Assessment

To:	Jill Van Wie
From:	Jon Moore
Date:	August 16, 2017
RE:	Assessment of Emergency Revetment and Shoreline Management Plans
Cc:	Dan Gira

Introduction

In accordance with our professional services agreement with the County of Santa Barbara (County), this memorandum summarizes our analysis and assessment of the Goleta Beach County Park (Park) emergency revetment and shoreline management plan. The Park has experienced episodic coastal erosion damages since 2000 that have progressively increased the need for shore protection measures to protect upland park space. After ten years of relatively wide beach conditions and no major threats to the Park, a series of severe storms occurred between 2014 and 2017 that eroded the beach and caused extensive damage. After the storm events of January 21, 2017 and February 16 to 19, 2017, the County has now protected all of the Park's shoreline with the addition of 870 feet of low crested stone revetment in the central area of the Park in an effort to limit further loss of facilities.

The County is currently considering alternative long-term shoreline management strategies for the Park as part of the Goleta Beach Adaptive Management Plan (AMP). Goals and objectives range from trying to protect as much park space as possible in balance with managing a healthy beach to progressive retreat measures to relocate and/or abandon facilities landward in response to future events. This memorandum summarizes our coastal engineering review of the park's historical past, present condition, and future expectations along with a brief assessment of the proposed alternative shoreline management strategies. The purpose of our assessment is to assist decision makers with their evaluation process and selection of an appropriate path forward.

Goleta Beach Shoreline Setting

Goleta Beach County Park is located within the southern coastline of Santa Barbara County approximately nine miles west from the City of Santa Barbara. The park was originally constructed in 1945 using non-select and mostly clay soil fill material. The beach consists of a south facing shoreline within Goleta Bay within a coastal reach that may roughly be defined as extending from the projection of Campus Point to the west and the rocky outcrop of tar seeps on the eastern side of Goleta Slough, approximately 4,500 feet east of developed areas of the Park. The bay forms an elongated pocket beach that is semi-protected by the Isla Vista headland. **Figure 1** shows a vicinity map of the regional coastline.

The Goleta Beach shoreline is a short reach within the Santa Barbara Littoral Cell that extends from Point Conception to Point Mugu in Ventura County. It is one of the longest littoral cells in Southern California and includes a variety of coastal types and shoreline orientations. The cell's principal feature is its predominate net alongshore littoral transport direction. Wave shelter provided by the offshore Channel Islands results in almost unidirectional sand movement from west to east in south Santa Barbara County. Some occurrences of Southern Hemisphere swell and pre-frontal storm seas can result in times of upcoast reversal, but the predominance of westerly waves means that any reversed transport volume is only a small fraction of the annual total. Although most beaches along this section of Santa Barbara County are relatively narrow and composed of thin lenses of sand over bedrock, the Goleta Beach segment is more sand abundant because it is located within a fluvial plain (Noble Consultants, 1989).

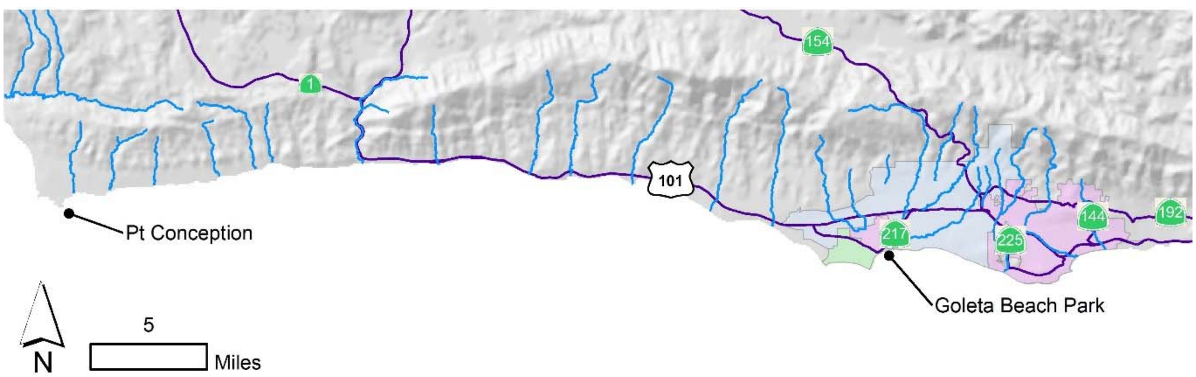

Figure 1. Vicinity Map

Sediment Sources

The littoral sediment at Goleta Beach is the product of fluvial delivery of sand from the upcoast mountain creeks and streams, cliff erosion, and discharges from Goleta Slough as illustrated in **Figure 2**. Stream flows within the small creeks and streams that populate the Santa Ynez Mountains are episodic but can produce significant yields at the mouths in response to sustained periods of rainfall. However, most of the larger creek systems, particularly those that drain into the Goleta Slough, are controlled with debris basins which capture most of the sand that would otherwise find its way to the beach.[1] Estimates of average annual fluvial sediment delivery between Point Conception and Goleta Beach are on the order of 190,000 cubic yards per year (Noble Consultants, 1989; Willis and Griggs, 2003).

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[1] Debris basins are generally confined to the urban area, with the large basins located within the Goleta Slough capturing particularly large amounts of sediment. Streams in rural areas along the Gaviota Coast do not typically support debris basins.

However, the sediment input in any year can be affected by rainfall amount, fires within the watershed, and flood events.

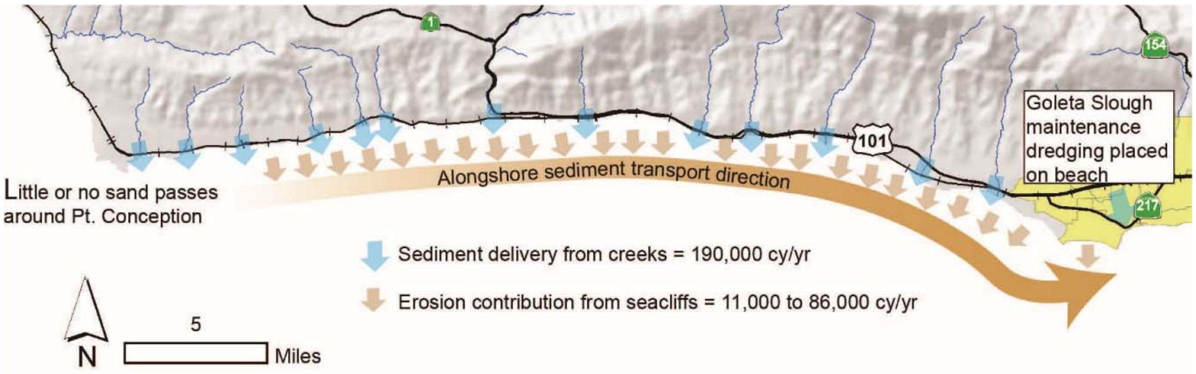

Figure 2. Sediment sources to Goleta Beach

Significant increases in sediment input from the mountains to the coast may result from the aftermath of major forest fires as storm water runoff within a denuded burn area can result in more soil erosion in the watershed that is ultimately discharged at the coast. The 1955 Refugio Fire, which burned approximately 123 square miles or 79,000 acres (CalFire, 2017) between Gaviota and Goleta, is theorized to have been responsible for a dramatic beach accretion period that peaked between 1966 and 1973 (See **Figure 3**). The majority of this area has not burned in the more than 60 years since that event.

Figure 3. Burn limits of the historic 1955 Refugio fire.

Wild fires within the Santa Ynez Mountains watershed are episodic, and cannot be predicted with certainty, although the US Forest Service has noted that wildfire frequency in California has increased substantially (Safford, 2017). Over the last 30 years, at least 5 major wildfires have occurred in the area of the Santa Ynez Mountains that may have contributed sediment to Goleta Beach. In 2016, the Sherpa Fire burned over 7,400 acres in the Del Capitan and Refugio Creek watersheds (CalFire, 2017). This fire was followed by heavy rain and localized flooding that potentially delivered more sediment into the littoral system upcoast of Goleta Beach. Most recently, approximately 6,000 acres of the 2017 Whittier Fire burned areas that contribute sediment to creeks feeding the littoral system that feeds Goleta Beach.

The contribution from eroding coastal bluffs was estimated by Diener (2000) based upon comparison of topographic maps published in 1947 and aerial photographs flown in 1997. He concluded that seacliff recession along the shoreline east of Goleta contributes about 106,000 cubic yards per year to the littoral system. Patch and Griggs (2005) further refined this estimate based upon their assessment that the bluff sediments consist of higher proportions of fine grained sediment that would not be compatible with the coarser grained beaches. Consequently, they believe that Diener's estimated source volume, in terms of beach benefit, may be overstated by a factor of three.

Goleta Slough has historically delivered sediment to the shoreline within a watershed that includes Tecolito, Los Carneros, Atascadero, San Jose, and San Pedro Creeks (see **Figure 3**). However, debris basins and flood control channels within the Slough and its tributaries now trap most of the material. Since the 1970s, the County has routinely maintained the channels to remove accumulated sediment, but it wasn't until 1994 that beach compatible sediment dredged from these basins started to be conveyed to the shoreline by either truck or hydraulic dredging (Santa Barbara County, 2010; Padre Associates, 2012). Large volumes of sediment can be trapped in the Slough channels during wet winter storm seasons. An extreme example was the January 10, 1995 storm when 200,000 cubic yards of sediment was deposited in the Slough's channels in less than twelve hours. Similar flooding and sedimentation occurred two months later on March 10, 1995 (BEACON, 2001). Sampling and testing of the sediment over the years indicates that the fraction of fine sand content varies from about 75 to 90 percent (County of Santa Barbara, 2010).

A summary of the volume of sediment that has been placed on Goleta Beach since this time is shown in **Figure 4**. Over one million cubic yards of beach quality sediment has been placed by the County between 1994 and 2011 during 11 nourishment cycles.[2] The sand source has predominantly been Goleta Slough, but on occasion sediment has been imported from accretion deposits in Santa Barbara Harbor. This volume total translates to an average annual nourishment rate of over 50,000 cubic yards at Goleta Beach over the 18-year period. The

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2 This volume excludes approximately 138,000 cubic yards of beach quality sediment that was acquired by a private developer in 1998 which made the material unavailable for beach replenishment (Spencer, 2017).

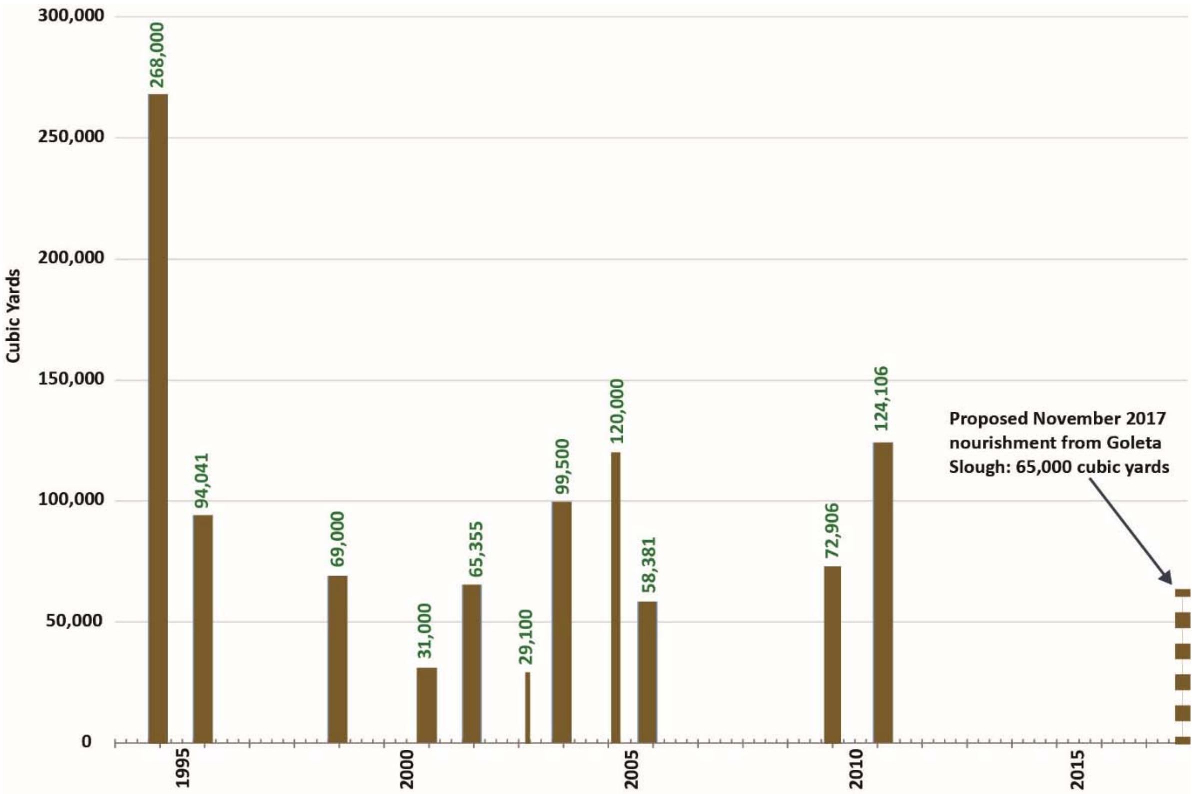

Figure 4. Goleta Beach Nourishment History The figure shows the volumes and approximate time periods of when sediment was placed on Goleta Beach since 1994. Most of the beach quality material was dredged from Goleta Slough and its tributaries, but on occasion, sand was imported from Santa Barbara Harbor. Source: Data from Coastal Frontiers Corporation, 2017 and Spencer 2017.

2012-2016 five-year long severe drought interrupted the regular beach nourishment frequency. However, even accounting for the recent severe drought, since the program commenced in 1994, the frequency of the County's beach nourishment cycles at Goleta Beach has on average occurred about once every two years. Nearly half or five have been major sand placements totaling approximately 100,000 cubic yards of more that occur at intervals of anywhere between one to eight years. Future nourishment cycles cannot be predicted with certainty. However, if the recent past is a reflection of future occurrence, the historical record indicates that sediment placement volumes from the Goleta Beach nourishment program will continue to be similar to what has been experienced thus far.

Shoreline Changes

Before placement of fill behind the beach in 1945, Goleta Beach was considered to be a shifting sand spit regularly breached by the Goleta Slough. Significant changes have been noted since that time. Historical aerial photographs flown between 1938 and 2003 were analyzed (Revell and Griggs, 2006; Revell, 2007) to review changes that were visible over that time period. A summary of the beach measurements is shown in the bar chart of **Figure 5**. The data indicates that the beach accreted between 1938 and 1966, eroded during the 1968/69 and 1972/73 El Niño storm seasons, and accreted again to its maximum recorded width by 1975. The effects of the record 1982/83 El Niño severe storm winter season are shown by the abrupt loss when the beach permanently receded by over 100 feet from its maximum recorded historic width. Thereafter, the beach has been steadily eroding at a rate that varies from about 3 to 6 feet per year as shown in the green inset box of **Figure 5** (Moffatt and Nichol, 2007; Everts Coastal, 2006).

Comprehensive shoreline monitoring of Goleta Beach has been performed by Coastal Frontiers Corporation since 2004. The program consists of precision beach profiles surveys conducted every Spring and Fall to observe seasonal and longer term trends. Three profiles are located within the park's shoreline, one is roughly central to the sand spit near the Goleta Slough mouth, and two end transects on the east and west ends are intended to note conditions upcoast and downcoast of the park limits. The results of their measurements to date are reproduced in **Figure 6**. The data indicates a strong correlation with the County's beach nourishment cycles and episodes of beach accretion.

The short term increases in beach width observed during the 9-year period between 2005 and 2008 and 2010 and 2012 are believed to be the direct result of two clusters of nourishment activity. Between nourishments, the beach exhibits a net erosion trend similar to previous observations (see **Figure 6**). The 2016 surveys reflect the cumulative results of the prolonged and severe five-year statewide drought and exposure to one of the most severe El Niño winters on record. Although Southern California was spared the brunt of the storm waves, sea and swell was nonetheless energetic, coincided with high tides, that stripped Santa Barbara County South Coast beaches of sand. Recovery of area beaches from these severe erosional events will likely require an infusion of increased sediment delivery to the coast to naturally replenish the littoral system and reverse the erosion trend. Such a reversal cannot be predicted, but it typically occurs during and after periods of heavy rainfall and flooding when the local streams and creeks, particularly within burned areas, generate significantly larger volumes of sediment runoff the flows to the coast or deposits within Flood Control collection basins. The latter then becomes immediately available for beach nourishment. As previously discussed, County records of Goleta Slough maintenance dredging activity indicate that major sediment deposition events occurred in five times between 1994 and 2011. However, when or whether the south Santa Barbara County shoreline can sufficiently rebound and recover from the recent major erosional episode remains to be seen.

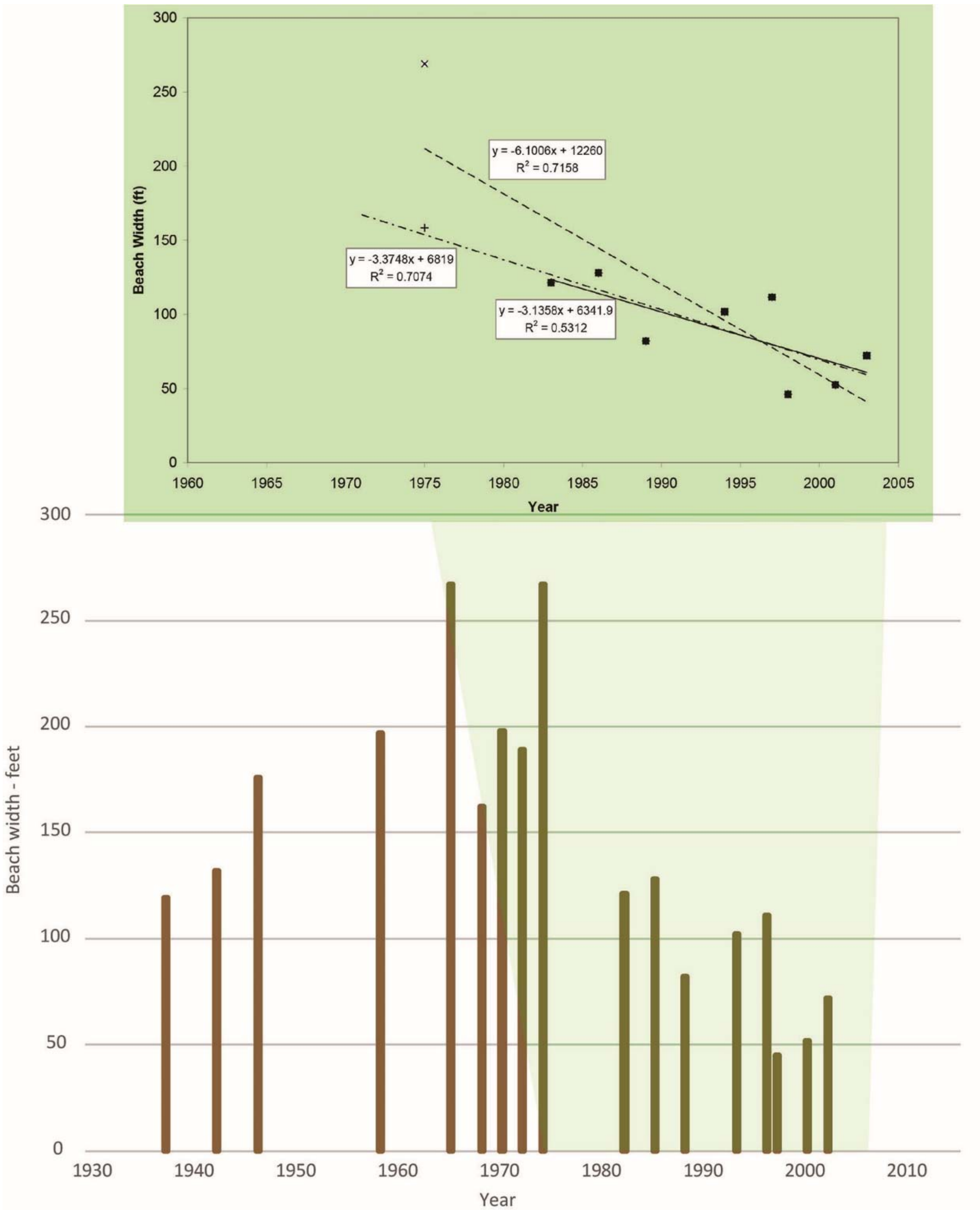

Figure 5. Goleta Beach widths 1938 to 2003. The figure shows historical beach widths measured from aerial photographs flown between 1938 and 2003 (Revell, 2007). The inset box is reproduced from Moffatt and Nichol (2007) and illustrates their interpretation of the erosion trend after the record 1982/83 El Niño winter when significant losses occurred. The regression lines represent recession trends of 3 to 6 feet per year depending on whether the 1982/83 losses are included in the analysis.

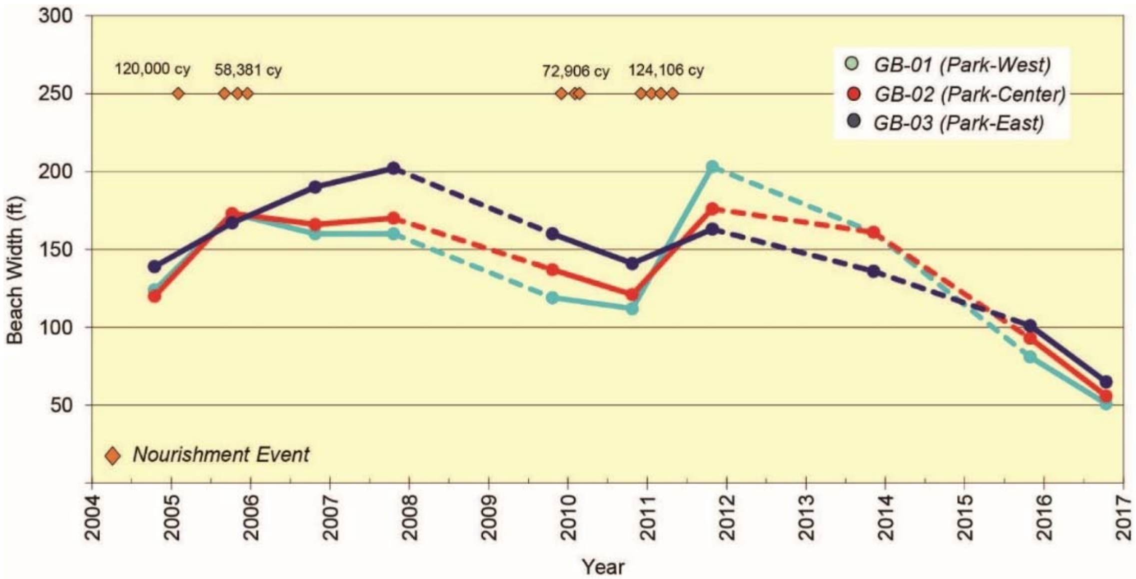

Figure 6. Goleta Beach widths 2004 to 2016 (Fall Only).
Reproduced from Coastal Frontiers Corporation, 2017.

A summary of wave conditions that effected Goleta Beach are shown in **Figure 7**. The figure illustrates the number of days that wave height exceeded either 8 or 12 feet and provides a general indication of wave climate over the beach monitoring period. The 2009/2010 and 2015/2016 measurement years reflect the increased duration of higher wave conditions associated with the more severe El Niño winter seasons that occurred.

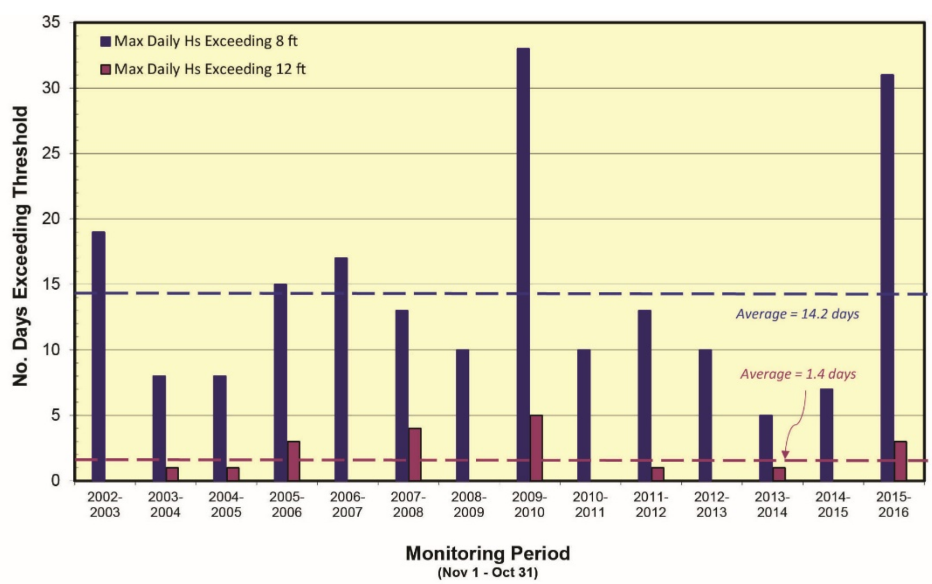

Figure 7. Wave data summary from CDIP Goleta Point Buoy
Reproduced from Coastal Frontiers Corporation, 2017.

Between 2004 and 2016, the long-term average annual volume loss, including drought years, at Goleta Beach has been about 50 cubic yards per profile (Coastal Frontiers, 2017). This implies a total sediment loss of approximately 150,000 cubic yards over the beach's 3,000-foot length. During this same period, nearly 400,000 cubic yards of material from Goleta Slough maintenance dredging and Santa Barbara Harbor sediment sources was placed at Goleta Beach (County of Santa Barbara, 2014). This implies that the overall sediment loss over the twelve-year period was about 550,000 cubic yards. Although the loss rate was variable between beach transects over the monitoring period, the survey data shows that the recession was relatively steady with some accelerated erosion occurring during the severe 2014 storm event and 2015-2016 El Nino winter season. The measurements suggest that an average annual sediment loss during this monitoring period is roughly on the order of 40,000 to 50,000 cubic yards per year. This number is about 20,000 to 30,000 cubic yards per year higher than previously estimated (Moffatt and Nichol, 2007). The discrepancy may partly reflect the cumulative effects of the recent drought which interrupted the County's beach nourishment activities between 2011 into 2017.

The benefits of the Goleta Beach nourishment program are clearly evident from the **Figure 6** beach monitoring data. The volume of sediment that was placed on the beach between 2010 and 2011 restored beach widths to their 2008 wide condition as shown in **Figure 8**. The 150 to 200-foot wide beach at that time enhanced the recreation opportunities and significantly increased the beach's storm protection buffer distance.

Figure 8. Goleta Beach in June 2012. The photograph shows beach conditions following the 2010-2011 beach nourishment cycle. Beach width is about 150 to 200 feet wide.
(Source: Amec Foster Wheeler, 2016).

By the fall of 2013 Goleta Beach remained a relatively wide sandy beach at about 140 to 160 feet wide. During the winter months, the beach width will typically be more narrow. The net shoreline erosion and the cumulative effects of the March 2014 storm, the 2015-2016 El Nino winter season, and cessation of beach nourishment activities since 2011 narrowed the Mean Sea Level widths to about 50 to 60 feet. The total average loss of beach width over the five-year period was approximately 125 feet. Assuming that each foot of recession equates to one cubic yard of volume, the total loss of sand that occurred between fall of 2011 and fall of 2016 over the 3,000-foot long shoreline segment is estimated to have been on the order of 375,000 cubic yards. **Figure 9** shows the beach as photographed in May 2017.

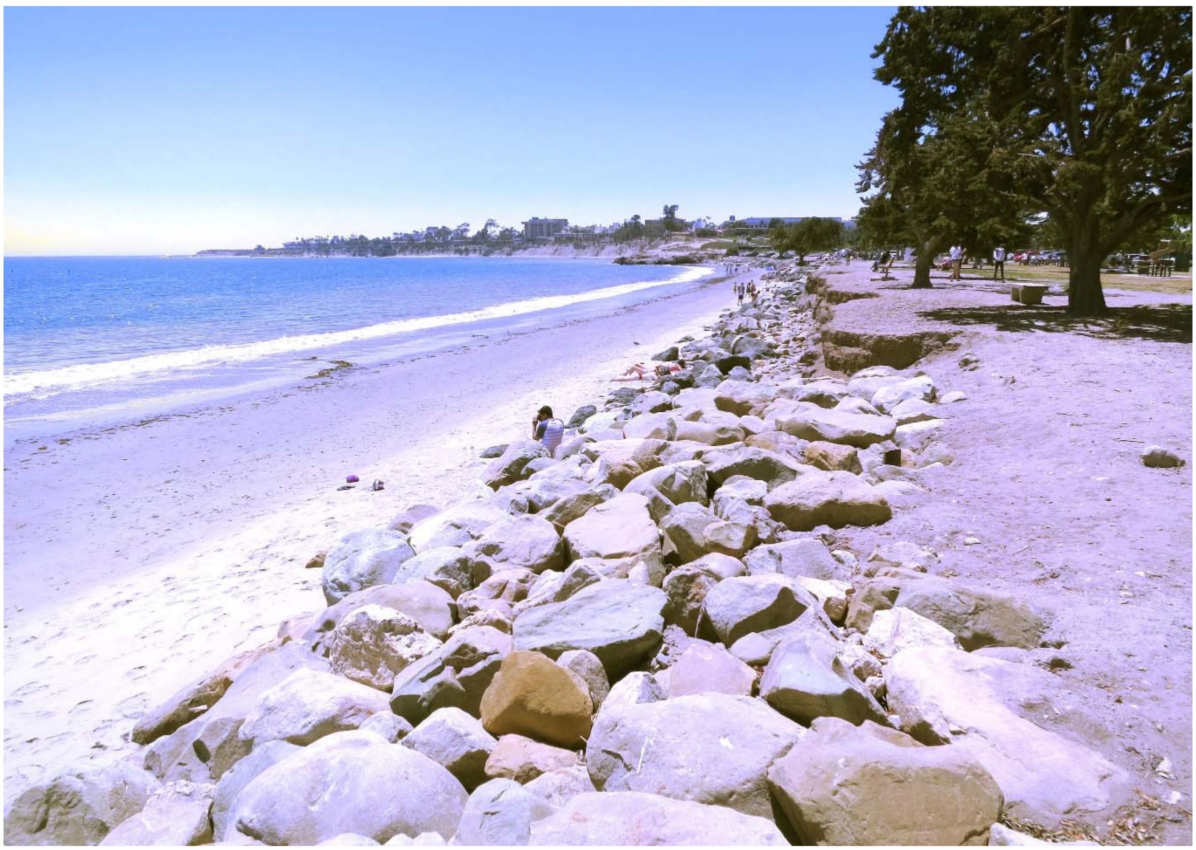

Figure 9. Goleta Beach on May 19, 2017.

Future Conditions

Current beach widths at Goleta Beach and elsewhere within the south Santa Barbara County region are some of the most narrow that have been observed. The cumulative effects of the severe California drought, the 2015-2016 El Nino winter season, continued exposure to winter storms and high tides, and an overall reduction in fluvial sediment supply from the coastal watersheds implies that the more recent observed erosion trend at Goleta Beach may persist for some time into the future. Natural recovery will require periods of heavy precipitation and benign winters with less energetic wave conditions. As previously mentioned, at least 375,000 cubic yards of sand is needed to restore beach widths to their 2008 and 2012 conditions. The County Flood Control District is currently planning a beach renourishment project for November of this year with an estimated nourishment volume of 65,000 cubic yards. This beach replenishment amount together with any natural replenishment that will occur by this fall will help with the restoration effort and at least cover the revetment. The remaining volume deficit will need to come from additional nourishment cycles and successive years of natural recovery.

Natural shoreline restoration throughout the County will require prolonged periods of increased precipitation and watershed runoff to deliver the volume of sand to the coast that is anticipated to be required. Natural sediment processes are relatively slow paced and if they occur, will do so over successive years. Watershed runoff within the recent burn area may help. The County's beach nourishment program that is connected to the Goleta Slough maintenance will become increasingly more important. Consideration of more regional beach restoration programs may also be appropriate as prescribed by regional sediment management planning. The upcoming Flood Control plan to deposit 65,000 cubic yards of sediment on Goleta beach this fall and winter will help to partially restore the beach. While not sufficient to restore the beach to the widest 2012 widths, this infusion of sediment may lead to creation of a wider beach and partially bury the revetment. The longevity of the nourishment will be dependent upon the subsequent wave climate and regional sediment inputs.

Collectively the south Santa Barbara County shoreline will require significant increases in sediment supply to the coast to help in the recovery of the beaches within the regionally depleted littoral system. Absent the beach nourishment input that historically occurred between 1994-2011, Goleta Beach should continue to remain narrow at best. The width of Goleta Beach is dependent upon the County's beach nourishment program. This program, that is necessary to protect the Airport and Goleta from flooding, is fully funded and authorized by all required permits. This dependency will become increasingly more important with future sea level rise.

Sea Level Rise

The long-term vulnerability of Goleta Beach Park will depend upon the magnitude of future sea level rise. As greenhouse gas emissions continue to impact the global climate, the warming of the atmosphere and oceans is projected to accelerate melting of glaciers and polar ice sheets, release more water into the oceans, and cause sea water to expand. The cumulative effect of these physical processes will result in ocean levels higher than today. Predictions of the magnitude and rate of rise are continually evolving as the science and understanding of the phenomenon becomes better understood and the ability to more accurately simulate the process with numerical models improves.

In the past 25 years, numerous studies have been published on the topic resulting in a confusing number of forecasts that don't all agree with one another. Three studies have recently emerged as the most relevant to the California coast. The National Oceanic and Atmospheric Administration's (NOAA) Climate Program Office summarized its assessment of future sea-level rise in their 2012 report (Parris et al, 2012). NOAA indicates that by 2100, global mean sea level is estimated to rise anywhere between 8 inches and 6.6 feet. The wide range in their forecast is because of the inability to confidently predict the future climate and how it will correlate to polar ice sheet losses and the other contributing sea-level rise components.

The National Research Council (NRC) published its sea-level rise assessment for the U.S. West Coast in 2012 (Committee on Sea Level Rise in California, Oregon, and Washington, 2012). The recommendations are largely based upon prior research published by others who forecast future sea level rise by modeling six different global warming scenario groups previously established by the Intergovernmental Panel on Climate Change (IPCC). Their predictions rely upon statistical models that use semi-empirical relationships between past and predicted future global temperature changes. The NRC forecast of sea-level rise by 2100 ranges from about 1.4 to 5.5 feet. In 2013, the State of California's Coastal and Ocean Working Group of the California Climate Action Team (2013) recommended that the sea-level projections estimated by the NRC be adopted. Their specific guidelines are reproduced in **Table 1** and were adopted by the California Coastal Commission in the their SLR policy guidance that was issued in 2015 (California Coastal Commission, 2015).

Table 1. NRC Sea-Level Rise Projection from Year 2000

	South of Cape Mendocino	
Time Period	Low Estimate	High Estimate
2000 to 2030	0.13 feet	0.98 feet
2000 to 2050	0.39 feet	2.00 feet
2000 to 2100	1.38 feet	5.48 feet

Source: Coastal and Ocean Working Group of the California Climate Action Team, 2013

In late 2013, the IPCC published its 5th Assessment on Climate Change report. The sea-level rise study (Church et al, 2013) that was commissioned as part of that effort, represents a departure from prior studies. The 5th Assessment's estimates of ice sheet loss, thermal expansion, and land water storage components were computed with the benefit of an improved physical understanding of the process models that were used. The working group's findings significantly lowered previous forecasts of sea-level rise to a range of between approximately 1.4 to 3.2 feet by 2100. Dr. James Houston (2016), former director of the distinguished US Army Hydraulic and Coastal Engineering Research Center (ERDC) has indicated that the

2013 IPCC study represents the most current and credible estimate of global sea level rise available that should be cited.

Figure 10 summarizes the current range of sea-level rise forecasts. The figure illustrates the dilemma that confronts planners and decision makers who are charged with management of Goleta Beach and its public facilities. The lack of certainty in how high sea level will rise and when it will occur makes it difficult to adopt implementation plans now for the future. Tide gage measurements currently indicate that sea level is rising at a rate of only 1 to 3 millimeters (0.0033 0,0098 feet) per year depending upon the gage location in Southern California. This rate translates to a total increase of no more than 0.1 feet over the next 20 years versus the 1.5-foot rise forecast by the high projection NRC scenario. The present uncertainty in the future suggests that an adaptive management strategy may be the most appropriate path forward to address how best to maintain existing facilities and respond to future conditions as certainty becomes more focused.

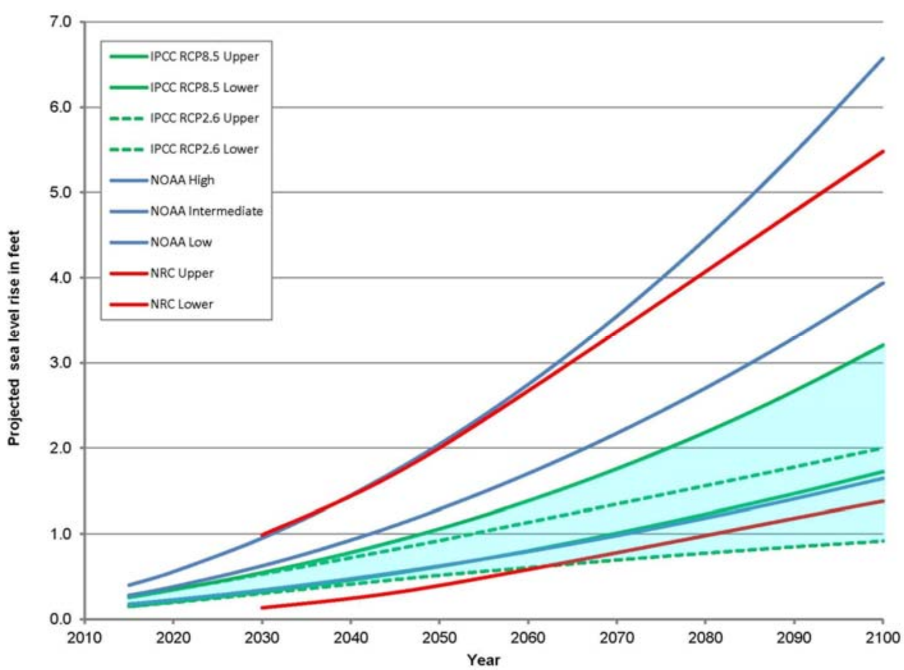

Figure 10. Current estimates of sea-level rise. The figure shows the variable range of future sea rise forecasts as predicted by NOAA, the State of California and NRC, and the IPCC. The blue lines represent the low, intermediate, and upper estimates by NOAA in 2012. The red lines show the probable range as predicted by the State's 2012 NRC sponsored study. The light blue band, represents the most recent forecast range published by the IPCC in 2013 using an improved understanding of the science involved and advanced numerical modeling techniques.

Revetment Impacts

Goleta Beach has become increasingly more dependent on shoreline protection measures over the past 17 years to limit coastal erosion damage and loss of park uplands, particularly during years of low sand supply. Until recently, most the 1,200 feet of revetment at the west end of the Park was covered with sand for most of the time between 2004 and 2014 (Santa Barbara County, 2017). During this period of wider beach conditions, these revetments had little or no interaction with waves and thus had no potential to adversely impact coastal processes or effect beach widths. Because the revetments were relatively high on the beach profile during this period, they acted as a silent buried sentinel poised to protect park facilities. The western 120 feet of this revetment was exposed by the March 2014 storm, with the remaining 900 feet of the western revetment uncovered during the 2015-2016 El Nino winter season. While these revetments minimized erosion and other damage to protected areas of the Park, they have been exposed for almost 1.5 years since that time. Subsequent to this, the eroding beach provided little protection to the remaining unprotected park segment. In the winter of 2017, the County acted to install revetments along this additional 870 feet section of park shoreline.

Goleta Beach's erosion has resulted in much of the beach becoming intertidal during moderate and higher tides. At the far east end of the Park, the revetments that protect Parking Lot 1 and the Beachside Bar and Café are generally exposed as is most of the revetment that was installed in winter of 2017 to protect central areas. Despite these conditions, the natural sand accretion that typically occurs during the summer and fall months of each year has occurred and resulted in complete or partial burial of revetment segments. Currently, about 400 feet of the 11-foot high revetment adjacent to Parking Lot 3 (immediately west of the restaurant), which was completely exposed in February 2017, has been naturally covered with sand. Additionally, a 200 to 300-foot long section of the older 1,200-foot long revetment at the west end of the park is almost completely buried with its top two to three feet visible. (Van Wie, 2017).

Fortification of the shoreline is a controversial subject and has been studied by numerous researchers for many years. The major literature sources on the topic include the Journal of Coastal Research, Shore and Beach magazine, the American Society of Civil Engineers' Journal of Waterway Port Coastal and Ocean Engineering, Proceedings of the Coastal Engineering Conference, technical reports published by U.S. Army Corps of Engineers, universities, U.S. Geological Survey, and others. A summary of the literature that has been reviewed for this study is discussed in the following paragraphs.

Many researchers have discussed the potential detrimental effects caused by the placement of shoreline stabilizing hard structures, including revetments, on beaches and have categorized beach degradation mechanisms as placement loss, passive erosion, and active erosion (Hall and Pilkey, 1991).

- Placement loss occurs when a shore parallel structure is placed seaward of high tide line, thus substantially reducing the width of the beach.

- Passive erosion occurs when the shoreline is armored or replaced by a permanent hard stabilization structure, thereby causing the landward boundary of the beach to have a fixed location.

- Active erosion defines any process that accelerates erosion due to the presence of revetments and similar structures. The impact involves the redistribution of sediment supply to a beach and/or any modification of shore zone processes due to the seawall.

Placement losses and passive erosion effects associated with revetments are well documented. However, the potential for a revetment to induce or accelerate beach erosion has been the topic of study and controversy over the past decade, and there does not appear to be any consensus within the literature.

Research Finding Limited Active Erosion Effects from Revetments

Research by Dean, Kraus, Griggs, Basco, and others suggest that revetments may not contribute to increases in the active erosion of an already eroding shoreline. Their studies and conclusions are summarized in the following:

1. Dean (1986) contends that passive erosion does occur in walled areas, but that active erosion caused by walls is insignificant. According to Dean (1986), coastal armoring does not accelerate beach erosion except in areas downdrift of groins (groin effect). Passive erosion, local scour effects in front of the structure, and end effects are the primary concerns of shoreline protection features. As summarized by Dean (1986): "*there are no factual data to support claims that armoring causes profile steeping, increase longshore transport, transport of sand to a substantial distance offshore, or delayed post-storm recovery*."

2. Kraus (1987, 1988) who has reviewed over 100 articles on effects of seawalls (including revetments) on beaches, concludes that beaches with and without seawalls exhibit similar behavior during short term events such as storms. Further, seawalls appear to be "relatively innocuous with regard to cross shore sediment processes," and are only potentially damaging to adjacent beaches when longshore processes are interrupted. He indicates that beach erosion adjacent to seawalls is similar to that on beaches without seawalls, if an adequate sediment supply exists. One of the difficulties with short term and event studies of seawall impacts is that beach degradation is often a long term (several decades) phenomenon. Clearly, from his reviews, much remains to be resolved about any active erosional impacts of seawalls. After conducting updated literature review, Kraus and McDougal (1996) found "*reflection (by revetments) is probably not*

a significant contributor to beach profile change or to scour in front of seawalls, at least for the duration of a storm". Further, they concluded "*during storms, the beach profile in front of a wall retains about the same amount of sand (has about the same general shape) as a beach without a wall, because wave reflection does not appear to greatly influence overall profile shape*", and "*the main difference is general downward displacement of the slope near the wall*".

3. Griggs and others (1994, 1997, 2005, 2010) carried out an 8-year field study along the Monterey coast of central California to resolve some of the seawall/beach impact questions. The study is still the only long-term beach-seawall monitoring research that has been conducted in California. The project involved monthly cross-shore surveys of beaches fronting and both up and down coast from several different seawalls and revetments along the shoreline of northern Monterey Bay. These beaches undergo significant seasonal erosion and accretion, but are not experiencing long-term retreat. Based on Griggs and others (2010), "*comparison of data from 8 years of surveys reveals no distinguishable differences between the winter or the summer profiles for the seawall and the adjacent control beaches*", and "*long-term field investigations of seawalls and adjacent beaches along the coastline of Monterey Bay, California, where littoral drift rates are high, indicate that seawall induced erosion is not a significant issue at this location*".

4. Basco and others (1991, 1993, 1997) examined approximately 120 years of shoreline recession rates to investigate whether a 50-year presence of seawalls on the Virginian coastline had altered the rate of shoreline recession. Their research was based upon a statistical analysis of field data collected at Sandbridge, Virginia. They found that the seawalls had not increased the rate of recession of the adjacent shoreline, while inhibiting retreat at the seawall positions. They further concluded "*the volume erosion rates are not higher in front of seawalls*", and "*seawalled beaches recovered about the same time as nonwalled locations*".

<u>*Opposing Points of View*</u>

Pilkey and Wright (1988), Hall and Pilkey (1991), Morton (1988), and others present opposing points of view from a geology perspective. Summaries of representative published literature is outlined below.

1. Pilkey and Wright (1988) conducted analysis and measured dry beach width along developed shorelines of South Carolina, North Carolina, and New Jersey. They discovered that "*a number of physical arguments do offer support for mechanisms by which active beach degradation by seawall may occur*", and "*dry beach width is consistently narrower in front of hard stabilization*". Hall and Pilkey (1991) stated "*the New Jersey shoreline, in many places stabilized for longer than a century, provides evidence of the*

degradational effect of hard stabilization on recreational beaches. The impact is apparent whether structures involved are shore parallel or shore perpendicular".

2. Morton (1988) noted that Texas beaches follow a four-phase cycle in storm recovery: forebeach recovery, aeolian processes, flooding during minor storm, and plant colonization. He indicates that the last three recovery phases are prevented by the presence of a seawall or similar structure which suggests that the presence of seawalls he studied impede the total recovery of the beach after storm erosion.

3. Kana (1982) raised a concern over what he observed to be higher erosion rates and slower beach recovery times at sections of a South Carolina armored beach.

The East and Gulf Coast case studies are generally characterized by beaches that have significant back beach dune systems and coastlines that are subject to severe hurricanes and high storm surges coincident with waves. Most of these cases are for beaches with characteristics that may not be applicable to the West Coast environment.

In summary, the list of potential impacts associated with armoring the coast that has been proposed over the years include removal of the landward bluff from the sand supply system, groin effects when the revetment or seawall projects into the littoral zone, inhibition of two-way sand exchange, shoreface steepening, and "telescoping" of the surf zone where breakers are confined to a more narrow portion of the beach profile. Some studies have found that these effects adversely contribute to accelerated beach erosion where structures have been built. Other studies have not supported this finding.

The coastal armoring impacts debate has been ongoing for at least 40 years, and is likely to remain unresolved for some time into the future. Those who believe that seawalls and revetments increase active erosion effects will remain skeptical of any engineering laboratory, field research, or analytical study that suggests otherwise. Pilkey, for example, dismisses engineering studies because, in his opinion, they are conducted over too short a study time span and therefore do not observe or account for adverse impacts that he believes sometimes take decades to develop. Dean (1986) published what he considers to be the common perceptions concerning the effects of coastal armoring and his assessment of the validity of those perceptions. His summary is reproduced in **Table 2**.

The Goleta Beach situation is typical of shoreline protection responses where the revetment has been built to address a pre-existing erosion condition. It follows that the revetment may not be accelerating what naturally already exists. The twelve-year monitoring program by Coastal Frontiers has shown that the beach has experienced two sequences of accretion and erosion. The accretion events are believed to be the direct result of the 475,000 cubic yards of sediment that has been placed on the beach by the County and others between 2003 and 2006 and 2009 and 2011. The replenishment helped to restore an overall beach width that has varied between 100 and 200 feet during a 9 to 10-year period. During that time the western 1,200 feet of revetment remained generally buried and not in direct contact with tides, waves, and currents. As the beach erodes and narrows, the revetment may become visible and more exposed during the more severe storm events. The recent prolonged period of extreme drought and severe 2015 and 2016 winter seasons has depleted the regional coastal sediment supply, reducing Goleta Beach to its narrowest condition observed since beach monitoring began, and has placed the revetment into service to protect upland park areas.

Table 2. Assessment of Some Commonly Expressed Concerns Relating to Coastal Armoring

Concern	Validity	Assessment
Coastal armoring placed in an area of existing erosional stress causes increased erosional stress on the beaches adjacent to the armoring.	True	By preventing the upland eroding, the beaches adjacent to the armoring share a greater portion of the same total erosional stress.
Coastal armoring placed in an area of existing erosional stress will cause the beaches fronting the armoring to diminish.	True	Coastal armoring is designed to protect the upland, but does not prevent erosion of the beach profile waterward of the armoring, Thus an eroding beach will continue to erode. If the armoring had not been placed, the width of the beach would have remained approximately the same, but with increasing time, would have been located progressively landward.
Coastal armoring causes an acceleration of beach erosion seaward of the armoring.	Probably false	No known data or physical arguments support this concern.
An isolated coastal armoring can accelerate downdrift erosion.	True	If an isolated structure is armored on an eroding beach, the structure will eventually protrude into the active beach zone and will act to some degree as a groin, interrupting longshore transport and thereby causing downdrift erosion.
Coastal armoring results in a greatly delayed post-storm recovery.	Probably false	No known data or physical arguments support this concern.
Coastal armoring causes the beach profile to steepen dramatically.	Probably false	No known data or physical arguments support this concern.
Coastal armoring placed well back from a stable beach is detrimental to the beach and serves no useful purpose	False	In order to have any substantial effects to the beaches, the armoring must be acted upon by waves and beaches. Moreover, armoring set well back from the normally active shore zone can provide “insurance” for upland structures against severe storms.

Source: Reproduced from Dean, 1986.

Based upon aerial photographs and beach profile survey data dating to 1982, Goleta Beach is continuing to erode (Moffatt and Nichol, 2007; Coastal Frontiers Corporation, 2017). Erosion occurs on both an annual basis and episodically due to major storm events such as what occurred during the 2015-2016 El Nino winter season. Thus far, the County’s flood prevention maintenance and beach nourishment program has been able to balance the losses that have occurred from 1994-2011. However, the cumulative effects of the recent drought and the severe storm events have erased the past nourishment gains. There are no signs yet that the beach’s long term net erosion trend will reverse therefore the County’s beach nourishment program is a critical component to help sustain adequate beach width. It is not known if future rainfall events and associated sediment input will help to restore the regional littoral system and offset Goleta Beach's erosion trend. The historic record shows that the County's beach nourishment program has been the key component in beach restoration as exemplified by the 2008 and 2012 nourishment cycles. The County's beach nourishment program will continue to play a key role in maintaining beach width.

Between 2005 and 2013, the County's replenishment program has been able to maintain a relatively wide and sandy beach that has not fallen below a width of 125 feet. The absence of nourishment due to the 5-year drought that ended in 2017 together with an increased storm severity has been responsible for the current state of depletion. If drought conditions worsen in the future, rainfall and sediment supply to the coast diminish, the County may be unable to furnish sufficient volumes of sediment from its slough maintenance dredging program on a regular basis to keep pace with long term and storm induced losses. If this occurs, the revetment at the west end of the Park as well as the new 870 feet of revetment in the central area of the Park will be exposed for a longer period of time until major storm events provide additional large scale sediment input. Conversely, if the County can enhance its beach nourishment program, the natural sediment supply to the coastline increases, and a regional sediment management program is implemented in Santa Barbara County, then Goleta Beach can continue to be maintained into the future with success.

Should a condition of sustained revetment exposure occur, past research suggests that the revetment will not necessarily adversely impact the nearshore coastal processes or impede any natural beach recovery. However, the revetment's presence will prevent the beach from being able to retreat further inland thereby initiating a passive erosion condition that will contribute to the loss of dry sand beach berm that will persist until the County can restore it via the Goleta Slough nourishment program and/or a regional sediment management replenishment project that places more volumes of sand on the beach to restore the beach to its wider 2012 condition. Regardless of which path forward is adopted at Goleta Beach, the erosion processes will be continual and the need for regular replenishment cycles will remain a perpetual commitment.

Shoreline Management Alternatives

Goleta Beach is not a natural shoreline having been significantly altered and engineered over time since the 1940s. The creation of Goleta Beach Park, construction of Highway 217 and Sandspit Road, and Santa Barbara Airport have substantially altered both the shoreline and sediment input into this area. As previously discussed, the beach monitoring data collected by Coastal Frontiers Corporation indicates that the beach has been steadily losing sand at a rate of about 40,000 to 50,000 cy per year since at least 2004. This implies that intervention, such as the funded and permitted County beach nourishment activities, as well as some type of shoreline protection will continue to be required if the park facilities and beach are to be maintained.

The 2015-16 El Niño was an extreme event that occurred at the end of a prolonged and severe statewide drought. As a consequence, the regional littoral system including Goleta Beach has been significantly degraded. It remains to be seen whether Goleta and the neighboring regional beaches will be able to sufficiently recover to their wider conditions. Based upon the lack of complete shoreline recovery that was witnessed after prior severe El Niño years, including the 1982/83 and 1997/98 seasons, Goleta Beach's complete recovery from the recent severe winters may also be in jeopardy. The County's beach maintenance program and consideration of more regional sediment management programs as discussed will play increasingly more important roles in this regard. The results from future beach monitoring will help to assess if the rainfall during the 2017 winter ultimately translates into enough fluvial sand delivery from upcoast such that the sand at least partially replenishes the beach profile.

Natural recovery of the overall system will require significant gains in sediment supply that historically have not been witnessed over a short time span. Some increases in the future could result from the aftermath of June 2016 Sherpa fire that burned about 7,500 acres in the Refugio/El Capitan watershed (CalFire, 2017), but the burn was only about one-tenth the size of the historic 1955 Refugio fire. Measured precipitation at the Goleta and San Marcos Pass rain gages for the 2017 water year were approximately 130% to 140% above normal (Santa Barbara County, 2017). Any additional sand from the Santa Ynez Mountains watershed from the Sherpa Fire burn area, the most recent Whittier Fire burn area, and other sources that is discharged to the coast as a result of this additional rainfall, will ultimately propagate alongshore and help in the recovery of the regional littoral system. This process may take a number of years before any of this sediment reaches Goleta Beach. It is not known if an adequate volume of sand will appear at Goleta Beach to reverse its current erosion trend or at least keep pace with the beach's existing net sediment deficit. The recovery potential will depend on rainfall intensity and the actual volume of sediment delivered to the shoreline. The Santa Barbara coast between Santa Barbara Harbor and Point Conception has always been sediment limited (Noble Consultants, 1989). This implies that the region's storm depleted beaches may not be capable of being fully restored naturally.

Since 1994, Goleta Beach has been successfully maintained by the County's nourishment program. The drought interrupted nourishment cycles are scheduled to recommence in three months (November 2017) when approximately 65,000 cubic yards of beach quality sediment will be placed on the beach. Until then, the width of Goleta Beach will be in its narrowest measured condition. If the beach nourishment efforts ceased altogether, it is likely that if the existing revetment is left in place, the beach will continue to recede, eventually reach the toe, and at best transform Goleta Beach into a low tide access only shoreline. However, as previously discussed, the County's ongoing beach replenishment efforts have been able to maintain a wide beach. However, the ability to return to 2012 beach conditions may require a supplemental regional sediment management program effort to help overcome the sand loss deficit that was experienced during the long term drought and 2015/16 El Niño when the Goleta Slough maintenance program was interrupted.

Five alternatives have been proposed by the County for consideration to deal with the future. Strategies entail elements of park protection, beach preservation, or both. Our comments on the different shoreline management plans that are currently under consideration are provided below.

Option 1 – Leave Goleta Beach Park and revetments in place and enhance monitoring for at least five years and preferably ten years

The estimated future scenario for Goleta Beach for the existing condition is discussed above. Existing Mean Sea Level beach width at Goleta Beach was last measured to be about 50 feet or less (Scott, 2017). With no significant beach berm width buffer remaining and the demonstrated current erosion trend at the beach, this alternative will result in times of intertidal beach especially during years of low sand supply within the region and following severe storm seasons. Temporary recoveries in beach width are expected to result from County nourishment cycles each time beach compatible sediment from Goleta Slough maintenance operations is placed on the beach. During such times, increased revetment maintenance may be experienced to maintain its erosion protection and wave overtopping resistance function.

Although the County is permitted to maintain the flood control channels annually, the availability and volume of sand that will be continue to be available from Goleta Slough and its tributaries will be dependent upon future rainfall and stormwater runoff within the watershed. The Coastal Frontiers' beach monitoring data clearly shows that the beach is eroding at a steady rate. Between 2008 and 2011 and 2013 and 2015, the net beach width reduced between 60 to 90 feet (see **Figure 6**). The total sediment volume loss rates between 2004 and 2016 translate to an annual average sediment deficit of approximately 40,000 to 50,000 cy per year. Since the last nourishment cycle in 2011, beach erosion was exacerbated some between 2016 and 2017 most likely in reflection of the drought related cessation of further beach nourishment cycles and the major storm occurrences that were experienced.

Since 1994, the County has been able to keep pace with the shoreline erosion via its beach nourishment program. Prior nourishment cycles at Goleta Beach indicate that the sand replenishment program can increase the beach width by nearly 100 feet each time. Longevity of the placed sand will vary with subsequent wave and high tide exposure, but the monitoring data to date suggests that the beach will erode to pre-nourishment widths within 3 to 5 years. One half of the nourishment can be lost in a single year if the winter season is severe enough.

The recent 5-year drought played a significant role in interrupting Goleta Beach's frequency of nourishment. By 2016, the beach probably would have been restored to its 2012 condition, but because of the reduction in sediment deposits in Goleta Slough there was no material available for beach placement. As previously discussed, the long term drought interrupted nourishment cycle timing and beach erosion was allowed to progress to conditions that are observed today.

During periods when beach nourishment volumes are reduced by low watershed runoff, this alternative would result in much of Goleta Beach remaining intertidal. The current beach conditions limit lateral coastal access as the beach is submerged at even moderate high tides of + 3-4 feet, MLLW. Vertical access is also affected due to the height of revetment exposure. The County's planned Goleta Slough flood control maintenance project scheduled to commenced in November of this year should benefit beach width. The resultant beach width and its longevity will depend on the subsequent wave climate exposure and what natural shoreline recovery occurs. Absent additional nourishment or sediment input, passive erosion may begin to occur over the long term. Although experts disagree over the potential effects of revetments on active erosion, past research performed on more exposed California beaches suggests that such erosion is unlikely to be a major factor in determining beach width at this location. Similarly, rigorous studies of other armored beaches in California also support the belief that the alternative is estimated to have very little if any impact to downcoast beaches that are already narrow, thin lenses of sand backed by high bluffs. An additional beach monitoring profile could be added further downcoast to verify this expectation.

AMP, Phased Retreat: Retain Existing 948-Foot Long Emergency Revetment and Pier Base Repairs (Phase 1); Remove Parking Lot No. 7 and 6 in two subsequent phases (2 and 3).

Phases 2 and 3 of the potential AMP will consist of a nominal retreat component by moving existing revetments fronting Parking Lots 6 and 7 at the west end of the Park 30 to 100 feet landward and transitioning 1.1 acres of upland area to beach. As this area is typically the narrowest part of Goleta Beach, in low sand years such as the current situation, this would likely create a pocket cove with limited dry sand beach as the ocean advances inland. Following beach nourishment cycles, the beach would be wider and a dry sand beach berm would form. Because the beach width at the west end of Goleta Beach tends to be the narrowest, the benefits of this action on creating a wider sandy beach under current eroded conditions may be modest. If Lots 6 and 7 are removed, the beach fronting the rest of the park will likely continue to behave as described above.

As shown in **Figure 11**, it is estimated that Goleta Beach will follow a cyclic variation in beach width similar to what Griggs and Tait (1997) describe in their Monterey field study research. Under the current sediment depleted conditions, the nearshore profile of Goleta Beach will likely continue to erode until the shoreline ultimately reaches the toe of the new central beach revetment. At this point continued erosion will occur within the Lot 6/7 pocket beach as sand volumes within the setback pockets are relatively small. If the new beaches are pre-filled, littoral transport will continue to move alongshore and downcoast even if the central beach further diminishes. An accretion cycle will be the reverse of this process. When Goleta Beach is renourished or if summer beach recovery is robust, the Lot 6/7 beach is estimated to accrete until it reaches alignment with that of the central beach revetment. At that point, additional recovery, if it happens, will occur in unison over the entire reach as the shoreline gains width as one. Based upon past history, sand nourishment placement has been most responsible for the accretion cycles at Goleta Beach.

Because of the relatively small size of the first phase Lot 7 beach, it may be best to combine Phases 2 and 3 into a single phase. The larger pocket beach footprint created from the retreat of both Lots 6 and 7 will have a higher potential for being a more sustainable and resilient.

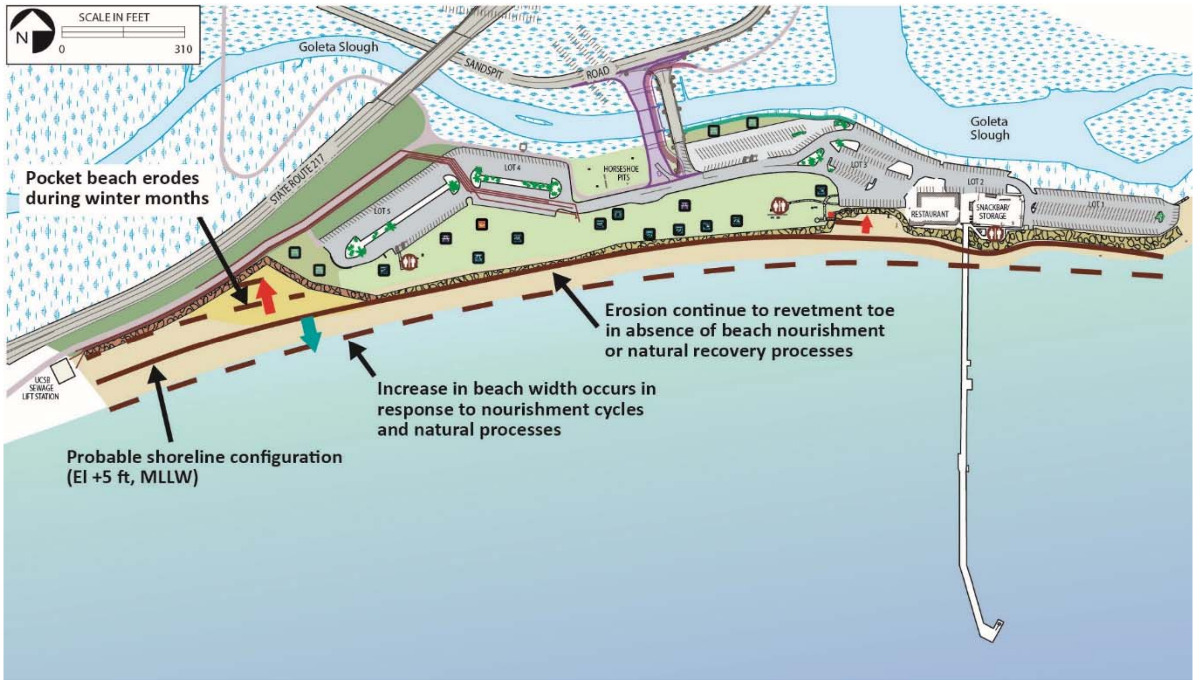

Figure 11. Schematic diagram of probable shoreline behavior for AMP Option 2.
Source: Base map from Amec Foster Wheeler, 2017.

AMP, Long-Term: Landward Retreat of Revetments & Park Facilities west of Pier:

Potentilly at this phase, the County would initiate retreat of Park facilities and revetments along approximately 2,100 feet of beach west of the pier to the historic back beach line, located approximately 30-50 feet landward of the existing shoreline. This would entail relocation of approximately 1,347 feet of existing revetments which would link to approximately 600 feet of revetments previously relocated under Phases 2 and 3. The new seaward edge of the Park would be within the middle of existing lawn area along the historic back beach line resulting in the addition of a 30 to 50-foot wide band along the Parks shoreline that could accommodate sandy beach of approximately 1.2 acres.

The shoreline behavior of this plan is estimated to be similar to that depicted in **Figure 10**. The steady shoreline erosion that has been recorded at Goleta Beach since the 1980s and the lack of observable natural accretion episodes implies that shoreline erosion will continue. The nominal retreat distance is estimated to only delay the time before the shoreline ultimately reaches the toe of the relocated revetment. Future beach width under this alternative scenario is still considered to be dependent upon the County's beach nourishment program as has occurred since 1994. The alternative is also not anticipated to result in any adverse downcoast impacts to coastal processes based upon the results of long term research of other armored coastal areas.

Option 2 – Remove Existing 873-Foot Long Emergency Revetment; Retreat Goleta Park to front of the back beach line

Option 2 is likely the long term fate of the park if the beach's erosion rate continues unabated and the Goleta Beach nourishment program is ended. If the revetment is ultimately removed, and sand nourishment does not keep pace with the natural shoreline recession, shoreline erosion will likely continue through the entire sand spit. If the upland erosion is allowed to happen naturally, there will be an increased potential for some issues associated with introduction of the park's clay fill into the foreshore. If the retreat plan is to be facilitated with pre-removal and grading of the non-beach compatible fill, there may be potential cost considerations associated with the demolition work and a requirement for regular maintenance to keep pace with the shoreline's natural recession rate.

The beach will still be dependent upon beach nourishment to maintain a wide beach. Without the benefit of the revetment, exposure to severe storm events and El Niño winter seasons will likely result in episodes of accelerated erosion that will create steep faced erosion scarps that will make beach access hazardous and difficult. In this manner the shoreline will progressively retreat landward over time as there will not be any limit line in place to stop erosion before a remedial beach nourishment cycle can be implemented. Therefore, it is estimated that over the long term the shoreline will continue to recede, the park will eventually run out of retreat space, particularly on the west end, and the beach itself may diminish to an intertidal feature. It is difficult to forecast with certainty how the area will finally evolve because sediment processes within Goleta Slough itself have been altered. One possible outcome is that the park area may eventually convert to wetlands and some sandy remnants may remain in the vicinity of the Slough channel and mouth.

Option 3 – Reduce revetment height

Reducing the height of the existing revetment will not result in any tangible benefit to either the beach or the park. The revetment will continue to impact available beach width via passive erosion effects as discussed above. If the beach continues to recede, the park's uplands will experience more damage as waves overtop the lower crested revetment with greater frequency causing its collapse in places due to washout of bluff material from behind.

Option 4 – *Replace revetment with a cobble berm*

Success of a cobble berm concept on the open coast is questionable. Waves will reform the cross section, and suitable sources of cobble in the gradation favored by the Coastal Commission and volume needed to adequately transform the entire beach length will be hard to find and historically have come from Ventura River or Santa Paula Creek sources. Large deposits of naturally formed cobble berms appeared in Encinitas/Solana Beach in the late 1990s and early 2000s. The visually impressive mounds of stone were short lived and completely disappeared within several years. If this option is implemented at Goleta Beach, one can expect the foreshore to convert into a swash zone of unstable footing and moving cobble that will be hazardous to waders who attempt to venture into the water. The cobble will need to be supplemented at some regular interval to replaced sloughed and depleted sections.

Examples of cobble berm projects and research on how the system functions in the open coast environment is very limited. One of the most recognized examples is the City of Ventura's managed plan for shoreline retreat at Seaside and Surfers' Point parks. In 2000, cobble mattresses and berms were studied in an effort to implement a natural shoreline protection feature that would enable the City to enhance public access and stabilize the City's westernmost shoreline. Research into existing natural systems and study of the Emma Wood State Beach cobble berm was done to better understand how natural systems functioned and if they could be artificially replicated or mimicked (Noble Consultants and Everts, 2000). In general, it was found that design and construction of cobble berms is not well understood and that the methodology should be considered as unproven and experimental. The preliminary guidelines for design consideration that came out of the Ventura study are summarized below in **Table 3**.

Table 3. Guidelines for the Design of Artificial Cobble Berms

Design parameter	Design consideration
Size	Bigger is better. Small gravel and sand is not recommended.
Gradation	Use natural, large, rounded gravel, boulders and cobble. Do not fill voids with small sized material that might create a pavement-like slope face.
Angularity	Use natural rounded stone similar to what exists in the natural environment
Porosity	Limit berms to boulders and cobble-sized stone and do not include small gravel or sand. This is believed to enhance berm stability.
Volume	More is better to cushion against losses
Crest elevation	Allowance for some overtopping increases berm stability. Consider a wider horizontal berm width.
Base elevation	The toe should be below the lowest anticipated beach scour limit.
Toe protection	Include a gravel, boulder, and cobble scour apron if scour depth cannot be attained.
Slope	The slope face should be between 4 to 5 to 1 to mimic the natural feature.
Alignment	Orient the berm normal to the alongshore component of wave energy to reduce alongshore transport of the material
Maintenance	Material will be lost over the life of the project. Maintenance will be required.

Compatibility with sand replenishment	Not compatible. Do not place sand on top of or bury the berm. This reduces berm stability when exposed.
Monitoring	Too much is unknown. Monitoring and adaptive management will be required in response to performance. The project should be perceived as an experiment.

Source: Noble Consultants and Everts, 2000

Several small pilot projects were performed in Ventura to test and observe the concept. In 2000, about 6,000 cubic yards of gravel, boulders, and cobble (GBC) was placed along about 550 feet of semi-protected shoreline. The placement functioned well for about ten years gradually sloughing and dispersing material. Efforts to put GBC on a steeper faced beach exposed to higher wave energy was less successful. After two unsuccessful attempts at trying to use GBC to protect the Promenade at Surfers' Point Park from shoreline erosion, the City abandoned the experiment and installed a conventional stone revetment under an emergency permit authorization.

In 2011, the westernmost portion of Seaside Park was converted into a managed retreat project where parking lots, roadway, and a bicycle path were relocated landward. The project included burial of a GBC berm beneath a short length of artificial sand dune. The berm has yet to be significantly exposed and tested by wave action. If and when it does become uncovered, it may help to provide information on a critical design criteria belief that sand burial is detrimental to GBC berm stability.

Figure 12 shows the Emma Wood State Beach GBC berm that was studied for replication at Ventura. The photograph provides an indication of the massive scale of the gravel, boulders, and cobble toe, slope face, and crest width that comprise the berm. The offshore extent of the toe may be another important factor on why the natural feature has been so stable. This toe coverage is nearly impossible to artificially create because of the volume of material that would be required to build it and the size of the bottom footprint that would be impacted.

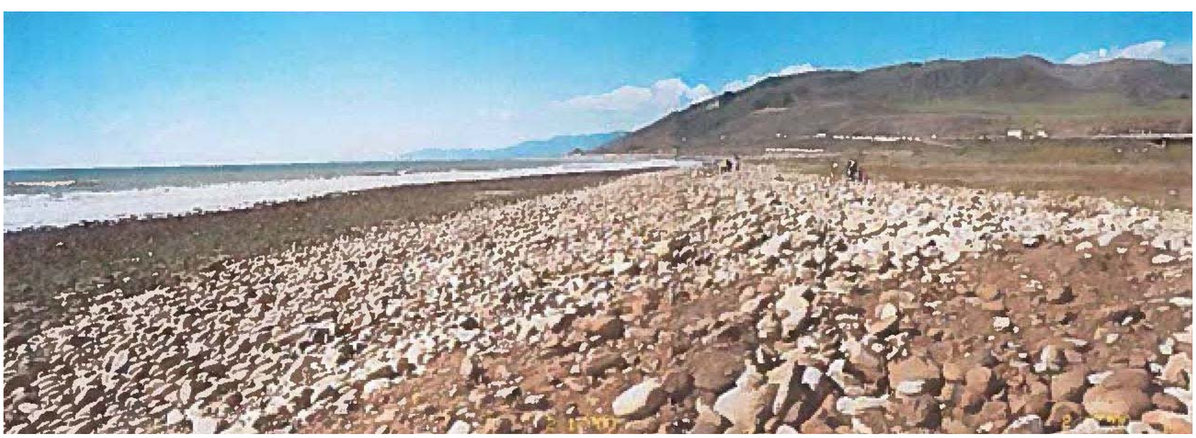

Figure 12. Emma Wood State Beach GBC berm

Figure 13 shows Haskell's Beach in January 2015, shows when a vast basement layer of gravel, boulders, and cobble material was uncovered at that time. If a cobble deposit is to be enhanced at Goleta Beach, significantly greater volumes of material than anticipated may be required.

Based upon the lack of proven examples and a limited understanding of how GBC berms function, the strategy should therefore be considered as unproven and experimental for Goleta Beach suggesting that the County could be responsible for potentially expensive and long term adaptive management maintenance. If implemented, this would be the first attempt at converting a section of sandy shoreline into a GBC environment. Additional discussion on the comparison of cobble berms with revetments for shoreline protection and their potential effects is provided in the attached report.

Figure 13. Haskell's Beach January 11, 2015. The photograph taken during a tide level of approximately +6' MLLW shows the massive natural basement layer deposits of gravel, boulders, and cobble that were exposed when all of the beach sand was stripped away by severe storm surf and high tides.

Additional hybrid option – Park protection and beach restoration

Another strategy that may be considered consists of maintaining an adequate revetment combined with a dedicated beach restoration and maintenance program. Under this strategy, the revetment could be left in place or nominally set back and hidden from view as a buried "silent sentinel". A significant volume of beach quality sand would be imported to restore Goleta Beach to its 1975 berm width of 200 to 300 feet. The resultant sand buffer would completely isolate the revetment from the active littoral zone such that it would only be exposed temporarily during the most extreme storm events. Preliminary estimates indicate that minimally 400,000 cubic yards of sand would be needed to fully restore the beach to its 2012 condition. A project of this scale will cost on the order of $10 million.

Once the beach is restored, regular cycles of sand renourishment similar to what has occurred since 1994 will be required to maintain the width of the restored beach and keep pace with its natural erosion rate. Material from the Goleta Slough flood channel maintenance dredging program would continue to be utilized for this task. However, additional resources would also need to be identified and committed to the program to ensure that adequate volumes of sand are always available when needed.

The difficulties in locating, permitting, and funding such a beach enhancement and maintenance program will be challenging. Sand deposits offshore of East Beach are the closest significant sediment source available and most compatible with Goleta Beach. Commitment to regular cycles of replenishment to keep pace with the beach's natural erosion rate and more significant storm induced losses will be expensive and perpetual.

The Beach Erosion Authority for Clean Oceans and Nourishment (BEACON) is a joint powers authority comprised of Santa Barbara and Ventura Counties and the coastal cities between Goleta and Port Hueneme. In 2009, the agency adopted its Coastal Regional Sediment Management Plan (CRSMP) in cooperation with the US Army Corps of Engineers and the California Resources Agency. The BEACON plan consists of recommended policy, study, management, and capital improvement activities to address the challenges and opportunities that face regional sediment management along the BEACON coast. A key recommendation of the plan is the creation of a Federal Project Authority that would allow federal and state participation to assist local partners to deal with the existing and future sediment management challenges. The long term management of Goleta Beach is specifically addressed in the BEACON plan and thus comprises a capital improvement and management activity that would greatly benefit from a more regional approach. The governance structure of BEACON is well poised to assist the County to seek outside funding assistance to tackle shoreline management issues that implications for the entire coastal region.

As discussed above, erosion at Goleta Beach Park reflects regional trends of erosion along South Coast beaches for a number of reasons including the 2015-2016 El Niño experience, the historic 5-year drought, and an overall reduction in sediment input to the littoral system. While County Flood Control's ongoing sediment disposal and beach nourishment program will help to reverse the beach erosion and create a wider beach following major nourishment events, natural sediment input may be insufficient to maintain wide beaches over the long term. Although wider beaches that result from major nourishment cycles may persist for a number of years, they will eventually erode and become more narrow particularly following major storm events. The duration of reduced beach width conditions may extend for several years similar what has already been experienced.

If the County wishes to ensure that the frequency and duration of narrow beach conditions are avoided or shortened, obtaining supplemental beach nourishment through BEACON and/or other agency partnerships is a viable strategy. For this reason, we recommend the following should the County wish to enhance its tools for more active coastal sediment management at Goleta Beach and the region:

- The County should explore with BEACON establishment of the Santa Barbara Littoral Cell Federal Project Authority to garner federal and state funding for shoreline management projects such as beach nourishment along the South Coast and at Goleta Beach.

It is recognized that similar to many other California jurisdictions, the County does not have a specific funding source identified for long term shoreline management efforts. Rather, the County responds to specific emergencies related to storm damage and shoreline erosion such as at Goleta beach, rather than through more comprehensive regional planning. If future sea level rise proceeds along the worst case projection scenarios, the potential for beach erosion and damage to public and private facilities will increase. This implies that the need for regular outside funding assistance to improve and maintain the County's shoreline will only grow.

Enhanced Monitoring Program

The existing beach monitoring program includes seasonal beach profile surveys to track beach width and sediment volume changes. Monthly visual surveys are included to log the condition of the existing revetment and the extent and duration of its sand cover. Given the current narrow width of Goleta Beach and the extent of the revetment's existing lack of sand cover, a potential trigger point for action may have already been reached if conditions do not improve. However, the County is planning the next cycle of Goleta Slough maintenance dredging and beach nourishment placement for this fall. Preliminary volume estimates of sediment volume to be removed from the flood control channels is 65,000 cubic yards (Spencer, 2017). This contribution has the potential to offset some of the losses that have recently occurred and portends the return of the more regular nourishment cycle.

Consideration of improvements to any beach monitoring program are often directed to frequency of surveys and definition of trigger points when specific actions may be needed to offset potentially adverse effects. In general, it is reasonable to prescribe action after deficiencies persist for an extended period of time to verify that observations represent true long term trends and not short term variations or the consequences of more far reaching distress within the region's littoral system. For example, a monitoring program of only 2 to 3 years could have fallen entirely within the period of the recent 5-year drought or captured

Goleta Beach at only its widest condition between 2011 and 2014 pre and post beach nourishment.

In consultation with Coastal Frontiers Corporation staff, the following preliminary enhancements to the existing Goleta Beach monitoring programs are presented for consideration.

1. Add New Survey Transect in Pocket Beach

If the Lot 6 and 7 retreat plan is implemented, a pocket beach will be created on the west end of the park from removal of uplands in that area. While survey Transect GB-01 is located near the east end of the proposed pocket beach, it is recommended that a new survey transect be established in the center of the pocket beach to better monitoring width and volume changes within the feature.

2. Add Up- and Down-Coast BEACON Survey Transects

In an effort to compare the shoreline fluctuations observed near Goleta Beach to those in the surrounding area, it is recommended that two survey transects historically monitored on behalf of BEACON be added to the Goleta Beach Shoreline Monitoring Program. The recommended transects are:

> Ellwood Beach (BCN-01) - Approximately 5 miles up-coast. Last surveyed in November 2003.
>
> Arroyo Burro (BCN-03) - Approximately 5 miles down-coast. Last surveyed in November 2003.

These additional survey profiles may be referenced to note shoreline changes on a more regional scale so that comparisons between changes at Goleta Beach and the upcoast and downcoast shoreline can be made to assess differences and similarities in behavior.

3. Install Site Camera(s) for Beach and Revetment Monitoring

Web-accessible site cameras designed for beach observation may be installed at one or more locations to monitor portions of Goleta Beach and the exposed portions of the existing and relocated revetments. The cameras can be programed to acquire and archive images at pre-determined locations / frequencies (e.g., daily). If properly calibrated, the archived images then can be used to determine the location and duration of revetment exposure and correlate major changes in the shorezone with specific storm events.

In addition to those uses specific to the shoreline monitoring program, the cameras could serve as a resource for County Staff and the general public. Potential installation locations include the Goleta Beach Pier (east end of the park) and the UCSB Lift Station located on the west end of the park.

4. Conduct Monthly Beach Width Measurements

The Mean Sea Level beach width at each survey transect can be measured more frequently to supplement the comprehensive profile data obtained in the Spring and Fall. Weekly or monthly surveys of berm width could be measured by County staff in collaboration with Coastal Frontiers' ongoing program to better track variability in Goleta Beach's width and sensitivity to benchmark wave and tide events.

5. Conduct Pre- and Post-Storm Beach Profile Surveys

Pre- and post-storm beach profile surveys should ideally be conducted on at least one occasion to determine if storm-induced scour is occurring at the revetment toe and to assess the shoreline response to individual storm events. Pre- and post-storm profile monitoring is difficult as one does not often have sufficient lead time or awareness of when critical events will occur. Post-storm changes can also rapidly change depending upon how soon the survey can follow the wave and tide incident before recovery occurs.

Trigger Metrics

Definition of prescriptive action triggers based upon the monitoring program is challenging in that it is difficult to include all possibilities and outcomes that might occur or should be considered before any specific mitigating action is mandated. In our opinion, the park's existing coastal development permit applies an extremely narrow length, duration, and action allowance regarding exposure of the existing revetment. The ability to remedy the condition is further exacerbated by the imposition of very small and impractical sand placement volume limits that inhibit chance of success. The limitation of allowable revetment exposure and the volume of sand that may be used to re-cover prevents the County from being able to satisfy the intent. We believe that trigger metrics within the coastal zone must of necessity be broader and more flexible so they can adapt to the dynamic complexities and variables that are inherent in the open coast littoral zone.

An outline of a revised plan that may be considered to allow for implementation of a more practical program to respond to Goleta Beach erosion events and trends is presented in **Table 4**. The program assumes that it is tied into the existing beach maintenance program, and potential future managed retreat plans, e.g., creation of a New Lot 6/7 pocket beach or a phased landward retreat plan of remaining park uplands.

Table 4. Preliminary Prescriptive Action Plan for Monitoring Program

Event	Duration	Action
The Mean Sea Level (MSL) beach width is reduced to ½ or less of its initial restored width.	One year post-nourishment (fall to fall season)	Watch
	Two years post-nourishment (fall to fall season)	Alert
	Three years post nourishment (fall to fall season)	Confirm that deficiency is not related to regional coastal processes deficiency as deduced in part from upcoast and downcoast control transect monitoring.
	Five years post nourishment	Implement re-nourishment cycle or retreat action.

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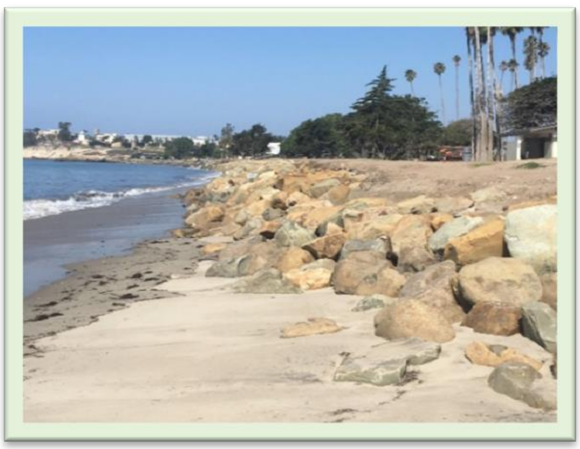
ATTACHMENT TO GBSMA REPORT
Comparison of Cobble Berms and Revetments Used for Shoreline Erosion Protection



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Introduction

This brief report is intended to summarize what is known about the relative performance of cobble berms and rock revetments in shoreline protection as well as potential adverse effects of both approaches. However, as discussed further below, analysis of the effectiveness of cobble berms in the scientific literature is lacking and no studies were located relating to potential adverse impacts of coble berms to coastal processes, habitats or public access.

Rock revetments have a long history of use in shoreline protection and a well-studied and documented level of effectiveness in avoiding or minimizing erosion of the protected shoreline. Rock revetments also have been extensively studied for potential adverse effects on coastal processes and beaches, including the potential for loss of sand supply from coastal bluffs, active and passive beach erosion, interruption of downcoast sand transport, potential effects on sandy beach habitats, and interference with lateral coastal access. The potential for such effects vary by location and circumstances and there is disagreement in the scientific literature about some effects and limited study of others.

Natural cobble berms are generally composed of gravel, boulder, and cobble material (GBC) that is often present in coastal littoral systems. Cobble berms for shoreline protection appear to have had relatively limited use but are thought by some to be a more natural method to provide some level of protection and avoid known or perceived adverse effects of rock revetments. For example, in Santa Barbara County, GBC material is often present on many beaches in small quantities. Beaches such as More Mesa or Ellwood Mesa often exhibit small cobble berms 5-15 feet in width and 2-5 feet in height. Larger accumulations of cobble, potentially sufficient to provide some coastal protection, are known to occur at several coastal points such as El Capitan Point, Fernald Point and Surfers' Point in Ventura. Cobbles are present at Goleta Beach, with cobbles exposed during the height of the 2015-2016 El Niño. However, cobbles do not appear to be a dominant element of the typical littoral system at Goleta Beach, are generally buried, and do not form extensive generally exposed tall mounds such as those found at El Capitan Point or Fernald Point.

Formerly wide South Coast beaches such as More Mesa were severely eroded by the 2015-2016 El Niño and remained narrow in 2017, exposing small natural cobble berms. This berm, 2.5 miles downcoast from Goleta Beach is approximately 15-20 feet wide and 2-3 feet high.

Methodology

In order to determine frequency of past use of cobble berms, their effectiveness in protecting shorelines from erosion, and potential adverse impacts, Amec Foster Wheeler staff reviewed publicly available resources related to cobble berms; shingle beaches; and gravel, beach, and cobble beach projects. Noble Consultants, an internationally recognized coastal science and engineering firm, also assisted with issues related to the effectiveness and design of cobble berms for shoreline protection. Noble Consultants provided the original design guidance and testing for the Surfers' Point cobble berm project in Ventura, which was intended to be used for construction of an artificial cobble beach stabilization project.

Project specific examples for use of constructed cobble berms located after substantial research include Cape Lookout State Park and Yaquina Bay, Oregon; Seaside Park and Surfers' Point, California; and Duxbury Beach, Massachusetts. Additional references to projects that included analysis of potential use of cobble berms for shoreline protection (i.e., Ram Island, Massachusetts) were compiled; however, no follow up information regarding whether the project was implemented or if it was successful was located (Ramsey, J; M. Osler; and T. Ruthven 1999). Two of these projects, Cape Lookout State Park and Surfers' Point were damaged post-construction by El Niño-related high tide and storm surge events that required substantial emergency repairs, including installation of additional cobble material and a rock revetment landward of the cobble berm to restore shoreline protection. Existing known cobble berm projects have been reviewed along with available scientific literature. Potential adverse effects of both rock revetments and cobble berms are discussed below and in Table 1.

Figure 1. Goleta Beach revetment (left) and Surfers' Point C-Street expansion cobble berm (right)
Surfers' Point Photo source: https://toolkit.climate.gov/case-studies/restoring-surfers-point-partnerships-persistence-pays

Shoreline Erosion Protection Effectiveness

Rock revetments are widely used in shoreline protection and are well documented to halt or minimize shoreline erosion behind the structure when properly constructed. The rock revetment at Goleta Beach was originally constructed on an emergency basis, lacks filter fabric to minimize loss of backfill through the stone voids, and at 11 feet in height is lower than a typically recommended height of 13-16 feet. Thus wave overtopping and infiltration during the 2015-2016 El Niño caused some 2 +/- feet erosion of the Park behind some segments of the revetment, although much less than the 15-25 feet experienced in unprotected areas of the Park.

Cobble berms are thought to prevent or slow erosion and impacts from large storm surges or waves by allowing the wave or swell to quickly percolate through the space between the individual cobbles thereby reducing the wave energy. Cobble berms are dynamic in that as waves and surge interact with the cobble, the berm is moved and shaped by the waves and nearshore current (O'Connell 2008)[1]. During winter months, cobble accumulates shoreward creating a steeper slope; in the summer, because of lower wave action, cobble tends to spread seaward (Everts et al. 2002). Such berms are thought to slow but not halt shoreline erosion. However, Noble Consultants has found that success of a cobble berm concept on the open coast is questionable. Further, very limited scientific literature exists that has measured and documented the effectiveness of cobble berms in slowing shoreline erosion. The dynamic

[1] Although limited information is available, the study appeared to have reviewed a low berm used in a sheltered area of limited wave energy.

nature of cobbles may in part explain substantial damage and required repairs that has occurred at two constructed cobble berm projects as discussed further below.

Initial research revealed four constructed cobble berm projects at Surfers' Point in Ventura, Cape Lookout State Park and Yaquina Bay in Oregon and Duxbury Beach, Massachusetts. The effectiveness of such berms does not appear to have been studied extensively; only two papers that assessed effectiveness were located, one of which was observational with no detailed assessment of effectiveness. These papers found that the berms at Yaquina Bay and Cape Lookout State Park were effective in slowing or halting erosion, but that cobbles required maintenance and replenishment. The Yaquina Bay berm appears to have been effective based on one study.

Cape Lookout State Park in Oregon suffered erosion damage in fall and winter of 2016 along the cobble and dune beach, destroying a segment of park access road. Note cobbles and eroded dunes in background. Oregon Shores Conservation Coalition, October 2016

The Cape Lookout State Park cobble berm project was originally constructed in 1999. High tides and storm surges associated with the December 2007 to January 2008 El Niño event caused partial dispersal of the cobble berm, erosion of the constructed foredunes resulting in exposure and damage to Park infrastructure including a septic drain field. The emergency permit response included placement of an additional 4,000 cubic yards of rock material raising the level of the remaining cobble berm by 9.8 feet. While detailed information was not located as to how this reconstructed cobble berm and dune system performed between major storm events (Komar & Allan 2010), major erosive damage was documented at this location as a result of the 2015-2016 El Niño event.

The City of Ventura conducted several pilot cobble nourishment projects in 2000 to test if artificial cobble berms and geotextile mattresses could be built. Approximately 6,000 cubic yards of GBC was placed over a 550-foot long section of semi-protected shoreline at Seaside Park. The cobble was placed at a 5:1 slope and extended from a toe elevation of approximately +8 feet, MLLW, to a crest elevation of +13 feet, MLLW. The berm provided nearly 10 years of erosion protection for the adjacent bicycle path before eventually sloughing and dispersing.

The second cobble berm at Surfers' Point was constructed via a 5-year permit between 2013 and 2017. The initial placement of approximately 4,000 cubic yards of GBC was intended to protect the most severely eroding section of the shoreline. The material placement extended from about 0 feet, MLLW, to a crest elevation to be +13.5 feet high, 94 to 110 feet wide at the base and covered with a layer of sand (City of Ventura 2013). The project is located at a natural cobble point that was also historically protected with concrete rubble and debris. During the 2015-2016 El Niño, the C-Street portion of the berm was dispersed by wave attack, scattering cobbles down the coast and exposing the park to erosive damage. Emergency repairs included construction of a 265-foot-long rock revetment and 6,000 cubic yards of additional cobble to protect the promenade and bike path located 60 feet inland of the berm. The emergency action cost $430,000 to install with potential for added expense for design, full completion and permitting. In review of the permit, the US Army Corp of Engineers found that while the project provided 10 years of protection, substantial additional work is now required. The recently completed managed retreat project along the westernmost portion of Ventura's shoreline involved relocation of parking, a bicycle path, and other improvements landward to create a set back buffer against future erosion episodes. Though research suggests that cobble berms become less effective and can be destabilized if covered with sand, a cobble berm was buried beneath an artificially created sand dune system. As of August 15, 2017, the berm has not been exposed to test its effectiveness and resilience against waves and run-up. .

Based on the limited available data, cobbles may provide some level of protection in slowing shoreline erosion as at Yaquina Bay, but require regular relatively costly maintenance, and can potentially be overwhelmed and suffer damaged from major storms, exposing landward facilities to storm damage as at Surfers' Point (Cowen 2016). Knowledge about how cobble berms function and respond to wave attack is very limited. The Ventura pilot projects demonstrated successes and failures for test sections located within 400 feet of one another. Based upon research conducted at Emma Wood State Beach in Ventura County, monitoring of the Ventura pilot projects, and an assessment of preliminary design guidance, Noble Consultants has found that the strategy of installation of a cobble berm at Goleta Beach should be considered as unproven and experimental and that the County could be responsible for potentially expensive and long term adaptive management maintenance. Noble Consultants also found that there appears to be no known precedent that has attempted to convert a sandy shoreline such as at Goleta Beach to a cobble environment and that such a conversion would require extraordinarily large volumes of cobble material. Further, there is still much that is not known about how cobble berms behave as detailed studies are lacking. This would make it very difficult for a coastal engineering firm to design and stand behind an improvement of the size and scale that would be required for Goleta Beach.

Figure 2. The 2015-2016 El Nino overwhelmed cobble berm protection at Surfers' Point, exposing park facilities to damage (left); in response, the City expended $430,000 to install a 260-foot long 13.5 feet tall emergency rock revetment and cobble replenishment. The project is not yet completed.

Photo Source: http://www.venturariver.org/

Although no preliminary or engineering design work has been performed, Noble Consultants would conservatively assume that to be effective in slowing shoreline erosion at this location, a cobble berm would be constructed at 5:1 slope, with a crest at top of existing grade approximately 13 feet high, with toe elevation at -2 feet MLLW, for a total berm height of 15 feet. If constructed to these dimensions, the toe of the berm could be 115 feet or more in width. To minimize undercutting, a horizontal toe apron for additional scour protection of another 25 feet would be ideal for a total conceptual width of 140 feet which may include a crest width of at least

40 feet wide. Such a robust design may be required to avoid damage such as that that occurred at Surfer's Point in Ventura.

Construction of such a cobble berm would be a major project. Assuming an approximate right triangle in cross-section with the inland edge of the berm laid up against the edge of developed areas of Goleta Beach Park, construction of this cobble berm would require approximately 78,000 cubic yards of cobble material. This would require approximately 5,200 truck trips at 15 cubic yards per trip to deliver the required material to Goleta Beach. While these numbers are strictly conceptual, they provide an order of magnitude of the type of structure required to provide effective protection at Goleta Beach Park to slow shoreline erosion. Downsizing of such berms, as occurred during the Surfers' Point approval process, could result in similar outcomes with potential for dispersal of cobble and damage to facilities during future major storms.

Potential Effects on Coastal Processes and Beach Width

Many studies have been performed on the potential adverse effects of revetments or coastal armoring on coastal processes and beaches, although no similar studies appear to have been conducted for constructed cobble berms. Potential effects of rock revetments on coastal process vary by location, placement of the armoring on the beach and long-term trends in beach accretion and erosion. Direct effects can include:

- *Placement Loss* – Occurs when a shore parallel structure is placed seaward of high tide line, thus substantially reducing the width of the beach. This can constrain access on narrow beaches, especially during winter time or times of limited sand supply, and also displace sandy beach habitats. Placement loss is generally agreed upon in the scientific literature, although the degree of effect is directly related to the width of affected beach and size of the structure.

- *Active Erosion* – Defines any process that accelerates erosion due to the presence of revetments and similar structures. The impact involves the redistribution of sediment supply to a beach and/or any modification of shore zone processes which is thought by some researchers to occur due to wave reflection, wave scouring, or end effects. Substantial disagreement exists within the scientific literature over whether active erosion in front of coastal armoring actually occurs. Please refer to Noble Consultants *2017 Goleta Beach Shoreline Management Assessment* for a summary of the literature and disagreements.

- *Passive Erosion* – Passive erosion occurs when the shoreline is armored or replaced by a permanent hard stabilization structure, thereby causing the landward boundary of the beach to have a fixed location. If the beach erodes back to the point where the revetment is exposed to repeated wave attack, the beach fronting the revetment can be "drowned" as adjacent unprotected shoreline continues to erode, leaving the revetment far forward on the beach profile. This can be seen along the coast at various older seawalls where coastal bluffs have retreated on either side of the seawall. Over time, at such locations, this leads to a narrowing of the beach in front of the structure. There appears to be agreement within the scientific literature over this impact on eroding shorelines.

- *Downcoast Erosion* – Coastal armoring can cause downcoast erosion by cutting off coastal bluffs from erosion or by interrupting downcoast sand transport, thus depriving downcoast beaches of sand.

Goleta Beach Revetments and Coastal Processes: Review of the existing revetments at Goleta Beach Park on coastal processes indicates that placement loss is approximately 18 feet due to the width of the revetment. During times of wide sandy beach from 2004 to 2014 when the beach averaged 125 feet in width, this created minimal effects. Under current eroded conditions where beach width was reduced to 50 feet in 2017, the revetment occupies a substantial portion of the beach, with more than 30% of available beach occupied by revetment. Thus while placement loss at Goleta Beach has not been an issue for the majority of the last 20 years, it is occurring under current depleted sand conditions.

The existing revetments at Goleta Beach, west of the Pier, are currently exposed and interacting with the surf during even moderate tides along most of their 2,000 feet. Those concerned about potential for active erosion impacts may conclude that the beach is narrow at least in part due to active erosion. However, the predominate cause of currently narrow beaches appears to be large scale beach erosion caused by a major storm in March 2014, the 2015-2016 El Niño and the lack of sediment and beach sand input to the system due to the historic 2012-2017 drought.

The western 1,200 feet of revetments were buried for all or most of the ten year period from 2004 to 2014, with the majority of these revetments in daily contact with the surf for approximately 1.5 years since the 2015-2016 El Niño. During this period, detailed beach surveys performed by Coastal Frontiers Corporation did not document any differential erosion between the beach fronting the revetments and unprotected areas of the Park indicating a lack of active erosion. The new 870 feet of revetment installed in 2017 has been in near daily contact with the surf. Those concerned about potential for active erosion impacts may conclude that the beach is narrow at least in part due to active erosion. However, during the short duration of this revetment's existence, others would argue against any substantial contribution to active beach erosion.

In halting landward erosion of Goleta Beach Park, under current severe beach erosion and historically low sand conditions, new and existing revetments have contributed to Goleta Beach becoming intertidal. The duration of this condition will depend substantially on renewed sediment input into the system

Planned monitoring by Coastal Frontiers Corporation in fall of 2017 and spring of 2018 will include review if there is active erosion occurring along the beaches fronting the revetments. These surveys will also monitor the effects of the planned placement of 65,000 cubic yards of sediment on Goleta Beach. Further, it is worth noting that experts such as Professor Gary Griggs of UC Santa Cruz found no evidence of active erosion in one extended study of revetments in Monterey Bay. However, substantial disagreement continues among experts on this topic.

The existing revetments at Goleta Beach west of the Pier are currently exposed along most of their 2,000 feet leading the beach to be submerged during even moderate tides. As noted above, this is predominantly the effect of a major storm in March 2014, the 2015-2016 El Niño and the lack of sediment and beach sand input to the system due to the historic 2012-2017 drought. Goleta Beach lost over 200,000 cubic yards of sand over the last three years leaving much of the beach intertidal. However, in fixing the shoreline in place and protecting the Park, the revetments have in effect drowned the limited remaining beach.

The duration of this current erosion trend is uncertain and is affected by both natural sediment supply from upcoast and County Flood Control nourishment projects such as the 65,000 cubic yards to be deposited in fall and winter of 2017. Another factor contributing to the current narrow beach could be a potential reorientation of Ellwood Beach which experienced significant erosion after the 2015-2016 El Niño event. Dr. David Revell observed that sand supply at Goleta Beach from upcoast may be interrupted as beaches at Ellwood and Isla Vista "refill" with sand after major 1997-1998 El Niño erosion at Ellwood (Revell et al. 2011). Other factors that could affect sand supply from upcoast include flooding associated with the Sherpa Fire and potential increases in sediment input from the Whittier Fire which have the potential to widen Goleta Beach five of more years in the future.

Regardless of the cause, under current extremely low sand conditions, while protecting the Park from erosion, the revetments at Goleta Beach are currently contributing to most of the beach being intertidal. Thus while the beach has been relatively wide and sandy the majority of the last 20 years, it is unclear how long this condition will continue and what effect the planned 65,000 cubic yard beach nourishment from the Santa Barbara County Flood Control District, the end of the drought and upcoast wildfires will have in offsetting this condition. Please refer to Noble Consultants *2017 Goleta Beach Shoreline Management Assessment* for a more complete discussion of these issues.

The revetments at Goleta Beach are unlikely to contribute to downcoast erosion. The revetments lay landward of adjacent natural features that may interrupt sand transport (e.g., point at west end of Goleta Beach). Further, Goleta Beach is a sand spit, not an eroding coastal bluff and is thus not a long term source of sediment for downcoast beaches.

Unlike revetment and coastal armoring, the effects of coble berms on coastal processes do not appear to have been the subject of substantial scientific analysis. Therefore, only an initial assessment is possible at this time.

With regards to placement loss, it is clear based on available examples (e.g., Surfers' Point) and initial assessment of what may be required at Goleta Beach to be successful, that cobble berms would have substantially greater impacts than rock revetments in terms of placement loss. For example, the Surfers' Point cobble berm is 5-6 times the width of the Goleta Beach revetments leading to significantly greater loss of beach than with rock revetments. In fact, cobble berm projects seem too often include either beach nourishment or dune creation to cover such cobbles, although when these features erode, the cobbles are then exposed. Proponents of cobble berm contend that in being natural and dissipating wave energy, a natural beach will return more quickly and bury such cobbles. However, scientific literature in support of this contention is lacking. Therefore, it seems likely that placement loss of such berms would be substantially greater than that for rock revetments.

Similarly, scientific literature of the effects of major constructed cobble berms on active and passive erosion appears lacking. Cobbles are a natural part of the system and are thought to absorb and dissipate wave energy avoiding active erosion and allowing for natural beach replenishment that could offset passive erosion. No studies were located regarding potential for major constructed cobble berms to avoid or reduce active erosion. To the extent that a major cobble berm substantially slows or halts shoreline erosion, such a feature may contribute to passive erosion by fixing the shoreline in place or at least potentially slowing retreat. Detailed research appears unavailable on this issue, but conceptual design guidance for GBC berm design was first proposed in 2002, based upon a study of Southern California natural cobble beaches, published research, and a detailed investigation of the Emma Wood State Beach GBC deposit (Everts et al. 2002). The study concluded at that time that cobble berm design is a pioneering effort and should be perceived as experimental.

With regards to downcoast effects, it is unclear to what degree, if any, a constructed cobble berm of 100 feet or more in width at Goleta Beach would have on slowing downcoast sand transport. However, such a structure would protrude far further seaward that the current revetments. Similar to the revetments, as Goleta Beach is not a source of land term sand to downcoast beaches, such a cobble berm would not block a source of sand.

Potential Effects on Public Beach Access

Vertical Coastal Access: Concerns have been expressed that rock revetments inhibit vertical coastal access. At Goleta Beach, when fully exposed to up to 11 feet in height, the revetments can increase difficulty of shoreline access. Field observations of exposed rock revetments at Goleta Beach and 11 other South Coast beaches show regular public access across exposed rock revetments with limited impediments to access by the able bodied. Revetments are relatively stable and typically offer level surfaces for foot and handholds. While not necessarily desirable, revetments appear to create only a modest barrier to vertical access to the able bodied, while presenting a barrier to the elderly or disabled.

Cobble berms appear to create potentially substantial barriers to vertical access due to the unstable nature of such berms, with cobbles moving under underfoot and shifting with wave run up. Crossing cobbles can be painful without sturdy footwear. Crossing a 13.5 foot tall cobble berm of up to 140 feet in width as suggested by the potential conceptual design parameters discussed above, would be a major barrier to vertical access. Even a smaller berm such as the 100-foot wide by 13.5 feet high berm Surfers' Point would pose challenges similar to or greater than those of crossing the revetment at Goleta Beach. Given potential dimensions of a potential cobble berm at Goleta Beach, such a berm would appear to pose a more severe impediment to public vertical access to the beach than the existing revetment.

Although concerns exists that revetments inhibit coastal access, able bodied beach goers regularly cross, sunbathe or rest on revetments at Goleta Beach and other South Coast Beaches.

Lateral Coastal Access: Concerns have been expressed that rock revetments inhibit lateral coastal access. Because of the current historically eroded beach and low sand conditions at Goleta Beach, the rock revetments inhibit lateral access along much of the beach, except at low and moderate tides. However, absent the revetment, the eroding 10 foot tall scarp of the upland portions of Park would present a similar lateral barrier until such a time as it eroded landward far enough to create a wider beach. It is unclear how far landward the park would need to erode under the current very low sand conditions to provide a dry sand beach.

Cobble berms would appear to create a similar or great lateral access barrier as revetments. First, a cobble berm would occupy perhaps 5-6 times the width of the revetments, and during the current historically low sand conditions as at Goleta Beach, sand would be displaced inhibiting lateral access at even the lowest tides. While the public could traverse the cobble berm, due to the unstable nature of such berms with cobbles moving under underfoot and shifting with wave run up, such lateral access would be uncomfortable and somewhat hazardous. Further, traversing cobbles can be painful without sturdy footwear. Noble Consultants has concluded that if this option is implemented at Goleta Beach, one can expect the foreshore to convert into a swash zone of unstable footing and moving cobble that will be hazardous to waders who attempt to venture into the water.

Compatibility with the Natural System

As noted above, while cobbles do occur at Goleta Beach and can be exposed during major El Niño events, they do not appear to be a major component of the natural system. Unlike points such as El Capitan, Fernald Point and Surfers' Point, there is no evidence of long term exposure of large mounds of cobble at Goleta Beach in anything like the quantities required to provide effective protection to even slow shoreline erosion. Therefore, a major cobble berm of the type required would not appear to be a more natural component of the shoreline than the revetment. A small cobble berm that occupied less of the beach and which could become covered in high sand years could be more natural; however, the ability of a small cobble berm to protect the Park or even slow erosion is unproven. As noted above, only limited scientific literature exists on the effectiveness of major constructed cobble berms. Further, even large cobble berms at Surfers' Point and Cape Lookout State Park in Oregon were overwhelmed by major storm events, exposing public facilities to damage and requiring costly repairs.

Biological Impacts

Revetments that fix the shoreline have been found is some studies to decrease the productivity of natural habitats, limit shorebird foraging and potentially interfere with grunion spawning (Dugan & Hubbard 2010). If a beach becomes intertidal and is submerged at moderate and higher tides as is currently the case at Goleta Beach under low sand conditions, the typical beach habitat profile is disrupted. The absence of a sandy berm and beach face prevents accumulation of beach wrack, reduces diversity of invertebrate habitat and beach habitat for shorebird foraging (Sobocinski et al. 2010). It also eliminates grunion spawning habitat. The duration of these adverse effects currently underway at Goleta Beach is unknown and appears largely related to sediment supply and potential to return to a wider beach.

As with other aspects of constructed cobble berms, their effects on beach habitats and wildlife appear unstudied. However, unless accompanied by major beach replenishment or dune restoration, a cobble berm of 100 to 140 feet in width and up to 15-feet high would appear to bury substantial areas of existing sandy intertidal habitat at Goleta Beach. Based on available literature, the effects of this on shorebird foraging appear relatively unstudied. Until sand returns to Goleta Beach, exposed cobbles may bury intertidal foraging areas for much of the time. However, such a relatively gently sloping cobble berm would potentially provide areas for beach wrack accumulation and invertebrate habitat, creating shorebird food source and roosting areas. Effects on grunion would require additional research to determine if grunion could spawn on such a cobble berm.

Maintenance Costs

Revetments are expensive to install, but once constructed require minimal maintenance. The revetments at Goleta Beach are likely to provide long-term protection while requiring little upkeep or maintenance. One exception is that portions of the old 1,200 feet of revetment at the Park’s west end would benefit from backfilling a gap behind the revetment with cobble or other material. As noted above, these revetments were installed on an emergency basis without attention to fine tuned design details.

Cobble berms are acknowledged in the limited literature to require relatively regular upkeep and maintenance (City of Ventura 2013, 2016; Komar & Allan 2010). By their dynamic nature, cobble disperse along the shoreline and, in order to maintain the integrity of the berm for coastal protection, would need to be periodically gathered up and placed back into the berm either by hand or with heavy equipment. Alternatively, new cobble would have to be imported via heavy haul trucks. As demonstrated at both Cape Lookout State Park and Surfers’ Point, periodic major repairs would likely need to be undertaken after major storm seasons such as an El Niño. Thus, although detailed studies are lacking, it would appear that direct maintenance costs of cobble berms are substantially higher than for revetments. As noted by Noble Consultants, relying on a cobble berm at Goleta Beach would likely commit the County to expensive long term maintenance with no surety of protection for the Park.

Finding adequate sources of GBC material will be difficult. Sources appear to be regionally limited to deposits in the Ventura River and Santa Paula Creek. A significant stockpile of GBC that was excavated during flood control maintenance in Santa Paula Creek in the early 2000s was coveted for commercial uses including landscape design and construction material. The GBC material was ultimately crushed for aggregate base material. The existence of competing use places an unknown commercial value on the material and creates potential uncertainty in project cost in the future. Between 2005 and 2013, estimates of the cost to purchase and import GBC for shoreline protection escalated significantly.

Table 1.Comparison of the Effects of Cobble Berms and Rock Revetments

Affected Resource	Cobble Beach Berm	Rock Revetment
Shoreline Erosion Protection	Experimental; may slow erosion; minimal scientific studies performed on effectiveness	Known to be effective in halting or minimizing shoreline erosion behind revetment
Vertical Coastal Access Impacts	No scientific studies available; unstable surfaces; difficult to cross; may restrict access when uncovered	Moderate impediment to access when uncovered
Lateral Coastal Access Impacts	No scientific studies available; difficult to cross when uncovered; dispersed cobles can interfere with beach walking	Restricted when uncovered if beach is intertidal in front of revetment
Naturally Occurring	Dominant feature in certain locations; absent or minimal in others such as Goleta Beach	Revetments are not natural, but boulder fields are widespread along segments of California coast
Biological Impact	Unknown, no studies available; potential loss of sandy beach habitat through greater coverage of beach compared to revetments	Potential impacts to beach habitats and wildlife if long term passive erosion/beach drowning occurs
Active Erosion	Unknown, no scientific studies appear available, but potential appears low	Disagreement in scientific literature if revetments cause active erosion; effects may be minimal or limited
Passive Erosion	No scientific studies appear available; potential for passive erosion by fixing shoreline/ slowing erosion	Known to have potential to cause passive erosion by fixing shoreline
Downcoast Beach/ Erosion Effects	No scientific studies available; large cobble berms may slow or inhibit downcoast sand transport	Revetments far seaward on beach may interrupt downcoast sand transport; unlikely to occur at Goleta Beach
Maintenance Costs	Limited scientific studies available; relatively regular replenishment of cobbles required at substantial expense	Low maintenance costs

Conclusions

In summary, based on review of available scientific literature, performance of known projects, and consultation with Noble Consultants, rock revetments and cobble berms have different degrees of effectiveness in shoreline protection and potential impacts on the local environment when emplaced:

1. Effectiveness in Shoreline Protection: Revetments are known to protect shorelines from erosion. Cobble berms are experimental, appear to have had few applications and can be subject to dispersal or destruction by strong storms, exposing facilities to damage or destruction.
2. Placement Beach Loss: Revetments are known to cause placement loss by covering sand; revetments are generally 15-30 feet in width. The effects of constructed cobble berms on placement loss do not appear to have been studied; however, such structures have a far larger footprint than revetments (e.g., 100+/- feet) and would appear to have substantially more severe placement loss then rock revetments.
3. Active Erosion: Substantial debate exists among coastal scientists if revetments cause active beach erosion, with many studies on the west coast finding no evidence of erosion. No studies appear available on whether major constructed cobble berms cause active beach erosion; proponents contend that such berms adsorb wave energy, limiting potential for impacts; however, no studies appear available to support this.
4. Passive Erosion: Rock revetments are known to fix shorelines in place and along eroding coast, such as coastal bluffs, can cause passive beach erosion. No studies on the effects of constructed cobble berms on passive erosion appear available.
5. Downcoast Erosion: Revetments can cause downcoast erosion by protecting coastal bluffs from erosion (loss of sand source) or by interrupting downcoast sand transport where the revetment projects far seaward. No studies appear available on the effects of constructed cobble berms on downcoast erosion, although if such berms are effective in slowing or halting bluff erosion, potential would exist for loss of sand supply. Such structures also protrude far further into the littoral zone than revetments with potential to slow sand transport, although dispersal of cobbles by waves may limit effects.
6. Vertical Coastal Access: Both revetments and cobble berms can inhibit vertical access, although the public regularly crosses both to reach area beaches.
7. Lateral Beach Access: Both revetments and cobble berms can inhibit lateral access, particularly if a beach is intertidal in front of either structure.
8. Natural Characteristics: Revetments are not naturally occurring structures. Cobble are present in the South Coast littoral system, but large mounds sufficient to provide erosion protection appear to be confined to certain locations, such as Emma Wood State Beach, El Capitan Point, Fernald Point or Surfers' Point. There is no evidence to suggest that large generally exposed mounts of cobble are a persistent feature at Goleta Beach.
9. Biological Impacts: Revetments may impact sandy intertidal beach habitat if active or passive erosion occurs and the beach becomes intertidal. The loss of beach berm and beach face habitat and area for beach wrack to accumulate can impact invertebrate populations, shorebird foraging, as well displacing grunion spawning habitat. No studies on constructed cobble berms exist, but the large footprint of such structures could displace sandy beach shorebird foraging habitat, although room for beach wrack accumulation and shorebird roosting would remain.

10. Maintenance Costs: Properly designed and constructed revetments require minimal maintenance. Cobble berms are acknowledged to require relatively regular replenishment of depleted cobbles and, based on known projects, periodic major repair. Sources of suitable GBC are not readily available and are generally limited to regional flood control channel beds. The material is also coveted by other commercial interests which makes project cost forecasting difficult.

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