CHAPTER 3

Coastal Processes and Human Adaptations

This Chapter examines the Oceanside Littoral Cell along with implications of human intervention, including sediment management, beach nourishment and the construction of groins, breakwaters, and seawalls.

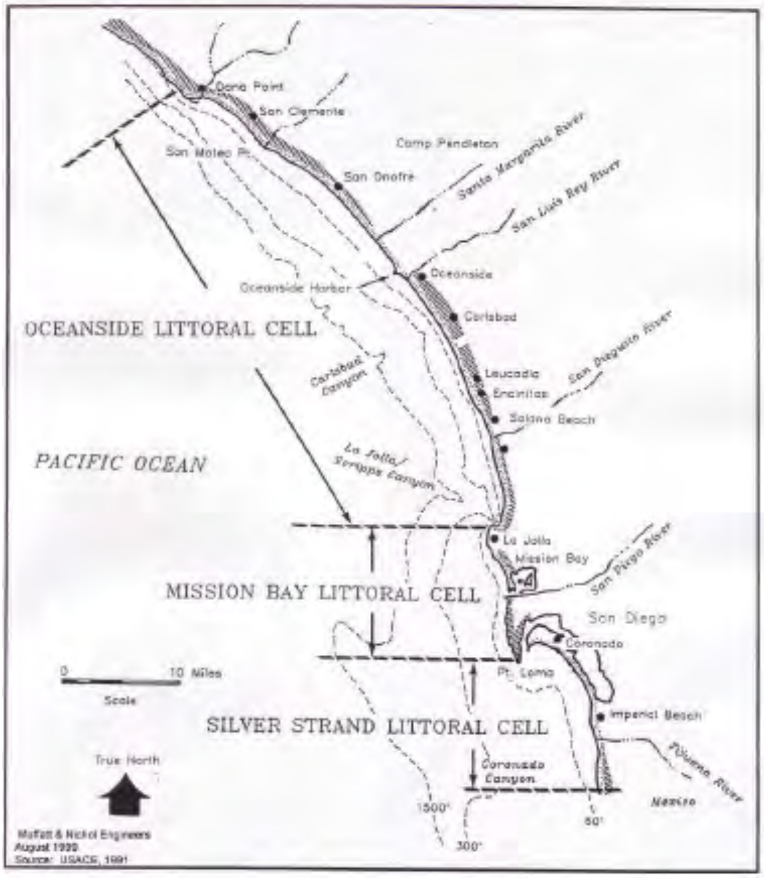
3.1 Oceanside Littoral Cell

Coastal processes drive the movement of littoral sediment, leading to beach erosion, beach stability, or beach accretion. Coastal erosion and accretion has always existed and these Coastal processes have long contributed to the present coastline. The California coast can be separated into discrete geographic areas called littoral cells. Littoral cells are the areas where sediment moves in various directions along the coast. Other features such as submarine canyons and headlands are also part of the coastal environment. The littoral cells within San Diego County (Figure 3.1.1) are the Oceanside Littoral Cell to the north, the Mission Bay Littoral Cell, and the Silver Strand Littoral Cell. Patsch et al (2007) provides a broad overview the Oceanside littoral coastal processes as follows:

"The Oceanside littoral cell extends approximately 50 miles from Dana Point Harbor south to La Jolla and Scripps Submarine Canyons. The large Oceanside Littoral Cell is artificially divided by Oceanside Harbor's north jetty, which effectively eliminates significant transport of littoral sand from the northern portion of the littoral cell to down coast of the Harbor. The shoreline of this cell consists of a continuous, narrow beach backed by sea cliffs or bluffs with the exception of the mouths of coastal rivers, streams, and harbors. Rocky headlands form the northern and southern boundaries of this cell. Sand entering the Oceanside littoral cell moves southward in the direction of the net alongshore transport and eventually enters the heads of La Jolla and Scripps submarine canyons, which are within a few hundred yards of the shoreline, just offshore from Scripps Institution of Oceanography. These canyons extend offshore in a southwesterly direction for approximately 33 miles, eventually depositing sediment into San Diego Trough, although it is widely believed that La Jolla Submarine Canyon is not a functioning sink for beach sand at the present time.

San Juan Creek and the Santa Margarita, San Luis Rey and San Dieguito rivers are the major sources of sand to the Oceanside littoral cell. These river sources originally only approximately 33% of sand to the overall littoral cell budget. Sand transport to the littoral provided approximately 66% of the sand to this littoral cell[1]. Post-damming, the rivers now provide coast from these rivers is highly episodic as a function of rainfall duration and intensity"[1].

Figure 3.1.1
Littoral Cells within San Diego County



Moffatt & Nichol Engineers
August 1999
Source: USACE, 1991

Large portions of the Oceanside littoral cell consist of sea cliffs and bluffs that range in height from 25 to 100 feet. The Torrey Pines area has cliffs and bluffs which reach heights of over 300 feet. In the Oceanside cell, approximately twenty percent of the sea cliffs have some type seawalls or revetments. Up to 80% of the sand from the erosion of sea cliffs and bluffs is of the grain size or that contributes directly to the coastal beaches. Table 3.1.1 from Patsch et al (2007)[1] provides details on cubic yards (cy) of sand per year (yr) contributed to the Oceanside littoral cell from major sources. The difference in contribution from rivers indicates reductions in sand sources to the Oceanside littoral are due to the damming of rivers and the armoring of sea cliffs. As described by Leighton and Associates (2001), "*Since 1919, dams have been built across all the major rivers systems in San Diego County that provides sediment to the beaches. With the construction of Lake Hodges in 1919, the effective sediment producing area of the San Dieguito River watershed was reduced from 346 square miles to 43 square miles. We can conclude that the beach width generally have been reduced since 1910 when the railroad was placed on the bluffs*".

Table 3.1.1
Overall sand contributions and reductions since 1910 to the Oceanside littoral cell[1]

Oceanside Littoral Cell			
Inputs	**Natural (cy/yr)**	**Actual (cy/yr)**	**Reduction (cy/yr)**
Rivers	286,500 (66%)	132,500 (33%)	154,000 (54%)
Bluff Erosion	118,000 (27%)	100,000 (25%)	18,000 (15%)
Gully/Terrace Erosion	31,500 (7%)	31,500 (7%)	0
Beach Nourishment		138,000 (34%)	+ 138,000 (0%)
Total Littoral Input	435,700 (100%)	401,700 (100%)	34,000 (8%)

Patsch et al (2007) provides a description of the reductions in the sand budget in the Oceanside littoral as follows: *"'Actual' sand yield refers to the estimated volume of sand reaching the coast under present day conditions taking into account reductions in sand supply from dams and sea cliff armoring as well as additions (e.g., sand provided by the dredging of Oceanside Harbor) to the budget from beach nourishment. In total, beach nourishment (not including bypassing from Oceanside Harbor) has provided approximately 7.2 million cubic yards of fill on the beaches in this cell, which is approximately 138,000 yd^3/yr over the last 65 years (1940-2005), representing 34% of the sand in the overall littoral budget. There appears to be a significant reduction in sand input to the cell compared to the original natural conditions as a result of most of the historic sand nourishment took place several decades ago. Construction of Oceanside Harbor in the early 1960s (which added sand to the region over the short-term, but significantly interrupted sand delivery from up coast over the long-term).'"*[1]

In the Moffatt & Nichol (2009) study for SANDAG, they noted the following recent SANDAG beach nourishment effort as follows: *"SANDAG performed beach nourishment from September to December 2012, including placements at Solana Beach. According to SANDAG, it is estimated that the southern Oceanside Littoral Cell needs 25 million cubic yards of sand nourishment for restoration and 320,000 of cubic yards of sand nourishment for maintenance"*[6].

3.2 Sediment Management

As described in section 3.1, the Oceanside littoral has a problem inadequate sediment delivery to the coast. Using sand from offshore deposits can serve to nourish stripped sand beaches as a public benefit. The objective would be to use sediment that is presently trapped upstream or up coast, or sequestered in offshore and terrestrial sand deposits. This may be effective for offsetting existing sediment losses from the coastal zone. In addition, the removal of existing surplus sediment from impacted areas such as clogged harbor entrances, lagoon mouths, and degraded wetlands can also benefit these natural features. Moffatt & Nichol (2009), evaluated Oceanside Harbor's northern jetty sediment transport impacts for SANDAG as follows:

"The interruption of sediment transport by Oceanside Harbor's northern jetty has created an extensive deposit of high quality sand up coast of the jetty, representing a large potential nearshore source if SANDAG and MCB Camp Pendleton can reach agreement on the procurement of that sand. This material would have naturally migrated to the southern portion of

the Oceanside littoral cell had the jetty not halted its migration. Therefore, it represents a sediment sink, and restoration of natural littoral cell dynamics could provide a large-scale source of “new” sediment for the southern littoral cell. Sediment bypassing from this fillet represents one, if not the most potentially productive contributions to the coastal sediment budget for the San Diego region. SANDAG investigated this potential source in late 2008 and found it suitable for nourishment, but concluded that additional investigation is needed to better define the highest quality portions of the deposit.” Restoration of sediment movement past the Oceanside Harbor jetty would contribute significantly to the region’s sediment budget. Bypassing of sediment from up coast of Oceanside Harbor is recommended to increase sediment volumes along North County beaches. Oceanside Harbor jetty retains a wide sandy fillet formation extending several miles north of the jetty into MCB Camp Pendleton (DBW/ SANDAG 1994)”[6].

The objective should be that nourishment rates at least equal loss rates. This rate should serve as the target for nourishment for future inputs to the region. Nourishment rates that exceed the loss rates should promote beach widening. Implementation of groins, breakwaters, and reefs to retain sand along the coastline should be investigated as a means to reduce the on-going need for sand nourishment. A Del Mar Sediment Management Plan will be prepared as a next step to further study and detail beach and dune nourishment as an adaptation measure.

3.3 Del Mar Shoreline Change Analysis

In Del Mar, approximately 66% of sediments in the sea cliffs have a grain size that is large enough to contribute to the beaches. Table 3.3.1 summarizes the quantity of beach-sand-sized material, based on the grain size that contributes to the beach. These sand volumes were averaged over a 6-year time span to calculate average annual sediment volumes of beach-sand-sized materials.

Table 3.3.1

Average annual eroded volumes (m^3/yr) - April 1998 to April 2004

	Total Eroded Sediment		Beach-Sand Content (total reduced for grain size[1])	
Section Name	Gully	Seacliff	Gully	Seacliff
Torrey Pines	8300	26,400	3500	11,100
Del Mar	600	4900	500	3700
Solana Beach	0	8300	0	6200
Cardiff	0	5800	0	4600
Leucadia	0	5900	0	4700
Carlsbad	0	4000	0	3200
Camp Pendleton	7600	5500	4100	2900
San Onofre	16,700	57,100	11,900	40,500
Oceanside Littoral Cell	33,200	117,900	20,000	76,900
San Clemente[2]	4700	7600	3800	6100
Dana Point[2]	0	4500	0	3600

2006 - Adam P. Young and Scott A. Ashford

[1] Grain size of sediments in the sea cliffs large enough to contribute to the coastal beaches.

[2] The total for the Oceanside Littoral Cells excludes the San Clemente and Dana Point sections.

Table 3.3.2 summarizes calculated south bluff retreat rates for the Del Mar area. A high percentage of the bluff erosion and retreat results from periods of substantial rainfall which tend to saturate portions of the bluffs and weaken the bluff materials to the point of failure. One can anticipate that similar magnitude of retreat rates of up to 12 feet of bluff erosion may occur in the next 20 years. Therefore, in several sections along the tracks, bluff retreat may impact the existing rails if mitigation measures are not implemented. The North County Transit District (NCTD) determined that installing soldier piles was the least environmentally damaging feasible alternative for an interim approach to track bed stabilization. Soldier piles can be considered to be underground, reinforced concrete columns. In the SANDAG Del Mar Bluffs Stabilization Project 3 (2010) submission to the California Coastal Commission, SANDAG defined soldier piles as follows: *"Soldier piles are essentially underground, reinforced concrete columns. Spacing the soldier piles along a bluff provides improved support, provided that the soldier piles are anchored in a relatively stable geological formation".* [10]

Table 3.3.2
Historical Del Mar calculated south bluff retreat rate [2,9]

Del Mar Calculated Bluff Retreat Rate		
Report	**Years**	**Bluff Retreat Rate**
AT&SF	1943-78	0.14 ft/yr
L&A	1978	0.22ft/yr
Benumof & Griggs	1999	0.4 to 0.6 ft/yr
FEMA	2000	< 1ft/yr

The underlying structure of the beaches in most northern San Diego County is a rock platform with a very thin coating of sand and sometimes cobble. Many of the northern San Diego County beaches have very little sand depth because of sand undernourishment caused by the reductions of sand from inland sources and local geology. Figures 3.3.1 and 3.3.2 show the average decline in Del Mar beach width just south of the San Dieguito river mouth from two monitoring stations since 1978. As outlined by Elwany, Hany of Coastal Environments (2016) in the annual the San Dieguito Lagoon Restoration Project Report, "*A study conducted in 2010 concluded that the rate of beach width decrease is about 2.0 ft/yr to 4.5 ft/yr."* [5]

Figure 3.3.1
Beach width history from 1978-2015 for monitoring point 1[5]

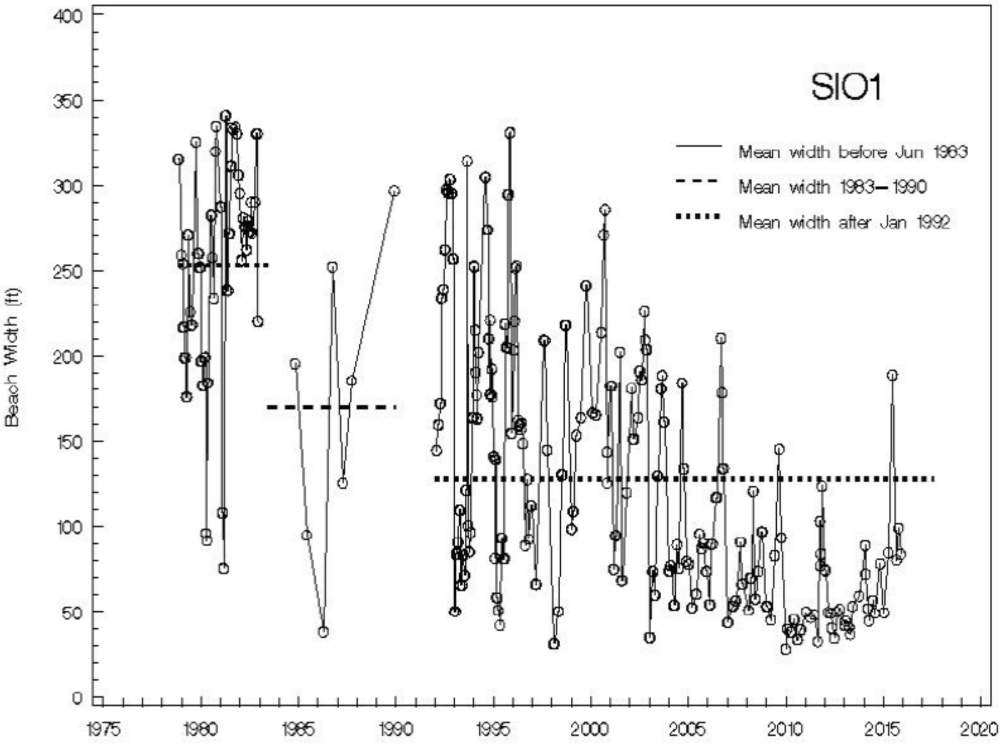
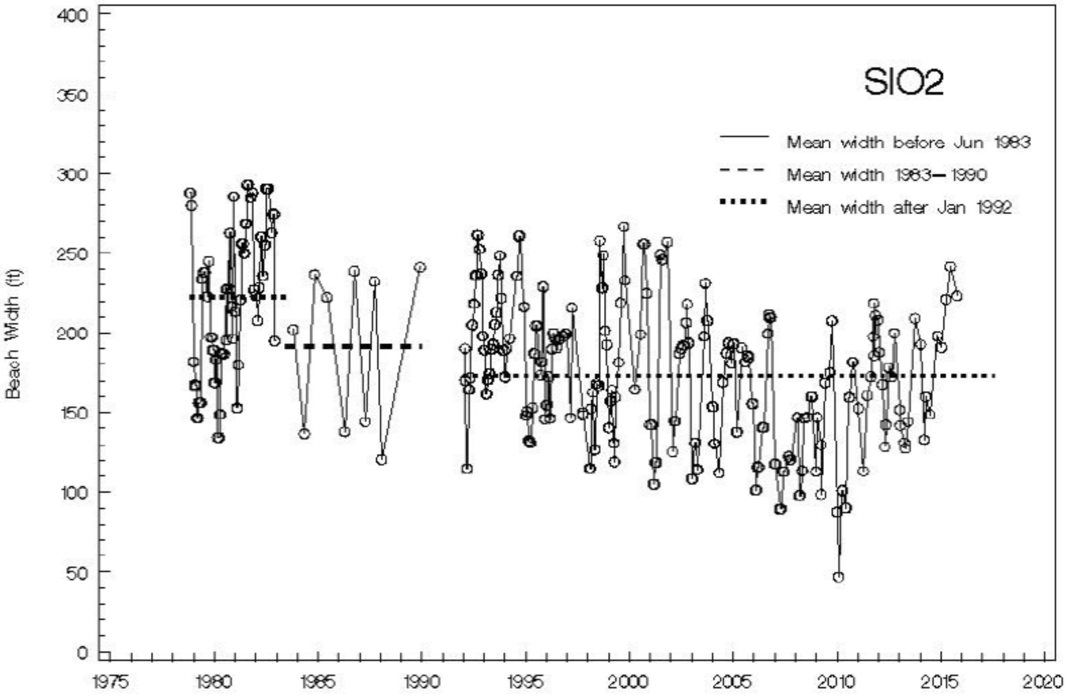


Figure 3.3.2
Beach width history from 1978-2015 for monitoring point 2[5]



3.4 Human Alterations to the Shoreline

3.4.1 Beach Nourishment

Beach and dune nourishment is an adaptation strategy that provides protection against coastal storm erosion while maintaining the natural condition, beach habitat, and processes (such as the ability of the beach to erode in response to winter storms and build up sand in response to summer wave conditions). Beach nourishment refers to placement of sand to widen a beach, which can be accomplished by placing a sediment-water slurry directly on the beach and/or mechanical placement of sediment with construction equipment (Figure 3.4.1.1). Sand can be obtained from inland sources (e.g., sand trapped in dam reservoirs, construction projects) and can be dredged from offshore.

Dune restoration would include placement of sand, grading, and planting to form “living” back beach dunes. Dune restoration is recognized as a natural way of mitigating backshore erosion as well as maintaining a wider beach through sacrificial erosion of the dunes. Dune restoration can provide aesthetic, ecology, and recreation benefits. A variant includes placement of cobble (rounded rock), which is often naturally present as a lag deposit1 below beaches in California (Figure 3.4.1.2). Burying a layer of cobble provides a “backstop” that is more erosion resistant and dissipates waves to a greater degree.

Figure 3.4.1.1
Beach Sediment Placement at Carlsbad

Figure 3.4.1.2

Beach Nourishment, Dune Restoration, and Cobble Placement Illustration

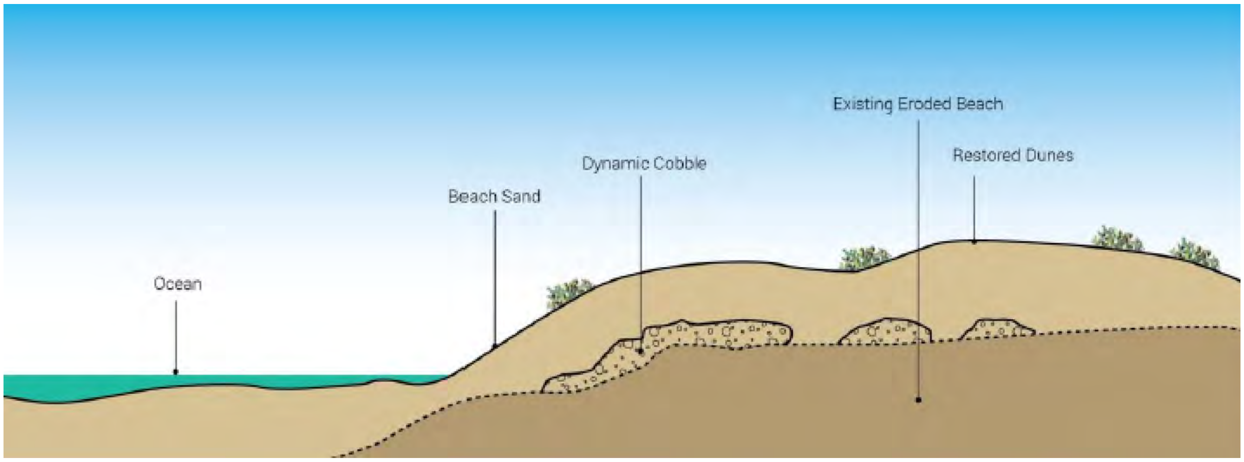


Table 3.4.1.1
Beach and dune nourishment benefits and constraints summary

Benefits	Constraints
• Preserves beach	• Limited sand sources
• "Living shoreline" provides beach and dune habitat	• Less effective over time with increasing sea-level rise
• Reduces flood and erosion risks	• Transportation of sediment to receiver sites
	• Short-term beach use and ecology impacts

Table 3.4.1.1 summarizes benefits and constraints of beach and dune nourishment. Potential problems with beach nourishment include loss of beach use during construction and impact to beach ecology[11,12], which are generally considered short term negative effects. Beach nourishment can also change beach conditions (e.g., texture and slope), if and when the placed sand is different than the “native” beach sand, which typically occurs due to the difficulty in finding sand with the same grain sizes. The success of the nourishment depends on the volume of nourished material, the grain size, and the proximity or use of sand retention measures (discussed separately in the next section).

Placement of sand typically provides a temporary benefit until the sand erodes and migrates away from the placement area. It is therefore important to consider the fate of the sand and implications of deposition in other areas. In general, increased sand supply is considered beneficial to most beach areas, but can be problematic at lagoon inlets and storm drain outlets. Sand deposition on rocky substrate may also adversely affect habitat and recreation such as surfing.

Key feasibility constraints to beach nourishment and dune restoration include the availability of appropriate sand sources and the required amount and frequency of nourishment. With a certain amount or rate of sea-level rise, the amount and frequency of nourishment may make the measure unsustainable. For the purposes of the Adaptation Plan, it is assumed that beach nourishment will be effective with up to 1 ft of sea-level rise based on the results of the Coastal Hazards, Vulnerability, and Risk Assessment and is, therefore, not included as an adaptation measure for sea-level rise above 1 ft.

Monitoring plays an important role in identifying the need for re-nourishments. Monitoring is typically focused on the annual maximum and minimum beach width and minimum dune width. The minimum dune width should provide an acceptable buffer for storm erosion (e.g., 2- to 5-year storm). At any time, beach nourishment may be required in response to erosion from a major storm event.

If beach-sized material becomes available via construction or other activity, the City will consider whether the material could be beneficially re-used on the Del Mar beach. Southern California Edison placed sand dredged from the San Dieguito Lagoon on the northern portion of North Beach in 2011 (40,000 cubic yards) and 2014 (15,000 cubic yards). Similarly, beach and dune nourishment can be combined with dredging of sediment from the San Dieguito River as a future adaptation measure to reduce river flood risks. SANDAG has conducted beach nourishment in San Diego County through the Regional Beach Sand Project. SANDAG performed beach nourishment from September to December 2012, including placements at Solana Beach. The City of Del Mar did not participate in the SANDAG Program, but could consider participating in any future nourishment to implement this adaptation measure. Additional information on regional sand management can be found via the Coastal Sediment Management Workgroup (CSMW, http://www.dbw.ca.gov/csmw/).

According to Van Rijn *et al* (2007), "*Overall, it is concluded from field practice that shore face nourishments have an efficiency (defined as the ratio of volume increase of the nearshore zone and the initial nourishment volume) of 20% to 30% after about 3 to 5 years*"[7]. This seems consistent with studies of nourishment projects in Californian which have shown that about 20% of the projects survived less than 1 year, 55% lasted only 1 to 5 years and about 20% survived over 5 years.

3.4.2 Groins

The principle objective of groins is sand retention. Groins are thin and long structures perpendicular to the shoreline extending into the surf zone. Groins typically extend slightly beyond the low water line. Groins are used to reduce the longshore currents and littoral drift in a surf zone and to retain the beach sand between the groins. Groins are used to stabilize and widen the beach or to extend the lifetime of beach fills. A groin field is a series of similar groins that may be constructed to protect a stretch of coast against erosion. Groins should be prefilled with sand upon construction, otherwise the groins will have adverse impacts when a structure-retained beach is allowed to develop with sand from the littoral system.

Van Rijn *et al* (2007) define two major types of groins, as follows:

- *"impermeable, high-crested structures: crest levels above +1 m above MSL (mean sea level); sheet piling or concrete structures, grouted rock and rubble-mound structures (founded on geotextiles) with a smooth cover layer of placed stones (to minimize visual intrusion) are used; these types of groins are used to keep the sand within the compartment between adjacent groins; the shoreline will be oriented perpendicular to the dominant wave direction within each compartment (saw-tooth appearance of overall shoreline);*
- *permeable, low-crested structures: pile groins, timber fences, concrete units, rubble-mound groins, sand-filled bags are used; permeability can increase due to storm damage; these types of groins are generally used on beaches which have slightly insufficient supplies of sand; the function of the groins is then to slightly reduce the littoral drift in the inner surf zone and to create a more regular shoreline (without saw-tooth effect); groins should act as a filter rather than as a blockade to longshore transport."*[7]

3.4.3 Detached Breakwaters and Reefs

Breakwaters are parallel structures that are used to protect a section of the shoreline by forming a buffer or barrier to the waves. Breakwaters obstruct the wave energy. There are two major categories of breakwaters: those that are positioned above the still water level (emerged); and breakwaters below the still water level (submerged Van Rijn *et al* (2007) define the various variants of breakwaters, as follows:

"There are many variants in the design of detached breakwaters, including single or segmented breakwaters with gaps in between, emerged (crest roughly 1 m above high water line) or submerged (crest below water surface), narrow or broad-crested, etc. Submerged breakwaters are also known as reef-type breakwaters and are attractive as they are not visible from the beach. A reef (hard or soft) is a relatively wide, submerged structure in the shallow nearshore zone.

Submerged structures cannot stop or substantially reduce shoreline erosion (dune-cliff erosion) during storm conditions, as most of the waves will pass over structure to attack the dune or cliff front. Supplementary beach nourishments are required to deal with local storm-induced shoreline erosion (especially opposite to gaps). Down drift erosion generally is manageable as longshore transport is not completely blocked by low-crested structures. A major problem of submerged breakwaters and low-crested emerged breakwaters is the piling up of water (wave-induced setup) in the lee of the breakwaters resulting in strong longshore currents when the breakwater is constructed as a long uninterrupted structure (no gaps) or in strong rip currents through the gaps when segmented structures are present. Other disadvantages of detached breakwaters are the relatively high construction and maintenance costs, inconvenience and danger to swimmers, and small boats and aesthetic problems (visual blocking of horizon)."[7]

3.4.4 Seawalls and Revetments

Seawalls and revetments are structures to armor the shore to protect the land behind it. They are shore-parallel structures that protect against storm-induced erosion and/or long-term chronic erosion by the sea. These structures have various shapes such as vertical, concave or sloping designs. When natural beaches can no longer prevent erosion due to high waves, seawalls are typically built along a limited section of the shoreline as a last defense line against the waves. If no other solution helps to solve the problems of erosion or flooding during high surge levels, the building of seawalls or revetments is considered to be a necessary and "end of the line" solution. Van Rijn *et al* (2007) define the various variants of breakwaters, as follows:

“A seawall is a vertical (or almost) retaining wall with the purpose of coastal protection against heavy wave-induced scour; it is not built to protect or stabilize the beach or shore face in front of or adjacent to the structure. Thus, chronic erosion due to gradients of longshore transport will not be stopped or reduced. A revetment is an armor protection layer (consisting of light to heavy armor layer, underlying filter layer and toe protection) on a slope to protect the adjacent upland zone against scour by current and wave action. To reduce scour by wave action and wave reflection at the toe of the structure, the slope of the revetment should be as mild as possible (not steeper than 1 to 3). The crest of the revetments should be well above the highest storm surge level resulting in a crest level at +5 m above mean sea level along open coasts and up to +7 m at locations with extreme surge levels.

Seawalls and revetments are very effective in stopping local shoreline erosion (dunes and soft cliffs), but these types of structures hardly change the longshore transport gradient often being the basic cause of chronic erosion. Hence, erosion of the beach and shore face in front of the structure will generally remain to occur. Down drift erosion will usually occur at locations where no structures are present. Continuing shore face erosion may ultimately lead to an increased wave attack intensifying the transport capacity and hence intensified erosion (negative feed-back system). Groins are often constructed to reduce scour at the toe of the revetment by deflecting nearshore currents”. [7]

Table 3.4.4.1 provides a comparison of hard shoreline protection measures and their effectiveness to reduce or stop shoreline erosion and their impacts on beach width. As described by Everts Coastal (2002*), “In Southern California, the most effective shore-connected sediment-blocking structures, such as groins, are located where the bearing of the open coast shoreline is between 240 and 310-320 degrees and there is a substantial net longshore sand transport rate.”*[13] It should be noted that Del Mar’s bearing averages 348 degrees, and therefore not optimum for groins, since the length of the groins would need to be relatively long to be effective. In summary, beach nourishment in conjunction with detached breakwaters or reefs that retain a salient might warrant further investigation by the City of Del Mar.

Table 3.4.4.1
Effectiveness of Hard Structures (adapted from Van Rijn et al, 2010[7])

Type of Structure	***Effectiveness***		
	Reduce shoreline erosion	***Stop shoreline erosion***	***Beach width***
Seawall Revetment	*yes*	*yes*	*none or very small*
Groins	*yes, especially at beaches of relatively coarse sediment (0.3 to 1 mm)*	*no, dune and cliff erosion will continue during major storms with high water*	*wider for narrower cells; smaller and saw tooth effect for wider cells*
T-head Groins	*yes, especially at very exposed, eroding beaches of fine sand*	*no, dune and cliff erosion will continue during major storms with high water levels*	*medium wide*
Submerged detached breakwater/reef	*yes, but minor*	*no, dune and cliff erosion will continue during major storms with high water levels*	*small*
Emerged breakwater (low crested)	*yes at lee side*	*no , dune and cliff erosion will continue during major storms with high water levels*	*medium to wide at lee side*
Emerged breakwater (high crested)	*yes at lee side*	*no, dune and cliff erosion will continue during major storms with high water levels*	*medium to wide at lee side*

3.5 References

1. Patsch, Kiki, and Gary Griggs. *Development of Sand Budgets for California's Major Littoral Cells*. Institute Of Marine Sciences, University of California, Santa Cruz, California Department of Boating and Waterways, California Coastal Sediment Management Workgroup, Jan. 2007.
2. Leighton and Associates, Inc. *Del Mar Bluffs Geotechnical Study, Part 1: Geotechnical Evaluation, Volume 1*, North County Transit District, 2001.
3. Scott, Alan, and Jane E. Smith. *Shoreline Protective Structures*. Staff Report to the California State Lands Commission, Apr. 2001.
4. Young, Adam P., and Scott A. Ashford. *Application of Airborne LIDAR for Seacliff Volumetric Change and Beach-Sediment Budget Contributions*. Journal of Coastal Research, Mar. 2006., 22:307-318.
5. Elwany, Hany of Coastal Environments. *San Dieguito Lagoon Restoration Project, 2015 Beach Data Annual Report, City of Del Mar, California*. Southern California Edison, February 5, 2016.

6. Moffatt & Nichol, *Coastal Regional Sediment Management Plan for The San Diego Region*, SANDAG and California Coastal Sediment Management Workgroup, Mar. 2009.
7. Van Rijn, Leo. *Coastal erosion control based on the concept of sediment cells*. Concepts and Science for Coastal Erosion, Conscience for the European Commission, Contract 044122 - D13a, Jan. 2010.
8. Adam P. Young, Jessica H. Raymond, John Sorenson, Elizabeth A. Johnstone, Neal W. Driscoll, Reinhard E. Flick, and Robert T. Guza, *Coarse Sediment Yields from Seacliff Erosion in the Oceanside Littoral Cell*, **Journal of Coastal,** May 2010, Volume 26, Issue 3, pg(s) 580- 585.
9. Hapke, C.J., and Reid, D., 2007, *National Assessment of Shoreline Change, Part 4: Historical Coastal Cliff Retreat along the California Coast*, U.S. Geological Survey Open-file Report 2007-1133
10. CC-020-10, SANDAG, Del Mar Bluffs Stabilization Project 3.
11. Charles H. Peterson and Melanie Bishop. *Assessing the Environmental Impacts of Beach Nourishment*, BioScience, Volume 55, Issue 10, 1 October 2005, Pages 887–896.
12. Schlacher TA, Thompson L. *Beach recreation impacts benthic invertebrates on ocean-exposed sandy shores*. Biological Conservation. 2012;147:123–32.
13. Everts Coastal. *Impact of Sand Retention Structures on Southern and Central California Beaches*. California Coastal Conservancy, June 2002. CCC Contract Number: 00-149.