

Dynamics Of Beaches Made Easy

*San Diego County Chapter of the
Surfrider Foundation*

1. Introduction

Beaches are made up of more than just sand. In California beaches are generally formed by erosion of uplifted plates resulting in cliff backed beaches or in the delta areas of rivers or watersheds. Beach sand is an important element of beaches but not the only element. Wavecut platforms or tidal terraces are equally important in many areas of San Diego.

The movement of beach sand is governed by many complex processes and variables. However, there are a few very basic elements that tend to control not only how much sand ends up on our beaches, but also how much sand exists near enough to the shore to be deposited on the beach under favorable conditions. The following is a brief description of the most important issues influencing the current condition of our local beaches with respect to sand.

2. Geology

The geology of San Diego County varies from sea cliffs to sandy beaches. Beaches are generally found at the mouths of lagoons or in the lagoon or river outfalls. Cliffs formed by tectonic activity and the erosion via marine forces deserve special mention.

Much of San Diego's coastline consists of a wavecut platform sometimes referred to as a tidal terrace. A wavecut platform is formed where a seacliff is eroded by marine action, meaning waves, resulting in the deposition of cliff material and formation of a bedrock area where erosion occurred. If sea level rises rapidly this area will be covered with water. If sea level recedes, stands still or rises rather slowly as it is in the present, a platform may become exposed. Much of San Diego's beaches, especially those in the north county are a result of this process. The platform can be covered with a thin veneer of sand giving the appearance of a completely sandy beach yet it is not. The wave cut platform formation process is shown in Figure 1.

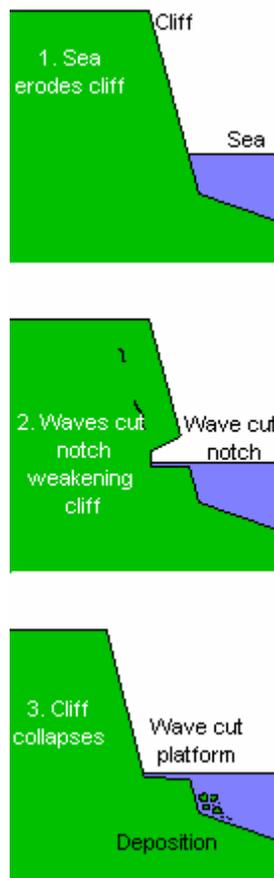


Figure 1 Wave Cut Platform Formation

3. The Littoral Cell

First, it is important to understand the concept of the littoral cell. A littoral cell is a discrete stretch of shoreline within which sand circulates relatively independently of the shoreline on either end of the cell. It is separated from the adjacent shoreline by either a headland or a submarine canyon at

each end. These headlands and submarine canyons essentially isolate a littoral cell by interrupting continuous sand transport. The San Diego coast is divided into three littoral cells: the Oceanside Littoral Cell bounded by Dana Pt. and the Dana Pt. Harbor to the north and the Scripps/La Jolla Submarine Canyon to the south shown in Figure 2; the Mission Bay Littoral Cell bounded by the Scripps Canyon to the north and Pt. Loma to the south; and the Silver Strand Littoral Cell shown in Figure 3 bounded by Pt. Loma to the north and Coronado Canyon to the south (which sits just below the Mexican border). “Long shore” movement in a littoral cell is the term which describes the movement of sand up and down the coast. In the San Diego region, the predominant long shore movement is to the south in the first in the Oceanside and Mission Beach cells and to the north in the Silver Strand Cell cell.

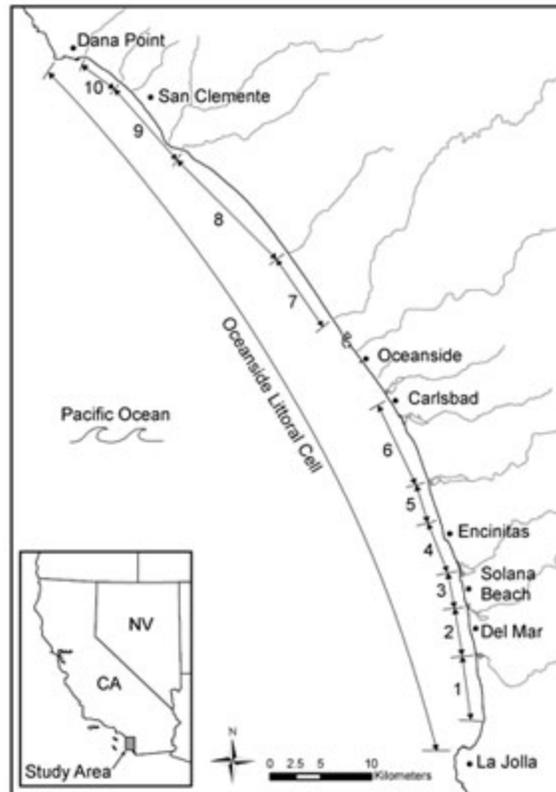


Figure 2 Oceanside Littoral Cell

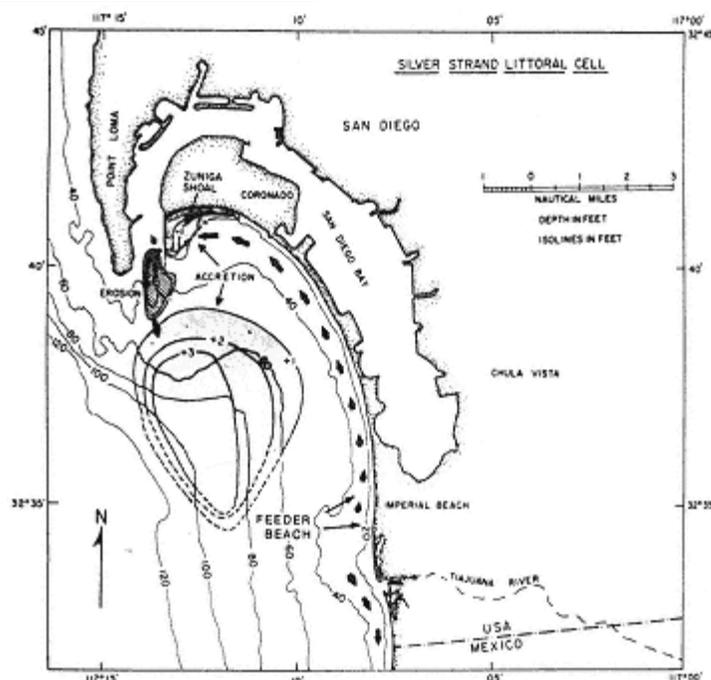


Figure 3 Silver Strand Littoral Cell

4. Sand Budget

Within a given littoral cell, sand can only move in a few ways. Figure 4 is an illustration of the sand budget of a littoral cell. As shown, sand can move along the beach in either direction, so called long shore transport, or it can move in a cross-shore direction back and forth between the beach and deeper water in response to the varying wave conditions.

These two coastal processes alone will eventually cause a net loss of sand from the littoral cell if adequate sand is not input to the littoral cell. Sand will either flow into a submarine canyon by the force of the long shore current, or get pushed by wave action in a cross-shore direction into deep water beyond what is known as the depth of closure (see Figure 5) where it can no longer be brought back to the beach by competing wave action. Without additional sand being input into the littoral system, the beaches will disappear altogether. This process is summarized by a simple formula.

$$\text{CHANGE IN BEACH VOLUME} = \text{SAND INPUT} - \text{SAND LOSS}$$

Historically the shoreline in San Diego County has been undergoing net erosion. Over the last several decades the rate of sand loss to deep offshore water and submarine canyons has greatly exceeded the amount of new sand brought to the beaches. As a result, most San Diego beaches are either receding, or have disappeared altogether. Many of the wider beaches have been augmented by either offshore or bay and lagoon dredging.

5. Sand Sources

Obviously, it is not enough to study the processes controlling the loss of beach sand without also addressing how and where beach sand is obtained. The following is a summary of sources for new beach sand which are the sand input describer above:

I. Natural Sources
A. River sediment
B. Shoreline erosion
C. Bluff or cliff Erosion
II. Un-natural sources (i.e. human made or driven)
A. Dredging of rivers, lagoons, bays and harbors
B. Construction of harbors and marinas
C. Off shore dredging
D. Opportunistic (e.g., excess sand from construction sites)
E. Imported
1. Commercial (e.g., purchased on the open market)
2. Exchanged (e.g., "trash for sand" project)

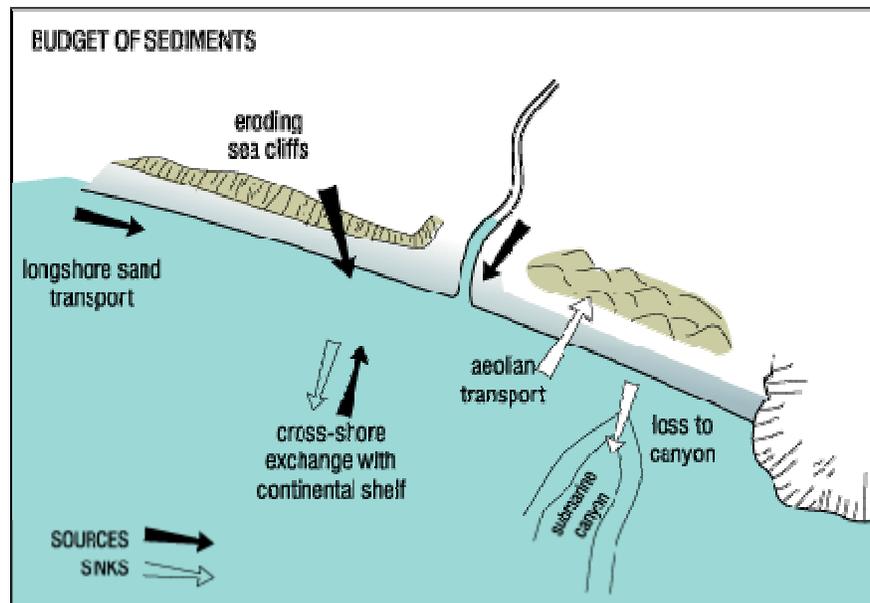


Figure 4 Sediment Sources

Figure 4 shows the net impact of our sand budget and our sources and sinks.

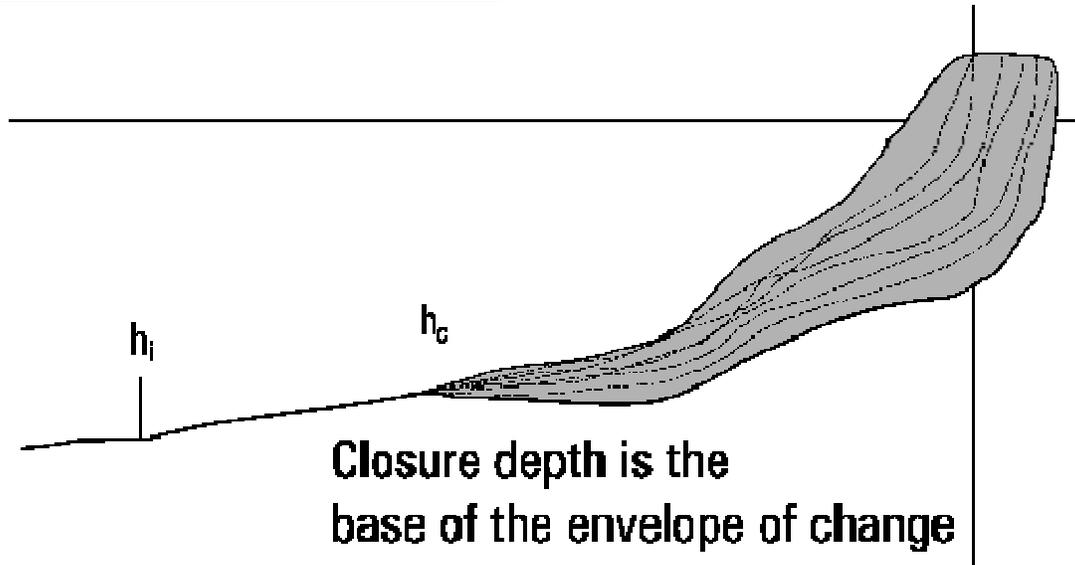


Figure 5 Cross shore profile and closure depth

Even before human activity began to impact the coastline, natural replenishment did not keep up with natural loss. A cursory look at a map of the San Diego coastline drives the point home. Note in Figure 2 and Figure 3 how the stretch of coast between La Jolla and Pt. Loma juts into the ocean. The harder coastal rock in that area resists erosion more effectively than the adjacent coastline, and has not receded as much.

Clearly, the shoreline has been in retreat for a long time. Unfortunately, the rate of retreat has been accelerated in recent years by human tampering. The damming of rivers has interrupted the natural flow of new sand to the beaches by an estimated 40-60%. We have further compounded the problem by interfering with the vigorous flushing of coastal lagoons at their river mouths and by building structures on the shoreline to prevent erosion. It is unlikely that the rivers will ever be allowed to run free in arid southern California, and unfortunately, shoreline erosion will probably never again be as significant a source of sand as it once was. There are several possible alternatives to create beaches:

1. Construct beaches by bringing in sand from un-natural sources
2. Minimize sand loss from the littoral cell.
3. Allow for the shoreline to migrate inland.

6. Sand Replenishment & Sand Retention

On the surface, bringing sand to the beach is a relatively simple process. Nonetheless, much time, energy, money and creativity are now going into developing the best ways to accomplish this task. It is not a question of whether sand must be brought in, but rather, where suitable material will come from, how much will be needed, and depending on these variables, how much it will cost. While sand replenishment is essential to rebuild the beach, it is also the least environmentally disruptive method available. Interventions that are intended to minimize sand loss to the littoral cell run the

risk of being counter productive and causing unacceptable secondary environmental damage. Such interventions include hard structures such as groins, breakwaters, jetties and submerged reefs, all of which are sometimes referred to as "sand retention devices". Other examples of active sand retention interventions include techniques like backpassing and dewatering. All of these devices have the net result of slowing the rate of longshore transport in the littoral cell (See Figure 4) resulting in a higher rate of downdrift erosion since less sand is transported to the area.

Because factors and conditions may vary significantly from one place to another, any plan to retard natural beach or near shore sand loss by active intervention must be subjected to rigorous analysis. More specifically, the following questions must be answered:

- Will the intervention really slow sand loss? If so, how?
- What will be the effect on long shore transport?
- What will be the impact on adjacent beaches?
- What will be the effect on offshore losses?
- What are the mechanisms that retard or accelerate offshore losses?
- Will the structure perform the same in all kinds of tide, wind and wave conditions?
- Which tide, wind and wave conditions are likely to predominate?
- How bad will the consequences be if a mistake is made?

If it is determined that a given intervention can have a net retarding effect on sand loss, it should be implemented only if there is no significant adverse impact to the following:

1. Surfing conditions
2. Sand supply to other beaches in the littoral cell
3. Public beach access
4. Lagoons and estuaries
5. Off-shore marine life
6. Water quality
7. Coastline aesthetics

Interventions must be evaluated on a case-by-case basis. However, while structures like groins and breakwaters might improve the condition of immediately adjacent beaches, there is no evidence that they retard loss from the littoral cell as a whole. In fact, in some situations they may increase sand loss to the littoral cell by directing sand off shore. As mentioned previously it is certain they will cause downdrift erosion by cutting the rate of littoral transport.

Just as common sense dictates, the accumulation of sand in one area is virtually always at the expense of other areas within the cell. For example, sand continues to accumulate north of Oceanside Harbor while the beaches to the south remain sand starved. In addition to their effects on longshore transport, sand retention devices are also undesirable because of their potential for negative impacts on aesthetics, surf conditions and public access. Submerged reefs are even more complicated. While they may be more environmentally friendly, their impact on sand loss is speculative and they could potentially damage surfing conditions. They might decrease shoreline erosion and off shore sand loss by dissipating large wave energy, but they could also increase sand loss by dramatically changing near-shore water movement. It is unlikely that they would have any positive impact on long shore sand transport.

Other interventions are more neutral, such as backpassing. This process involves capturing sand before it is lost in submarine canyons and redepositing it on the beach. Theoretically, this could be done with minimal adverse environmental impact. The usefulness of this technique is most likely to be limited by its expense. Dewatering involves pumping water out of existing beaches, thus making the sand less likely to float away when subjected to wave action. This technique could be particularly useful around coastal lagoons if the suctioned water was pumped into the lagoon to aid lagoon flushing.

7. Sea Walls

Sea walls deserve special mention. In general, they can only have a neutral or negative impact on beach erosion. Sea walls are usually constructed to protect shoreline infrastructure and property. If there is an extensive beach in front of the sea wall which prevents direct wave action on the sea wall, then the structure will not adversely affect beach erosion. However, sea walls that are regularly battered by wave action may cause more rapid erosion of the beach as rebounding waves take the sand away from the shoreline. Sea walls also prevent shoreline erosion which can be a significant source of beach sand. Therefore, sea walls are not an effective intervention when beach preservation is the goal. A summary of seawall impacts is listed below.

- 1) Passive erosion, from THE PROTECTION OF CALIFORNIA'S COAST: PAST, PRESENT AND FUTURE by Gary B. Griggs Shore and Beach V. 67, Jan.1999 P. 18-28, "Wherever a hard structure is built along a shoreline undergoing long-term net erosion, the shoreline will eventually migrate landward beyond the structure. The effect of this migration will be the gradual loss of beach in front of the seawall or revetment as the water deepens and the shoreface moves landward.... While private structures may be temporarily saved, the public beach is lost. This process of passive erosion appears to be a generally agreed upon result of fixing the position of the shoreline on an otherwise eroding stretch of coast, and is independent of the type of seawall constructed." It is evident that passive erosion will eventually destroy the recreational beach area unless this area is continually replenished. Excessive passive erosion may impact the beach profile such that shallow areas required to create breaking waves for surfing deepen. This deepening will also prevent access to the beach. Passive erosion is illustrated in Figure 6.

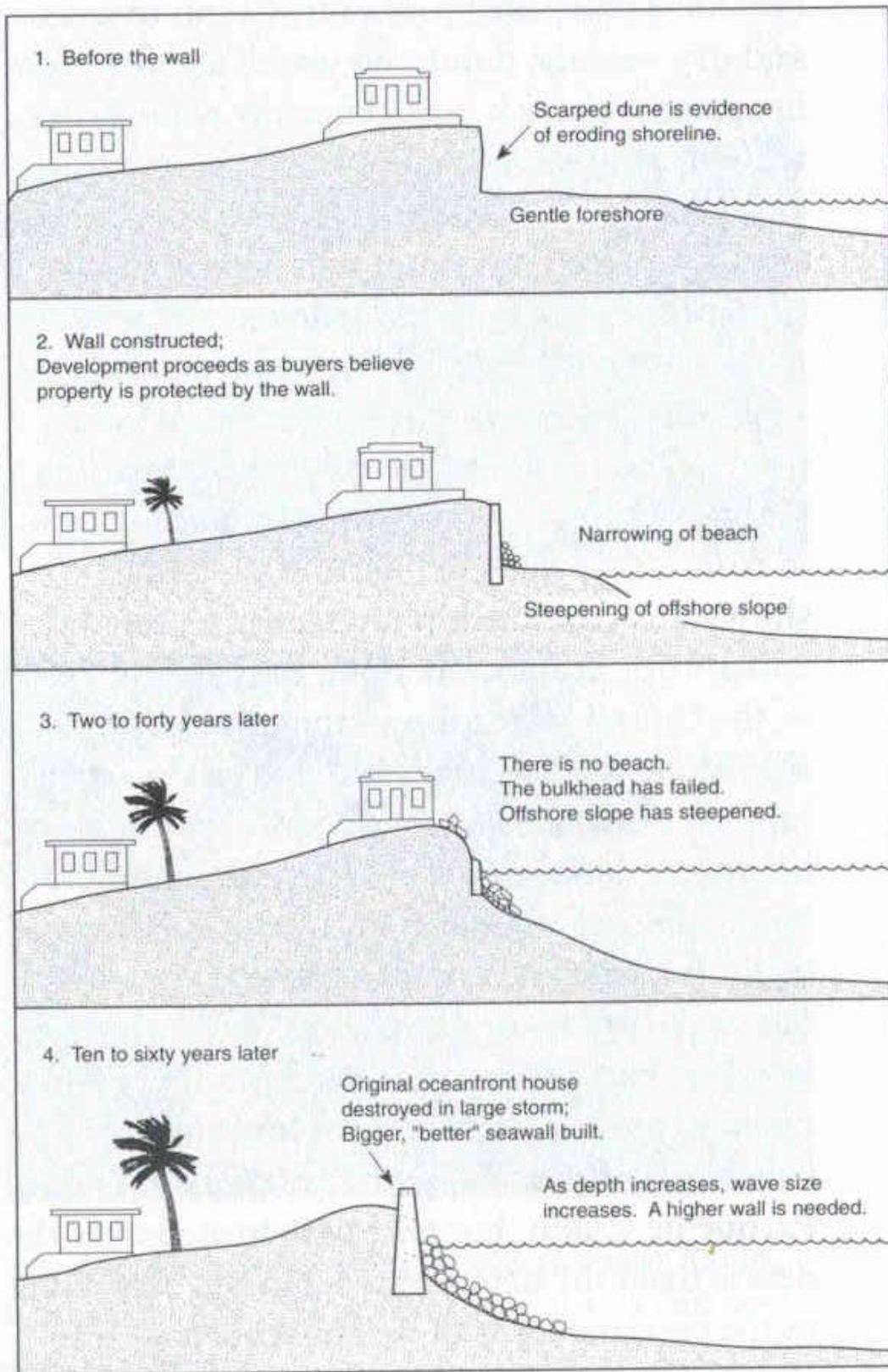


Figure 6 Passive Erosion due to a seawall

- 2) Placement loss - In many cases, construction of seawalls is on public property (beach). In Solana Beach for example most land for seawalls is leased free of charge to the property owners. This is a taking of extremely valuable public property.
- 3) Active Erosion - Refers to the interrelationship between wall and beach whereby due to wave reflection, storm surf zone narrowing and a thousand other processes the wall may actually increase the rate of loss of beach. This is site specific and dependent on sand input. There are varying opinions on if this effect actually exists. However, as watchdogs of the coast, until there is overwhelming evidence that this effect is not significant, many of us have opposed seawalls on this basis.
- 4) Public access impacts, these can be a result of passive erosion, placement loss or active erosion.
- 5) Visual/aesthetic impacts to our beautiful coastline.
- 6) Economic issues - local, state or federal subsidies or construction to protect private property, or insurance coverage. The cities of Encinitas and Solana Beach have recently approved matching funds for an Army Corps of Engineers study to build seawalls in these areas. Further, State Land is used as the foundation of many of these walls and construction is performed on State Land. The public has not been sufficiently compensated for this loss.
- 7) Loss of sand supplied by eroding bluffs that are armored. A minimal fee for this sand is collected from property owners for the sand that would provide beach material. Additionally, the eroded area would create a beach. We do not feel the public is sufficiently mitigated for the loss of sand and beach.
- 8) The most important thing to remember is that a seawall is never built to protect the beach. Rather, it is built to protect property, structures or a cliff from erosion.

8. Summary

Within San Diego County, no one questions that most of our beaches are currently in a state of severe sand depletion. Given the structure and state of the littoral cell, sand loss will continue to be greater than sand input. Therefore, given that natural replenishment will never be able to keep up with the current rate of sand depletion, un-natural sources of sand used in ways that emulate natural processes are the only recourse for improving and maintaining favorable beach conditions. Techniques to retard sand loss are both expensive and questionably successful. Many are unacceptable because of their potential for adverse impact. Realistically, though, not all sand retention techniques are the same, and they need to be evaluated on a case-by-case basis. Pilot programs for the most promising and safest techniques should be considered and pursued.

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