2. CALIFORNIA BEACH SETTING

The California coast, composed of sandy beaches, sea cliffs, rocky headlands, and lagoons, extends 1,100 miles from Oregon to the U.S.-Mexico border. It can be divided into two distinct regions: southern and northern. The boundary occurs at Point Conception, where both the coastal alignment and the physical environment change abruptly. The northern California shoreline is fully exposed to winter storm waves generated in the North Pacific, while southern California is afforded partial shelter from these waves by Point Conception and numerous offshore islands.

South of Point Conception, the shoreline typically is backed by coastal plains and marine terraces. Long sandy beaches predominate, as in the case of Santa Monica Bay, although they may be separated by rocky headlands such as Palos Verdes.

The northern California coastline tends to be more rugged. At many locations, the mountains extend to the shoreline with only a narrow sliver of sand at their base. Prominent headlands interspersed with stretches of sea cliffs and small sandy beaches are common. Some areas, such as Big Sur, contain rocky bluffs and outcrops with relatively few beaches.

2.1 Beaches

Beaches are an invaluable social, economic, and cultural resource in southern California. Favorable weather and ocean conditions, combined with the high population density of the region, have resulted in these beaches becoming the most popular recreation destination in the state. Numerous activities are available, including swimming, surfing, boardsailing, boating, volleyball, diving, fishing, hiking, biking, camping, and sunbathing.

In their natural condition, many southern California beaches were incapable of supporting the recreational needs of the developing region. Wide, sandy beaches tended to be the exception rather than the rule, and were concentrated near river mouths or where sand was retained by sediment-blocking features such as headlands and reefs (Everts, 2000).

Today, however, broad, sandy beaches abound in southern California due to nourishment programs. Renowned sites such as Santa Monica and Venice, generally regarded as some of the finest beaches in the world, exist in their present condition only because they have received extensive sand through nourishment. These and other enhanced beaches provide numerous benefits, including increased recreational and tourism opportunities, restored wildlife habitats, improved coastal access, and greater protection against coastal storms.

Many beaches in northern California remain in a near-natural condition, largely due to the lack of intense coastal development. Exceptions do exist, however, including the highly urbanized San Francisco shoreline and the communities surrounding Monterey Bay.

The nature of coastal recreation and usage in northern California is distinctly different from that in southern California. A cooler climate and more severe wave conditions in the north limit the popularity of water sports. The coast is valued for its scenic beauty, in that it contains some of the most spectacular vistas in the country. As a result, recreation frequently involves leisurely travel along the coast for enjoyment of the rugged scenery. In addition, abundant inland recreation alternatives and a lower population density result in less beach visitation than in southern California.

2.2 Sand and the Beach Environment

The geography of the California coast effectively separates the coastline into discrete coastal compartments termed littoral cells. A littoral cell is a self-contained system that may be bounded by rocky headlands or by a submarine canyon that intercepts the sand as it moves along the coast. Sand is supplied to the beaches primarily by rivers or bluff erosion, moves within the system under the influence of waves and currents, and eventually may be lost from the littoral cell. Typically, there is little sediment exchange between adjacent cells.

Most California beaches, particularly those valued for recreation, are comprised of sand. Their width is dependent on many factors, including the sand supply, the wave climate, the presence or absence of sediment-retaining features, and the configuration of the sea bottom. Wide beaches tend to exist where the sediment supply is plentiful or the sand is trapped by headlands or reefs. Conversely, a beach may be narrow or non-existent if deprived of sediment or if the sea bottom is very steep.

Up to 90% of the natural sand supply for California beaches is provided by rivers and streams. Most of this material is transported to the coast during winter storms. Eroding sea cliffs and bluffs provide a secondary source of sediment (DNOD, 1977; Part III, this report).

Once it arrives at the coast, the sand is distributed by waves and currents. Adjacent beaches are replenished as the flow of sand proceeds alongshore. Notwithstanding seasonal and local variations, the predominant direction of alongshore sand movement in California is north-to-south.

Sand also moves onshore and offshore in what is largely a seasonal process. During winter storms, sediment from the dry beach often is transported seaward and deposited in nearshore sand bars. When summer arrives, milder wave conditions tend to move the sediment back to the

dry beach. As a result, the beach may become narrow in winter and then recover much or all of its original width in summer.

Sediment eventually may be lost from the littoral system by transport into one or more sinks. The most common sinks along the California coast are submarine canyons, harbor entrances, lagoon inlets, and coastal dunes. Sand also may be lost offshore, beyond the depth at which waves are capable of transporting it back to the beach.

A delicate balance exists between sediment supplies, sand transport, and sediment losses. Alterations to the system, both natural and man-made, can result in accelerated beach erosion or accretion. Natural changes in sediment supply occur in response to weather conditions, with greater quantities of riverine sand delivered to the coast during floods than during dry periods. Human-induced changes can result from flood control measures, sand nourishment, and construction of sediment-blocking structures.

2.3 Impacts to the Natural Condition

After a century of intense development, the condition of the California coastline is influenced largely by human activity. This is particularly true in southern California, where urbanization has progressed most rapidly. Continued human involvement is necessary to maintain existing recreational beaches, mitigate erosion, and provide storm protection for public development.

Significant changes in the natural condition of the shoreline began in the early 1900's. Human intervention commenced with the channelization and damming of rivers to limit inland flood damage and create reservoirs for water supply and irrigation, and the construction of coastal harbors to support commerce and recreation. The flood control measures reduced the amount of sand reaching the coast, while the harbor structures effectively obstructed alongshore sand movement. The result was a series of erosion problems, on both local and regional scales.

Flood control measures are particularly widespread in southern California and include dams, debris basins, and river channelization. Consequently, many of the region's beaches have been impacted by a reduced contribution of sediment. The most drastic sand deficit exists along the Orange County shoreline, where the natural sediment supply has declined by as much as 85% (Flick, 1993).

Coastal erosion problems have arisen not only from dams, debris basins and stream channels, but also from the tendency of coastal harbors to restrict alongshore sediment transport. As with flood control measures, harbor-related problems tend to be more pronounced in southern California. The problems often are recurring and must be addressed on a regular basis. Where harbors have

led to erosion problems, sand bypassing or other nourishment programs have been implemented to restore eroded downcoast beaches.

Not all coastal development has produced negative impacts. Several of the region's most popular beaches were created and are sustained by sand nourishment projects and retention devices. The world-famous shoreline of Santa Monica Bay, for example, was produced by numerous beach nourishment projects, most conducted prior to 1970 (Leidersdorf et al., 1993). Similarly, the predominantly wide, sandy beaches of northern Orange County are largely a product of regional sand replenishment and beach compartmentalization projects. These famous shorelines, once starved for sand, now attract millions of visitors each year, adding billions of dollars to the state economy.

2.4 Natural Sediment Supply

California's beaches depend upon periodic nourishment of sand-size sediment from rivers and streams, gully and terrace erosion, and coastal bluff erosion. Budgets of littoral sediment from natural sources have estimated that rivers and streams supply, on average, 70 to 90% of the beach sand in California (Bowen and Inman, 1966; Best and Griggs, 1991), with the remaining 10 to 30% of sand provided by gully, terrace, and bluff erosion.

California's coastal watersheds are of two general types: (1) the steep, erodible, conifer-forested Coast Range basins north of Monterey Bay, which are characterized by high seasonal rainfall and perennial streams, and (2) the more arid basins of central and southern California, which often drain chaparral- or grassland-covered headwaters, with broad alluvial valleys in their lower reaches. California's coastal rivers have exceptionally high sediment loads due to the steep topography, the geologically-young and tectonically-active terrain, and, in central and southern California, the relatively sparse vegetative cover. In both northern and southern California, almost all sediment is delivered to the coast during winter storms between November and March. This seasonal pattern of rainfall and sediment delivery is heightened by infrequent, exceptionally wet years when large floods flush enormous quantities of sediment out of coastal watersheds (Inman and Jenkins, 1999). When sediment is delivered to the coast, the fine silts and clays are quickly moved offshore by wind- and wave-generated currents, while the sands and gravels are deposited at the river mouth as beach or delta deposits that are available for transport along the coast by longshore currents.

The coastline of California can be broken down into three very general categories: 1) high relief, steep cliffs; 2) bluffs eroded into lower relief (less than 300 ft [100 m] in height) marine terraces; and 3) coastal lowlands or plains. Erosion of California's cliffed coastline provides sediment to the coastal zone. The amount of sand-size material supplied to the coast through cliff erosion depends on both the type of rock and terrace material that make up the cliff and the rate of cliff

erosion. The high-relief, steep cliffs of California are composed predominantly of resistant rocks and generally are not a major contributor of sand-size material to the littoral budget. The lower-relief marine terraces, however, play a more important role in terms of sand contribution. Marine terraces are comprised primarily of marine sedimentary rocks, capped by terrace deposits which, when eroded, will produce a greater percent of sand-size material than the high-relief, steep bedrock cliffs.

The two main natural sediment sources for California's beaches—coastal streams and bluffs—have been impacted by development in coastal watersheds and along the coast. Dams and debris basins, in-stream sand and gravel extraction operations, and stream bank and bed channelization have reduced fluvial sand supplies, particularly in highly urbanized southern California. Similarly, coastal armor, built to protect bluff-top coastal structures, has halted bluff erosion, preventing the sand portion of the bluff from reaching the beach.

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