# BLUFF RETREAT RATE ESTIMATION METHODS

## BACKGROUND

To evaluate the approximate length of time until the parking lot is undermined, bluff retreat rate data was reviewed. An assessment of the rates of the coastal erosion along the southern California coastline in general, and along the Encinitas segment in particular, is a complex task. The rates vary greatly along the coast, depending upon the variety of natural geological, hydrological, oceanographic, meteorological/climatic, and other processes operating in the natural (prior to development) coastal environments. Furthermore, in highly developed coastal San Diego County they are greatly influenced by anthropogenic (man-induced) factors, such as construction of the structures interfering with the sand supply, over-irrigation and improper drainage, disturbance of the natural soil and vegetation cover, and others.

After 1972, when geologic reports became a requirement prior to the development of the coastal areas, retreat data reported for coastal San Diego County are controversial and incomplete. The low quality data were often attributed to the lack of understanding of the processes causing the erosion, as well as a bias on the part of the private consultants favoring a certain point of view (Gayman, 1985).

Very few scientific studies were conducted with the objective of measuring erosion rates in the Southern California area. In 1983, the National Ocean Survey (NOS) section of the National Oceanic and Atmospheric Administration conducted a study of the southern California coastline based on detailed cartographic data over the past 100 to 130 years. Unfortunately, the maps produced were too controversial. Part of the problem was in plotting errors, lack of adjustments for seasonal changes, and errors in elevations. In some areas, the shoreline known to be erosional (losing sand) was interpreted to be accretionary (gaining sand) based on NOS data.

In 1994, the state-of-the art soft-copy photogrammetric and geographic information system imaging laboratory (Coastal Geology and Imaging Laboratory) at University of California Santa Cruz, funded by the Federal Emergency Management Agency, used high-precision mapping techniques to determine accurate long-term recession rates along the San Diego County coastline by eliminating mapping errors (Benumof and Griggs, 1999).

A typical Encinitas seacliff is formed primarily by two geologic formations: a Tertiary sedimentary unit in its lower part, and the terrace deposits comprising its upper part, or bluff. Retreat of the resistant lower cliff occurs mainly due to the wave action and marine erosion. Erosion of the relatively soft terrace deposits, which lie generally beyond the reach of wave action, is caused primarily by subaerial and other non-marine processes. The edge of the bluff thus recedes significantly due to the change of the upper-bluff slope angle from an original 60- to 90-degree slope to an approximately 35-degree slope. This retreat is significant, episodic, and often incorrectly attributed to marine processes.

It is necessary to make a distinction between short-term (historical, cyclic) and long-term (geologic, chronic), and site-specific and average rates of erosion. Most often reported short-term rates vary from 0 to 1.3 feet per year for the California coastline (Gayman, 1985). High rates of

erosion are generally reported in the areas of seacaves, where the nature of erosion is episodic and its short-term rate is extremely high for the narrow zone of the collapsed cave. The average rate of erosion would vary greatly depending on a percent of the shoreline occupied by, for instance, seacaves or less resistant formations. The rates tend to increase greatly following heavy winter storms, such as the 1982-83 El Nino episodes (being 100-year events according to U.S. Army Corps of Engineers [Corps] estimates). In 1970, a seacliff base recession study was conducted along a 21-mile segment of coastline from Leucadia to Point Loma (Artim, 1985). A total of 93 monuments were monitored from 1970 to 1982. The average rate of retreat was reported to be 0.04 foot per year, but may be as high as 0.5 foot per year. The predicted future rates should be based upon accurate determinations of erosion covering both short- and long-term periods (Gayman, 1985).

## ANALYTICAL METHODS

A thorough discussion of the analytical methods used to assess relative rates of coastal erosion is presented in the Corps (1996) geotechnical report for the reconnaissance study of the Encinitas shoreline. The Corps groups the methodologies in the following five general categories.

- Historical analyses use historical records, such as maps, aerial photographs, surveys, and such. This method is proven useful in assessing the short-term retreat rates over relatively narrow study areas.

- Geomorphic analyses take into account all geomorphic processes to assess variations in the shoreline erosion. For instance, along a relatively geologically uniform section of the coastline, such as the Encinitas coastline, a rate of bluff retreat can be assessed qualitatively based on variations in the shape of bluff profiles along the coast.

- Analyses of human activities are necessary considering the enormous human impact on the coastline for the past 40 to 50 years.

- Impact of long-term sea level changes is considered when long-term rates of erosion are evaluated.

- Empirical and analytical techniques are numerical models developed to assess shoreline erosion rates. The brief overview of these techniques is given in the Corps Reconnaissance Report (1996). The landward long-term seacliff base retreat may be estimated based on the shelf-slope method and littoral lens method (Zeiser Kling Consultants, 1994). A short-term landward retreat of a seacliff base may be estimated for any beach width for a single storm of a certain recurrence interval using the probabilistic method of Everts (1991). The long-term down wearing (or vertical scour) rate of the platform may be estimated as approximately 0.02 to 0.04 times the horizontal seacliff retreat rate (Zeiser Kling Consultants, 1994).

## RATES OF RETREAT IN THE VICINITY OF BEACON'S BEACH

A summary of the geologic erosion rates and measurements of coastal bluff retreat, based on a review of available geologic data from a variety of sources, is presented in Table B-1.

## Table B-1: Summary of Coastal Retreat Rates at Beacon's Beach and Vicinity

| Coastal Landform | Retreat Rate (feet/year) | Study Period | Location | Source |
|---|---|---|---|---|
| ***Short-Term Rates Based on Measurements*** | | | | |
| Seacliff face | 0.05 | 1970-1976 | Encinitas | Lee & others, 1976* measurements |
| Seacliff base | 14 feet at specific sites | 1982-1983 | Grandview Street to Leucadia Boulevard | Kuhn and Shepard, 1979 |
| Seacliff face | Average of 0.04 | 1970-1976 | San Diego coast | Lee & others, 1976* measurements |
| Beach | 2 | 1954-1988 | Oceanside to Del Mar | Everts, 1991* |
| ***Long-Term Rates*** | | | | |
| Seacliff face | Average of 0.25 | 1932-56 maps, 1994 imagery | Encinitas | Benumof and Griggs, 1999, historical long-term rate** |
| Bluff top | 0.28 | 1937-1977 | North of 630 Neptune | Corps, 1996 |
| Seacliff | 0.4 | Estimated future rate based on historical data since the late 1800s | Beacon's Beach | Corps, 1996 |
| Bluff face | 0.16 | 1928-1974 | 1050 Neptune | Corps, 1996 |

*Corps, 1996

**Based on measurements over a 68-year period. Caution should be exercised when using data extrapolated for over a 100-year period for long-term predictions.

Benumof and Griggs (1999) correlated long-term erosion rates for Encinitas with the quantitatively characterized physical properties of the cliff-forming materials and erosional mechanisms (primarily wave conditions). They concluded that at Encinitas, seacliffs are composed of relatively high intact rock strength material and are relatively resistant to erosion. Encinitas cliffs are rated similar to the Solana Beach and La Jolla cliffs, which are composed of the older sandstones and siltstones. Geological structure, particularly joint orientation, is of great importance for seacliff stability. Benumof and Griggs (1999) specifically noted for Encinitas that even though large storm waves occurring at high tides are particularly effective in causing basal cliff erosion, wave energy reaching the cliff base is significant also during low tide conditions.

They also concluded that more resistant Encinitas-type cliffs do not contribute a significant amount of sediment to the beach system.

For the purposes of this study, a long-term average erosion rate in the Beacon's Beach area of 0.4 feet per year (or 40 feet in 100 years) is predicted. This was chosen considering the relatively storm-free period (prior to the El Nino storms of 1982-83 and 1997-98 [Flick, 2001]) during which the data were collected, the historically greater amount of protective beach sand, and the new data (San Diego Union-Tribune, 2001) indicating a greater potential for future erosion due to more wave energy from a more southerly storm track.

Based on the above average rates of bluff retreat, it can be estimated that an additional 5 to 10 feet of bluff retreat will undermine the existing sidewalk adjacent to the parking lot. At the average retreat rate, this 5 to 10 feet of bluff retreat will take approximately 10 to 20+ years.