ϕ_{16}, ϕ_{50}, and ϕ_{84} are the 16, 50, and 84% coarser phi diameters from the cumulative frequency size distribution.

In an arithmetic normal distribution the spacing between the 16th and the 84th percentiles is two standard deviations. This suggests the definition of the phi deviation measure, which indicates the spread or sorting of the sample from the median size. These percentiles are also used to define the phi mean diameter by averaging the phi value at two separated reasonably representative values. The phi skewness measure gives an indication of the displacement of the median value from the mean value and thus indicates the sample skewness. The phi deviation measure is used in the denominator so the phi skewness measure is independent of the actual sediment size.

The descriptive measures defined in Table 8.2, when evaluated for the sample described by Figure 8.1 yield

$$M_{d\phi} = 2.13$$
$$M_{\phi} = (2.61 + 1.01)/2 = 1.81$$
$$\sigma_{\phi} = (2.61 - 1.01)/2 = 0.80$$
$$\alpha_{\phi} = (1.81 - 2.13)/0.80 = -0.40$$

A discussion of beach sediment sampling and grain size analysis is presented in Chapter 9.

8.2 Beach Profiles and Profile Change

Waves that reach a sandy shore, then break and run up on the beach face, will continually reshape the beach. This continuous reshaping occurs because the incident wave characteristics (height, period, and/or approach direction) are seldom constant for any significant time span. Reshaping of the beach is caused by the wave-induced currents that develop in the surf zone and, by the direct action of the waves through turbulence generated by the breaking waves and the surge of water up and down the beach face. Concurrent reshaping of the beach owing to wave-induced sediment transport takes place both in the on-/offshore directions and in the alongshore direction. Although these effects occur together it is easier to consider them separately. This section focuses on the natural beach profile geometry and the wave-induced changes that occur for a typical shore-normal beach profile. Alongshore processes will be considered in the two subsequent sections.

Mechanisms Causing Beach Profile Change

There are a number of mechanisms that can cause the transport of sand across a beach profile. Some of these mechanisms will only transport sand in the offshore direction leading to profile retreat, while others will only transport sand onshore building up the profile. And, there are mechanisms that can cause either profile

buildup or retreat depending on the wave and water level conditions, local beach slope and sand characteristics. These mechanisms are described below.

- As a wave propagates shoreward in the nearshore zone there is an asymmetry in the horizontal water particle velocities at the sea floor, with a higher and shorter duration onshore velocity under the wave crest and a lower and longer duration offshore velocity under the wave trough. The resulting shear stress exerted on a bottom sand grain depends on the water particle velocity squared. Consequently, there will be a larger onshore stress followed by a significantly lower offshore stress. The net bottom stress will act in the onshore direction. The resulting onshore transport tendency is increased owing to the fact that a certain threshold stress must be exceeded for a bottom particle to move.
- Beaches typically slope seaward across the entire profile (except for a short segment on the landward face of offshore bars). Thus, a component of gravity will typically act in the offshore direction on a bottom sand grain.
- Wave-induced setup in the surf zone will lead to a bottom return flow in the seaward direction (undertow) that will exert a seaward stress on sand grains. Also, on a long segment of beach where a significant alongshore current develops, there may be spatially periodic seaward flowing rip currents (see Section 8.3) that can transport large volumes of beach sand seaward.
- Turbulence caused by breaking waves in the surf zone will suspend sediment – the suspension being intermittent with the breaking of successive waves. The net transport of sand will be controlled by the net time-integrated horizontal flow velocity during the interval of sediment suspension. This mechanism may transport sediment in either the onshore or offshore direction.
- Onshore winds will exert an onshore stress on the water surface and a consequent return flow at the bottom that can assist in transporting sand seaward.

This summary indicates the complexity of mechanisms that operate to form a beach profile and to establish the grain size distribution across this profile. This complexity is compounded by the fact that the different mechanisms have significantly different strengths and these relative strengths vary as the wave, wind and water level conditions vary.

Beach profiles measured normal to the shoreline over the zone of active coastal processes are of great importance to coastal engineering studies. This active zone normally extends from the onshore cliff, dune, or structure line to a point offshore where there is little significant wave-induced sediment movement (at a typical depth of about 10 m for the open ocean). Over this active zone a portion of the beach profile can change drastically in a few hours because of a sudden increase in wave activity.

Beach profile data are important for an understanding and quantification of coastal zone processes and the related interaction of coastal structures with these