WAVES AND SEDIMENT TRANSPORT IN THE NEARSHORE ZONE

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Summary

The nearshore zone extends from the low tide line out to a water depth where wave motion ceases to affect the sea floor. As waves travel from the outer limits of the nearshore zone towards the shore they are increasingly affected by the bed through the process of wave shoaling and eventually wave breaking. In turn, as water depth decreases wave motion and sediment transport at the bed increases. In addition to the orbital motion associated with the waves, wave breaking generates strong unidirectional currents within the surf zone close to the beach and this is responsible for the transport of sediment both on-offshore and alongshore.

1. Introduction

The nearshore zone extends from the limit of the beach exposed at low tides seaward to a water depth at which wave action during storms ceases to appreciably affect the bottom. On steeply sloping coasts the nearshore zone may be less than 100 m wide and on some gently sloping coasts it may extend offshore for more than 5 km - however, on many coasts the nearshore zone is 0.5-2.5 km in width and extends into water depths >40m. The most significant processes in the nearshore zone are those associated with waves moving shoreward from the open ocean, shoaling and breaking as they move across the bottom; and with wave generated currents which can transport sediment onshore, offshore and alongshore.

The nearshore acts as a link between the coast and the inner continental shelf, and materials can move in both directions across it. Sediment brought to the beach by rivers, or eroded from cliffs or the nearshore bed, can be transported alongshore to be deposited in bays and estuaries, and to build large depositional features such as barrier spits. Removal of material from the base of cliffs and underwater erosion in the nearshore zone allows wave action to continue to erode coastal cliff systems. Tidal and wind-driven currents can remove fine sediments and pollutants offshore and coarse sands can be transported offshore beyond the normal wave base by intense storms such as hurricanes.

Ecologically the nearshore zone is a complex and dynamic environment where there is sufficient light to permit plants to grow attached to the bed and which supports rich ecosystem communities such as those associated with sea grass beds, coral reefs, and kelp. Commercially the nearshore zone is important as a nursery for many fish species, and as a source of fish, mollusks and crustaceans such as lobster and crab.

The organisms within the nearshore zone are adapted to wave action and to the currents generated by waves, winds and tides which serve to bring in nutrients. Knowledge of the processes operating in the nearshore zone is thus a key component of developing an understanding of the physical processes responsible for shaping the ongoing evolution of the coast and for developing management strategies to deal the impact of human activities on the coastal zone and as well as for adapting to the hazards associated with living on the coast.

2. Definition of the nearshore zone

The nearshore zone is the area of the sea and the sea bed adjacent to the shoreline and which is bounded on the landward side by the shoreline and beach (where one exists) and on the seaward side by the inner shelf, which itself is a part of the offshore zone (Figure 1). The landward boundary is the low tide line which marks the transition to the beach or intertidal zone. The offshore boundary is generally defined as the water depth where the orbital motion associated with the largest storm waves is no longer able to affect the bed significantly or to transport sediment. This occurs at depths >0.5 of the wave length L_0 (where the subscript denotes deep water). Similarly we can define shallow water as $h < 0.05\ L_0$ and depths between these are defined as intermediate depth. Waves transgressing the nearshore are generally in intermediate depths until a point a bit seaward of the breaker zone and in shallow water in the breaker and surf zones. Because there is a spectrum of waves affecting the coast at any time and because wave conditions vary with exposure and storm intensity, the choice of a particular wave to define the outer limit of the nearshore is somewhat arbitrary and serves to emphasize that there is not usually a sharp transition from the nearshore to the inner shelf, but rather it is a transitional zone. On the basis of changes in wave characteristics the nearshore can be divided into three sub-zones (Figure 1, Photo 1) consisting of: 1) the **outer shoaling zone** where wave interaction with the bed is small and wave transformation takes place slowly; 2) the **inner shoaling zone** where there is more intense interaction between the waves and the bed and where there is rapid transformation of waves; 3) the **surf zone** where all but the smallest waves break and where broken waves and surf bores extends to the beach. Wave orbital motion and wave generated currents dominate processes in the inner two zones but wind-driven circulation and tidal currents become increasingly important in the outer shoaling zone. The term shoreface is often used to describe the zone over which there is substantial transport of sediment by wave action - the inner shoreface where most sediment movement takes place corresponds roughly to the inner shoaling zone and the surf zone as defined here, and the outer shoreface to the outer shoaling zone.

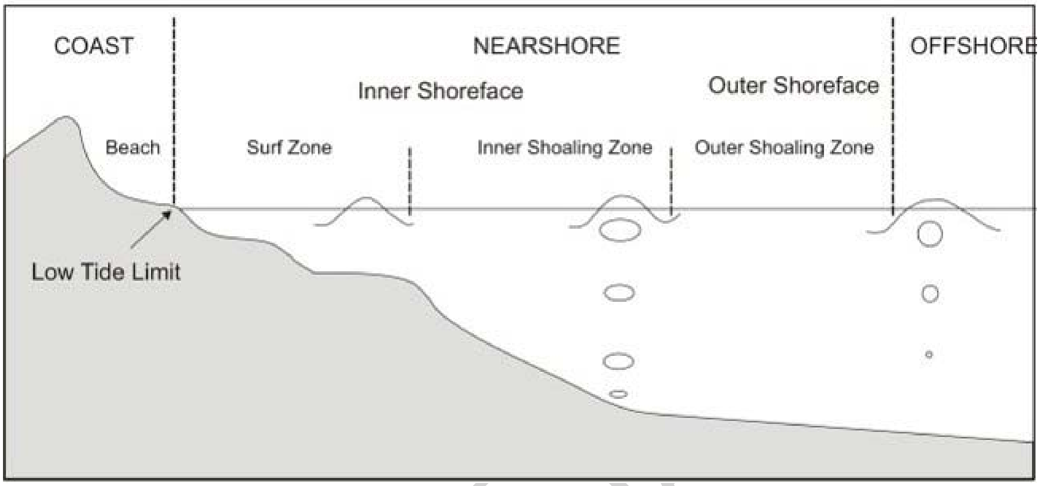

Figure 1: Profile normal to the shoreline showing location of the nearshore zone in relation to the coast and commonly used subdivisions within the nearshore based on wave conditions and sediment transport.

Photo 1: Long period swell waves (T = 12 seconds) shoaling and breaking on a gently sloping beach, west coast of Ireland. The approximate positions of the zones outlined in section 2 are shown. Note the decrease in wavelength and increase in wave height as the waves approach the break point.

The slope of the nearshore and of the land at the shoreline are important controls on processes occurring in the nearshore zone because they determine, together with the size of the incident waves, the width of the nearshore zone itself and the nature and location of wave breaking processes. On cliffed coasts with steep slopes the nearshore zone will be narrow and waves may break right on the cliff or at the shoreline at the cliff toe, and there will be considerable reflection of wave energy - the surf zone will be absent and the breaker zone will be very narrow.

On very gentle slopes the nearshore zone is wide, wave breaking will generally occur some distance offshore and there will be a wide surf zones. The presence or absence of a surf zone and nature of wave breaking also depends on the size of the incident waves, so that under low wave conditions on all but the gentlest slopes wave breaking will occur at the shoreline. On intermediate slopes the width of the zones will vary between these two extremes.

On sandy shorelines most sediment transport takes place within the littoral zone which comprises the inner three of these zones. The outer limit of the littoral zone is marked by the zone of closure which occurs at a depth h_L defined as the depth at which annual changes in bed elevation become very small. Alternatively it can be defined as the outer limit of the sweep zone defined by the envelope of cross-shore profiles taken over a number of years.

The form of the nearshore profile on sandy beaches can also vary from planar to one where there are one or more sand bars and associated troughs landward of the bar. Where this occurs there may be breaker zones associated with each bar crest and a zone of wave reformation in the succeeding troughs and the locations of these zones will change over time as the bars migrate (see *Morphology and Morphodynamics of Sandy Beaches*).

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Bibliography

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Biographical Sketches

Robin Davidson-Arnott obtained his Ph.D. in Physical Geography from the University of Toronto in 1975. After a year teaching at the University of Toronto he joined the Geography Department at the University of Guelph in 1976 and is now Professor. He has carried out research on nearshore bars and sediment transport in the nearshore zone, on the erosion of coastal bluffs and especially erosion of till in the nearshore zone, on sedimentation in marshes in the Bay of Fundy, Canada, and on coastal sand dunes and barrier systems. He has also played a significant role in the development of coastal management policies for the Great Lakes and has been a consultant to the Canada/US International Joint Commission and the Government of Ontario.

Brian Greenwood obtained a Ph.D. in Physical Geography from Bristol University, U.K and a Ph.D. Hons.Causa, from Uppsala University, Sweden.. He joined the Department of Geography at the University of Toronto in 1967 where he is now Professor and a member of the Environmental Sciences Faculty at the Scarborough Campus. He has carried out research on nearshore bar systems and nearshore sediment transport in a number of areas including the Great Lakes, the east coast of Canada and in Denmark. He is a Principal Investigator in the Canadian Coastal Sediment Transport Program which is a cooperative program involving large-scale field experimentation. His current research interests include: sediment transport in wave-current boundary layers; shoreface morphodynamics especially the dynamics of nearshore bar systems; simulation of bedforms under waves and currents; development of wave-current boundary layer sensors; numerical models of coastal sediment transport; and bedforms and sedimentary structures under combined flows.