1.0 Introduction

1.1 THE COAST DEFINED

To put it very simply the coast is the line of meeting between the land and the sea. If this interface would have been static, it would be relatively easy to show it as a line on the map and even easier to define it. But the natural processes that shape the coast are highly dynamic, varying in both space and time. Hence, in reality, this line of contact is always shifting. Therefore, instead of a 'line of contact' the coast may be thought of as a 'zone' or 'area' of interaction between the land and sea. The coast can be defined as *the band of dry land and adjacent ocean space (water and submerged land) in which terrestrial processes and landuse directly affect oceanic processes and uses, and vice versa*. Thus the COAST may be viewed as a broad zone that extends from the landward limit of marine processes to the seaward limit of alluvial processes. It includes beaches, chenier plains, barrier islands, deltas, estuaries—all those parts of a coastal region affected by the proximity of a shoreline: *a whole assemblage of landforms*.

The SHORELINE, on the other hand, is a linearity between the sea and a beach. It therefore is local and non-permanent.

The coast can be viewed as serving two important functions: • it stops the waves and tides from travelling into the land *and* • it receives, stores and redistributes sediments

There are some important reasons why the coast should be viewed in this way. Coastal landforms are all transient features. Powered by the waves, tides, currents and wind, they erode and accrete, depending on the environmental condition at any particular point of time.

The coasts are extremely dynamic environments that change in response to a variety of inputs. Hence, the study of coasts is concerned with a range of scales in both space and time. The shoreline migrates daily with the tide; it can change seasonally and also over longer timescales as the coast erodes or deposits, or as sea level changes. Coastal sediment deposits are shaped and reshaped by wave and current processes, which in turn vary through space and time. The scale of study can also vary in relation to the lithological and sedimentary characteristics of the coast. Rocky cliffs can extend for hundreds of kilometres and change little in either time or space. On beaches, however, sorting of sand of various grain sizes and micro-topography of bars can result in variations along the shoreline over a few metres, which change over the progress of a tidal cycle or in response to storms (Table 1).

Many of these changes, reflected in the coastal morphology, are CYCLIC in nature. What might appear like a PROGRESSIVE change in a human timescale often turns out to be cyclic when larger timescales are considered.

Table 1

Timescales and coastal changes

TIMESCALE	COASTAL PROCESS
Seconds	Sediment grain movement. Changes in a ripple and dunes.
Minutes	Passage of waves and currents
Hours	Diurnal tidal cycles.
Days	Passage of storm surges. Breaching of a coastal defence.
Weeks	Spring-neap cycle. Shore profile changes.
Months	Seasonal adjustments. Shore profile changes.
Years	Beach cycles. Effects of longshore transportation and coastal protection works.
Decades	Formation or loss of habitats—marshes, dunes etc.
Centuries	Historic coastal changes—erosion of settlements.
Millennia	Responses to sea level changes. Delta development. Cliff recession

A COASTAL SYSTEM depicts a complex interaction between the morphology, processes and materials. It is sediment input, transport and deposition that provide the coupling between landform and process, with sediment properties influencing which processes occur and sediment availability controlling the extent to which potential transport is realised (Fig 1).

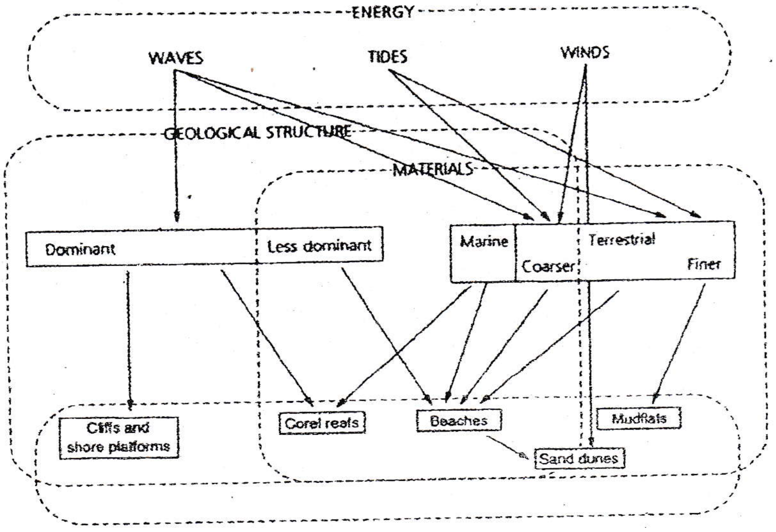


Fig.1 The coastal system, *(source Hansom, 1988)*

The coastal system conjures up the entire spectrum of interactions between the coastal sediments and the three most important variables that govern coastal morphodynamics (Fig. 2):

1. Sediment input by rivers
2. Sediment reworking by waves and
3. Sediment reworking by tides.

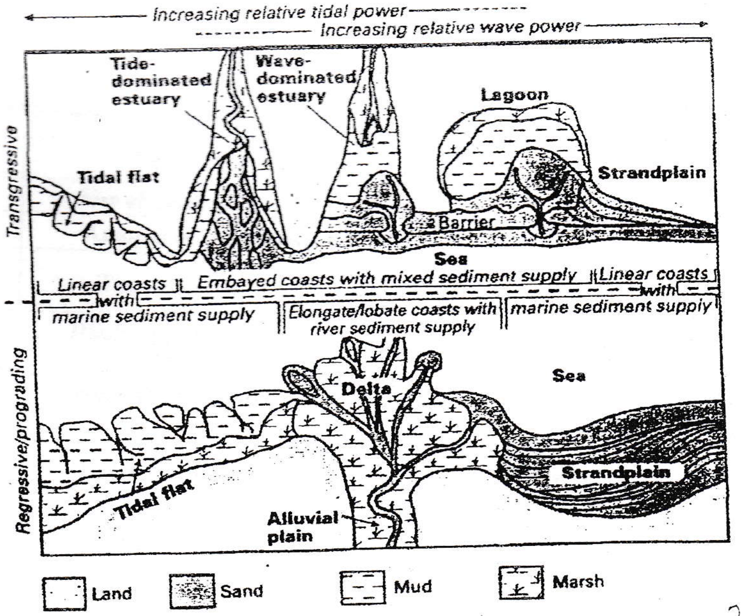


Fig.2 Plan view of transgressive and regressive / progradational coasts under varying conditions of tidal power and wave power and of marine or fluvial supply

In this write-up, all these concepts are elaborated to highlight the processes through which the variables control coastal morphodynamics and how these variables may be integrated in a coastal classification scheme. Lastly, three case studies on coastal shifts in West Bengal are briefly described to illustrate the consequences of anthropogenic intervention in a morphodynamically balanced coastal system. A note on their management possibilities is also added.

WHY COASTAL AREAS WARRANT SPECIAL ATTENTION?

Consider these facts: • An estimated 60 per cent of the world's population live in coastal zones today. • This equals the entire global population of the 1950s. • In the next 30 years more people will occupy the coastal zones than are alive today! • The coast is a rich storehouse of resources, which are being exceedingly exploited, often without any consideration about this fragile ecosystem.

Many excellent texts on coastal geomorphology and coastal management issues are now available in the market. Among these, the reader may be referred to Pethick (1984), Carter (1988), Viles and Spencer (1995), Reading (1996), French (1997), Clark (1998), Kay and Alder (1999) and Woodroffe (2002) for more detailed and comprehensive treatment of the subject. The materials presented here are mostly drawn from these sources.

2.0 The Morphodynamic variables

2.1 SEDIMENT

Coastal sediments are important in relation to geomorphology in two aspects. *First*, these are the materials from which landforms are constructed and by which the coastal system adjusts. This is most clearly demonstrated on sandy beaches, where the waves expend energy, redistributing sediments so that the beach is reshaped towards equilibrium with the waves. *Second*, the sediments are important because their deposition and preservation provides evidence of past coastal geomorphology. It is not always possible directly to observe the coast evolving; in which case inference from coastal sedimentary record provides an invaluable tool for interpreting the nature of the past processes and the history of coastal evolution.

2.1.1 Sediment supply

There are important sedimentary properties, referred to as petrological characteristics that are used to describe sediments. These include grain size and shape. According to grain size sediments are classified based on the Udden-Wentworth scale in mm and Krumbein scale in phi (defined as the negative logarithm, to the base 2, of the grain diameter in mm)—the details are as follows (Table 2).

GRAVEL	Boulder	More than 256 mm in diameter
	Cobble	64–256 mm in diameter
	Pebble	2–64 mm in diameter
	Sand	0.062–2 mm in diameter
	Silt	0.002–0.062 mm in diameter
	Clay	Less than 0.002 mm in diameter

Table 2

- The major sources of coastal sediments include:
  1. Rivers (including estuaries and delta distributaries), by far the most important source
  2. Point- and multiple-source alluvium fans and scree cones
  3. Coastal erosion *and*
  4. Biogenic contribution
- Some 15 × 10^9 t of sediments are supplied annually by rivers into the receiving ocean basins.
- Another 0.5–1.5 × 10^9 t yr^{-1} come from coastal erosion and cliff recession.
- Grain size characteristics and abundance of these sediments are determined by • catchment size, • geology, • relief, • tectonics *and* • vegetation.
- River discharge properties represent a CONTINUUM between two extremes—shown below as two sets of attributes (Table 3). A number of morphological properties are intrinsically linked to this continuum (Fig. 3).

ATTRIBUTE SET-1 •	PROPERTIES	• ATTRIBUTE SET-2
Small •	**Size of catchment area**	• Large
Small •	**Amount of sediments**	• Large
Mainly coarse grained: • sands, gravels	**Type of sediments**	• Mainly fine grained: silts, sands
Fluctuating / Intermittent •	**Discharge of water and sediments**	• Steady
Predominantly longshore •	**Sediment transportation**	• Predominantly onshore/offshore
High relief close to the • shoreline, high-gradient, stepped beach profile. Reflective coastal domain	**Coastal Morphology**	• Gentle relief close to the shoreline, low-gradient, flat beach profile. Dissipative coastal domain

Table 3

- The terrigenous sediments other than muds do not easily pass into the shelf because of the presence of the LITTORAL ENERGY FENCE, where shoaling and breaking waves have the potential to move more sediment load landward than seaward (Fig. 10). This fence, however, can be bypassed by one of the following three processes:
  1. RIVER MOUTH BYPASSING, especially during the flood stage
  2. ESTUARY MOUTH BYPASSING, mainly by ebb-tide currents and
  3. SHORE-FACE BYPASSING, by which shoreface sediments are removed by wave-induced currents during storm wave conditions (Fig. 4).

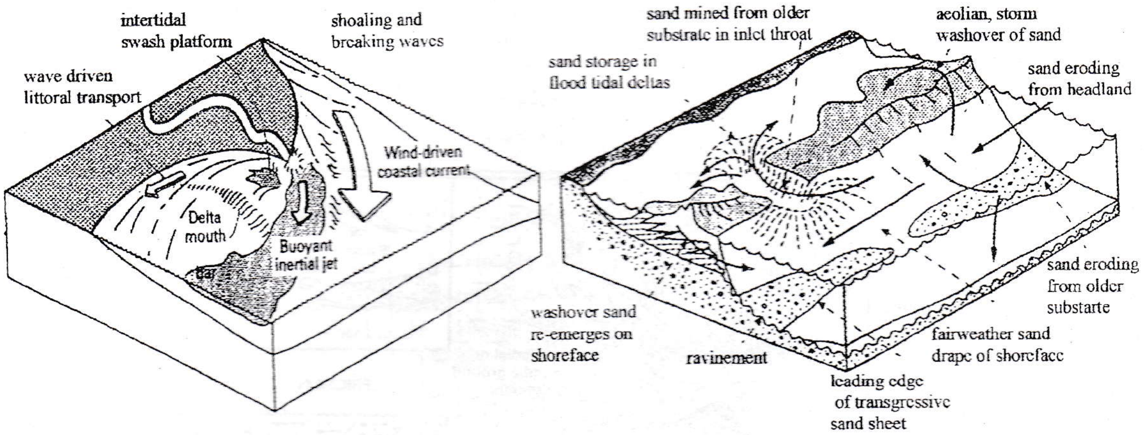


Fig.4 Two principal methods by which sediment is transported onto the shelf through a littoral energy fence. (a) River mouth bypassing – a river flood transports sediment on to a delta mouth bar and beyond. Sand is mostly stored I the mouth bar and slowly re-entrained in the littoral sand stream. Fine sand, silt and clay are carried as buoyant half-jet. (b) Shoreface bypassing – storm washover sand is buried and eroded as it emerges on the shoreface. Erosion of shoreface allows transport along shore.

2.1.2 Sediment Dispersion

Sediment dispersion along a shoreline depends among other factors on the density characteristics of the river water and the water of the receiving basin. This can be of three types: hypopycnal, homopycnal and hyperpycnal—hypopycnal conditions being the most common (Table 4, Fig. 5).

DENSITY CONTRAST		CONDITION	SEDIMENTATION PATTERN	EFFECTS ON MORPHOLOGY
RIVER WATER	BASIN WATER			
Less dense	More dense	Hypopycnal	Extends into the receiving basin as a buoyancy-supported surface jet or plume. It is especially common where rivers enter the sea. Very effective in separating bedload from suspended load.	Buoyancy-dominated river mouths. Evolves common river deltas.
Equally dense	Equally dense	Homopycnal	Intense local three-dimensional mixing at the river mouth causes high sedimentation, especially of bed load.	Evolves lacustrine deltas.
More dense	Less dense	Hyperpycnal	Occurs during floods, especially in cold river waters containing coarse grained sediments. Passes beneath the basin water as density currents—causing sediments to bypass the shoreline and to be deposited as the lower delta front or prodelta.	Inertia-dominated river mouths. Inhibits delta progradation.

Table 4

②

2.2 WAVES:

2.2.1 Generation

Sea waves represent mechanical energy that has been imparted to the sea water by the stress of the wind acting on the sea surface. To any layman waves represent the sea surface in motion as the water rises to form the wave crest and sinks in the wave trough. Thus the sea surface shows periodic ups and downs as the wave is propagated across the air-sea interface.

The waves are described by the following parameters (Fig 6):

Wave height (H) – it is the vertical distance separating the highest point on the crest from the lowest point on the trough.

- *Wave amplitude* – the equivalent of one-half of a wave's height.
- *Wave length* (L) – the horizontal distance between a point on one wave and a corresponding point of an adjacent wave.
- *Wave period* (T) – the time taken by two successive crests to pass a stationary point, for example a pole.

The variety and size of wind generated waves are regulated by four principal factors: • wind velocity, • wind duration, • fetch and • original state of the sea. As wind speed increases, so do the wave length, period and the height of the resulting waves. In fact these wave parameters are used by physical oceanographers to classify waves (Table 6).

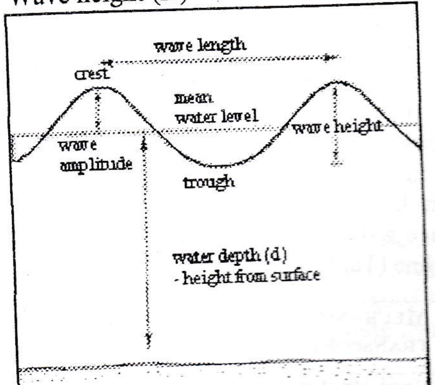


Fig.6 Wave parameters

2.2.2 Motion

Two fundamentally different kinds of motions are associated with ocean waves: • the orbital motion of water particles beneath the surface wave and • the forward movement of the wave form itself.

The motion of water particles beneath the surface waves: the back-and-forth and up-and-down motion that occurs with the passage of one wave describes an orbital trajectory, in which the water particles rotate through a vertical circle with a diameter determined by the wave's height. The bigger the wave, the larger the circular orbit. As each revolution of wave is completed, kinetic energy is transferred to the water particle that lies on the path of the travelling wave. Thus, wave energy, *not* water particles, travel across the sea surface. The orbital diameters described by water particles decrease rapidly with distance below the water surface. Wave- induced water motion essentially ceases at a critical depth (the wave base) that is equivalent to one half the wave length. The orbital diameter decreases exponentially with water depth. The orbits described by water particles beneath waves are not closed, but open, so that a slight net displacement of water occurs in the direction of wave advance. This unidirectional flow of water is termed mass transport (Fig.7).

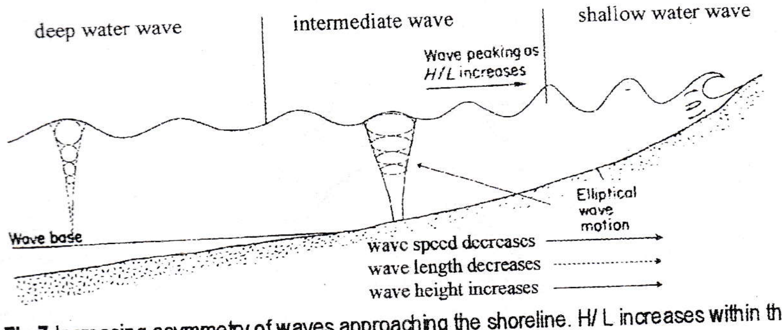


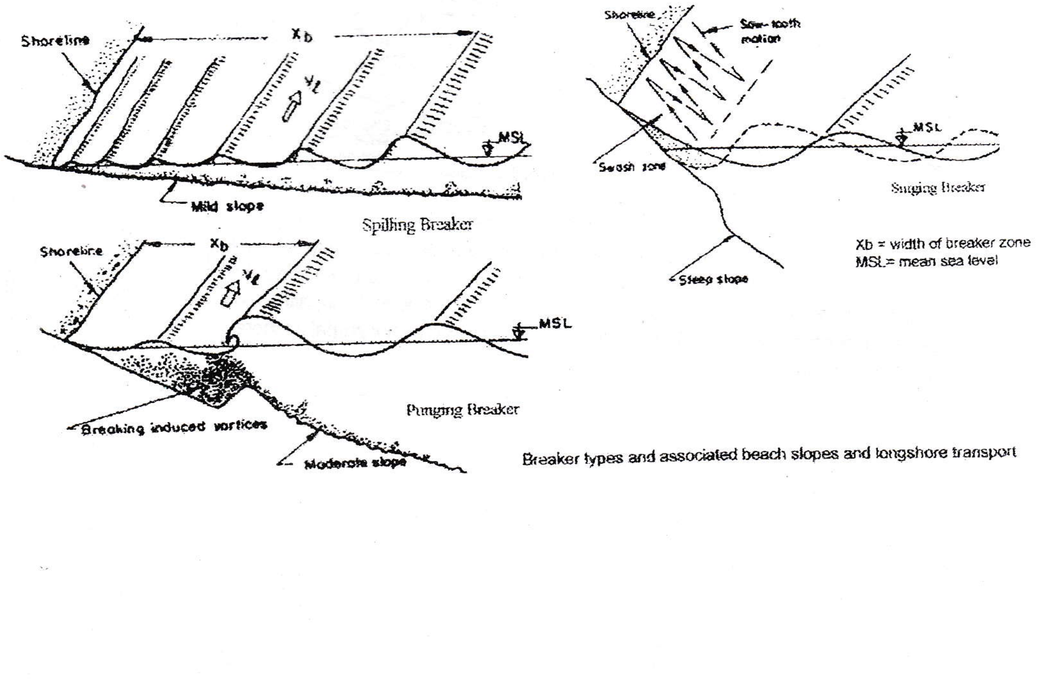
Fig.7 Increasing asymmetry of waves approaching the shoreline. H/ L increases within the wave base and water particle orbits become elliptical and then fail to close, indicating mss transport. In a two dimensional context this leads to a return flow at depth, although in three-dimensions this vertical return current may be replaced by horizontal onshore/ offshore circulations

The motion of the wave form: Although waves do not transport significant masses of water particles, the wave form itself clearly moves laterally over the sea surface. The stored mechanical energy in progressive waves is released when they break along a shoreline. In deep water, the larger the wave and the longer the wave period, the faster the wave. As the waves approach shallow water condition, the wave parameters viz. height (H), length (L) and speed or celerity (C) undergo significant transformations. The most obvious shallow water wave transformation is vertical growth of the wave form. This is apparent even to a layman. As waves approach shallow water, their length (L) decreases. The result is a sharp increase in wave height (H). This increase in WAVE STEEPNESS manifests itself as a wave crest that becomes progressively more peaked, until the wave height is 1/7th of the wave length (H:L = 0.147). At this critical point, the crest is over-steepened, becomes unstable and the wave collapses or breaks. The point at which the wave breaks is known as the BREAKER ZONE or the SURF ZONE. The SWASH ZONE is the segment of the beach landward of the surf zone, where the water rushes up the beach after a wave breaks.

When waves approach a shoreline at an angle, in addition to the normal changes in celerity, height and length they suffer REFRACTION i.e. they swing around and tend to align themselves to the bottom contour. As wave celerity decreases with depth, wave length also decreases proportionally. Variations in wave velocity (celerity) occurs when the part of the wave in deeper water moves faster than the part in shallower water and this variation causes wave crests to bend in alignment with the contours. As the waves break at an angle to the shore they generate currents moving parallel to it. Wave refraction determines the distribution of wave energy and the pattern of sediment movement along a coastline (Table 5, Fig. 8).

BREAKER TYPE	**CHARACTERISTICS**	**ENERGY CONDITION**	**MECHANISM OF SAND TRANSPORT**	**EFFECT ON COASTLINE**
Spilling	The upper crest steepens and spills down the front of the wave.	Slow dissipation of energy in the surf zone	Sand is put into suspension, turbulence does not reach the bed	Gentle swash and backwash, generally cause deposition of sand along beach and longshore transport
Plunging	The wave front over-steepens, curls and plunges forward.	Instant release of large amount of energy	Sand is put into suspension by breaking, causing violent turbulence and vortex motion	Vigorous vortex motion churns up sediment from bed, breaking may cause erosion
Surging	The flat waves do not break, but move up and down the beach face.	Much energy is reflected seaward.	Sand is carried in longshore direction by saw-tooth motion in swash zone	Strong beach combing due to energetic swash-backwash.

Table 5



Breaker types and associated beach slopes and longshore transport

6

WAVE TYPES, CHARACTERISTICS AND MORPHODYNAMIC IMPLICATIONS

WAVE TYPES			**CHARACTER / DESCRIPTION**	**BED FORMS**	**AREA AFFECTED**
ORIGIN	Swell waves		Long period fast-travelling waves. May be generated thousands of kilometres out in the ocean.	–	–
	Sea waves		Short period waves, generated by nearby storms or prevailing winds	–	–
WAVE TYPES	Deep		Orbiting diameter of water equals wave height at the surface and decrease progressively with depth, without any distortion.	No bed form can develop	Offshore
	Shallow		As they enter shallow water, the waves start to 'feel' the sediment surface at a point termed *wave base* at D=L/2 (where D = depth of water and L = wave length).	–	Offshore-shoreface transition & shoreface
		Oscillatory	Between D = L/2 and D = L/4–6, the passage of each wave results in a symmetrical to-and-fro motion, aligned to the direction of wave propagation, in the sediment surface.	Symmetrical ripples	
		Shoaling	At D < L/4–6, waves change from a symmetrical, sinusoidal form to an asymmetrical form. *Wave velocity* and *wavelength* <u>decrease</u>; *wave height* and *steepness* <u>increase</u> while the *wave period* remains <u>constant</u>. Wave motion involves a brief landward surge and a larger, *weaker* seaward return flow. In effect, *a net landward movement of sediments* occurs.	Asymmetrical wave ripples and dunes	
		Breaking	As the velocity of the orbiting particles overtakes the velocity of the shoaling wave, it causes the wave to break—initiating the high-energy breaker zone.	Plane bed	Shoreface & beach
TRANSFORMATION	Surf zone		The breaking of the wave directs a high-velocity bore up the shoreface up to the foreshore—forming the surf zone.		
	Swash zone		At the landward limit of wave penetration, each wave produces a shallow, high-velocity landward directed *swash* followed almost immediately by a seaward directed *backwash*, which may disappear by infiltration in the bed.		Beach

Table 6

- The general trend across the shoreface and beach is the one in which oscillating flow transforms into asymmetrical, land-directed flow of increasing power.
- Positions of the above-mentioned wave-transformation zones vary diurnally and seasonally according to TIDAL OSCILLATIONS and alterations of STORM and FAIRWEATHER CONDITIONS.
- Wave energy at the shoreline depends on FRICTIONAL ATTENUATION in addition to deep-water wave energy and water depth of the basin. The frictional attenuation, on the other hand, depends on the nature and width of shelf and rate and type of sediment supply to the nearshore zone.
- Wave-influenced shorelines can be of *three* types (or DOMAINS): REFLECTIVE—where waves break directly on the beachface (common in steep gravel beaches); DISSIPATIVE—where waves break a considerable distance away from the shore (common in sandy/muddy beaches with irregular and gentle profiles) and TRANSITIONAL (Fig. 3).

3

2.3 WAVE INDUCED CURRENTS

2.3.1 Longshore Currents and Rip Cells

- Operate in the breaker and surf zones.
- As waves approach the shoreline, they are refracted in a complex manner due to irregularities in depth of the self and the coastline. This produces zones of CONVERGENCE and DIVERGENCE—both of wave and energy.
- The resultant WAVE SET-UP—the rise in the MWL above still water level due to the presence of waves—gets higher in the zones of convergence and lower, in zones of divergence. This produces a nearshore circulation cell—also called rip cell—with:
  1. Landward directed mass transport where the set-up is high; getting transferred at the breaker zone into:
  2. A LONGSHORE-DIRECTED current in the surf zone *and*
  3. A SEAWARD DIRECTED flow by RIP CURRENTS that transport water and sediments back into the sea (Fig. 11and 12). Rip currents occupy the position where the waves diverge and the wave set-up is low. During storms rip current velocities may typically reach from 2–3 m s^{-1} to 10 m s^{-1} and become major instrument of erosion of the shoreface. Rips erode shallow channels that pass seaward into rip fans containing seaward-directed current ripples and dunes.
- Presence of cellular circulation along straight beaches with no irregularities suggests that some other mechanism must also operate to change the height of wave set-up. This probably involve EDGE WAVES—oriented at 90° to shoreline and formed by the RESONANCE between waves arriving at the shore (INCIDENT WAVES) and those REFLECTED from it. The resonance rises the height of the wave set-up at regular intervals parallel to the shore. Oblique wave approach causes longshore transportation to become unidirectional.
- Regardless of their forming mechanisms, once established the circulation cells become largely self-sustaining. The offshore sediment transport in rip current zones and onshore or shore-parallel sediment transport between them alter the form of a beach rhythmically to enhance the cell circulation pattern.

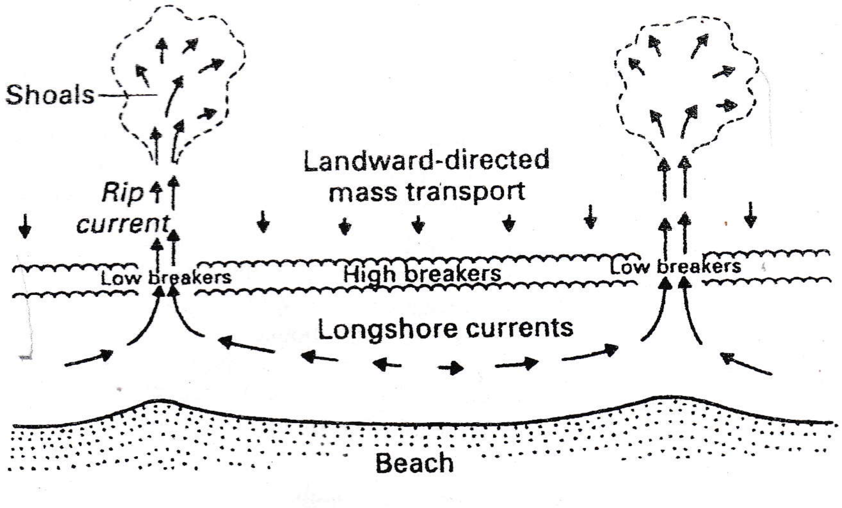


Fig. 11 Wave induced nearshore circulation system of longshore currents and seaward-directed rip

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2.4 STORM-FAIRWEATHER HYDRAULIC REGIME: THE BEACH CYCLE

Along most shorelines, meteorological factors dominate the hydraulic regime, which is characterised by strongly seasonal wind- and wave-induced currents and marked alternations between fairweather and storm conditions. The hydraulic regime, to a large extent, controls the coastal morphodynamics (Table 8).

PROPERTY	FAIRWEATHER CONDITION	STORM CONDITION
Wave amplitude	Low	High
Dominant wave type	Long period swells	Short period wind waves
Wave base	Shallow (about 10 m)	Deep (maximum up to 200 m)
Shoreline	Tends to be reflective	Tends to be dissipative
Morphology	• The lower shoreface and the offshore zones are not affected by waves. So, fine-grained sediments are deposited from suspension and are reworked by organisms. • On the upper shoreface and foreshore, wave-induced currents, associated with shoaling breakers, transport sediments landward. • Little sediment is lost through seaward-directed rip currents. • Longshore transportation predominates. • The shoreface tends to be smooth, with no bars. • The beach AGGRADES.	• Much of the lower shoreface and possibly the offshore area experience oscillatory shoaling waves and associated processes. • Onshore/offshore transportation predominates • The upper shoreface and the beach are extensively ERODED. • Sediment is both deposited landward (e.g. as washover fans in lagoons) and swept seaward in offshore bars by rip currents, wind-driven storm currents and, in the tropics, storm surges.

Table 8

- It becomes clear from above that a beach aggrades during fairweather and erodes during storms. This response is termed BEACH CYCLE (Fig. 14).
- The sediments that are taken away from the beach during the storms are deposited in offshore bars. In the fairweather condition, this reverses. Sediments are moved away from the bar and redeposited on the beach. The zone, extending from the beach to the bar—where the cyclic movement takes place—is called the SWEEP ZONE.

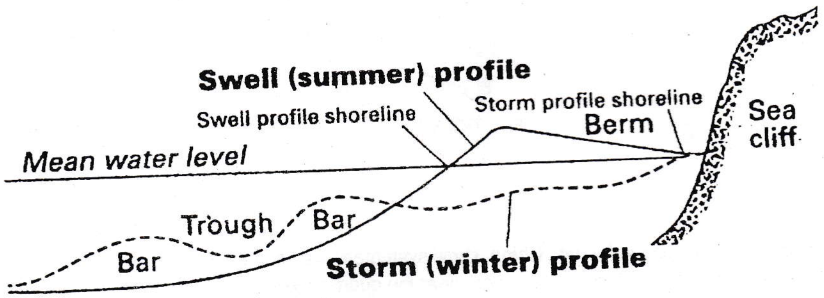


Fig.14 The beach cycle of alternate swell profile when a pronounced berm is built up and storm profile when sediment is shifted to the shoreface, and offshore bars are formed

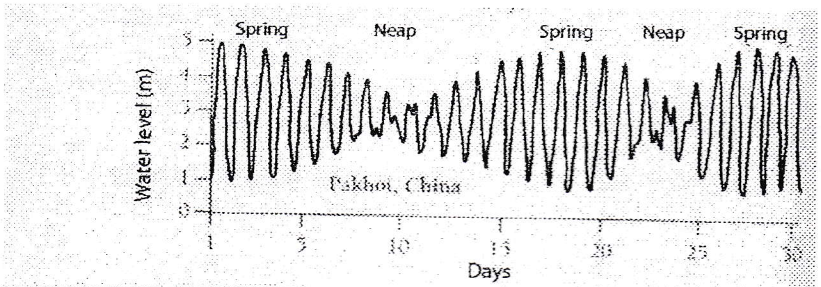
2.5 TIDES: NATURE AND INFLUENCE

2.5.1 Nature

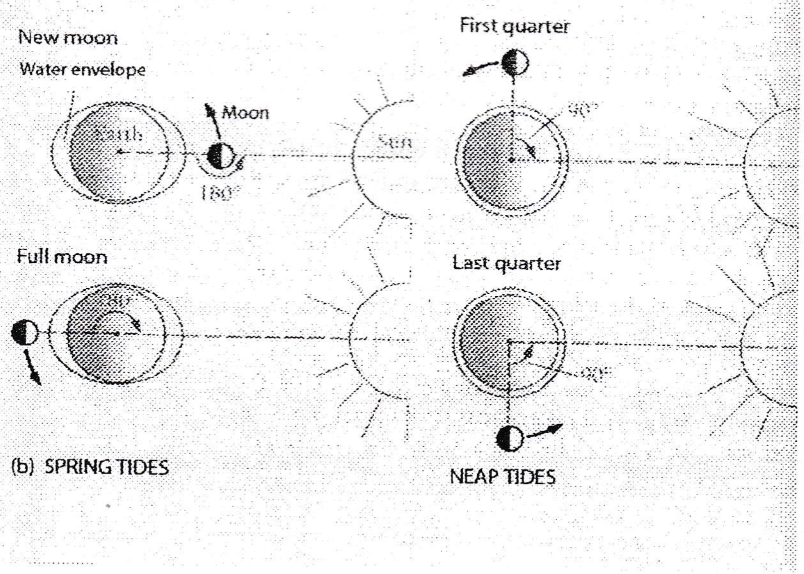
Tide in the sea result from the gravitational pull of the moon, the sun and the planets and from local meteorological disturbances. The effect of varying gravitational pull can be predicted with high degree of accuracy. The meteorological effects are random in their occurrence and apart from some general seasonal trends, can only be predicted a short time in advance.

The moon orbits the earth once in 28 days and the whole system orbits round the sun in 365.2 days. The paths of the moon round the earth and the earth round the moon are both elliptical, so the gravitational force of attraction passes through a maximum and a minimum during each orbit. The largest component of the force is due to the moon because the sun is almost 390 times farther from the earth than the moon is. The moon has a PERIOD of about 24 hr, 50 min (diurnal tides) or 12 hr 25 min (semi-diurnal tides) during which it revolves round the earth. The total tidal force due to the combined action of the sun and moon is greatest when they act together, i.e. when the sun and moon are nearly in line with the earth. This occurs twice a month, when the moon is on the same side of the earth as the sun, and when they are on opposite sides, i.e. at new moon and new moon. When this happens, spring tides occur, having a range of movement, greater than the average. When sun and moon are in right angles to each other, their effect give rise to smaller than average neap tides, which also occur twice a month. Spring water levels are about 20 per cent *higher* and the neap water levels are approximately 20 per cent *lower* than normal water level

Thus we see that, • due to the orbital period of the moon around the earth we have daily fluctuations in the water level. The face of the earth facing the moon experiences a bulge in the water surface known as high tide while the face away from it experiences low tide; • due to the alignment of the earth, moon and sun we have monthly fluctuations in the water level i.e. the spring and the neap tide. (Fig. 15)



(a) VARIATIONS IN TIDAL RANGE



(b) SPRING TIDES

NEAP TIDES

Fig. 15 (a) Month-long records of tides at Pakhoi, China, show systematic variations in tidal range. The maximum tidal range occurs near the full moon phases; the minimum tidal range, near the quarter-moon phases. (b) During the new and full moons, spring tides result from the alignment of the moon, sun and earth. Under such conditions, tide raising forces of both the sun and the moon act in conjunction. Tidal ranges are minimal during neap tides, because the 90° geometry described by the planetary bodies produces opposing tide-raising forces from the sun and the moon

- CORIOLIS FORCE substantially influences patterns of tidal currents.
- Overall, although tides have less effect on transportation of sediments and on coastal morphology than waves, they affect the coasts in two important ways. They govern:
  1. The strength and flow patterns of regularly fluctuating tidal currents.
  2. The amounts of tidal rise and fall.

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2.6 WIND

- The STORM-FAIRWEATHER HYDRAULIC REGIMES are directly controlled by meteorological factors, mainly wind.
- WATER WAVE heights and periodicities are dependent upon:
  1. Wind speed,
  2. Length of fetch
  3. Wind duration.

  Considerable variation exists, however, in the efficiency of the energy transfer from the wind to the water and eventually to the sea bed.
- WIND-DRIVEN CURRENTS result from wind shear on the water surface, with energy transferred through turbulent mixing. These currents are indirectly the result of atmospheric circulation systems and operate over a wide range of temporal and spatial scales. Surface currents generated by wind stress deviate from the wind direction in response to the CORIOLIS EFFECT. With depth, this deviation is further intensified by the EKMAN SPIRAL EFFECT. The unidirectional wind-driven currents flow MAINLY OFFSHORE. The fluctuations in current strength correlate with variations in wind speed.
- STORM SURGE is a specific storm-related condition caused by a marked reduction of air pressure and/or high wind stress, which produce abnormally high water level at the shoreline followed by a drastic lowering of the water level. Intense wave agitation and COASTAL EROSION accompany these surges.
- Winds also play an important role to evolve COASTAL DUNES and associated aeolian features. Coastal dunes only develop on certain coasts; they are most extensive where there are suitably strong onshore winds, sufficient sediment supply of medium to fine well-sorted sand suitable for entrainment, and vegetation to assist in the trapping of that sand. Foredunes (the first dune ridge forming at the back of the beach) play an important role storing sediment and protecting the land from extreme wave and tide conditions. Dunes represent a sand reserve from which material can be borrowed (by erosion) under extreme conditions to reshape the near-shore, with return of those sand volumes during ambient conditions. Erosion and scarping of dunes by waves begin a cycle from which the dune recovers when it has achieved a stable slope and becomes revegetated.

⑦

2.7 GRAVITATIONAL PROCESSES

Gravitational reworking is important in some coastal settings. Sediment is redistributed both in subaqueous and subaerial condition by a whole range of processes on unstable slopes:

1. Creep
2. Slide
3. Sediment flows.