



SWANSEA METROPOLITAN UNIVERSITY
PRIFYSGOL FETROPOLITAN ABERTAWE



WAVES AND BEACHES

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Built and Natural Environment





Presentation Structure:

- **Waves – physical properties**
- **Wave – beach interaction**
- **Beach material and behaviour**
- **Sediment transport, erosion landforms and sediment cells**



“What more noble pursuit of man than to intersperse a barrier between land and sea?”

**Sir John Rennie
(1794 – 1874)
President of the
Institution of
Civil Engineers**

**Nature to be
commanded
must be obeyed
F. Bacon**



NINTH WAVE

AIWAZOVSKY, 1850
ST. PETERSBURG
MUSEUM

- RHYTHM OF
IRREGULAR WIND
WAVES
- ORDER IN CHAOS
- $N = \text{NUMBER OF WAVES IN A WAVE GROUP} = \exp(0.5 \cdot k^2)$
- WIND WAVES OF
NARROW BAND
SPECTRUM $k = 2 - 2.2$ $N = 9$
- (GODA, 1970)



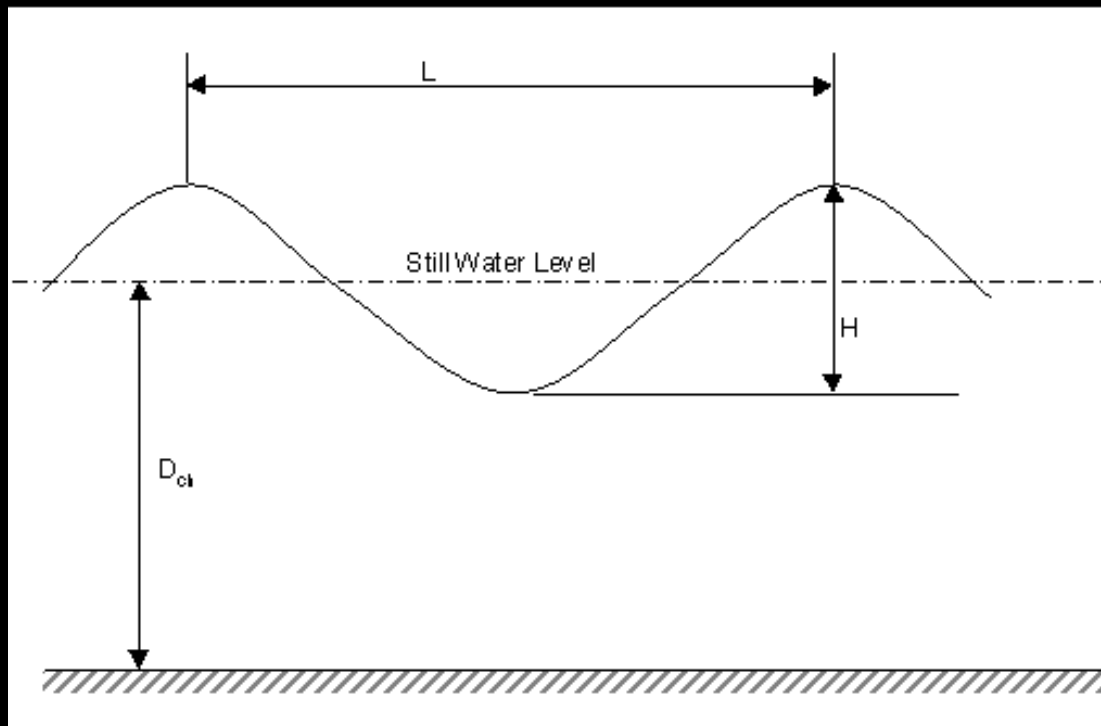
WAVES

Created by transfer of energy from wind blowing over the sea.

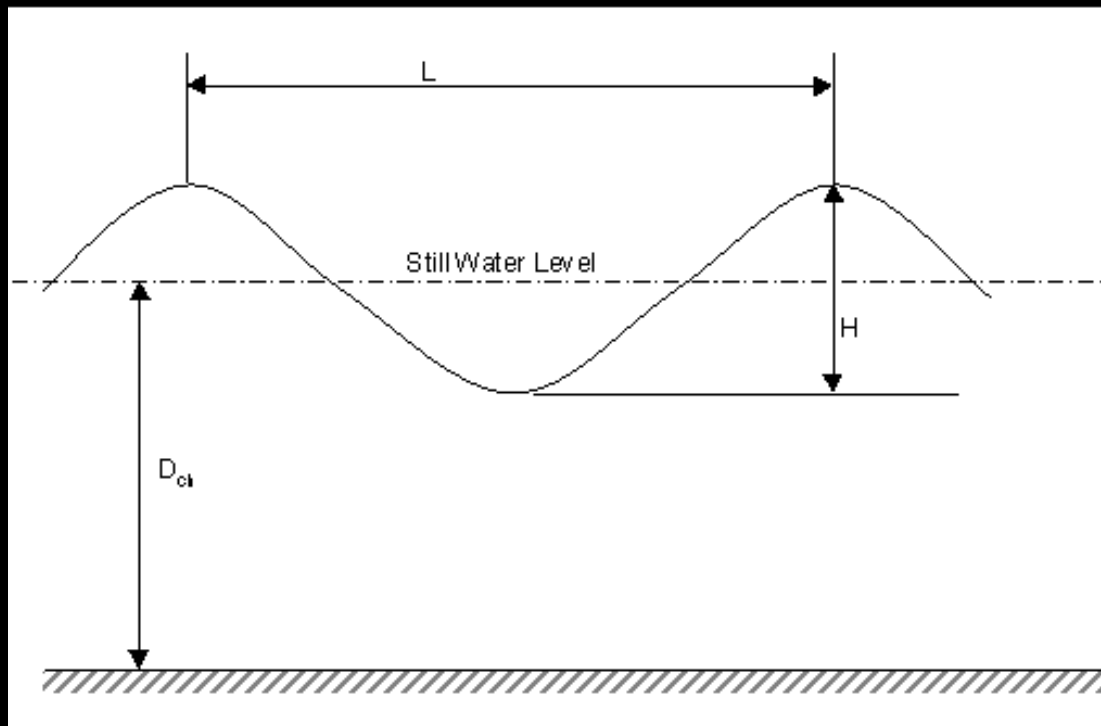
Increase wind speed >
increased drag >
increased wave size.

Waves from local winds travel short distances –
Sea waves

Waves from distant storms travel long distances –
Swell



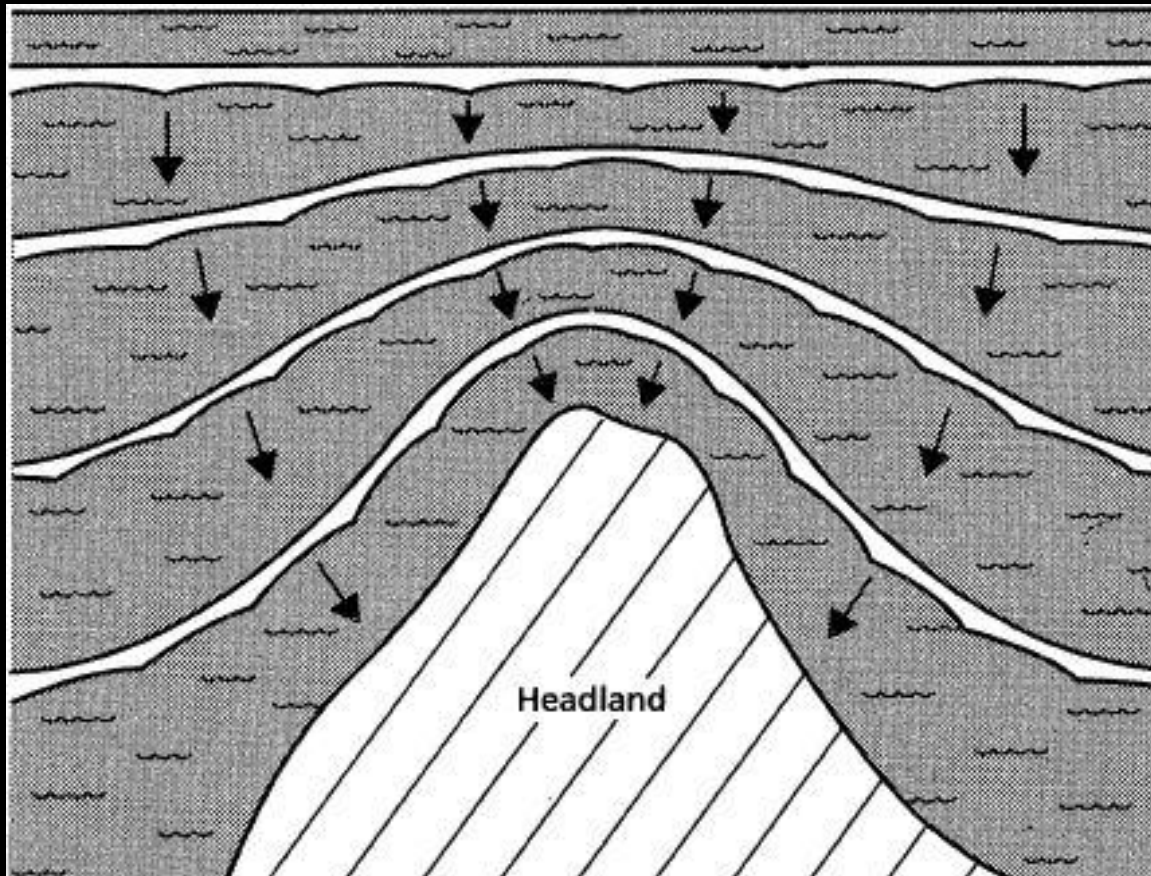
- Wave Height (H) = Crest to Trough (rarely exceeds 6m)
- Wave Period (T) = time between successive waves
- Wave length (L) = distance between two successive crests $L = g/2\pi(T^2)$ or $1.56 T^2$
- Wave Velocity (C) movement of crest in given time $L = CT$



- Wave Steepness (H/L):
Ratio cannot exceed 1 : 7
(0.14) - BREAK
- Steepness determines
whether waves will build up
or degrade beaches
- Steepness of most waves in
the range 0.005 to 0.05
- Wave Energy (E) $\propto LH^2$
- Winter wave average 11
tonnes m^{-2} (3 times greater in
storms – sea defences)



- **Deep Water Waves:**
Water Depth $D = > L/2$
(vertical motion with little horizontal displacement)
- **Shallow Water Waves:**
Water Depth $D = < L/2$
(friction of sea bed increases)
- **Plunge line – point at which wave breaks ($L \approx D$)**
- **SWASH** - foaming water rushing up the beach
- **BACKWASH** – returning water (under gravity)



- **Coastlines erode over time.**
- **Headlands are formed because the rock is more erosion resistant**
- **Bays are formed by erosion of less resistant rock between headlands**
- **Waves approaching an irregular coastline are refracted, that is, they become increasingly parallel to that part of the coastline**



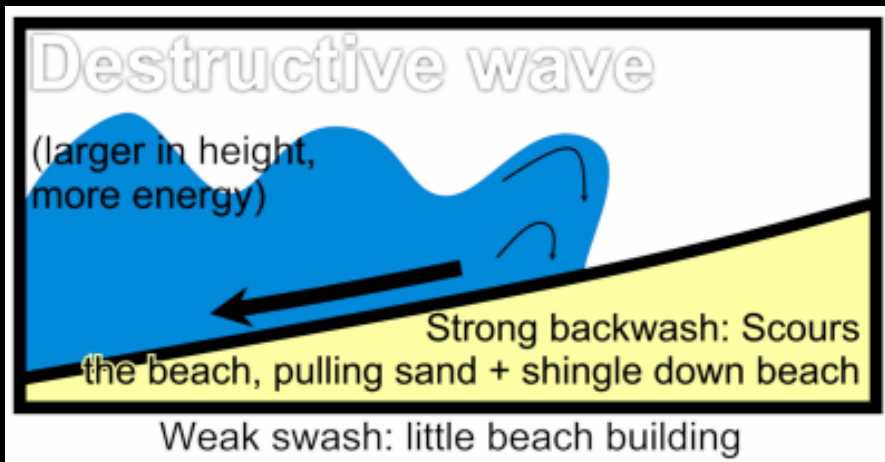
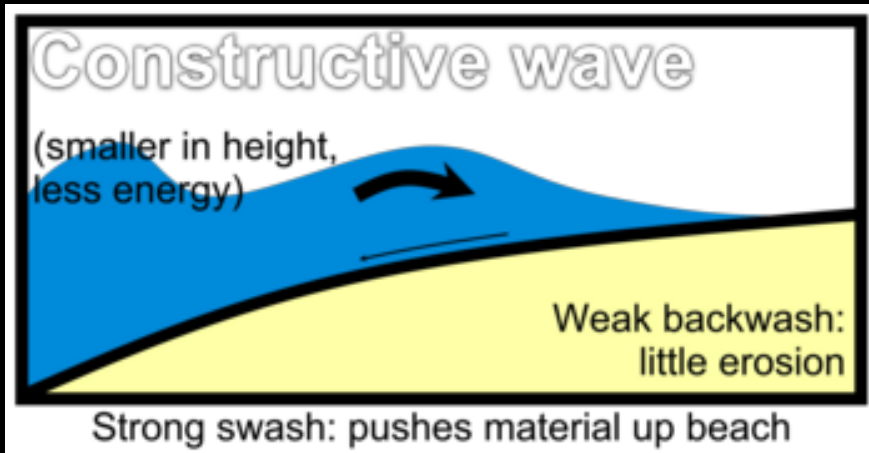
Beaches may be divided into three sections:

- 1. Backshore (usually above the influence of waves)**
- 2. Foreshore (inter-tidal or surf zone)**
- 3. Nearshore (breaker zone)**

Offshore is beyond the influence of waves

Beach profiles fall between two extremes:

**wide and relatively flat;
narrow and steep.**



- There is a close relationship between beach profile and action of constructive and destructive waves;
- **Effects of wave steepness on beach profile is complicated by particle size;**
- **Sand produces a different profile to shingle. Generally, the larger the particle size, the steeper the beach;**
- Constructive (surging or spilling) waves result from swell and will move material up the beach. Low in height ($<1\text{m}$), long wave lengths (up to 100m between crests) and long wave periods (6 to 8 breaking per minute);
- **Destructive (surfing or plunging) waves result from additional energy during storms and will move material down the beach. Height ($>1\text{m}$), short wave length (about 20m between crests) and more frequent wave period (10 to 14 breaking each minute)**



It is suggested that particle size complicates the influence of wave steepness on beach morphology because of rates of percolation. Particle size is sorted by wave action and increased size results in increased steepness/gradients.

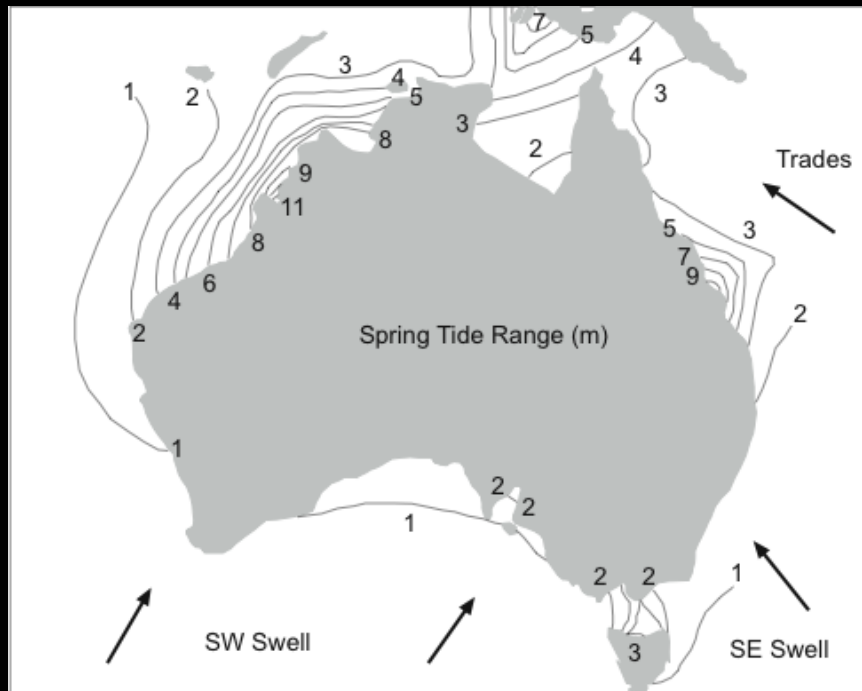


Sand usually produces beaches with gentle gradients. As tides ebb, the beach surface is dried by on shore winds and if these are dominant (strong) or prevailing (frequent) then sand dunes develop beyond the backshore zone



The interrelationship between wave energy, beach material and beach profiles may be summarised by the following generalisations:

- **Destructive waves carry material down the beach;**
- **Constructive waves carry material up the beach;**
- Material is carried upwards on shingle beaches;
- **Material is carried downwards on sandy beaches.**



- Beach systems are dependent on four factors:
- H_b Wave height
- T Wave period
- W_s Sediment size (fall velocity)
- TR Spring tide range
- These can be quantified using the **dimensionless fall velocity** (Gourlay 1968; Wright & Short, 1984)
 $\Omega = H_b/T W_s$
- **Relative tide range** (Masselink & Short, 1993)
 $RTR = TR/H_b$



RTR < 3

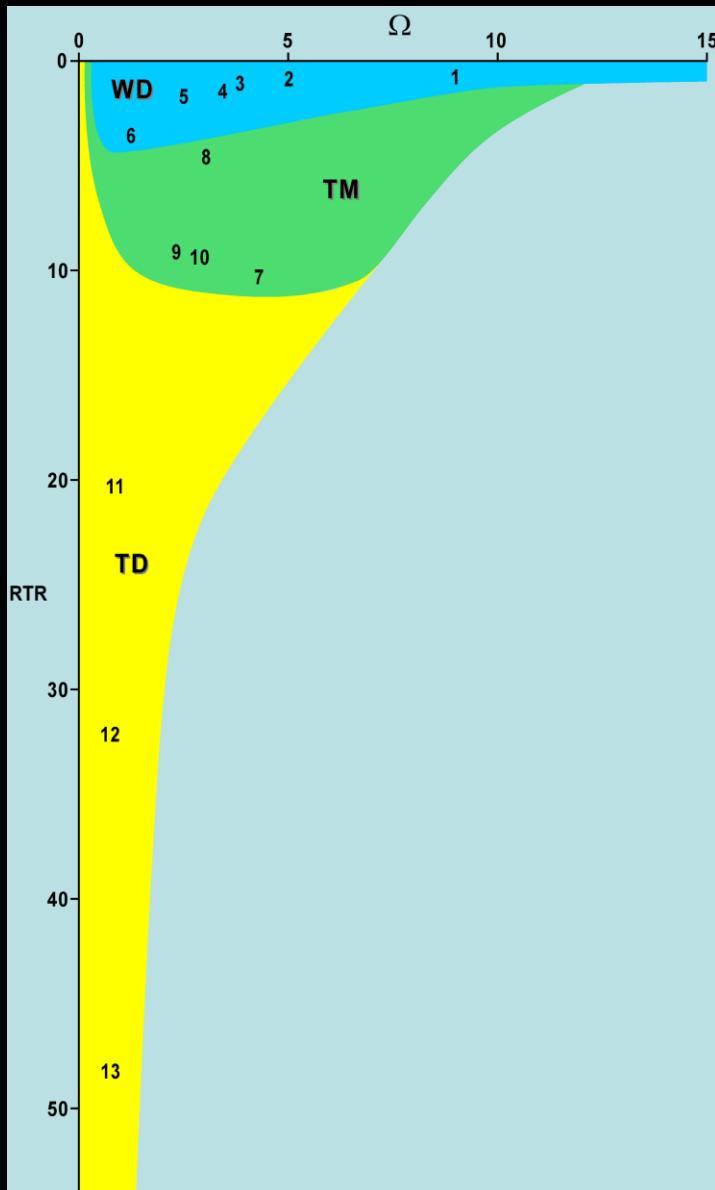
- $H_b = 0.5 - 3 \text{ m}$
- $T = 5 - 12 \text{ s}$
- $TR = 0.4 - 3 \text{ m}$
- (Wright & Short, 1984)

RTR 3 - ~10

- $H_b = 0.5 - 1 \text{ m}$
 - $T = 5 - 12 \text{ s}$
 - $TR = 3 - 9 \text{ m}$
- (Masselink & Short, 1993)

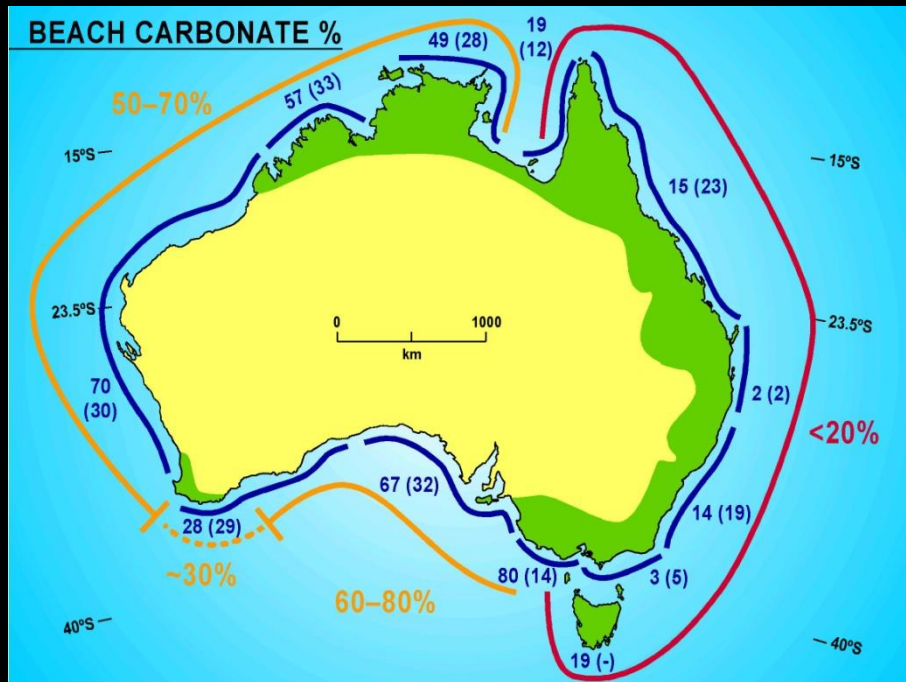
RTR ~10 - 50+

- $H_b = 0.1 - 0.5 \text{ m}$
 - $T = 3 - 5 \text{ s}$
 - $TR = 3 - 9 \text{ m}$
- (Short, 2000)



Erosion never causes a problem in unmodified areas and often results in a net benefit; but it presents a serious recurring problem for human development.

(Schroeder, 2000; Phillips, 2000)



Beach type is controlled by the RTR

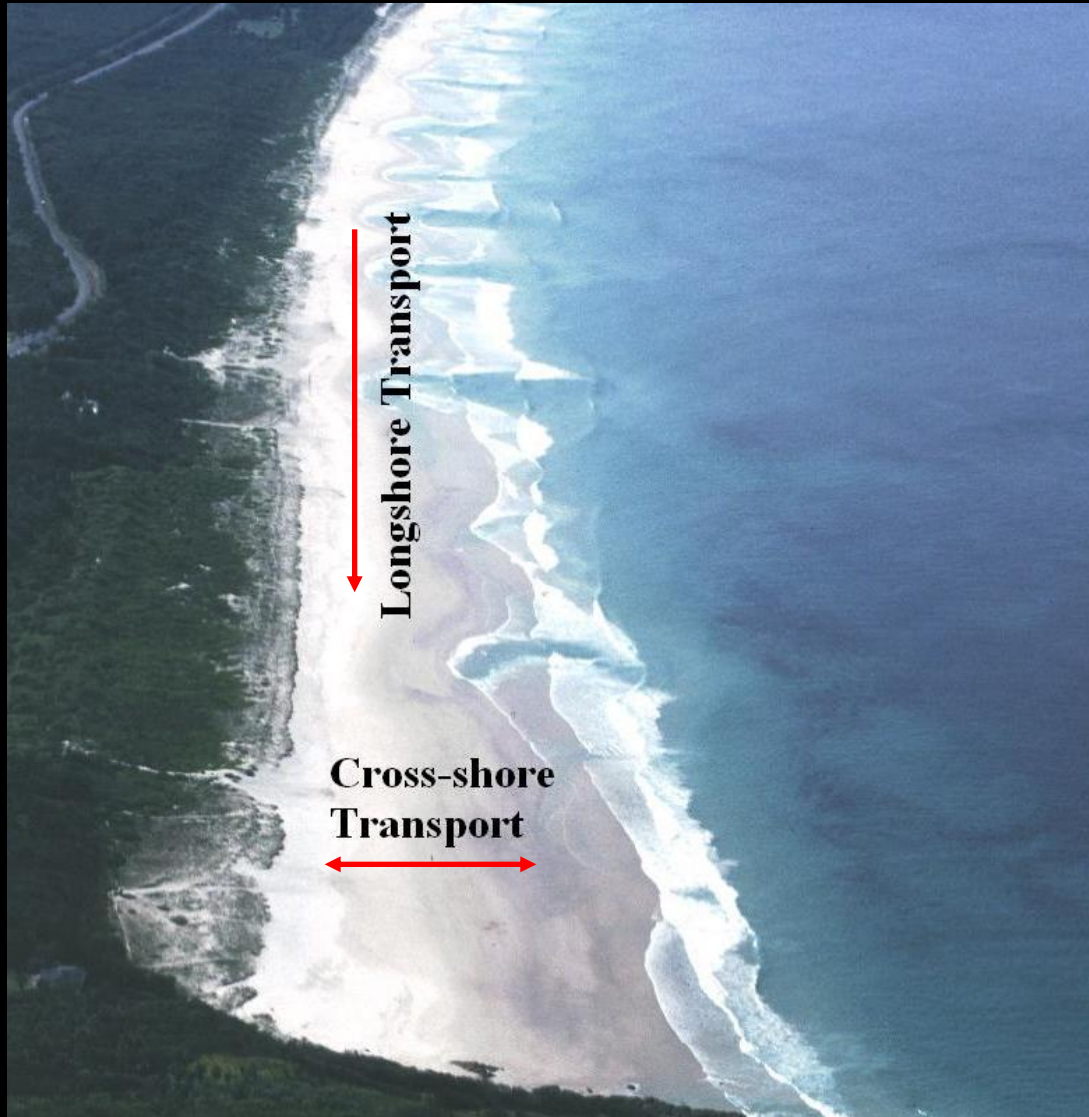
Beach state is controlled by RTR & Ω

- Based on RTR beaches classified into three beach types
 - Wave-dominated RTR <3
 - Tide-modified RTR 3-10
 - Tide-dominated RTR 10-50+
- Based on Ω each type can be classified into 13 beach states

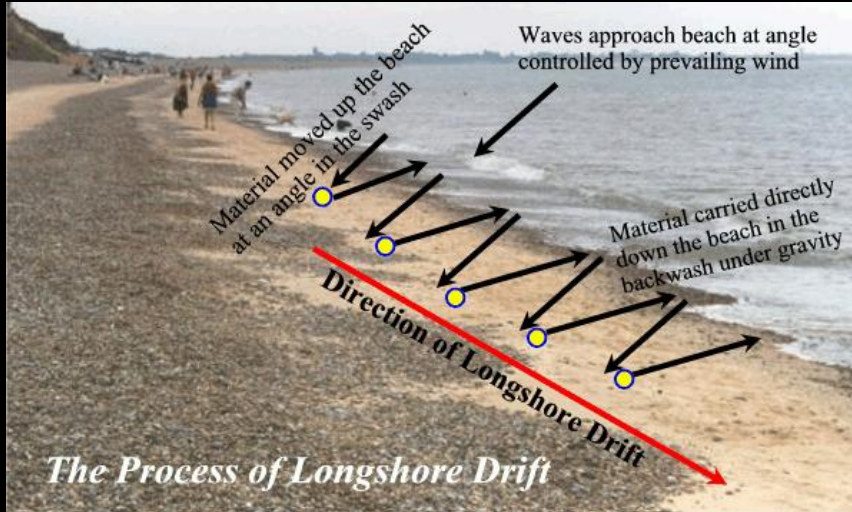
6 wave - dominated

3 tide - modified

4 tide - dominated



Cross-shore transport or on-shore off-shore movement is often critical in beach erosion. This movement occurs during storms.



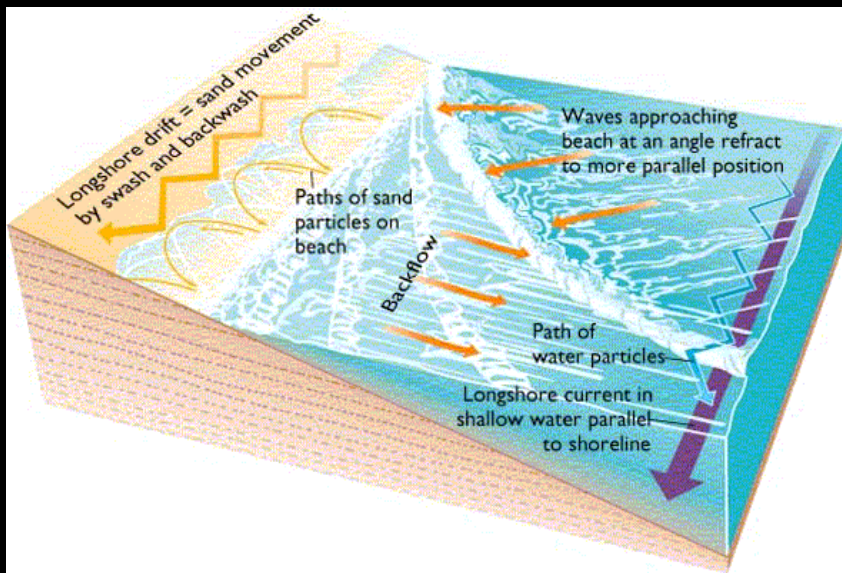
Longshore drift:

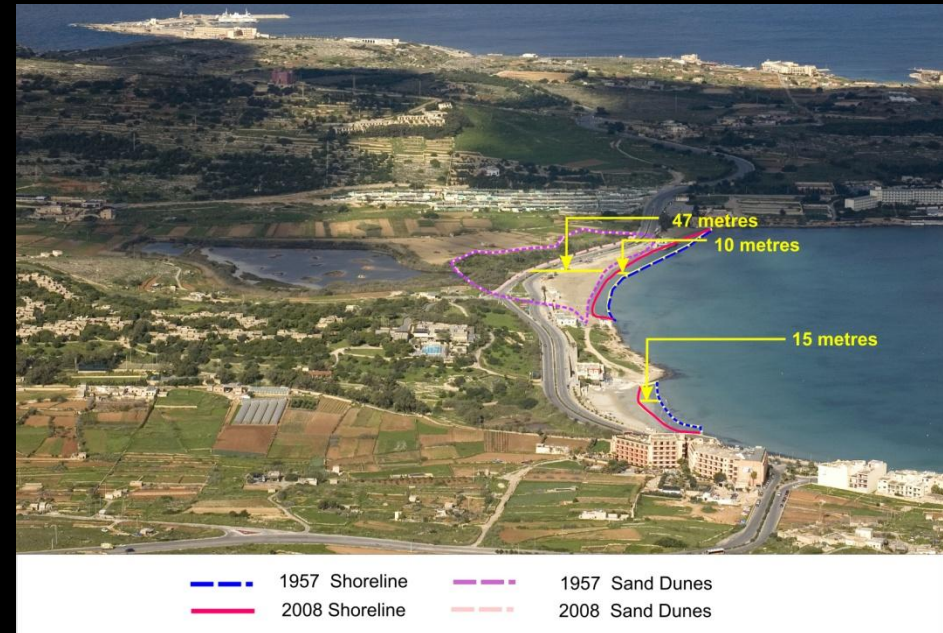
The angle at which waves approach the land is determined by wind direction, local configuration of the coastline and refraction at headlands.

Swash carries material up the beach in direction of wave approach;

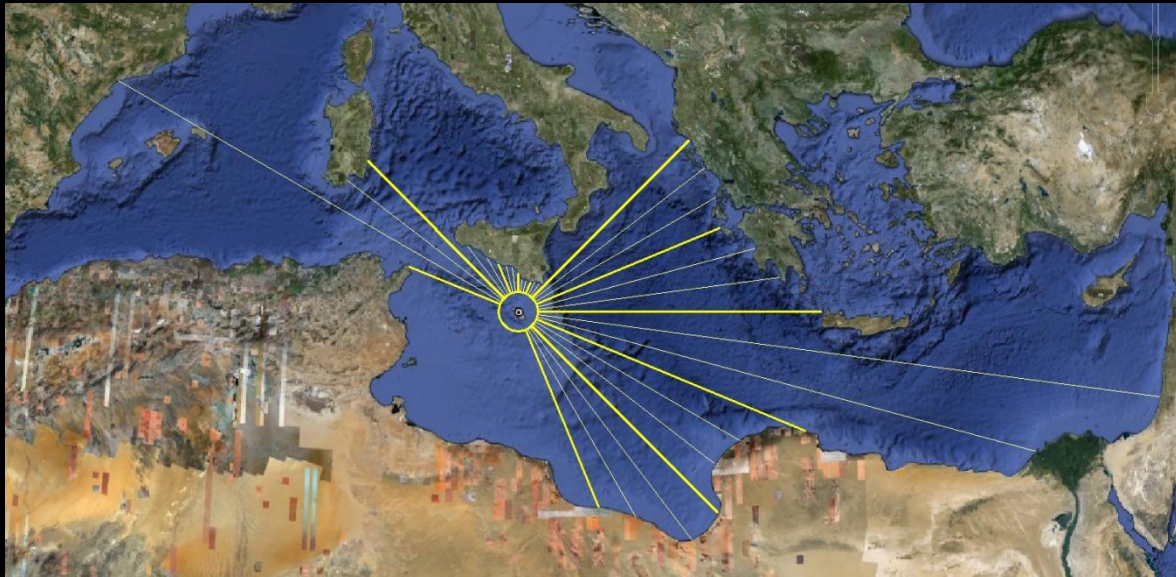
Backwash returns material at right angles to the water line under action of gravity.

Net longshore transport

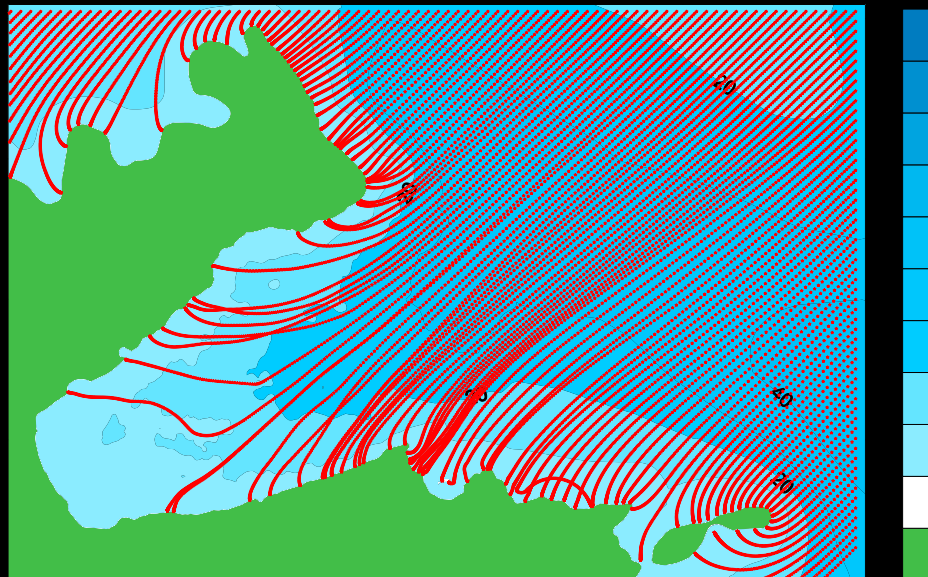




Ghadira (Mellieha) Bay, Malta



**Fetch
distances**



**Wave
orthogonals
(10 year return
period)**



EROSION LANDFORMS:



- **Headlands and bays:** found in areas of alternating resistant and less resistant rock.
- Initially weaker rock eroded under wave action and more resistant rock forms headlands;
- **Subsequently, the headlands experience higher energies and the bays experience low energy breakers which cause sediment to accumulate**



Wave cut or shore platforms

- **Wave energy is at its maximum when a high steep wave breaks at the foot of a cliff;**
- This results in undercutting of the cliff to form a notch;
- **Continual undercutting causes tension stresses in the rock and collapse;**
- **Process is repeated until a gently sloping platform ($<4^\circ$) is left**



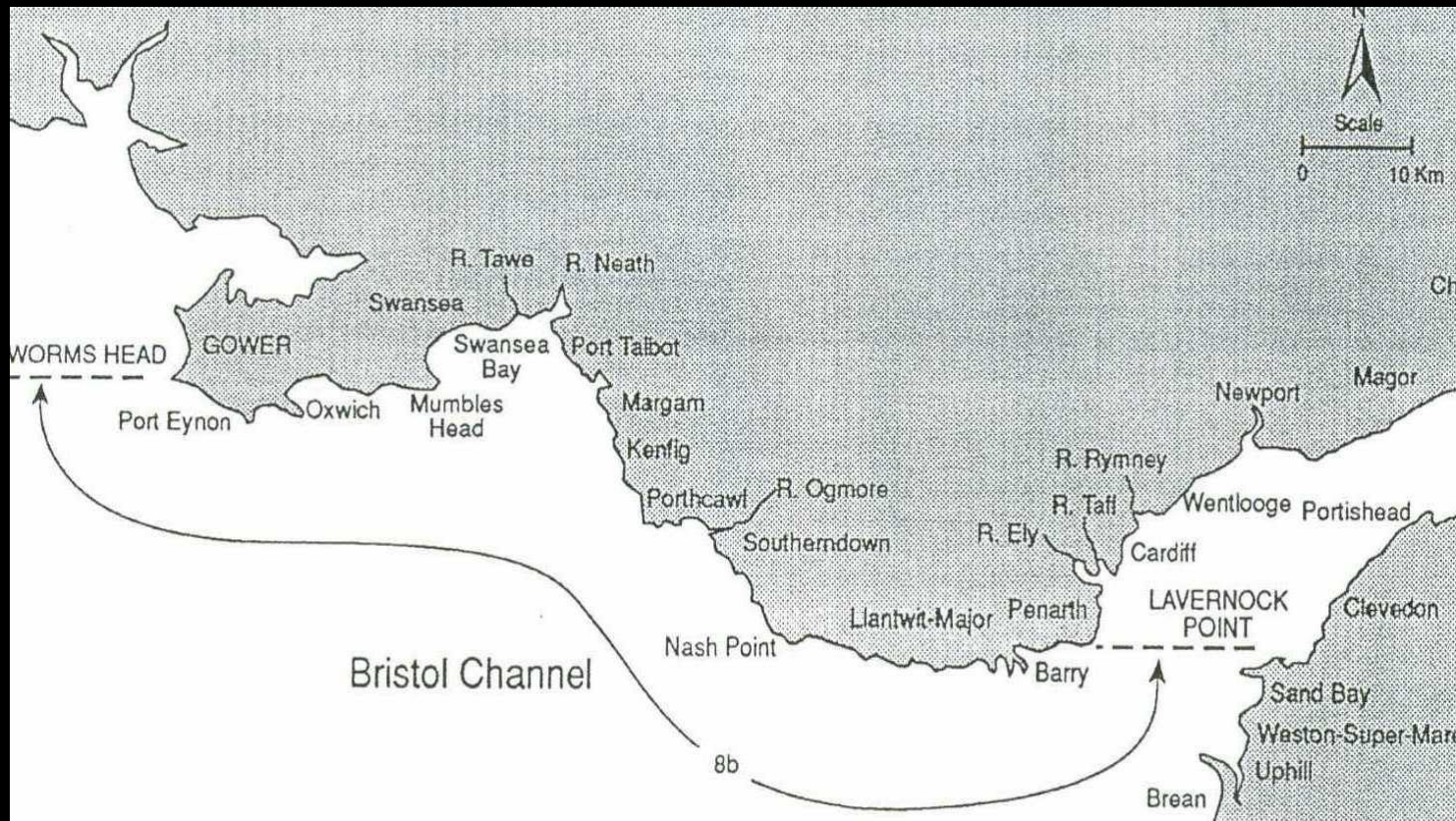
Caves, blowholes, arches and stacks.

Wave action attacks lines of weakness, faults, joints, chemical action etc form different erosion landforms.



FACTORS AFFECTING RATES OF EROSION

- Breaking point of the wave (e.g. foot of cliff or offshore);
- **Wave steepness (sea waves);**
- **Depth of sea, length and direction of fetch, configuration of the coastline (steeply shelving beaches create steeper waves; longer fetch more opportunity to collect wind energy; headlands concentrate wave energy by refraction);**
- Supply of beach material
- **Beach width;**
- **Rock resistance for cliffs.**



Coastal zone will demonstrate wide variations in geological and geomorphological processes, tidal range, hydrodynamics, history, coastal defence, conservation priorities and public use



Coastal Zone Management is a process driven approach where any intervention works with natural processes rather than against them (EC, 1999)

Davies (1974) introduced concept of coastal sediment compartment – open and closed

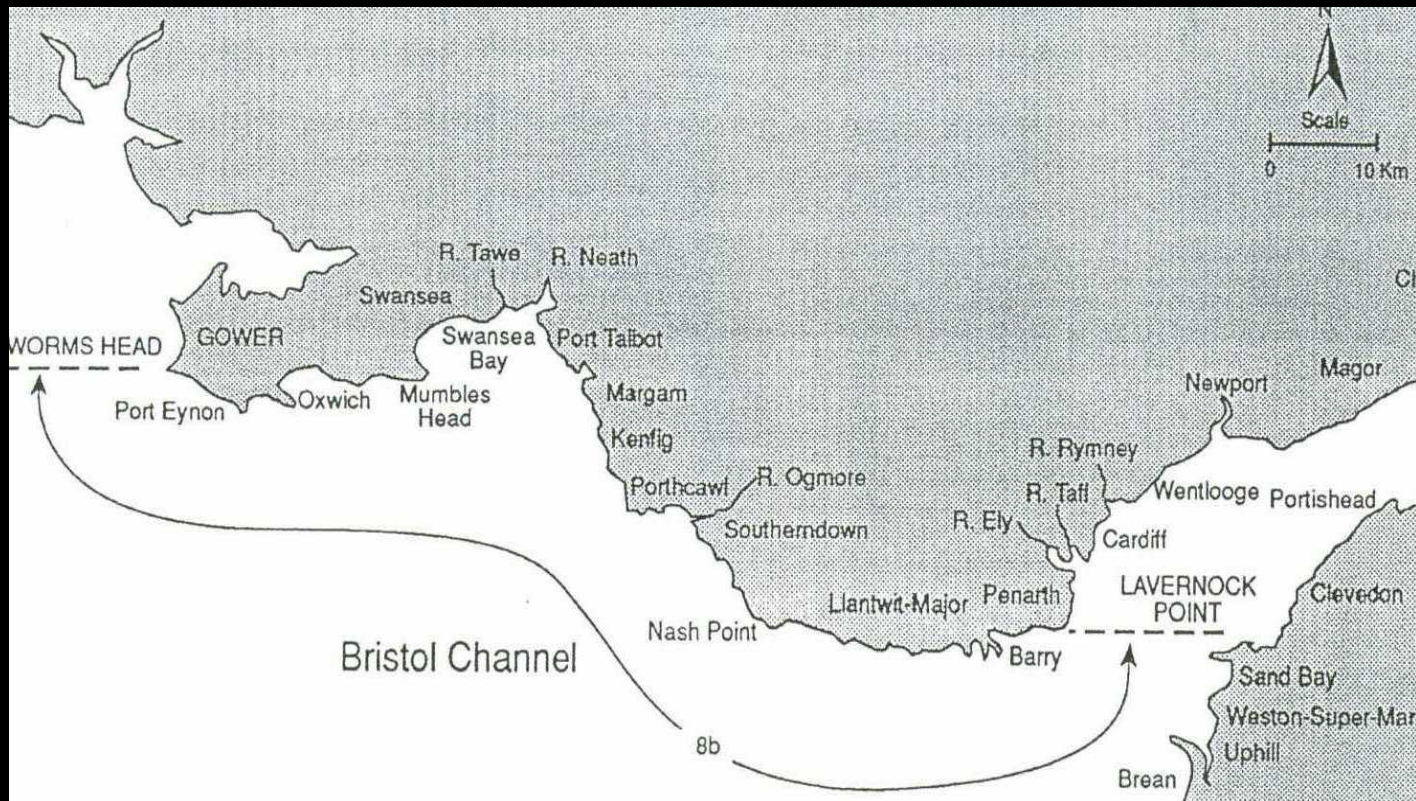
Carter (1988) introduced coastal cells defined as fixed and free



- **Fixed boundaries:** morphological features that exert a control over wave refraction and/or hinder sediment transport (headland, etc);
- **Free boundaries:** difficult to locate – updrift limit of erosion or downdrift limit of deposition;
- **Difference between compartments and cells is that boundaries of cells fluctuate according to angle of wave approach whereas compartments are immobile;**
- Ideal for sediment and wave energy budgets but not as strategic management tools.



- In UK two approaches defined on basis of coarse sediment movement with aim to inform coastal defence;
- Cells defined to concentrate on movement of beach material (sand and gravel) not clay or silt (too fine) – Motyka and Brampton (1993);
- Structures impacting on sediment movement should be confined within a cell;



Two types of cell boundaries:

1. Littoral drift divides – sharp changes in coastal orientation or sediment movement in opposite directions (rocky headland or wave climate)
2. Sediment sinks where sediment collects from two transport paths (sheltered or indented bays);

Due to their size, they are often divided into sub-cells



Morris Island,
South Carolina



**THE END
(FOR NOW)**