PHYSICAL GEOGRAPHY: **Coastal environments**

Coasts as SYSTEMS:

- Inputs
  - river sediments, sediment from cliffs that were eroded/had landslides, sediment transported by waves from offshore
- Processes
  - wave action, tidal movement, erosion, weathering, transportation, deposition
- Outputs
  - sediments washed out to sea / deposited further along the coast

- Sediment Cells: are lengths of coastline that are self-contained, each being a coastal system. Processes in one cell don't affect another.

WAVE ACTION

- Waves are created by wind blowing over the sea. Friction between wind and the surface gives the water a circular motion.
- The effect of a wave on the shore depends on its height which is affected by WIND SPEED and FETCH.
- Waves break as they approach the shore. Friction w/ sea bed slows the bottom, and the crest then collapses.
- Two types of wave:
  - CONSTRUCTIVE: low-frequency (6-8 waves/min), low and long. More powerful swash than backwash. Shorter waves ie shorter fetch.
  - DESTRUCTIVE: high-frequency (10-14 waves/min), high and steep. More powerful backwash than swash. Higher waves ie longer fetch.
  - waves in an area are usually mainly destructive or constructive

Landforms are created and destroyed on the area between HWM and LWM.

Sub-aerial processes occur along the coastline. Coastal processes not linked to the action of the sea.

- freeze-thaw weathering, salt weathering. Weathering weakens cliffs = more vulnerable
- throughflow (water through cliffs) and runoff caused by heavy rain can make cliffs more unstable, increasing likelihood of mass movement
- mass movement = movement of material downhill due to gravity. Landslides, slumping and rockfalls.

COASTAL EROSION

Erosive processes

- Abrasion / corrosion: rock & sediment transported by waves smash and grind against rocks and cliffs, breaking bits off and smoothing surfaces
- Hydraulic action: air in cracks in cliffs compressed by waves – breaks off rock pieces
- Quarrying – energy of wave as it hits cliff is enough to break rocks off
- Corrosion / solution: soluble rocks dissolved by seawater
- Attrition: rock in water smash against each other, break into smaller bits

Factors affecting rate of coastal erosion

- width of beach: distance between HW and LWMs. Beaches slow down waves
- breaking point of waves – wave breaking at foot of cliff transfers more energy, wave hitting cliff before breaking / breaking before cliff transfers less energy
- aspect – if coastline faces prevailing wind and wave direction; faster erosion
- fetch – waves with longer fetch have more energy and are higher and steeper
- rock type – hard rocks are more resistant than softer rocks

Longshore drift

Currents move material along the coast in longshore drift.

- Swash carries sediment up the beach, parallel to the prevailing wind.
- Backwash carries sediment back down the beach, at right angles to the shoreline.
- When there's an angle between the prevailing wind and the shoreline, a few rounds of swash and backwash move the sediment along the shoreline.

COASTAL LANDFORMS

Landforms of erosion

- Cliffs – over time cliffs retreat due to the action of waves and weathering
- Wave-cut notch – weathering and wave erosion cause a notch to form at the high water mark. This eventually develops into a cave.
- Wave-cut platform – rock above the cave becomes unstable, and collapses, leaving behind a flat surface, visible only at low tide.

- Headlands and bays form where there are bands of alternating hard rock and soft rock at right angles to the shoreline (discordant coastline). The soft rock is eroded quickly forming a bay, while the harder rock is eroded less and sticks out as a headland

- Weak areas in rock are eroded to form caves
- Occasionally the roof of a cave is weakened along a major joint by hydraulic pressure, and the roof collapses to form a blow hole
- Caves either side of a narrow headland may eventually join up to form an arch
- When an arch collapses, it forms a stack

Landforms of deposition

- Beaches are formed when constructive waves deposit sediment on the shore
    - shingle beaches are steep and narrow
      sand beaches are formed from smaller particles and are wide and flat

      Beaches have their own associated features:
    - Berms are ridges of sand and pebbles (1-2m high) found at high tide marks. Formed by deposition of coarse material at the limit of the swash.
    - Runnels are grooves in the sand running parallel to the shore. Formed by backwash draining to the sea.
    - Cusps are crescent-shaped indentations that form on beaches of mixed sand and shingle. They develop in areas where waves break parallel to the beach and where there's a large tidal range.

- Spits tend to form where the coast suddenly changes direction eg across river mouths
    - longshore drift continues to deposit material across the river mouth, leaving a bank of sand and shingle sticking out into the sea
    - occasional changes to the dominant wind and wave direction may lead to a spit having a recurved end
    - over time several recurved ends may be abandoned as the waves return to their original direction
    - the area behind the spit is sheltered from the waves and often develops into mudflats and salt marshes
- Bars are formed when a spit joins two headlands together. This can occur across a bay or across a river mouth if the river isn't too strong. A lagoon forms behind the bar.

- Sand dunes are formed when sand deposited by longshore drift is moved up the beach by the wind.

    - sand trapped by driftwood or berms is colonised by plants and grasses eg marram grass. The vegetation stabilises the sand and encourages more sand to accumulate there, forming embryo dunes
    - over time the oldest dunes migrate inland as newer embryo dunes are formed. These mature dunes can reach heights up to 10m.

- Salt marshes form in areas of sheltered water eg river estuaries
    - as silt and mud are deposited by the river or the tide, mud flats develop
    - the mud flats are colonised by vegetation that can survive the high salt levels and long periods of submergence by the tide (halophytes)
    - the plants trap more mud and silt, and gradually they create an area of marshland that remains exposed for longer and longer between tides.

SEA LEVEL CHANGES

Sea level varies on a daily basis with the tidal cycle. Onshore winds and low atmospheric pressure systems also cause the sea surface to rise temporarily.
On a much longer time scale, global sea level is rising at ~2mm/yr, which is forecast to increase to 4-5mm/yr by 2100. This will increase both the frequency and severity of flooding in low lying coastal areas.

- Eustatic sea change is global, main causes are:
    - tectonic movements that alter the same of ocean basins
    - changes in climate
        - increase in temp causes melting of ice and thus increased sea level
        - decrease in temp causes more precipitation to fall as snow, increasing volume of water stored in glaciers and thus reduced sea level.
- Isostatic sea change is caused by vertical movement of the land relative to the sea. Downward movement of the land causes sea level to rise locally, whereas uplift causes sea level to fall. Main causes:
    - tectonic uplift or depression: mostly at plate margins
    - compression or decompression of the Earth's crust due to accumulation or melting or ice sheets. Accumulation of sediment, mostly at river mouths, can also cause compression
    - subsidence of land due to shrinkage after abstraction of groundwater.

Impacts of sea level rise

- more frequent and more severe coastal flooding (eg 1900 St Mark's Square in Vencie flooded <10 times/yr, 1996 flooded 100 times)
- submergence of low-lying islands
- changes in the coastline
    - if sea level rises 30cm from current, 8000 sq. km will be lost in Bangladesh.
- plus impacts on coastal infrastructure, decrease in tourism, agriculture, loss of homes etc.

Sea level rise results in COASTLINES OF SUBMERGENCE

- Rias are formed where river valleys are partially submerged (eg Milford Haven, South Wales). Rias have gentle long and cross-profiles. They're wide and deep at their mouth, becoming narrower and shallower the further inland they reach.
- Fjords are similar to rias, but are drowned glacial valleys. They are relatively straight and narrow, with very steep sides. They have a shallow mouth caused by a raised area of ground (the threshold) formed by deposition of material by the glacier. They are very deep further inland.
- Where valleys lie parallel to the coast, an increase in sea level can form a dalmation coastline – valleys are flooded, leaving islands parallel to the coastline (named after Croatia's Dalmation coast)

Sea level fall results in COASTLINES OF EMERGENCE

- Raised beaches are formed when the fall in sea level exposes wave-cut platforms and their beaches. Over time, beach sediment becomes vegetated and develops into soil
- Cliffs above raised beaches are no longer eroded by the sea and slowly get covered by vegetation. They are called relict cliffs. It is not uncommon to see wavecut notches, caves, arches and stacks within relict cliffs. These raised features are gradually degraded over time.

COASTAL FLOODING

PHYSICAL causes of coastal flooding:

- Low pressure atmospheric systems such as hurricanes reduce atmospheric pressure on the sea surface, causing it to rise. This is a storm surge.
- Strong onshore winds can force water to higher levels along the coast, allowing waves further inland
- Tidal currents and surges may be funnelled into a coastal bottleneck such as the Bay of Bengal, or English Channel, forcing sea levels higher
- High rainfall may cause high river discharge. If sea level at the river mouth is high eg due to high spring tides / storm surges, the large volume of river water may be unable to drain into the sea and can cause flooding.
- If a combination of the above factors coincide.
- Tsunamis are huge ocean waves caused when water is displaced by landslides, volcanic eruptions or submarine earthquakes that shift the ocean floor. When travelling in open water they have a very small height and travel and hundreds of km/h. As the waves approach the coast, the bottom of the waves slow considerably due to friction with the sea bed, causing wave height to increase enormously.

HUMAN causes of coastal flooding:

- management of river systems – some management strategies eg dams trap sediment and so reduce deposition at river's mouth. Causes deltas and salt marshes to shrink – providing less protection against high tides and storm surges
- management of coastal systems – some strategies alter sediment movement, reducing amount of protective beach material available further along the coast (eg Barton, Hampshire defences have reduced sediment to the east, allowing Hurst Spit to be breached more often and flood lowlands behind)
- building on coastal lowlands, especially sand dunes, has restricted sediment supply to protective beaches and marshes. Development of coastal lowlands also increases the impact of any coastal floods
- reclamation of coastal lowlands such as in the Netherlands, and reclaimed marshes along England's east coast. Draining this land to reclaim it causes the land to shrink, becoming lower than sea level.

COASTAL MANAGEMENT

The aim of coastal management is to protect homes, businesses and the environment from erosion and flooding. Flooding and erosion of the coastline can have severe social, economic and environmental impacts. We have to do cost:benefit analyses of defences.

Options for coastal management:

- hold the line – maintain existing coastal defences
- advance the line – build new coastal defences further out to sea than the existing line
- do nothing – build no coastal defences, and deal with erosion/flooding as it happens
- retreat the line – build no coastal defences but move people away from the coast

HARD ENGINEERING

- sea wall – reflects waves back out to sea, prevents erosion of coast, acts as barrier to prevent flooding.
    - expensive to build and maintain. Creates strong backwash which erodes under the wall
- revetment – slanted structures built at the foot of cliffs. They can be made from concrete, wood or rocks. Waves break against the revetments which absorb the wave energy and so prevent cliff erosion.
- gabions – rock filled cages. A wall of gabions is usually built at the foot of cliffs. The gabions absorb wave energy and so reduce erosion
    - cheap, but ugly
- rock armour, or rip-rap – boulders piled up along the coast absorb wave energy and so reduce erosion
    - fairly cheap, but can shift in storms
- groynes – fences built at right angles to the coast. They trap beach material transported by longshore drift. This creates wider beaches, which slow the waves (reducing their energy) and so gives greater protection from flooding and erosion
    - quite cheap. But starve down-drift beaches of sand – thinner beaches don't protect the coast as well, leading to greater erosion and flooding.
- breakwaters – concrete blocks or boulders deposited off the coast. They force waves to break offshore. The waves' energy and erosive power are reduced before they reach the shore.
    - expensive, can be damaged in storms
- earth banks – mounds of earth act as a barrier to prevent flooding
    - quite expensive, can be eroded
- tidal barrier – built across river estuaries. Contain retractable floodgates that can be raised to prevent flooding from storm surges
    - VERY expensive
- tidal barrage – dams built across river estuaries. Generate hydroelectric power. Water trapped behind dam at high tide. Controlled release of water through turbines in the dam at low tide generates electricity. Also prevents flooding from storm surges
    - VERY expensive, also disrupts sediment flow which may cause erosion elsewhere in the estuary

SOFT ENGINEERING

- beach nourishment is where sand and shingle are added to beaches from elsewhere, creating wide beaches which reduce erosion of cliffs more than thin beaches
- beach stabilisation can be done by reducing the slope angle and planting vegetation, or by sticking stakes and old tree trunks in the beach to stabilise the sand. It also creates wide beaches, which reduce erosion of cliffs.
- dune regeneration – sand dunes are created or restored by either nourishment or stabilisation of the sand. Sand dunes provide a barrier between land and sea, absorbing wave energy and preventing flooding and erosion.
- land use management is important for dune regeneration. The vegetation needed to stabilise the dune can easily be tramped and destroyed, leaving the dune vulnerable to erosion. Wooden walkways across dunes, and fenced off areas that prevent walkers, cyclists or 4x4s from gaining access, all reduce vegetation loss.
- creating marshland from mudflats can be encouraged by planting appropriate vegetation (eg glassworts). The vegetation stabilises the sediment, and the stems and leaves help reduce the speed of the waves. This reduces their erosive power and how far the waves reach inland, leading to less flooding of the area around the marsh.
- coastal realignment or managed retreat involves breaching an existing defence and allowing the sea to flood the land behind. Over time, vegetation will colonise the land and it'll become marshland.

Hard engineering is often expensive, and disrupts natural processes. Soft engineering schemes tend to be cheaper and require much less time and money to maintain than hard engineering schemes. Soft engineering is designed to integrate with the natural environment and it creates areas like marshland and sand dunes, which are important habitats for coastal plants and animals. Soft engineering is a more sustainable strategy than hard engineering because it has a lower environmental impact and economic cost.
Management strategies must be sustainable

- rising sea level means more coastal management will be needed to protect coastal settlements and developments. Storms also seem to be getting more frequent and more severe.
- growing emphasis on the need for more sustainable management strategies
- deciding how to manage a coastline is now done in a more integrated way to improve sustainability. eg a Shoreline Management Plan (SMP) is a plan for how the coastline in one sediment cell should be managed. They are developed by local authorities: all the LAs in one cell cooperate when planning their management strategies, so defences in one area don't increase erosion in another.
- the process of trying to come up with an integrated sustainable management plan is Integrated Coastal Zone Management (ICZM).

<u>CASE STUDIES OF COASTAL MANAGEMENT</u>: <u>THE WIRRAL PENINSULA, NW ENGLAND</u>

NB the Wirral Peninsula is within the Solway Firth to Great Orme sediment cell, so approaches are coordinated under a Shoreline Management Plan by the "North West England and North West Coastal Group."

<u>HARD ENGINEERING</u>: <u>NEW BRIGHTON</u>

- recently rejuvenated coastal town; many new attractions constructed on the sea front including 'Marine Point' (most recent: shops, restaurants, cinema), and less recently the Floral Pavilion theatre which is the primary source of visitors to the area. Land use includes both economic and residential.
- at particular risk of coastal flooding and erosion due to location
    - on NW tip of Wirral, New Brighton receives a pounding from the sea. Waves have a high energy as they have approx. 200km fetch from the Irish Sea, and a low pressure system around the area means storm surges are a common occurrence.
    - worsened by the fact that New Brighton is only a few metres above sea level
- to protect NB, several sea defences employed:
    - against coastal erosion and flooding, a large <u>sea wall</u> in the 1930s (King's Parade Sea Wall). 4m tall along 2.3km of coastline, using spoil from the excavation of the Queensway tunnel.
        - wall specifically designed to reduce impact of waves as much as possible, and increase its lifespan. Concave shape reflects waves back and dissipates their energy. Reduces rate at which sea wall is worn down since it is slowly being worn away.
        - Issue: requires periodic maintenance, which is expensive
        - but has been very effective at preventing erosion and flooding. Allowed 100m of land to be reclaimed. No cases of cliff collapse in many years, and no major floods.
        - as with all, it has its limitations: 2013/14 winter saw a storm surge which flooded The Light cinema and resulted in its closure for 3 months.
    - <u>coastal zoning</u> has also taken place, to reduce the impact of any flooding that does occur. The 100m of reclaimed land is undeveloped apart from parkland, as should the sea wall be breached it would be flooded very rapidly (eg 2013/14 storm surge destroyed the 'mini golf'). Most of the residential developments are atop the relic cliffs, giving some protection in the event of a flood.

<u>SOFT ENGINEERING</u>: <u>THURSTASTON</u>

- opposite side of the peninsula to New Brighton, with much reduced risk (shorter fetch etc), has very little in terms of human developments; is an SSSI, mostly plants and wildlife with some interesting sandstone landforms. Due to the lack of human development, it is not a priority for funding, but soft engineering has taken place.
- cliffs at Thursaston are very susceptible to erosion despite the waves being mainly weak constructive, due to their weak sandstone and boulder clay & bedding plains dipping towards the sea. Also susceptible to sub-aerial weathering and frequent mass movements.
- soft engineering strategies:
    - <u>gabions</u> placed around the bases of cliffs, ideally to reduce undercutting of the cliffs by the sea, but they haven't been massively successful since the cliffs are still collapsing today. Main benefit nowadays is that they provide a small habitat for several species of plant and insect – the plants have helped to blend them in.
    - <u>drainage pipes in the cliffs</u> were to reduce mass movement. If the boulder clay cliffs were saturated with water they would be quickly lubricated and slumping would occur – the pipes were to remove water and stop the cliffs becoming saturated, but this was totally ineffective.
- the cliffs at Thurstaston are likely to continue collapsing, but there is one thing that might save them – a salt marsh appears to be developing before the cliffs, and with some human intervention, this could be enough to stop the cliffs from collapsing. However, if a salt marsh were to develop out into the River Dee, this would disrupt its recreational use by the local sailing clubs, and so locals are actively trying to stop this happening.