Coasts

Definition: The interface between land and sea.

Coastal regions cover only 10% of the inhabited land space, yet they are home to more than 60% of the world’s population, all concentrated in a narrow ribbon of land around the planet’s oceans, seas and lakes.

Processes of Coastal Erosion

1. Attrition:
   - "Rock on rock"
   - Particles carried by the waves crash against each other and are broken up into smaller particles.

2. Corrasion (also known as abrasion):
   - "Rock on cliff"
   - Particles carried by the waves crash against the cliffs, eroding the cliffs.

3. Corrosion:
   - "Rusting / dissolving"
   - Salt in the seawater slowly dissolves the cliffs.
   - The material produced is carried away by the process of solution.

4. Hydraulic Action:
- “Pressuring”
- The water traps air in cracks and caves in the rock.
- This air is compressed by the incoming waves placing great pressure on the rocks, causing them to crack eventually.

**Waves**

- Waves are responsible for most of the erosion along coasts. Wind blowing over a smooth sea surface causes small ripples which grow into waves.

There are two types of waves:

1. those generated by wind
2. those generated by tectonic activity, i.e. tsunami

*Wave height and length*

The amount of energy in waves depends on their height. As a result, when high waves hit a coastline, erosion and transport are greatly increased. But why do waves vary in height? Three factors affect waves height and wave energy.

1. Wind speed. When the weather is very windy, damaging storm waves crash against the coastline.
2. Wind duration - the length time over which a wind blows.
3. Fetch, which refers to the distance of open sea over which a wind has blown.
**Constructive waves** form where fetch is long, small waves, flat and with a long wave length. Low frequency. Wave spills over; resultant swash is stronger than backwash. Sand and shingle moved up the beach. Material moved up the beach creating a berm – flat topped ridge.

**Destructive waves** more common where fetch is shorter. Large waves, steep with short wave length. High frequency. Steepen rapidly and plunge over. Powerful backwash moves sediment down the beach. Most material moved down to form a longshore (breakpoint) bar.

**Coastal Transportation and Deposition**

- Deposition is the geological process by which material is added to a landform or land mass
- Depositional landforms include - spits, tombolos, sand dunes

**Coastal transportation**

**Long shore Drift**
- Material is moved along the coastline by the waves.

- Waves will often approach the coast at an angle, carrying material with them. This is carried up on to the beach by the **swash**.

- The material is then dragged out to sea by the **backwash**, but this time it travels at right angles to the beach, as it will roll down the steepest gradient.

- This movement will slowly transport material laterally along the coast.

_Sediment movement:_

Long shore drift is the overall process of transportation, however the material actually moves through the four transportation processes seen in rivers. **These depend on the size of sediment:**

i) **Traction** - the rolling of large material along the sea floor by the waves.

ii) **Saltation** - the bouncing of slightly lighter material along the sea floor.

iii) **Suspension** - Small particles of material carried by the water.

iv) **Solution** - Material is dissolved and carried by the water.

_Coastal Deposition:_

- The process associated with constructive waves.
- Material is dropped by waves once they lose energy, either by rolling up a beach or where a river estuary causes a disruption to the normal movement of material along the coast.

- Creates features such as beaches, spits, bars and tombolos.

**Spits**

**The Formation of a Spit**

![Diagram of a spit](image)

**Tombolos**

![Diagram of a tombolo](image)

If a spit joins the mainland to an island it is called a **tombolo**. This diagram above shows the tombolo - Chesil Beach.
Coastal Erosion Features

Headlands and Bays

- Formed on discordant (rocks types perpendicular to coast eg Swanage Bay) coastline due to the softer rock being eroded quicker than the harder rock.

- Beaches form in the bays where the soft rock has been eroded away.

- Headlands of more resistant, hard rock are left behind.

Cliffs & Wave Cut Platforms

- Cliffs are formed when destructive waves attack the bottom of the rock face between high and low water mark.

- The area under attack is eroded using the major processes of coastal erosion.

- Points of weakness, such as faults and joints are attacked most, and eventually a wave-cut notch is gouged out.

- The rock above overhangs the notch, and as it is cut deeper into the rock, gravity causes the overhanging rock to collapse.

- The loose rocks are removed by the sea and transported along the coast by long shore drift.

- The whole process of undercutting the cliff begins again.
- As the cliff is eroded backwards it leaves behind a **wave-cut platform**, at the level of the low water mark.
- This platform is rarely eroded, as the waves energy is concentrated on eroding the area between the high and low water mark, and not the rock that is underneath them.

**Caves, Arches, Stacks and Stumps**

- Mainly seen on headlands.
- Waves start by attacking the main points of weakness in the rock: the joints and faults.
- A point of weakness is increased in size until it becomes a **cave**.
- The waves continue to attack the cave, which finally results in an **arch** being formed through the headland.
- The arch is attacked both by coastal erosion and sub-aerial erosion and finally the roof of the arch falls into the sea.
- This leaves behind a **stack**, which is then slowly eroded down to become a **stump**.

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**Figure 1.55 Features of headland erosion.**

Hydraulic action erodes a crack in the rock that sometimes reaches the cliff top resulting in a **blow hole**.

A crack is widened by hydraulic action and abrasion.

Continued erosion turns a notch into a **sea cave**.

A wave cut platform is the base of the original headland and is visible at low tide.

Continued erosion of sea caves on either side of a headland will form an **arch**.

When the roof of an arch collapses it leaves a **sea stack**.

A sea stack is eroded away leaving a **stump**.

As the base of the cliff is eroded it leaves the rock above unsupported resulting in rock falls.
The Holderness Coast is one of Europe's fastest eroding coastlines. The average annual rate of erosion is around 2 metres per year. This is around 2 million tonnes of material every year. Under lying the Holderness Coast is bedrock made up of Cretaceous Chalk. However, in most place this is covered by glacial till deposited over 18,000 years ago. It is this soft boulder clay that is being rapidly eroded.
The Holderness coast is in the north east of England. This is one of the most vulnerable coastlines in the world and it retreats at a rate of one to two metres every year.

The problem is caused by:

- Strong prevailing winds creating longshore drift that moves material south along the coastline.
- The cliffs are made of a soft boulder clay. It will therefore erode quickly, especially when saturated.

The village of Mappleton, perches on a cliff top on the Holderness coast, has approximately 50 properties. Due to the erosion of the cliffs, the village is under threat.

In 1991, the decision was taken to protect Mappleton. A coastal management scheme costing £2 million was introduced involving two types of hard engineering - placing rock armour along the base of the cliff and building two rock groynes.

- Mappleton and the cliffs are no longer at great risk from erosion.
- The rock groynes have stopped beach material being moved south from Mappleton along the coast. However, this has increased erosion south of Mappleton. Benefits in one area might have a negative effect on another.

The increased threat of sea level rise due to climate change, other places will need to consider the sustainability of coastal defence strategies for the future.
CASE STUDY  The Pevensey Bay Sea Defence Scheme

GET STARTED

What would make a coastal defence scheme sustainable?

Sustainable coastal management: how do soft engineering methods work with the natural environment?

Soft engineering methods try to work with the natural physical processes in an area, rather than building large concrete barriers or using massive bundlings to protect the land from wave attack.

One of the most successful ways of reducing the threat from storm waves is by developing and preserving a wide, gently sloping beach that can absorb most of the energy from breaking waves. Soft engineering methods are usually based on preserving and managing the beach. This can be done in a number of ways, including:

- **Beach replenishment**: replacing the sand or shingle that has been removed by longshore drift
- **Beach reprofiling**: shaping the beach so that it absorbs more energy during storms
- **Fencing/escalading**: building fences or planting self-resistant bushes at the back of the beach to reduce the amount of sand being blown inland by strong winds

- **Planting vegetation**: planting grasses or bushes in low-lying sandy areas to stabilise the beach material.

The following example shows how soft engineering methods are being used in East Sussex.

The Pevensey Bay Sea Defence Scheme

Pevensey Bay is a low-lying area in East Sussex that is vulnerable to coastal flooding (Figure 1.29). The use of heavy engineering methods to protect the area would not be appropriate because of the scenic and environmental value of the area.

Why does the area need protection?

- Longshore drift is removing increasing amounts of beach material.
- Over 50 km of flat land would be flooded if coastal defences failed.
- The Pevensey Levels, an environmentally sensitive area (SSSI) would be flooded with salt water if coastal defences failed.
- There are over 10,000 properties in the area.
- It is a tourist area with a number of caravan parks.
- The main coastal road and rail links run along the coast.

What has been done at Pevensey Bay?

Beach replenishment

Longshore drift in the area means that beach material is constantly being lost. This material is replaced by dragging it from the seaward and then spraying it back onto the beach. This is carried out by a specially adapted boat, which can come very close to the beach at high tide. This operation is carried out during the summer months when there are fewer storms.

Beach reprofiling

During the winter storms, destructive waves move the beach sediment down the beach towards the sea. This makes the upper beach levels very low and liable to wave attack. Bundlings are used to move the material back up the beach and reshape the beach so that it has an even, gentle slope.

Beach recycling

The natural processes of longshore drift at Pevensey Bay act like a conveyor belt. Beach material is moved from west to east, resulting in the western end of the beach becoming increasingly depleted. Three times a year, large trucks are used to move the beach material that has accumulated in the east back to the western end of the beach. This ensures that the beach has an even profile and no particular point is subject to wave attack.

Why is the scheme seen as sustainable?

- It works with the natural environment.
- It does not involve massive building costs.
- It does not damage the environment.
- The resulting beach has amenity value for the local people and is an important tourist attraction.

However, the scheme does require ongoing maintenance, which is expensive.

ACTIVITIES

1. Why is there a need for coastal management at Pevensey Bay?
2. Explain what is meant by the following:
   a. Beach replenishment
   b. Beach reprofiling
   c. Beach recycling
3. The beach is the main protection against storms. Explain this statement.
   a. Explain how the Pevensey Bay defence scheme is good for both the local environment and economy.
   b. Is the scheme at Pevensey Bay truly sustainable? Write an extended answer to give both sides of the argument.

RESEARCH LINK

Find out more at the Pevensey Bay website.

PLENARY ACTIVITY

Why may hard engineering methods not be appropriate for some coastal areas?
CASE STUDY Cuckmere Estuary, East Sussex

Is managed retreat the best strategy to prevent coastal flooding?

The Environmental Agency has proposed a plan to allow the existing coastal and river defences to fall into disrepair so that the area reverts back to a salt marsh environment.

Reasons for the proposed plan
- The existing defences are coming to the end of their life.
- The cost of replacing the defences would be approximately £20 million.
- Current maintenance costs are over £50,000 a year.

How the plan will work
- Once the sea defences have been breached, the lower part of the estuary will be flooded and the natural shape of the land will prevent inland areas from flooding.
- An earth bank will be built at the northern end of the estuary to protect inland areas from flooding.
- Footpaths will be raised or moved to higher ground.
- Changes to the area will be monitored to ensure that no buildings are at risk of flooding.

KEY TERMS

Amenity value - used for recreational and leisure activities.
Managed retreat - allowing the sea to flood lowland areas.

ACTIVITIES

1. Use an annotated diagram to explain 'managed retreat'.
2. It is important to consider the four questions listed in the Fact file before carrying out a managed retreat scheme: why is this?
3. a. Describe the main features of the Cuckmere Estuary Managed Retreat Scheme.
   b. What are the advantages of the scheme?
   c. Why may some people object to the scheme?

BACKGROUND INFORMATION

- The Cuckmere Estuary and coast have been protected from flooding by a series of flood walls and artificial banks.
- The estuary attracts large numbers of visitors who come to enjoy walking the footpaths, bird watching, cycling and canoeing on the existing river meanders.

What are the advantages of the plan?
- It will create over 200 acres of salt marsh, attracting increasing numbers of birds.
- Without artificial defences, the landscape will look more natural.
- The natural artificial landscape will provide flood protection, especially as sea levels rise.
- It works with the environment and has low maintenance costs. This makes it more sustainable.

RESEARCH LINK

Find out more about the proposed plan at the BBC website.

PLENARY ACTIVITY

Discuss the view that ‘Managed retreat works with the environment rather than trying to control it’.
Protection and management of coasts

How does removing coastal wetlands increase the risk of flooding?
In a number of areas in the UK, salt marshes have been drained to provide farmland or space for building development. This drained land is then protected by a sea wall. At high tide the sea will often reach the sea wall, especially during storms, leaving no beach or marshland to absorb wave energy. In this situation the sea wall is under constant attack by waves, and will eventually fail if not regularly maintained. If the sea wall is breached by the storm waves, large areas of land will be flooded (Figure 1.73).
**REVETMENTS**
Sloping ramps that face the sea and absorb the energy of breaking waves.

**RIP-RAP**
(rock armour)
Large boulders piled up in front of cliffs or sea walls to protect them from erosion.

**SEA WALL**
A concrete barrier that protects areas from wave attack and flooding. Curved sea walls deflect waves during high tides to reduce the risk of flooding.

**GABIONS**
Wire cages filled with rocks and stacked to form a barrier against breaking waves.

**OFF-SHORE BREAKWATER** (reef)
Rock structures are built parallel to the coast. They force waves to break before they reach the shore.

**GROYNES**
Wooden or concrete barriers built at right angles to the beach. They trap drifting sand and help to develop a wider beach.

*Figure 1.76* Hard engineering techniques.
Coastal Management

As things like coastal tourism have become more frequent, humans have found it increasingly necessary to attempt to control the effects of the sea. The main reasons for coastal management are:

- to protect the coast from the erosive effects of the sea.
- to increase the amount of sand on the beach.

Many strategies have been tried around the world, and these can be divided into two main groups, hard and soft engineering. Hard engineering methods aim to stop the coastal processes from occurring. Soft engineering methods try to work with nature to protect the coast. Examples of these two strategies are:

Hard Engineering

Sea Walls:

Often built in front of seaside resorts.

- Very expensive.
- They aim to completely block the waves and their effects.
- Life span of approximately 75 years.
- Can cause the erosion of the beach in front of them.
- Socially reassuring for local residents.

Wooden Groynes:

- Wooden “fences” built at right angles to the coastline.
- They aim to stop the movement of material along the beach due to long shore drift.
- Their primary intention is to build up the amount of sand on the beach.
- They have a life span of approximately 25 years.

Gabion Groynes:

- Large steel mesh cages filled with large rocks.
- Aligned at right angles to the coastline.
- They aim to do a similar job to wooden groynes.

- Expected life span of 20 – 25 years, as the steel will rust.

**Rip Rap / Rock Armour:**

- Large boulders, of 10 tonnes or more, are used as a sea wall.

- The gaps between the rocks allow water through, which means that the energy of the waves is dissipated very effectively.

- It is important that the boulders are big enough to withstand being eroded themselves and therefore becoming part of the coastal system.

**Soft Engineering**

**Beach Replenishment**

- Sand is either brought in from elsewhere, or transported back along a beach, usually once a year.

- This is done using trucks, and is therefore very costly and time consuming.

- Over the next 12 months the material is washed along the coast by long shore drift, before being replaced again.

The final method of coastal management is of course to do nothing and allow the sea attack the coastline naturally.
### Management strategies

Physical management of the coast attempts to control natural processes such as *erosion* and *longshore drift*.

### Hard engineering

Hard engineering options tend to be expensive, short-term options. They may also have a high impact on the landscape or environment and be unsustainable.

### Hard engineering solutions

<table>
<thead>
<tr>
<th>Type of defence</th>
<th>Pros and cons</th>
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<tbody>
<tr>
<td><strong>Building a sea wall</strong>&lt;br&gt;A wall built on the edge of the coastline&lt;br&gt;Waves in Porthleven during a storm</td>
<td><strong>Advantages</strong>&lt;br&gt;Protects the base of cliffs, land and buildings against erosion. Can prevent coastal flooding in some areas.&lt;br&gt;&lt;br&gt;<strong>Disadvantages</strong>&lt;br&gt;Expensive to build. Curved sea walls reflect the energy of the waves back to the sea. This means that the waves remain powerful. Over time the wall may begin to erode. The cost of maintenance is high.</td>
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<tr>
<td><strong>Building groynes</strong>&lt;br&gt;A wooden barrier built at right angles to the beach&lt;br&gt;Hopton Sea Wall, Norfolk</td>
<td><strong>Advantages</strong>&lt;br&gt;Prevents the movement of beach material along the coast by longshore drift.&lt;br&gt;Allows the build up of a beach. Beaches are a natural defence against erosion and an attraction for tourists.&lt;br&gt;&lt;br&gt;<strong>Disadvantages</strong>&lt;br&gt;Can be seen as unattractive.&lt;br&gt;Costly to build and maintain.</td>
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Rock armour or boulder barriers
Large boulders are piled up on the beach.

A boulder barrier in Nice, France

Advantages
Absorb the energy of waves.
Allows the build up of a beach.

Disadvantages
Can be expensive to obtain and transport the boulders.

Soft engineering options
Soft engineering options are often less expensive than hard engineering options. They are usually more long-term and sustainable, with less impact on the environment.

There are two main types of soft engineering.

1. Beach management
   - This replaces beach or cliff material that has been removed by erosion or longshore drift.
   - The main advantage is that beaches are a natural defence against erosion and coastal flooding. Beaches also attract tourists.
   - It is a relatively inexpensive option but requires constant maintenance to replace the beach material as it is washed away.

2. Managed retreat
   - Areas of the coast are allowed to erode and flood naturally. Usually this will be areas considered to be of low value - eg places not being used for housing or farmland.
   - The advantages are that it encourages the development of beaches (a natural defence) and salt marshes (important for the environment) and cost is low.
   - Managed retreat is a cheap option, but people will need to be compensated for loss of buildings and farmland.

Disadvantages of Coastal Management

Cost: Most of the solutions detailed are very costly, and in many places questions are being asked as to whether they are actually worth the money.

Problems of disrupting the natural coastal system:
Whenever you tamper with nature there are going to be knock on effects, which could, in time, become worse than the original problem.

Coastal defence strategies are often very localised, and can cause problems further down the coast. One such example could be seen where groynes are used to trap sediment. Further down the coast there could be a reduction in the amount of material available to protect the coast there. This in turn would mean an increased amount of coastal erosion.
Arch  When caves, which have developed on either side of a headland, join together they form a natural arch.

Attrition  The process whereby rock particles wear down through collisions with other rock particles. This often occurs when pebbles are thrown against cliffs, boulders or other pebbles, causing them to shatter and break.

Backwash  Water moves up a beach as a wave breaks. This is called the swash. The return movement of the water, back down the beach, is called the backwash.

Bar  A bar is very similar to a spit. It is a ridge of sand or shingle which forms across the mouth of a river, the entrance to a bay or harbour. It is usually parallel to the coast.

Bay  A wide indentation into the land by the sea, protected on each side by a headland. The water in a bay is usually relatively shallow; the wave action less strong than at the headlands.

Beach  A gently sloping deposit of sand, pebbles or mud, deposited along the coast.

Blow hole  A blow hole is formed when a joint between a sea cave and the land surface above the cave becomes enlarged and air can pass through it. As water flows into the cave, air is expelled through the pipe like joint, sometimes producing an impressive blast of air or spray which appears to emanate from the ground.

Cave  A weakness, such as a joint, is enlarged by wave action, finally creating a cylindrical tunnel which follows the line of weakness. Caves developing back to back may give rise to arches and stacks.

Cliff  A steep, and usually high, rock face found at the edge of the land where it meets the sea. Cliffs can be formed from most rocks, height generally increasing with hardness of rock.

Cliff Line  The margin of the land. The cliff line is identical to the coastline, but consists of cliffs rather than lower features such as dunes and beaches.

Coastline  The margin of the land. Where the margin consists of cliffs, it is known as the Cliff line.

Constructive wave  When waves break at a rate of ten or less per minute each wave is able to run up the beach and drain back again before the next wave arrives. The swash is more powerful than the backwash so deposition can occur.

Corrasive action  This is a form of wave erosion. Pebbles, boulders and rocks are thrown against the cliff face by breaking waves. This causes undercutting of the cliff and leads to the breakup of both the cliff and the objects being thrown against it.
**Destructive wave** When waves break at a rate of more than ten per minute each wave is able to run up the beach but unable to drain back again before the next wave arrives. Thus the backwash of the previous wave interferes with the swash, reducing its efficiency. Such waves remove material from a beach and are destructive.

**Estuary** The mouth of a river where fresh water and sea water mix, and tides have an effect. Estuaries are often to be found on submerged coastlines, where a river valley has been flooded by the sea. See ria.

**Fetch** This distance of open water over which the wind can blow and form waves.

**Headland** Areas of harder rocks tend to resist the erosive powers of the sea. The resulting area of land, jutting out into the sea, is a headland. Bays are to be found between headlands.

**Hydraulic action** When a wave breaks against a cliff it causes air, trapped within cracks, to suddenly become compressed. As the water retreats the air is allowed to expand, often explosively. Repeated expansion and contraction of the cracks leads to the break up of the surrounding rock.

**Lagoon** When a spit extends across the mouth of a river, to the extent that it causes the river to become diverted along the coast, an area of water is created separated from the sea by a narrow strip of land. This is a lagoon.

**Load** Solid matter carried by water, including material in solution, material suspended in the water, and larger material moved along the water / ground interface.

**Longshore Drift** When waves break on to a beach at an angle, material is pushed up the beach at an angle by the swash, but pulled back down the beach by the backwash at ninety degrees to the coast. In consequence, material is slowly moved along the coast, in the direction of the waves. of the surrounding land may become islands. Plymouth Sound and Southampton Water are examples of rias in the United Kingdom.

**Spit** Longshore Drift transports material along the coast. When the mouth of a river, or an indented area, is encountered material starts to be deposited. The deposition begins where the coast changes direction and extends down coast in the direction of longshore drift. The result is a narrow ridge of material (sand or pebbles) attached to the mainland at one end and terminating in the sea. The spit may extend sufficiently to form a lagoon.

**Stack** When a natural arch collapses, the remaining upright sections form stacks, isolated rocks sticking up out of the sea.

**Swash** The movement of water in a breaking wave as it moves up the beach.

**Tides** The daily movements of the sea as it covers and exposes the area between the high tide and low tide marks. Tides are the result of lunar activity, and to a much lesser degree, winds and atmospheric pressure.

**Tombolo** A bar linking an island to the mainland.
Wave-cut Platform As cliffs become eroded down to beach level they appear to migrate inland. The remains of the former cliffs form a flat rock platform. This is known as a wave cut platform.