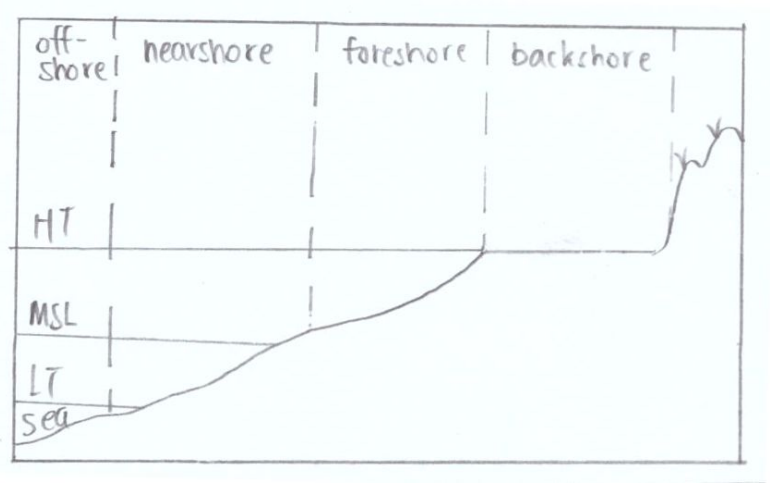
GATEWAY 1: How and why are coastal environments different and dynamic?

What are coasts?

- **Coast** is **area where land meets sea, covering land that is affected by waves and tides.**
- Coast can be **cliffed, sandy, rocky, muddy**.

Factors affecting coastal environments

- **Waves** affect coastal environments - constructive waves and destructive waves.
- **Tides** affect coastal environments by affecting processes like coastal erosion, sediment transport and deposition.
- **Currents** like longshore current helps transport sediments, giving rise to a sandy coast.
- **Geology** like hard resistant rocks leads to less erosion and less resistant rock leads to more erosion
- **Human** activities create pollution and can affect a coast.
- **Types of ecosystem** can cause differences. Mangrove systems or coral reefs can affect how a shore develops as they reduce the impact of waves on a coast.



What are waves and how are they generated?

Wave terminology

- **Wave length** is the horizontal distance from crest to crest or trough to trough.
- **Wave height** is the vertical distance between crest and trough.
- **Wave frequency** is number of wave crests or troughs that pass through a fixed point.
- **Wave steepness** is ratio of wave height to wavelength.
- **Wave period** is time waves take to travel through one wavelength.
- **Crest** is highest part of wave
- **Trough** is lowest part of wave.

Factors affecting wave energy

- **Wind speed** because the faster winds blows, the greater the wave energy.
- **Wind duration** because the longer the wind blows, the larger the waves are.
- **Fetch**, which is the distance over which the wind has travelled over seas and oceans to form waves affects wave energy too because the greater the fetch the more energy waves have
- **The higher the wave energy is, the steeper the wave and shorter it becomes.**

Waves in the open ocean or close to the coastline

- Waves in the open ocean have a long wavelength and low wave height, particles in the ocean also move in an orbit.
- Waves close the coastline, however, do not move in an orbit.
    - The water close to the coastline is shallow and waves start to interact with the seabed, changing shape.
    - As the waves continue travelling in shallow water, the base of the wave slows down due to friction.
    - This causes wave height to increase and wavelength to decrease.
    - Eventually this reaches a point where the base of the wave stops but the wave crest becomes steeper and topples over.
    - This causes the process of waves breaking onto the coast.

How do waves affect coastal areas?

Waves on the beach

- **Swash** is formed when waves break and water rushes up a beach. Swash moves up the beach in direction of waves, carrying sediments with it.
- **Backwash** is created when the swash loses energy due to gravity and friction to the sea and returns back to it, forming backwash. Backwash carries sediments from shore to the sea perpendicularly to the shoreline.

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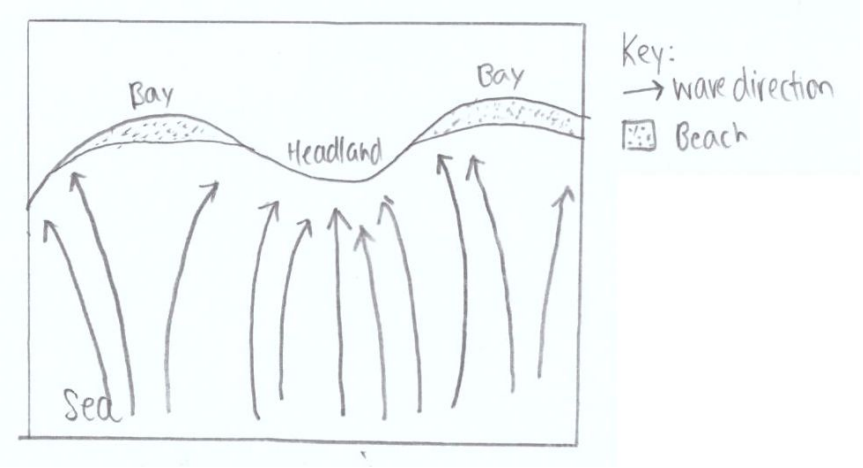
Types of waves

Type of wave	Constructive waves	Destructive waves
Places where they occur	• Low gradient, low energy environment. • Occur on gentle coastal slope and sheltered coast.	• Steep gradient, high energy environment. • Occur on steep coastal slope and open coast.
Shape of wave	• Small, low waves • Low wave height, long wavelength	• Large, high waves • High wave height, short wavelength
Frequency of waves	• Occur 6-8 per minute	• Occur 10-14 per minute
Prominence of swash or backwash	• Swash more powerful than backwash • Deposition process more prominent • Accumulation of sediments results in creation of sandy coasts.	• Backwash more powerful than swash • Erosion process more prominent • Transport rocks and material away and erode coasts.
Type of coast formed	• Form gentle, sandy slopes.	• Form steeper, coarser slopes.

Wave refraction

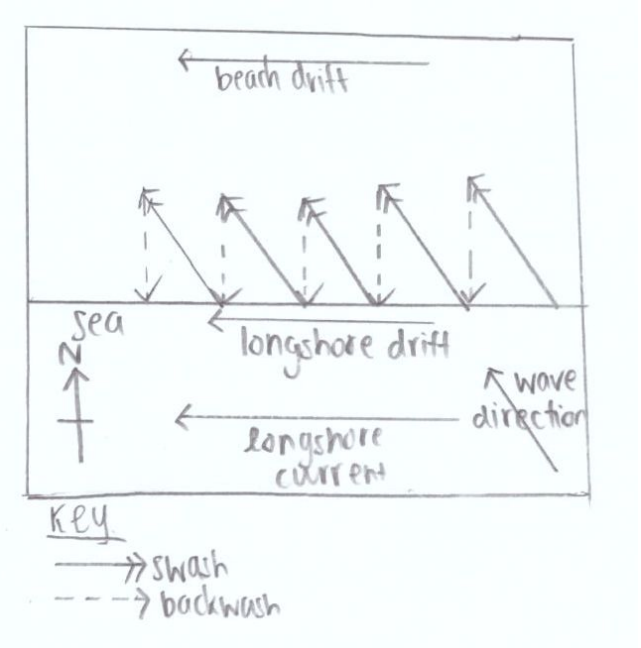
- **Wave refraction** is the process in which waves change direction as they approach a coast
- Waves tend to **converge on headlands**, leading to a higher concentration of wave energy which means larger waves which are usually destructive, leading to enhanced erosion.
- Waves tend to **diverge in bays**. The dissipation of wave energy leads to smaller waves which are usually constructive, leading to less erosion and more deposition.
- When they approach a straight coast at angle, they break parallel to coast.



Why do coastal landforms and features vary from place to place?

Coastal erosion (CASH)

- **Corrasion**, where the impact of the sediments carried by the waves grinds against the rocks, weakening them and breaking them down.
- **Attrition**, where the sediments in the wave hit and rub against one another, breaking into smaller pieces and becoming rounder and smoother.
- **Solution**, where chemicals contained within sea-water may dissolve some rocks found on coast (e:g; carbonic acid against limestone)
- **Hydraulic action**, where the impact of waves against the coast compresses air in between the rock's joints and cracks and then releases it. This repeated action causes the joints to weaken and the rocks to shatter.



Sediment transport

- **Beach drift** and l**ongshore current** are the results of waves approaching coasts at angle, together they form **longshore drift.**
- When waves approaching coast break at an angle to beach the beach, sediment move up beach at angle as swash and perpendicularly down as backwash.
- The resulting zigzag movement is **beach drift.**
- When wave approach coast at angle, they create **longshore current** in **nearshore zone** and move sediment along shore. **Longshore currents** are ocean currents that flow parallel to coast.
- The combined effect is known as **longshore drift**.

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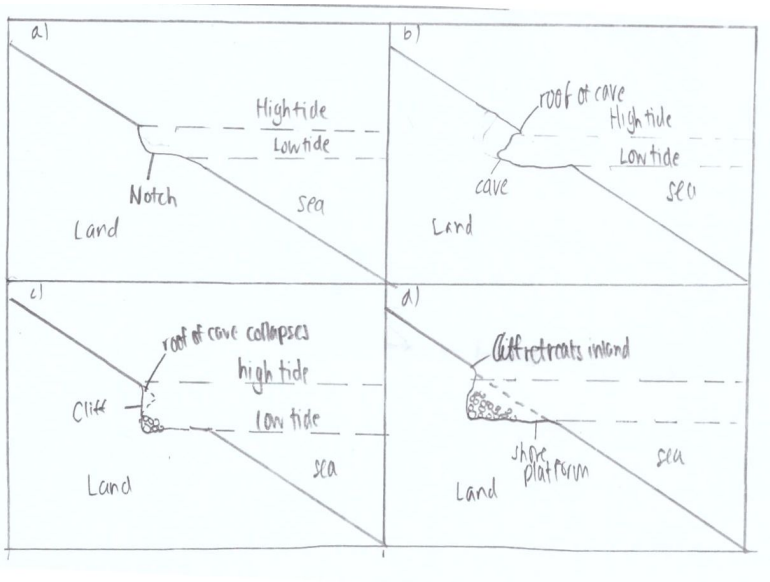
Sediment deposition

- **Sediment deposition** typically occurs in areas where which have these characteristics.
    - Sheltered from strong winds.
    - Uncommon destructive waves.
    - Calm waters like those of mangrove coasts.
    - Deep bays sheltered by headlands
    - Common constructive waves
    - Shallow offshore water (allows sediments to rise above sea level quickly)
    - Light winds which will result in lower wave energy hence more deposition,
    - Prevalence of material that can be transported away as this will result in more deposition.

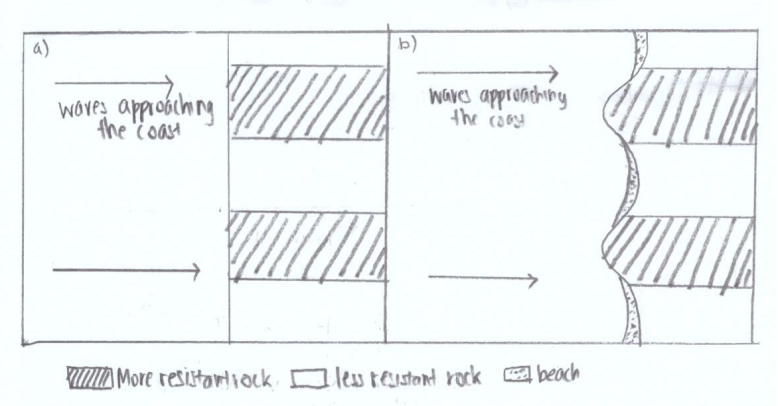
In what ways do coastal landforms and features vary from place to place?

Formation of cliff and shore platforms



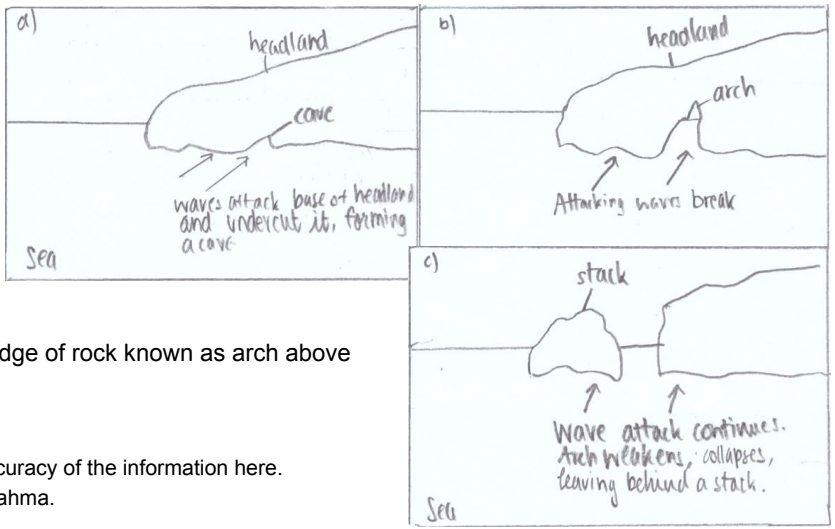
- A **cliff** is a near-vertical and steep rock face found along coasts.
- Hydraulic action and abrasion may erode a crack or joint on rock surface, gradually enlarging crack or joint to form notch.
- Notch may be further deepened to produce bigger hollow space called cave.
- As process of erosion continues, overhanging cliff is formed, eventually collapse and materials deposit at foot of cliff.
- Some material may be carry by waves and throw against base of cliff, cause further erosion.
- Over time cliff retreat inland and gently sloping platform appears at base of where cliff used to be.
- Platform is called **shore platform**, which is submerged during high tide.
    - When drawing diagram, label shore platform, roof of cave, cave, cliff.

Formation of headlands and bays



- Some coastlines have alternating bands of more resistant and less resistant rock.
    - Give example, e:g granite vs chalk
- Less resistant rocks will be eroded faster than more resistant rocks.
- Less resistant rocks that are eroded away form bays, wide indented coasts.
- More resistant rocks extend out into sea as headlands.
- Result in indentedcoastline.
    - When drawing diagram, label sea and show direction of waves. Include legend on rock type (e;g more resistant rock, less resistant rock)

Formation of cave, arches, stacks and stumps



- Waves attack lines of weakness at base of headland (e;g crack, joint, or fault) and undercut it. Action forms a cave at area that is hollowed by wave action.
    - Hydraulic action and abrasion may erode a crack or joint on rock surface, gradually enlarging crack or joint to form notch.
    - Notch may be further deepened to produce bigger hollow space called cave.
- Cave develop on each side of headland, further erosion may eventually join them together, leaving a bridge of rock known as arch above the opening.

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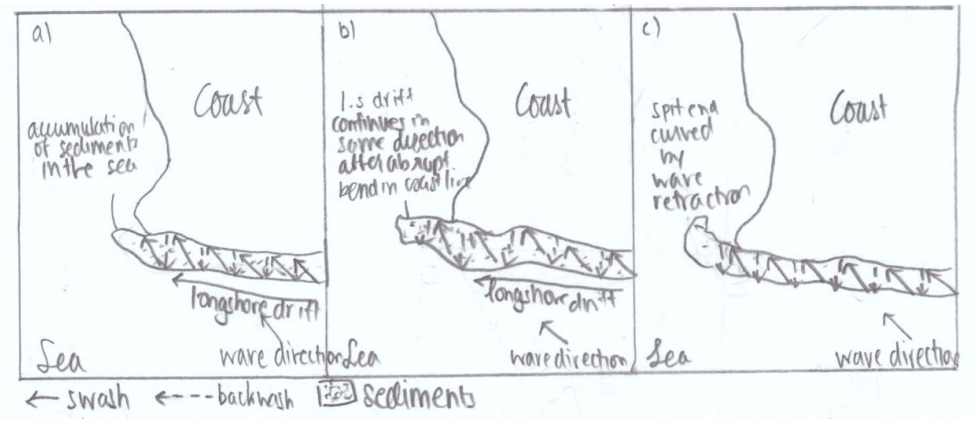
- After further erosion, roof of arch may collapse to form stack, which is a pillar of rock left in sea after a arch collapse
- If stack collapses further, a stump is formed.

Depositional coasts

- Beach is zone of sediment deposition.
    - Beach materials may come from eroded cliffs, river deposits or sediment present in waves.
- Slope of beach determined by grain size.

Formation of spits and tombolos



- A **spit** is long, narrow ridge of sediments with one end attached to land.
- Formed by longshore drift.
- When there is abrupt bend in coastline, longshore drift continue to transport material in original direction for some time.
- Materials are deposited in the sea after bend where they accumulate over time along original direction of coastline
- Form a ridge of sediments from the point where the coastline changes direction.
- A hook or curve may develop at one end of the spit, due to wave refraction concentrating at that point.
- **Tombolo** is spit has one end connected to mainland, another end jutting out into sea.
- If offshore island lies near mainland where spit is forming.
- Spit may continue to extend until it connect to offshore island to mainland.
- This is tombolo, tombolo may also join two existing islands.

GATEWAY 2: Why are coastal areas valuable?

How do people use coastal areas?

- **Fisheries and aquaculture**
    - **Fisheries** are area where fishes are bred and raised to meet demand for fish.
    - **Aquaculture** is when you farm fishes in cages or ponds close to coasts, in river or converted wetlands.
        - **Ca Mau, Vietnam** is an example of a place where aquaculture is practised.
        - In 1980s, more than 60,000 hectares of coastal mangroves were cleared for building materials, firewood, charcoal and medicinal herbs and converted to shrimp farms.
        - Areas cleared from mangrove forests are good for shrimp production as they are already waterlogged, remaining mangroves protecting area from storms and coastal flooding
        - Ponds are constructed from mud or concrete to hold water and shrimps.
        - Clearing of mangroves tho has left Vietnam's coastline more vulnerable to erosion and pollution from pond waste.
- **Housing and transportation**
    - Some houses are built on water (stilt houses) and boats also facilitate movement and are common modes of transportation.
        - **Kukup, Malaysia** is an example of a place where coastal areas are used for this purpose.
        - Kukup is a town located about 25 kilometres west of Singapore.
        - It is a place with stilt house communities. Air Masin is one such village in Kukup with community of 180 stilt houses. Floating fish farms are a common sight.
        - Two modes of transportation available here. Boats and scheduled ferry services.
        - Over time, Kukup has become tourist destination, economy driven by income from local and foreign tourists.
- **Tourism and recreation**
    - **Tourism** involves temporary movement of people (tourists), primarily for leisure and recreational purposes.
    - **Recreation** involves activities done for enjoyment for when one is not working.
        - **Sentosa, Singapore** is an example of a place where tourism and recreation occurs in coastal areas.
        - An integrated resort, casino and a marina ensure that Sentosa will be able to attract a lot of tourists.

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Why are coral reef ecosystems distinctive and valuable?

- **Coral reefs** are structures that develop at, or slightly below sea level on sea bed.
    - They are built and made up of thousands of tiny animals known as coral polyps, secreting rock-like deposits of calcium carbonate to protect their soft and delicate body.

- **Distribution of coral reefs**
    - Coral reefs widely distributed but mostly found between **Tropic of Cancer in north** and **Tropic of Capricorn in south**.
    - There are several areas and regions in which they are concentrated.
        - The **Caribbean** has a decent concentration of coral reefs.
        - **Great Barrier Reef** off the coast of Australia is a collection of coral reefs.
        - **South East Asia**, however, has the greatest concentration and largest area of coral reefs.

- **Environmental conditions for growth**
    - **Level of salinity**
        - Average seawater salinity of **34-37 parts per thousand** is optimal.
    - **Oxygen content**
        - A **moderate amount of water movement** ensures that corals receive sufficient levels of oxygen.
    - **Lack of sedimentation**
        - Sediments may suffocate living corals.
    - **Sea surface temperature**
        - Sea surface temp not lower than **17 to 18 degrees centigrade**.
    - **Amount of sunlight available**
        - Clear saline water **between 10 and 60 metres** deep allows sufficient sunlight to penetrate allowing algae photosynthesis.
        - **Turbidity of water**, or level of murkiness, must be low enough to allow sufficient sunlight to penetrate.

- **Value of coral reefs**
    - Coral reefs **support natural ecosystem**s, supporting more than 25% Earth's marine fish species.
    - Coral reef can **absorb wave energy**, protecting adjacent land mass from erosion.
    - Coral reefs **provide food** because they are good fishing sites.

- **Pressures that threaten coral reefs**
    - **Overcollection of corals** for personal or commercial use weakens coral reefs and disrupts the ecosystem, making them more vulnerable to threats.
    - **Fishing methods** may endanger coral reefs.
        - Dynamite blasting and the use of cyanide to stun fish destroys coral reef habitats.
        - Spearfishing may lead to selective depletion of fish population, impacting food chain.
    - **Recreational use of coast** for tourism and anchoring of boats can lead to coral reefs being polluted or destroyed by boat anchors.
    - **Coastal development** along coasts may impact coral reefs.
        - Reclamation of land can suffocate coral reefs as the sediments will suffocate them, destroying coral reefs.
        - Expansion of coastal resorts and urban housing results in more waste being deposited into the sea, suffocating coral reefs.
    - **Climate change** such as rapid changes in sea temperatures and sea levels may be faster than the ability of reefs to adjust, resulting in coral bleaching where higher sea temperatures result in loss of algae.

Why are mangrove ecosystems distinctive and valuable?

- **Mangrove ecosystems**
    - Mangrove species are **salt-tolerant, tropical or subtropical** plants that grow in conditions (**tidal mud and sheltered coast**) that most plants are unable to cope in.
    - They are halophytes, plants that have adapted to grow in saline environments.
- **Distribution of mangroves**
    - Mangroves are typically found on the coasts of countries.
    - These countries are usually found between the Tropic of Cancer and the Tropic of Capricorn.
    - They are most abundant along tropical coastlines like South East Asia.
        - New Guinea
        - The Sundarbans in India and Bangladesh
        - The Malay Peninsula
        - Borneo
        - Mangrove forests are found in coastal areas between the Tropic of Cancer and Tropic of Capricorn (23.5 degrees north and south of the equator)
    - Mangroves only grow on coastal areas which are sheltered and have low-lying muddy or waterlogged land.

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- **Structure of mangroves**

Zone	***Coastal***	***Middle***	***Inland***
Characteristics of Zone	Frequent flooding with saltwater	Mud is deep and rich in organic matter	Infrequently flooded
Roots of mangroves found	Pencil-like	Prop/stilt roots	Kneed roots
Example of plants	Avicennia Sonneratia	Rhizophora	Bruguiera
Characteristics of plants	Most salt resistant		Least salt resistant

- **Mangrove adaptations**

Part of Plant	***Adaptation***
Leaves	• **Avicennia** leaves have salt glands that secrete salt which is then washed away by the sea during high tide • **Rhizophora** and **Bruguiera** absorb the salt in old leaves which are then discarded when they fall.
Roots	• Aerial roots of **Avicennia** and **Sonneratia** help plants take in oxygen directly from atmosphere because of low oxygen content under muddy ground. • Prop-roots like those of **Rhizophora** help plants anchor themselves firmly on the ground so that they are not easily swept away by waves. • Kneed roots like those of **Bruguiera** have kneed roots which help to trap soil between their roots which is essential for plant growth
Fruits and Flowers	• Fruits can germinate while still attached to the plant so that they can drop and directly grow without being washed away. • Some mangrove fruits are javelin-shaped, allowing them to pierce soft mud and grow into a sapling immediately. • Some fruits are buoyant, allowing them to float on water so that they can be carried away by it to other coastal areas.

- **Values of mangroves**
  - Mangroves can **reduce coastal erosion** because their dense network of roots absorb wave energy, thus stabilising coast lines.
  - They can also **mitigate natural disasters** such as in the case of tsunamis as they act as natural barriers.
  - They are **breeding grounds and habitats** for a range of marine creatures and act as a nursery for juvenile fish species.
  - They provide **valuable wood for fuel, charcoal and construction.**
  - They can **improve water quality** because they accumulate sediments that act as a natural filter.
  - They are also **valuable food sources** because organisms which live there like crabs or atap seeds can be eaten.
- **Pressures on mangroves**
  - **The demand for fuelwood and charcoal** results in mangroves being cleared, leading to breeding grounds being threatened and more erosion of coasts like in Ca Mau, Vietnam.
  - **The need for more farming areas** where the conversion of mangroves into paddy fields or shrimp farms like in Ca Mau results in coasts being more vulnerable.
  - **Land reclamation** for housing, industry and recreational uses leads to mangroves being destroyed, such as in Jurong, Singapore.
  - **Water pollution** from pollution can lead to the poisoning and death of mangroves, such as in Ca Mau where shrimp waste discarded into the river lead to the death of mangroves.
  - **Climate change and rising sea level** may lead to trouble for mangroves colonising inland because they will then be in direct competition with humans.

Gateway 3: How can we manage coastal areas in a sustainable manner?

- **Measures to protect the coast from erosion**

Type of structure & examples	***Description & example***	***Advantages***	***Disadvantages***
HARD ENGINEERING METHODS			
Seawall	• **Seawalls** are walls made of concrete or stone built to absorb wave energy. • They are often built parallel to the coast. • **E.g. Drakes Island in England**	• They look more aesthetically pleasing than other engineering methods while still maintaining the same functionality of being able to reduce wave energy.	• Seawalls are advantageous in that they look more aesthetically pleasing than other engineering methods while still maintaining the same functionality of being able to reduce wave energy.

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			• However, seawalls are costly to build and maintain. If they are not maintained properly, they can collapse like the seawall at Drakes Island, England.
Gabions	• Gabions are wire cages usually filled with crushed rocks • They are usually built along a shore or behind a beach. • **E.g. Seaton Beach in Devon, England**	• Gabions weaken wave energy and absorbs wave energy better than sea-walls by allowing water to filter through. • This makes them better against high-energy waves.	• Gabions are unsightly. • They are costly and need to be maintained regularly • They are easily corroded by seawater and damaged by excessive trampling or vandalism ○ For instance in East Coast Park when it was first reclaimed, gabions had to be removed immediately after they were vandalized.
Breakwaters	• Breakwaters are usually made of rock. • They are built either parallel to coast or with one end attached to coast. • They create a zone of calm water behind them when constructed offshore, allowing materials to build up and form beaches. • **E.g. East Coast Park**, **Singapore**	• They take the full force of waves and as such reduce overall energy. • They create a natural harbor which can be used to dock boats in this area of calm water. • They do not interfere with water flow.	• They are unaesthetically pleasing. • They are expensive to build. • They protect the coast unevenly. • Zones not protected by breakwaters still subjected to wave action and erosion. o Breakwaters in **Portland Harbour, England**
Groynes	• Groynes are low walls constructed at right angles to shore. • Sometimes angled at about 10 degrees depending on circumstances. • **E.g. Dawlish Warren**, **England**	• Absorb or reduce energy of waves • Retain materials that might otherwise be removed by longshore drift by causing materials to be deposited on the updrift side of groyne facing longshore drift.	• Unsightly and ugly • Expensive to build and maintain • No new materials carried deposited on downdrift side not protected by groyne, thus eventually eroding away unprotected area of beach. o **Sandy Hook in New Jersey USA** where large amts of sediments were eroded on the downdrift side of the groyne there.
Tetrapods	• Tetrapods are four-pronged concrete structures that help dissipate wave energy. • They are stacked offshore in interlocking positions. • **E.g.** tetrapods in Hokkaido, Japan	• Allow water to pass through them rather than hit against them, preventing powerful backwash which reduce possibility of tetrapod being damaged by waves • Cast into final shape before being positioned, can be placed quickly compared to other methods which take time to build while coasts under attack from waves.	• Unsightly and unaesthetically appealing • Expensive to build • Dangerous to swimmers, surfers and boaters.

SOFT ENGINEERING METHODS			
Type of structure & examples	***Description & example***	***Advantages***	***Disadvantages***
Beach nourishment	• Beach nourishment refers to using sand from external source to replenish sand on depleted beach	• Can successfully change a coast into a wide, sandy beach that offer protection to immediate inland area.	• Trucking/piping in sand expensive and time consuming. • Coral reefs may be destroyed as sand used for beach nourishment is washed out from sea and suffocates corals.

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	• Sand may come from another beach or from sea floor. • E.g. Sentosa, Singapore	• Slows down erosion of beach. • Can restore depleted beaches.	o E.g. Wakiki Beach in Hawaii • Re-nourished beaches can still be eroded unless other management strategies are in place.
Planting vegetation eg. mangroves	• Example of vegetation that can be planted is mangrove. • E.g. along West Bali Beach	• Mangroves can absorb wave energy through their dense root system whilst providing many benefits passively to the environment such as cleaner water or acting as a habitat.	• May take a long time (years) to be established before it can resist natural elements like storms or human elements like vandalism or trampling.
Stabilising dunes	• Vegetated beaches are beaches with vegetation • E.g. Triton Place, West Australia	• Planting vegetation can help stabilize coastlines because roots anchor sand and prevent erosion. • Lower cost of maintenance once dune is established because vegetation propagates itself.	• Take number of years to be established before it can resist natural elements like storms or human elements like trampling or vandalism. • To prevent them from being disturbed, fences and access paths need to be built. Thus there is cost incurred. o E.g. Triton Place, West Australia • They may also need to be replaced with taller ones as dunes grow taller.
Growing coral reefs	• Coral reefs can be created by placing lasting materials like steel and concrete on sea floor, allowing them to be colonised by corals. • Coral and other marine creatures like vegetation then colonise them and it function as natural reef. • E.g. Palau in northern Pacific where sunken ships have been colonized by coral	• Coral reefs help weaken wave energy. • Serve as breeding ground and nursery for fish	• Not easy to encourage coral growth cause sites need to be surveyed to ensure max opportunity for growth. • Dangers of siltation need to be overcome or avoided. • Coral growth may be slow, taking 20-30 years before results appear.