Unit 1 Environmental change and management

Coastal change and management

Coasts are areas where the land meets the sea. Home to more than one billion people around the world, coastal areas are some of the most visited and heavily populated areas on the planet. Human activities in coastal areas have affected many of the natural environmental processes there. This has led to a wide range of issues including a loss of biodiversity, high levels of pollution, erosion, and rising sea levels due to climate change. In fact, coasts are one of the Earth's most threatened environments.

Coasts are critically important – not only to the people who live along them, but also to the health of the planet. Around the world, geographers are playing a vital role in developing strategies to manage these problems and protect coasts for future generations. In this chapter, we will examine some of the problems facing coastal areas today and explore some of the strategies being implemented to balance human needs with the needs of the environment.

chapter 3

Source 1 Welcome to Hong Kong, China – one of the most densely populated coastal cities on Earth. Changes brought about by human activities in coastal areas like Hong Kong need to be carefully managed in order to protect the environment for future generations. One of the most critical problems currently facing coastal areas today is rising sea levels. In China alone, it is estimated that up to 145 million people living in coastal areas could be displaced by rising waters by 2070.

3A
How is the coastal environment changing?

1 As a class, discuss the ways in which human activities have impacted on the coastal landscape shown in Source 1.

2 How would a 2-metre rise in sea level affect this coast?

3B
How can coastal changes be managed?

1 In Source 1, what evidence can you see of management strategies to control or limit human activities that may have a negative impact on the natural environment?

2 Brainstorm further strategies that could be put in place to protect this coast. Why do you think these have not been used in this environment?

3C
How can geographers help to manage coastal changes?

1 While the impacts of human activities are obvious on this coastline, their root causes are less obvious. What might some of these fundamental causes be?

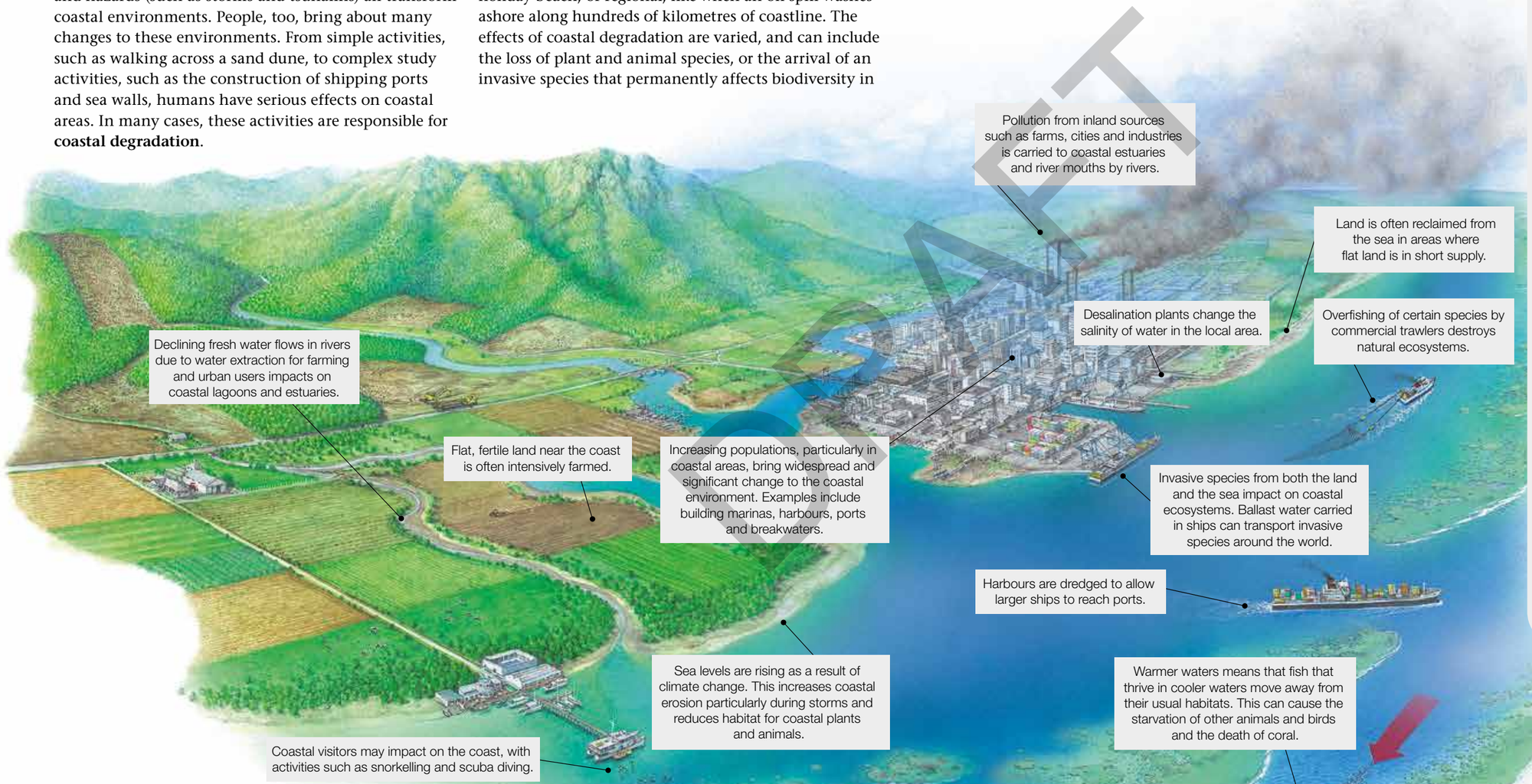
2 Why do changes at coastal environments differ from place to place?

3.1 Change in coastal environments

Coasts are very dynamic places – they are constantly changing. Crashing waves, strong currents, tidal waters and hazards (such as storms and tsunamis) all transform coastal environments. People, too, bring about many changes to these environments. From simple activities, such as walking across a sand dune, to complex study activities, such as the construction of shipping ports and sea walls, humans have serious effects on coastal areas. In many cases, these activities are responsible for **coastal degradation**.

Coastal degradation can be observed on many scales. It may be local, like when litter is dropped on a popular holiday beach, or regional, like when an oil spill washes ashore along hundreds of kilometres of coastline. The effects of coastal degradation are varied, and can include the loss of plant and animal species, or the arrival of an invasive species that permanently affects biodiversity in the area. Examples of coastal degradation can include sand dunes being washed into the sea, changing the coastline, or blooms of toxic algae damaging the marine environment. Source 1 provides an overview of some common forms of coastal degradation.

Over the course of this chapter we will be exploring some of the changes that are having the greatest impact on coastal environments. These include climate change, population growth in coastal areas, the loss of coastal biodiversity and marine pollution.



Source 1 Some common examples of coastal degradation

Check your learning 3.1

Remember and understand

1 What are some of the changes currently impacting coastal environments?

2 Are coastal environments close to cities more at risk from degradation than those in remote areas? Give some reasons for your answer.

Apply and analyse

3 The three main drivers of environmental degradation are climate change, population growth and economic growth. Examine Source 1.
   - **a** Classify each of the causes of coastal degradation shown according to one of these three drivers.
   - **b** Are there any changes that could not be classified in this way?
   - **c** Which of the three drivers appears to be responsible for most of the changes shown?
   - **d** Classify each of the changes shown according to whether they are taking place on the local, regional, national, international or global scale.

4 Use the geographical concept of interconnection to describe the links between changes on the land and changes at the coast.

Evaluate and create

5 Select one of the causes of coastal degradation shown in Source 1. Suggest a solution for the problems this creates.

3.2 A dynamic balance

While this chapter focuses primarily on the ways in which human activities bring about changes to coastal environments, it is also important to remember that natural processes are constantly shaping and changing the coast too. Rocks are eroded and material such as sand is transported by the energy of waves, tides and currents, creating a landscape that is constantly evolving. All this change means that coasts are very complex environments to study and understand.

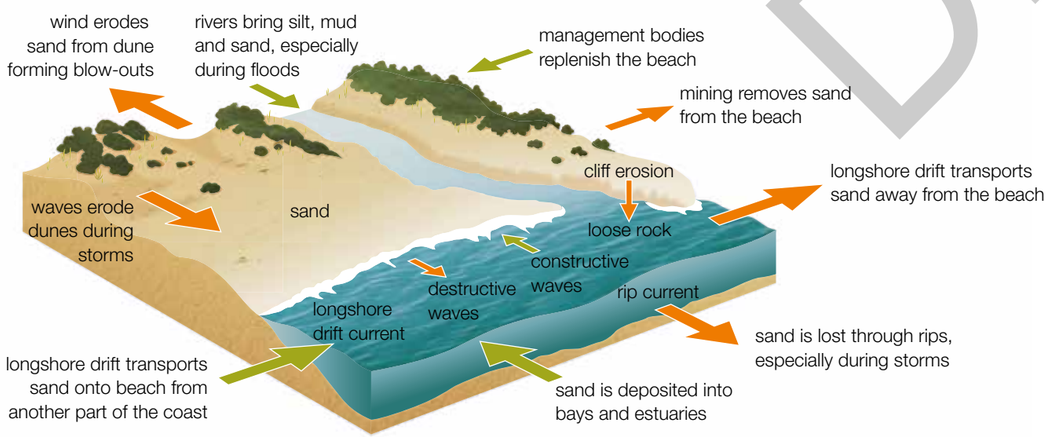
Source 2 A range of coastal landforms are evident at Cape Byron, the easternmost point on the Australian mainland.

Understanding natural processes in coastal environments

Geographers often use models – such as the systems model – to understand environments, study the relationships between environments, and learn more about the intricate forces that cause changes.

To apply a systems model to a coastline, each individual **landform** is considered to be a separate compartment. Energy such as wind and waves, and matter such as water and sand are studied as they arrive at and leave each compartment. Arriving energy and matter are referred to as inputs and leaving energy and matter are outputs.

If the inputs are greater than the outputs, then the coastline and its landforms such as dunes and **spits** increase in size and the coast grows outwards. If the outputs are greater than the inputs, then landforms decrease in size and the coast retreats (see Source 1)



Source 1 How natural processes change coastal environments. Green arrows represent inputs while red arrows represent outputs.

keyconcept: change

Dynamic equilibrium

Energy inputs on the coast – the waves and wind – often erode and transport matter, particularly sand. When matter is transported, the shape of the beach changes. When coastal landforms are in balance with energy inputs this is known as dynamic equilibrium. In this state, energy inputs are absorbed with no movement of matter, and the shapes of the landforms remain unchanged.

When dynamic equilibrium does not exist, inputs and outputs do not remain in balance, and the landscape changes.

In the case of a storm, energy inputs will not be constant, so erosion and deposits will not be in balance. Matter is eroded and transported offshore and the shape of the beach changes. Once the storm ends and the energy inputs return to 'normal' again, dynamic equilibrium returns and the beach will remain unchanged for as long as the energy inputs remain constant.

For more information on the key concept of change, refer to page XX of 'The geography toolkit'.

Source 3 In June 2016, a massive storm hit the east coast of Australia, claiming up to 15 metres of the coastline in some places. The owner of this property in the Sydney suburb of Collaroy returned to his home to find his backyard and in-ground swimming pool claimed by the waves. This storm is an example of how the dynamic equilibrium in this environment was disrupted.

Check your learning 3.2

Remember and understand

1 What are the main energy and matter inputs in coastal environments?

Apply and analyse

2 Use the systems model to describe the changes that are taking place in Source 2.

3 Examine Source 3.
- a What evidence is there for the movement of sand?
- b How has this movement changed the shape and location of the coastline?
- c Explain whether this is an example of dynamic equilibrium.

4 Select a coast that you know well (or one that you have visited on a field trip). Describe the energy and matter inputs and outputs in this environment and explain how these have shaped the coastline. For example, a series of sand dunes may have been formed by low energy waves bringing sand from a river mouth.

Evaluate and create

5 While many coastlines were heavily eroded by the 2012 storm on the north-east coast of the United States, others hardly changed.
- a Brainstorm some reasons why variations exist in the way coasts are changed.
- b Rank your reasons from the one most likely to explain these variations to the one least likely. Justify your rankings.

6 Complete a field sketch of Source 2. On your sketch, label the individual compartments that geographers would study.

3.3 Climate change and coasts

The world's climate is changing. Human activities such as land clearing and fossil fuel burning have led to increased amounts of carbon dioxide in the atmosphere. This is leading to **global warming**. As a result, the Earth's natural ecosystems are changing or adapting to the higher temperatures. Plants and animals that are unable to adapt to the warmer conditions are either moving towards the poles, where conditions are cooler, or facing extinction.

Global warming is also affecting coasts. In fact, coastal systems are undergoing greater change than virtually any other environment. As the interface between the land and the sea, coastal systems face pressures from changes in both of these places. Source 1 summarises the effects of climate change on coastal areas. One of the greatest concerns for Australian coastal areas is the rising of sea levels.

The influence of climate change

- **Higher temperatures**
  - **Sea levels rising by about 1.8 mm every year**
    - Saltwater intrusion changes ecosystems, e.g. wetlands turn into salt marshes
    - Increased coastal erosion
  - **Sea surface temperatures are rising, leading to warmer temperatures in coastal regions**
    - Increased algal blooms
    - Reef-building animals are dying and coral reefs are bleaching
  - **Tropical cyclones and other storms have increased in intensity**
    - Increased coastal erosion
  - **The northern ice cap and permafrost melts, exposing polar coastlines**
    - Increased coastal erosion
- **More carbon dioxide absorbed in the oceans**
  - **Oceans becoming slightly more acidic**
    - Reef-building animals are dying and coral reefs are bleaching
- **Changing rainfall patterns**
  - **Change to sediment supply at the coast, particularly at river mouths and estuaries**
    - Increased coastal erosion and changed ecosystems

Source 1 The influence of climate change on the coast

Australia's rising seas

It can be difficult to convince people that sea levels are rising. This is because ocean and coastal waters are constantly changing as waves, tides and currents keep them in movement. Also, sea levels are rising very slowly. This doesn't mean that they are not rising, however. In fact, sea levels have been rising for at least a century. Scientists use a combination of tide gauges and new technologies such as satellite altimeters (instruments used to measure altitude) to monitor and measure sea-level changes. These measures show that sea levels have risen by about 1.8 millimetres per year over the last century and by about 3 millimetres per year since the mid 1990s.

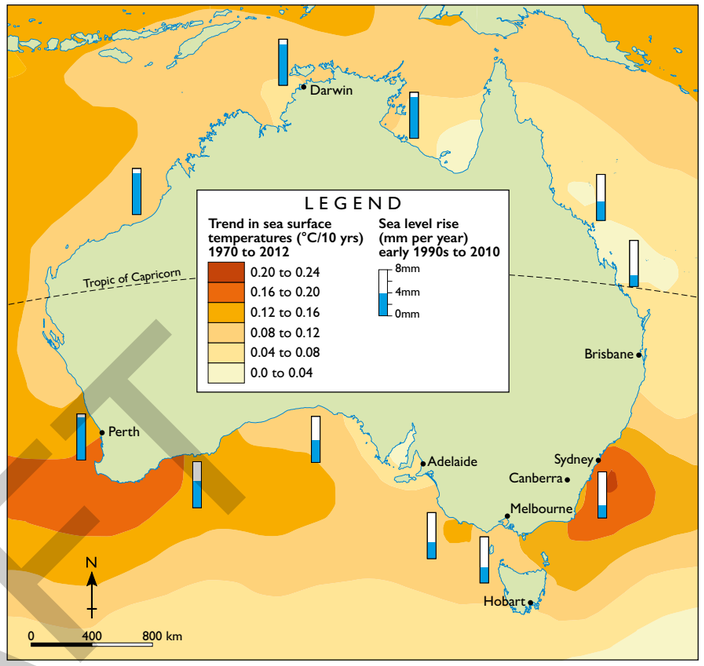
The physical impact of rising seas

An Australian government report in 2011 stated that, 'Sea levels are rising around Australia. A sea-level rise of a metre or more during this century is plausible. It could be less or much more. Between 16 000 and 250 000 individual homes are potentially at risk of inundation from a 1.1 metre rise in sea level.'

As well as the risk to homes situated on the coastline, rising sea levels are expected to cause:

- an increase in the erosion of beaches, with some beaches expected to disappear completely
- an increase in the incidence of flooding in low-lying coastal areas
- saltwater to enter coastal aquifers, destroying freshwater sources
- an increase in the severity of extreme weather events such as cyclones, bringing with them increased incidences of serious storm damage.

AUSTRALIA: TREND IN SEA SURFACE TEMPERATURES AND SEA LEVEL RISE



Source 2 Source: Oxford University Press

Coastal squeeze

As sea levels rise, important coastal ecosystems such as mangroves and salt marshes respond by retreating inland. However, in many places, sea walls and other coastal structures mean they cannot move and are therefore trapped in a narrowing strip of land (see Source 3). This process is known as coastal squeeze. This has led to healthy salt marshes and mangrove forests that are highly effective natural barriers to erosion being killed off by built structures that, in many cases, are much less effective at controlling erosion.

Source 3 This sea wall in Manche, France, is squeezing the salt marsh (centre) into a narrower strip as sea levels rise.

Check your learning 3.3

Remember and understand

1 What is coastal squeeze? What causes this problem?
2 Why is coastal erosion expected to increase as sea levels continue to rise?

Apply and analyse

3 Examine Source 2.
  a Describe the general pattern in sea surface temperature rises around Australia over the period 1970–2012.
  b Which regions of Australia experienced the greatest rises in sea levels from the early 1990s to 2010?
  c Based on the data provided, are you able to identify any links between sea surface temperature rise and rises in sea level around Australia? Why or why not?
4 Add four boxes to Source 1 to provide additional examples of the impacts that rising sea levels and sea surface temperatures will have on natural and human environments.
5 Visit the OzCoasts website (www.ozcoasts.gov.au) and locate the sea level rise maps section. Use these maps to examine the predicted sea level rise in a capital city or region of your choice. Describe the impacts that a 110-centimetre sea level rise would have.

3.4 The impact of climate change on the Great Barrier Reef

Queensland's Great Barrier Reef is not only one of the world's most beautiful natural treasures; it is also one of its most important. Extending over 2300 kilometres and 14 degrees of latitude, the reef contains over 2900 separate coral reefs and some of the world's most extensive mangrove and seagrass ecosystems. But the combined effects of a changing climate – rising sea temperatures, rising sea levels, **ocean acidification**, and extreme weather events – are causing problems for this remarkable natural environment.

Rising sea temperatures

Studies show that the current temperatures of the Coral Sea are warmer now than at any time over the last 300 years. On average, temperatures are 0.4° Celsius warmer than they were in the late 1800s. As average temperatures rise, warm weather events heat the sea surface to a temperature that coral polyps (the tiny organisms that construct the coral reef) cannot tolerate. The coral polyps feed on algae, but the warmer water temperature causes a build-up of poisons in the algae. In order to survive, the polyps expel the algae on which they feed, as well as some of their own tissue.

This process turns the coral white and is known as coral bleaching. Over the short term, bleaching does not kill the coral polyps. However, if sea temperatures remain high over an extended period, the coral polyps eventually starve and the reef will die out.

Rising sea levels

As the climate warms, land ice is melting. For example, the Greenland ice sheet, which covers 80 per cent of Greenland, is melting an average of 195 cubic kilometres per year. The water from this melting ice ends up in our oceans. Rising sea temperatures are also causing the ocean to expand as a result of the warmer water.

In the Coral Sea, sea levels are rising by about 3 millimetres per year. This is expected to have little impact on the coral reefs as they can grow upwards by about 6 millimetres per year. Surrounding ecosystems, however, are likely to be severely affected. As saltwater intrudes further inland, environments such as mangroves and freshwater lakes are expected to change significantly. Low-lying islands are also expected to disappear beneath the rising seas, changing the distribution of nesting birds and turtles.

Ocean acidification

Ocean acidification is a term used to describe the change in water chemistry caused when the carbon dioxide we pump into the atmosphere is absorbed into the ocean. The extra carbon dioxide in the water makes it more acidic. Ocean acidification can have dire consequences for a coral reef.

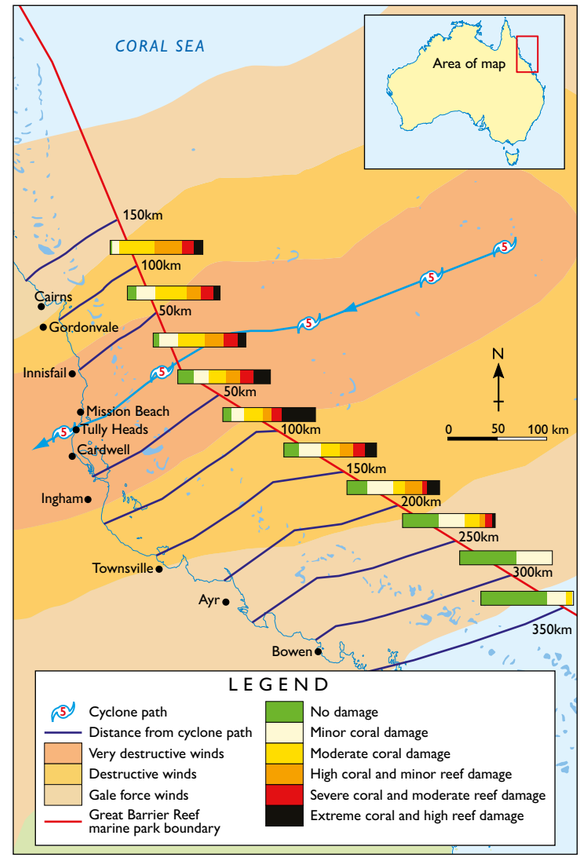
As carbon dioxide is absorbed into the ocean, it reduces the amount of carbonate (a kind of salt) in the water. Marine animals need this carbonate to make their shells and skeletons. Reef-building animals such as coral polyps then use these shells and skeletons to create a reef. With fewer shells and skeletons available, construction of the reef is seriously limited. Over the long term, ocean acidification is expected to be the greatest challenge facing the Great Barrier Reef.

Extreme weather events

Increases in the severity and frequency of flooding and tropical cyclones also pose serious threats to the reef. Flooding brings increased sediment to the reef and this sediment smothers plants. Pesticides and other chemicals are also carried by floodwaters, adding to the levels of pollution in the water around the reef.

Cyclones generate large and powerful waves which damage corals and the reef structure. One of the worst cyclones to hit the reef in recent times was Cyclone Yasi in 2011 (see Source 3). Reefs are able to recover from these natural events but need time to do so. As extreme weather events become more frequent, reefs have less recovery time.

GREAT BARRIER REEF: DAMAGE FROM CYCLONE YASI, FEBRUARY 2011



Source 3 Source: Oxford University Press

Source 1 An example of mass coral bleaching on the Great Barrier Reef

Source 2 The Great Barrier Reef islands such as Heron Island are important nesting sites for the endangered loggerhead turtle.

Check your learning 3.4

Remember and understand

1 Why are sea levels around the world rising?
2 How do rising sea levels impact on nesting birds and turtles?

Apply and analyse

3 Examine Source 3.
- **a** Describe the track of Cyclone Yasi and the areas in which the winds were most destructive.
- **b** In which areas was reef damage the greatest? Which areas suffered the least damage?
- **c** Describe the relationship between wind speed and reef damage.

Evaluate and create

4 Construct a flow chart or mind map showing the impact of ocean acidification on coral reefs.
5 Rank the four impacts of climate change described here from the one likely to have the greatest impact on the reef to the one likely to have the least impact. Write a paragraph justifying your ranking.
6 Imagine that the Great Barrier Reef disappeared due to the combined effects of climate change. How would this affect the Queensland coast and the Queensland economy?

3.5 The impact of population growth on coasts

About one-quarter of the world's population live within 100 kilometres of the coast. Most of the world's megacities in both the developed and developing world are located on the coast and many of them are growing rapidly. In China, for example, 1000 people a day move to coastal cities from the country's interior. The impact of billions of people in millions of coastal cities, towns, villages and farms has caused one United Nations expert to state that 'humankind is in the process of annihilating coastal and ocean ecosystems.'

The impact of human settlements on coastal areas

The coast has always been an attractive place for human settlement. Coastal regions provide access to food and water, and people have long used boats and ships for transportation. But the growing number of people along the coast, together with increasing levels of trade and movement between settlements have had many detrimental effects on coastal ecosystems:

- Engineering structures such as sea walls, **groynes**, breakwaters, training walls and marinas have hardened the coast and changed natural cycles of **erosion** and **deposition**.
- Changing the natural flow of water by dredging channels, diverting rivers and building dams has altered the amount of fresh water and sediment arriving at the coast, impacting on natural ecosystems and landforms.
- Discharging sewage into the ocean, the run-off of fertilisers from farms and other contaminants entering coastal waters have caused pollution in the oceans.
- Increased numbers of people in coastal areas has led to overfishing of the fish and shellfish. In some places coastal fish stocks have fallen by 90 per cent in the last 30 years.
- Ports are often an entry point for invasive species that bring dramatic changes to coastal ecosystems.
- The presence of large numbers of people on beaches have an impact: people leave litter on beaches, they walk over native plants and impose walkways, they can destroy breeding areas of sea birds and bring predators such as dogs into the environment.

Source 1 The contrast between the natural and built-up environments of Tokyo Bay, Japan. A beach in Tokyo Bay (left), and reclaimed land near the CBD (right).

Continued growth and competition for land

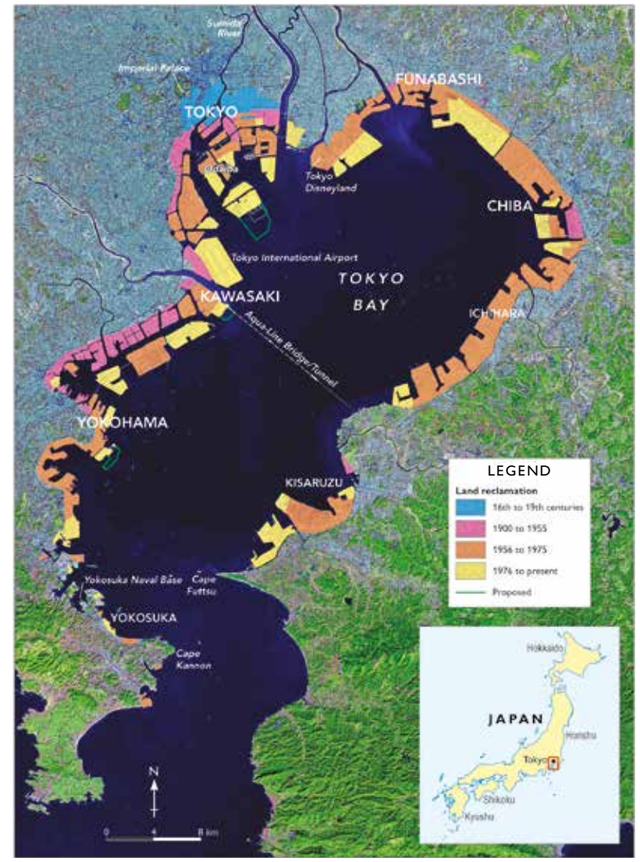
Many coasts have been converted from natural ecosystems to human landscapes. Cities need space to grow and harbours for trade and transport. Mangroves, marshes and **estuaries** have been drained and filled in, sand dunes flattened and built over and communities of coastal plants cleared. In some places, land for expansion has been so scarce that new land has been built in bays and estuaries from rocks, rubbish and silt from the sea bed (known as **land reclamation**).

Case study: Tokyo Bay

The largest example of reclaimed land is Japan's Tokyo Bay. Twenty per cent of the bay has been filled in to create 250 square kilometres of new land. This new land was created around the edge of the bay using urban waste and silt from the bottom of Tokyo Bay. The reclaimed land is now home to some of the world's most expensive real estate including an international airport and Tokyo Disneyland.

In September 2013, Tokyo was selected as the host city for the 2020 Summer Olympic Games. Many of the sporting venues will be built on reclaimed land and this is expected to further increase the property values in the areas surrounding Tokyo Bay.

TOKYO BAY: EXTENT OF RECLAIMED LAND



Source 2 Source: National Geographic

Check your learning 3.5

Remember and understand

1 What is land reclamation and why is it used?
2 Describe the changes to coastal ecosystems as a result of coastal city growth.

Apply and analyse

3 Use an atlas to research the location of the world's megacities (cities with over 10 million people). How many megacities are coastal? How many of these coastal megacities are on river mouths or estuaries?
4 Why would the impacts described on these pages be particularly serious for small island communities?
5 Would the population impact on coasts be greatest in developing or developed countries? Discuss this with a partner and then with the class.

Evaluate and create

6 Construct an overlay map of Tokyo Bay using Source 2. On the base map show the natural outline of the bay. On the overlay show the total area of reclaimed land. Describe the spatial change over time shown on your map.
7 Use Google Earth to explore the coastline of Tokyo Bay. Estimate the percentage of the coastline that is:
   a heavily modified (for example, reclaimed land)
   b lightly modified (for example, sea walls or groynes constructed)
   c not modified.

3.6 Loss of coastal biodiversity

The number of plant and animal species on a global scale is in decline. The drivers of this wave of extinction are all caused by human activities such as the destruction of habitats, overexploitation of ecosystem services, pollution, climate change and the introduction of invasive species. Recent studies of the four key coastal ecosystems – mangroves, seagrass beds, salt marshes and coral reefs – reveal that all are declining in size and biodiversity.

Mangroves

Mangroves provide a wide range of crucial ecosystem services in many tropical areas, including providing wood, protecting communities from the effects of offshore storms and as a breeding ground for fish and crustaceans. Despite their importance, about one-fifth of the world's mangroves have been lost since 1980, an estimated area of 36 000 square kilometres (see Source 1). Countries such as Kenya, Liberia and Puerto Rico have already lost over 70 per cent of their mangrove forests. Currently, the United Nations estimates that mangrove forests are being cleared at four times the rate of land forests. Mangroves have been cleared to make way for agricultural land, harbours, housing and fish farms.

Source 1 Many mangrove forests, such as here in Malaysia, have been cleared to make way for shrimp farms.

Source 3 The amazing leafy seadragon, threatened by a loss of seagrass near Australia's southern cities.

Seagrass beds

Seagrass beds are an important ecosystem for dugongs and manatees (both large sea mammals) and the leafy seadragon (see Source 3), as well as providing food for hundreds of other species. Seagrass beds are also important for stabilising sediments in the water, absorbing carbon dioxide and protecting against erosion. Over the last 200 years, about 30 per cent of the world's seagrass beds have disappeared, many of them within the last few decades. The main threats to seagrass beds and the biodiversity they support are the dredging of the sea bed, the development of tourist marinas and water pollution from rivers and streams.

Salt marshes

Salt marshes are intertidal habitats, meaning they are above water at low tide and under water at high tide. Salt marshes are essential for healthy fisheries and coasts. They provide food, refuge and a habitat for the offspring of more than 75 per cent of marine species, including shrimp, crab and many fish. Birds also feed on the marshes. Salt marshes protect shorelines from erosion and reduce flooding by slowing and absorbing rainwater (see Source 2). They also help to maintain water quality by filtering runoff and absorbing excess nutrients. Twenty-five per cent of the world's salt marshes have already been lost; many turned into agricultural land for farming.

Source 2 Salt marshes protect shorelines from erosion and reduce flooding.

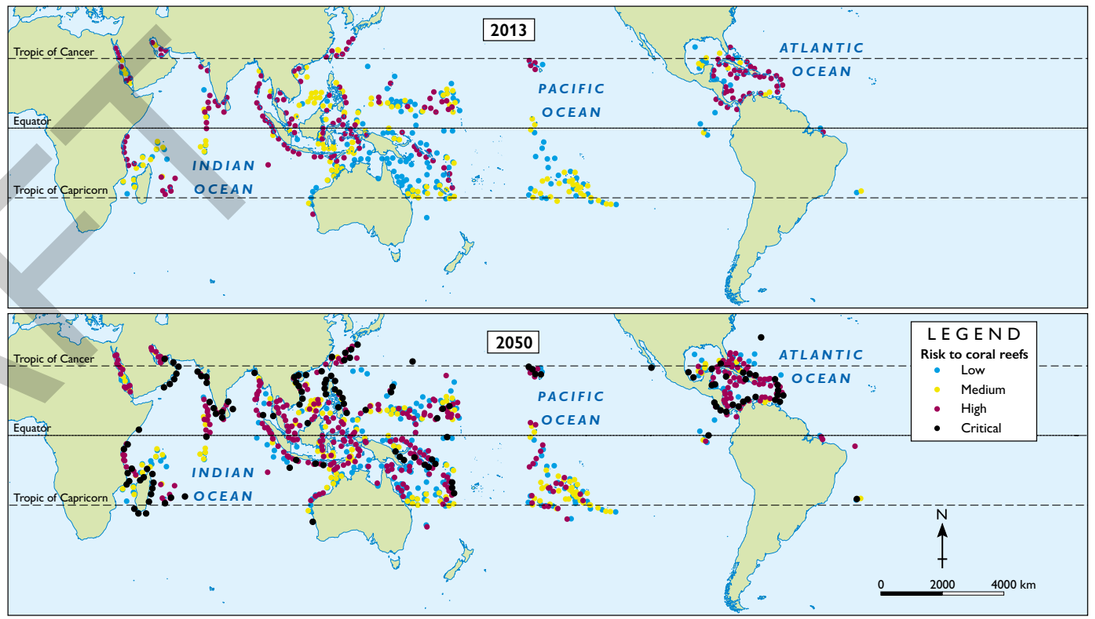
Coral reefs

Coral reefs are home to one-quarter of the world's fish species. The richest area of coral is the western Pacific Ocean. In the 1980s, 66 per cent of the region's reefs were covered in living coral, but by 2004 this had declined to just 4 per cent. In the Caribbean Sea, the amount of living coral fell by one-quarter in a single year.

Up to a billion people rely on the ecosystem services provided by coral reefs, including food, protection from waves and storms and income from reef-based tourism. Despite their importance, the coral reefs are under threat.

As well as the threats from warmer sea temperatures causing coral bleaching, coral reefs are also in danger from human activities such as land-based industries increasing the levels of sediment and pesticides in the ocean, and from invasive species such as the crown-of-thorns starfish.

WORLD: CORAL REEFS AT RISK IN 2013 AND PROJECTED TO BE AT RISK IN 2050



Source 4 Source: Oxford University Press

Check your learning 3.6

Remember and understand

1 What ecosystem services are provided by the four coastal habitats discussed? Classify these as sinks, sources, services or spiritual functions.

Apply and analyse

2 What are the five drivers of biodiversity loss in coastal habitats? Give an example of each of these.

3 Examine Source 4.
- **a** Describe the distribution of the world's coral reefs using the PQE method. For more information on the PQE method refer to page XX of 'The geography toolkit'.
- **b** Which reefs were most at risk in 2013?
- **c** Which reefs are projected to be at risk by 2050?

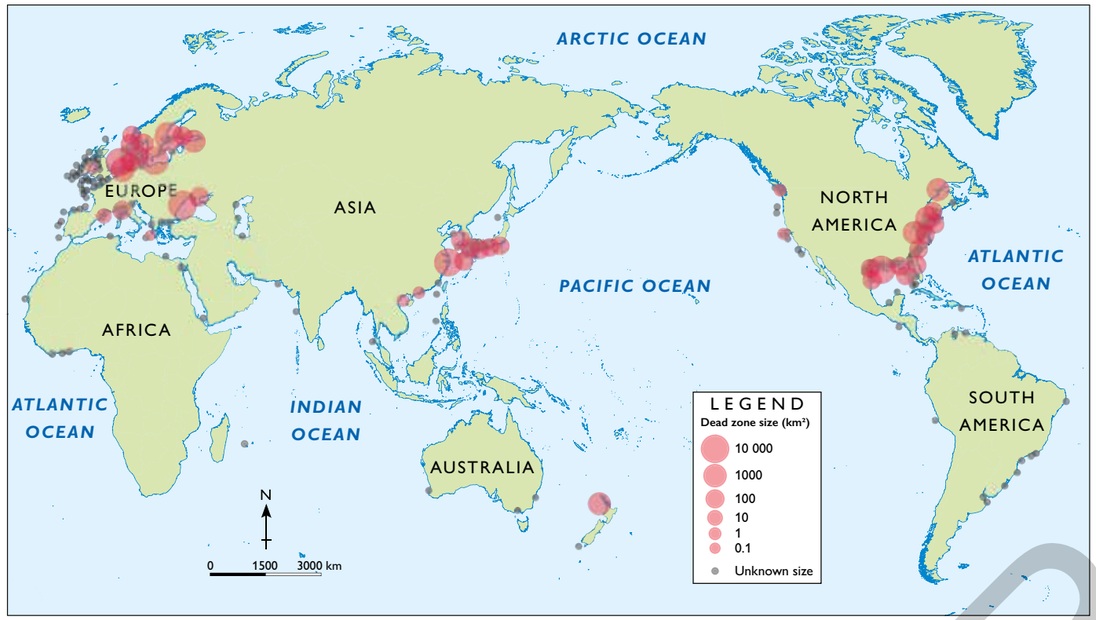
Evaluate and create

4 Sketch Source 1 and shade intact mangroves and disturbed mangroves using two different colours. Label features of the natural and human environments.

5 Research the threats faced by one coastal species in Australia such as the dugong, orange bellied parrot, coastal emu, grey nurse shark, marine turtles or sea snake, and present your findings to the class.

3.7 Coastal and marine pollution

WORLD: LOCATION OF MARINE DEAD ZONES



Source 1 Source: Oxford University Press

A pollutant is any substance released into the environment that has a harmful or negative effect on the natural environment. Coasts are particularly vulnerable to the damaging effects of **pollution** as pollutants released on land and in the sea usually find their way to the coast, carried by rivers, tides, waves and ocean currents.

Sources of coastal pollution

While it might be tempting to think that most coastal pollution comes from people using the coast such as beach-goers and people fishing, this is generally not the case. Rivers carry urban pollutants such as sewage, industrial waste, chemicals and water washed from streets and yards as stormwater to the coast. Rivers also bring pollutants from rural areas such as animal manure, pesticides and fertilisers washed from the land in heavy rain. Deforestation in river catchments also increases the amount of sediment and fresh water carried to the coast. One of the most serious consequences of coastal and marine pollution is the formation of dead zones in the ocean (see Source 1).

Source 2 This bloom of algae, triggered by fertilisers washed from farms, covered beaches in southern China in 2011.

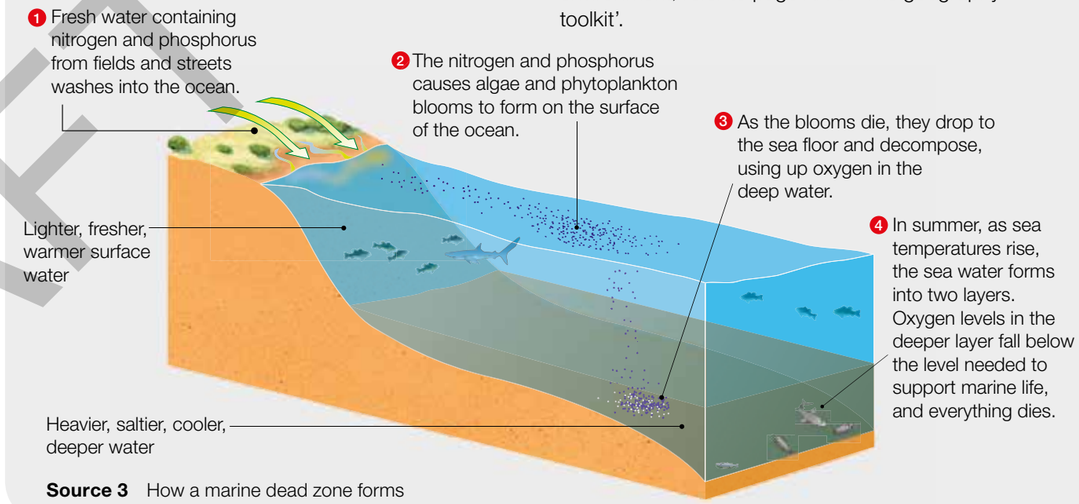
key concept: environment

Marine dead zones

Marine dead zones are areas of fresh water or salt water where oxygen concentration has become too low to support life. Some rivers carry a cocktail of pollutants, all of which arrive at the coast. Waves, tides and currents then carry these pollutants along the coast and out to sea where they can cause great environmental damage. Arguably the most serious damage is the creation of marine dead zones in the ocean, devoid of oxygen and marine life. Dead zones form in summer with the warmer weather conditions encouraging algae blooms which then go on to deplete oxygen levels in deeper seas (see Source 3).

Although the number and size of marine dead zones fluctuate, they are on the increase. In the 1960s, only 39 dead zones were identified, compared with 405 in 2000. Some dead zones are only a few square kilometres in size and last only a few months. The largest dead zones, however, are massive. Dead zones in the Baltic Sea and Gulf of Mexico can be more than 18000 square kilometres in size.

For more information on the key concept of environment, refer to page XX of 'The geography toolkit'.



Source 3 How a marine dead zone forms

Check your learning 3.7

Remember and understand

1 What is meant by the term 'marine dead zone'?
2 What are the causes of marine dead zones and what are the effects of these zones?

Apply and analyse

3 Examine Source 1.
  a Describe the distribution of the world's largest marine dead zones using the PQE method. For more information on the PQE method refer to page XX of 'The geography toolkit'.
  b Describe and account for the relationship between marine dead zones and areas of high population density.
4 Why do dead zones grow and decline throughout the year?

Evaluate and create

4 Marine dead zones can be explored through the geographical concept of environment, but they could also be used as an example of the geographical concept of interconnection. Describe how dead zones relate to interconnection.
6 In small groups, discuss possible solutions to the problem of marine dead zones and present your ideas to the class. You may wish to research the ways in which communities and nations have responded to a large dead zone in the Black Sea as a starting point.

3A rich task

Dunwich's disappearing churches

Dunwich is a small coastal village located in south-eastern England. Its current population is only 100 people, but in the 13th century Dunwich was one of the largest ports in eastern England. With a population of around 3000 people, it was one of England's 10 largest towns. Merchants traded wool, grain, fish, wine and furs across the North Sea to Iceland, the Netherlands and France. Dunwich had eight churches, three chapels and two hospitals.

Storms, tides and longshore drift have all combined to make Dunwich a very different place today. The coastline at Dunwich has receded, on average, 1 metre per year and is now 2 kilometres west of its position in Roman times in the 4th century CE. Buildings that sit on the present-day cliffs were once 2 kilometres inland.

Large storms in 1286 and 1328 swept large areas of the town into the sea. Because there was so much material deposited in the sea, the harbour was blocked by the growth of a large spit. Trade and fishing were ruined and the population declined. By 1347, a quarter of the city had been lost, and the remainder of Dunwich disappeared into the sea over the next few hundred years. Most of the original buildings have disappeared, including all eight churches. The last one disappeared early in the 20th century (see Source 1).

Source 1 The last of Dunwich's old churches photographed in 1908 shortly before it collapsed into the sea.

skill**drill:** data and information

Mapping environmental change using multiple overlays

Creating overlay maps is a useful technique for showing and measuring environmental change. To complete a multiple overlay map follow these steps.

Step 1 Construct a base map of the region using the current topographic map. This should be traced rather than drawn freehand to make it as accurate as possible. Include key natural and human features such as the coastline, towns, roads and the extent of the marshes.

Step 2 Add labels such as rivers and town names. Add a north arrow, legend, title, scale and source.

Step 3 On a plastic sheet or piece of tracing paper, construct a map of the same region from the earliest map you have at the same scale. Remember that this map will sit on top of your base map, so features such as rivers that have remained the same should line up.

Step 4 Place the overlay map carefully on top of the base map and use a piece of tape like a hinge along one side to anchor the overlay in place.

Step 5 Add a title to the overlay map that does not cover the one on the base map. A north arrow, legend, scale and source should not be needed as these are the same as for the base map.

Step 6 Repeat steps 3–5 to complete an overlay from another map of the same region from another time. Hinge this at the opposite side of the base map with a piece of sticky tape.

Apply the skill

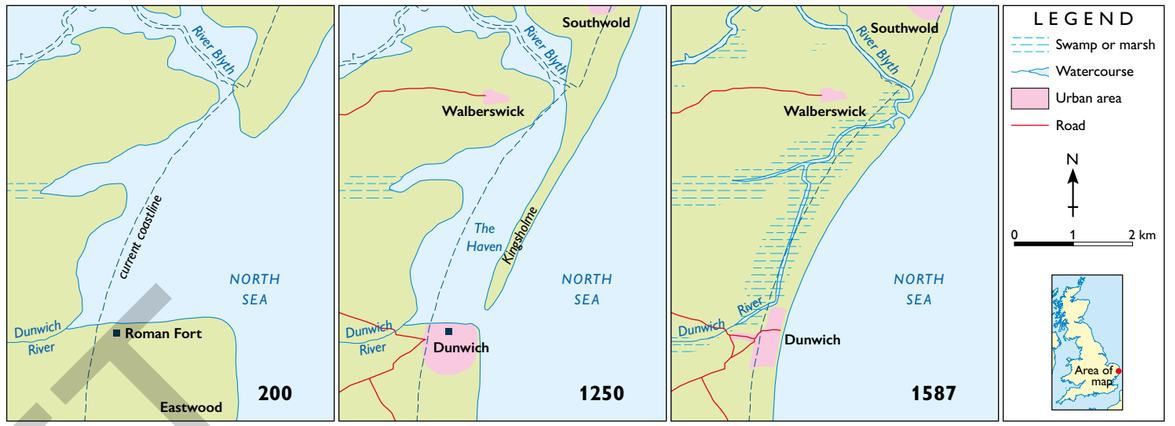
1 Complete a multiple overlay map using the topographic map in Source 3 as the base map, the 200 map as the first overlay and 1587 as the second overlay (both Source 2).

2 Describe the changes that occurred to this coastline between 200 CE and 1587. Was the dominant process during this time erosion or deposition?

3 What other features on the 200 map might help to explain the dominant process that occurred between 200 and 1587?

4 What effects did these changes have on human activities?

DUNWICH: CHANGING COASTLINE

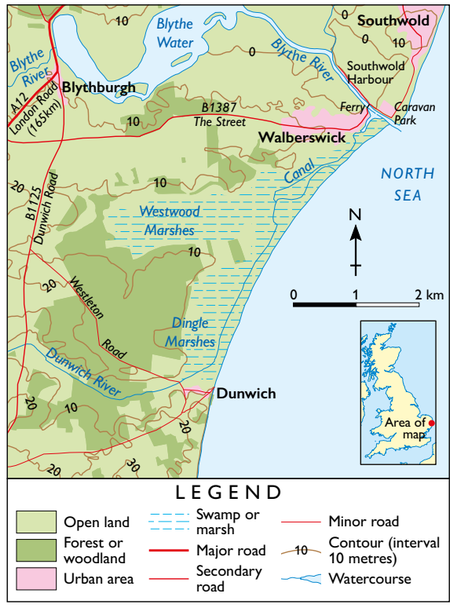


Source 2 Source: Oxford University Press

5 Describe the changes that have occurred to this coastline since 1587. Is the dominant process erosion or deposition?

6 Estimate the area of lost land since 1587. Do this by multiplying the length of this strip of land by its average width.

DUNWICH: TOPOGRAPHIC MAP



Source 3 Source: Oxford University Press

Extend your understanding

Conduct some extra research on the Internet and complete the following tasks.

1 In an effort to stop further erosion of this coastline the local authorities have commissioned a study into possible protection measures. The study reports that there are three main options available to the local community: sea walls, groynes and breakwaters. Which of these measures would you recommend the local authorities adopt to manage erosion on this coastline? Give at least three reasons for your answer.

2 Some members of the local community have campaigned against the hard engineering techniques suggested in the study. They argue that a managed retreat system is the only sustainable option. Conduct research on this approach and decide if you agree with them. Give some reasons to support your decision.

Source 4 The steep face of dunes at Dunwich are the result of continued erosion.

3.8 New ways of managing coasts

Many attempts have been made by people in the past to try to control the natural coastal processes of erosion, transportation and deposition. Unfortunately, due to a poor understanding of these natural processes, attempts have often made problems worse or simply moved them to another part of the coast. In addition, issues have tended to be managed on a local scale without regard for the broader environments that influence the coast such as river catchments and marine ecosystems.

More recently, a greater understanding of natural processes as well as a recognition of the widespread impacts of coastal management has led to new approaches. These include soft engineering (using natural processes), integrated coastal zone management (ICZM), and the protection of coastal ecosystems with special marine reserves.

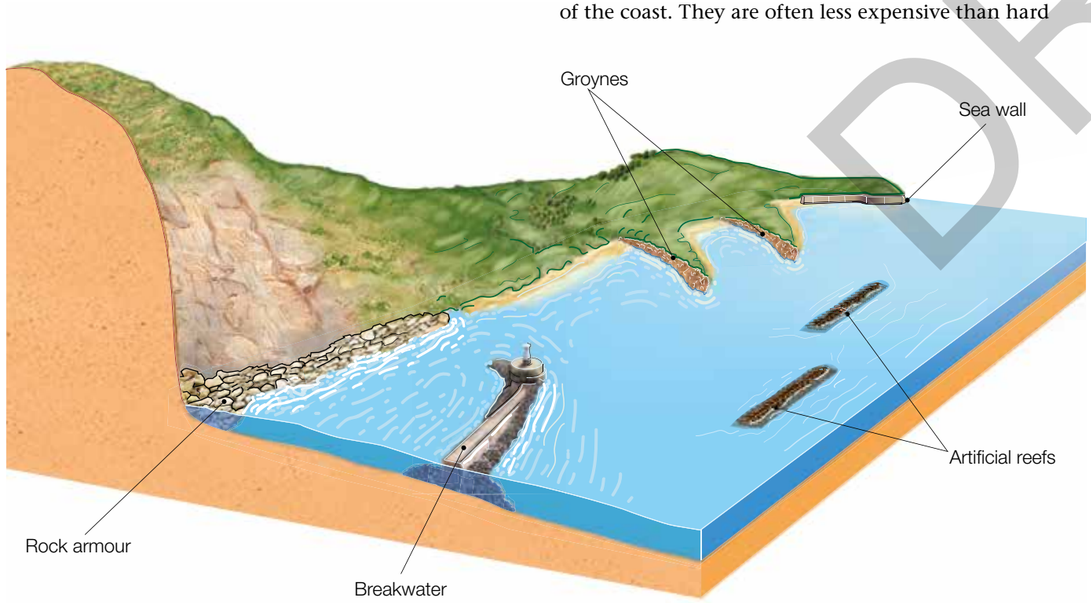
Managing natural processes: hard vs soft engineering techniques

One of the key principles underpinning effective coastal management is to work with natural processes. In the past, coastal management has tended to use 'hard' engineering. Hard engineering refers to the building of structures such as sea walls, groynes, artificial reefs, rock armour and **breakwaters** to protect coastlines from the erosive effects of waves or to trap sand. The main hard engineering techniques are shown in Source 1.

Many people in coastal areas like these hard options as the results are obvious and immediate. These structures tend to be expensive, however, and to have a high impact on natural environments. In many cases, they also create other problems or simply move the problem further along the coast.

By comparison, soft engineering coastal management techniques use the natural processes of the coast. They are often less expensive than hard engineering options, and are considered to be more sustainable as they have less impact on the natural environment. There are two main types of soft engineering – beach nourishment and managed retreat.

- Beach nourishment replaces beach material such as sand that has been removed by erosion or longshore drift (see Source 2). Beaches are a natural defence against erosion and coastal flooding and are a desirable feature of the landscape for residents and tourists alike. The natural process that eroded the beach in the first place will continue, however, so the beach needs to be nourished again and again.
- Managed retreat involves the relocation of human settlements and hard engineering defences such as sea walls and groynes so that the natural processes of erosion and deposition can take place. In many cases, low-lying areas flood allowing salt marshes, wetlands and mudflats to re-establish themselves in these areas (see Source 3). Over time, these habitats provide a natural defence against further erosion. Unlike many hard engineering techniques, managed retreat can be relatively inexpensive. However, people living in these regions can be unwilling to relocate and need to be compensated for the loss of their properties.



Source 1 A stretch of coastline showing a number of hard engineering techniques commonly used around the world today

Source 2 In the Netherlands a vast sand peninsula 2 kilometres long and 1 kilometre wide has been constructed. Dubbed the 'sand engine', waves and currents are redistributing the peninsula along the shore where it is expected to nourish the beaches and form sand dunes.

Source 3 Managed retreat at Abbotts Hall Farm in Essex, England, has allowed salt marshes to be re-established.

Check your learning 3.8

Remember and understand

1 What are the main differences between hard and soft engineering techniques?
2 Describe the process that is occurring at Abbotts Hall Farm (see Source 3).

Apply and analyse

3 What is beach nourishment? Outline some of the possible positive and negative environmental impacts of this soft engineering technique.

Evaluate and create

4 Match the hard engineering technique with its function and possible disadvantage.

Technique	Function	Possible disadvantage
Sea wall	Absorbs the energy of waves and allows the build-up of sand to form a beach	Can be difficult and expensive to find and place suitable rocks to form the wall
Groyne	Protects cliffs, land and buildings from erosion and can also lessen the risk of coastal flooding from storm surges	May weaken longshore drift and allow sand to build up – sometimes creating a tombolo
Rock armour	Absorbs the energy of waves and provides a safe harbour for boats	Can ruin the appearance of the beach and be costly to maintain
Breakwater	Traps material carried by longshore drift and allows a beach to be built up	Can be very expensive to build and maintain. The breakwater reflects rather than absorbs wave energy so waves may continue to cause erosion elsewhere.

3.9 Change at Rainbow Beach

Rainbow Beach is a small community located on a massive dune system that runs along the Queensland coast near the southern tip of Fraser Island. Formed over two million years, the dunes are part of one of the world's greatest sand dune complexes that includes Fraser Island – the world's largest sand island. In places, the dune system is 200-metres high and is held in place by large areas of scrub, forest and grasses.

While Aboriginal occupation of the region dates back 5500 years, European settlement began with a sand-mining operation north of the town in the mid 1960s. A road built to reach the sand mine was soon used by tourists to access Fraser Island and the new town of Rainbow Beach (see Source 1). The sand-mining operation finished in 1976 but the population of the small town continued to grow slowly. Now home to about 1000 full-time residents, visitor numbers swell in summer holiday periods as people arrive to use the camping ground as well as several motels and resorts.

The key management issue faced by the region is the erosion of the sand dunes, particularly during storms. This is an example of a potential conflict between natural processes and human activities. Sand dunes naturally change in response to long-term and short-term changes in wind patterns, sand supply and sea levels. The erosion of the foredune at Rainbow Beach (a dune ridge running parallel to the ocean) is a natural event. However, as the erosion is now putting buildings at risk and making the beach unsuitable for recreation activities, some local residents and the Gympie Regional Council are proposing to try and control the erosion.

Source 2 A 2009 storm severely eroded the Rainbow Beach foredune, placing the Surf Life Saving tower in danger of collapse.

A study of the region found that the risk of severe dune erosion at Rainbow Beach is very low but some people are still concerned that during a severe storm important buildings could be lost. The council plans to install large sandbags at the base of the dunes in front of the Surf Life Saving tower, along 260 metres, to slow erosion and protect a new amenity block that has been built on top of the dunes.

Source 1 An oblique aerial photograph of Rainbow Beach, looking south. The foredune and two blowout dunes (known locally as the Carlo Sand Blow and the Little Sand Blow) can be seen to the south of the town.

keyconcept: place

Coastcare at Rainbow Beach

There are 2000 Coastcare groups in Australia. Each group is made up of volunteers who work with local governments to identify problems and then work together to solve them. At Rainbow Beach, the local group has identified the loss of native vegetation, the trampling of dune vegetation by visitors accessing the beach, sand skiing on the sand blows, coastal erosion, environmental weeds, beach parking and rising sea levels due to climate change as the key issues in the area.

Some of the projects the Coastcare group at Rainbow Beach have undertaken include restoring native plants and removing weeds, protecting the dunes, monitoring bird populations and improving wetland areas.

For more information on the key concept of place, refer to page XX of 'The geography toolkit'.

Source 3 Rainbow Beach has a very active Coastcare group.

Source 4 A range of management strategies are in place at the main beach in Rainbow Beach. The fencing and walkway direct people to enter the beach on this path, protecting surrounding dunes.

Check your learning 3.9

Remember and understand

1 Describe the natural environment of Rainbow Beach.
2 Describe the human activities bringing about change to this place.
3 What is Coastcare?

Apply and analyse

4 Is the plan to place sandbags at the base of the dunes an example of hard or soft engineering? Give some reasons for your answer.
5 What management strategies can you identify in Sources 3 and 4? What is each strategy designed to achieve and how effective do you think each will be in achieving its aims?
6 What are the similarities and differences between changes at Rainbow Beach and changes at Abbotts Hall Farm in Essex (see Source 3 on page XX)?

Evaluate and create

7 The Little Sand Blow is increasing in size as it moves westward. Construct a flow diagram or field sketch that shows the:
- natural processes responsible for this movement
- human activities that may be contributing to the movement
- impacts of this movement on the environment
- possible responses by the local government and Coastcare group.

3.10 Integrated Coastal Zone Management (ICZM)

In response to the serious issues facing coastal and marine ecosystems, a major United Nations conference held in 1992, called the Earth Summit, proposed a new system for managing coastal environments. Known as Integrated Coastal Zone Management (ICZM) it is now a widespread practice in many coastal nations, such as New Zealand, India, Canada, Bangladesh and the Netherlands.

The United Nations recognises that one of the common issues associated with coastal management is that government departments and interest groups often propose very different solutions to issues depending on their own needs and interests. In most cases, these solutions ignore the needs of other coastal users. The many coastal interest groups include residents, the tourism industry, fisheries, farmers, forestry, manufacturing, mining, waste disposal, marine transportation and real estate developers.

The key to ICZM is that it seeks to pull together the many groups and individuals with an interest in the coast in an integrated way when devising a management plan. The key principles of ICZM are outlined in Source 1. The success of ICZM is then dependent on funding, consistent government priorities and the expertise available to organise and manage large projects.

Eight principles of Integrated Coastal Zone Management

- Involve all relevant governments
- Take a long-term view
- Use a holistic approach
- Consider local conditions
- Work with natural processes
- Get people involved
- Use a range of approaches
- Be prepared to change strategy

Source 1 The eight key principles of Integrated Coastal Zone Management

Source 2 The challenges facing many coastal environments require an integrated approach.

Case study: ICZM in Bangladesh

Each ICZM plan is designed to best address the issues of the country it has been developed for. In Bangladesh, for example, the key issues are rising sea levels that bring saltwater floods to low-lying communities and the impacts of cyclones and storm surges. It is estimated that a one-metre rise in sea level would leave 17 000 square kilometres of land in Bangladesh submerged and 15 million people without a home (see Source 3). It will affect 1 million hectares of farmland and threaten the fresh water supplies of three major cities.

In response to these threats the Bangladeshi government, with the assistance of the World Bank and expertise from the Netherlands, has developed an ICZM strategy that focuses on disaster mitigation. To date 150 000 hectares of mangroves have been replanted and more than 2500 cyclone shelters constructed.

Source 3 A nursery for mangrove trees. These will be used to replace some mangrove areas lost to farming and forestry and help to reduce flooding.

BANGLADESH: PREDICTED IMPACT OF 1-METRE SEA-LEVEL RISE

Source 4 Source: Oxford University Press

Check your learning 3.10

Remember and understand

1 What is ICZM?
2 How and why has ICZM been implemented in Bangladesh?

Apply and analyse

3 Source 3 on page XX illustrates a significant problem in many coastal areas – marine dead zones. Work with a partner to use the eight key principles of ICZM to suggest how people could manage this issue. For example, using a holistic approach might mean getting farmers to be more careful in their use of fertilisers. Perhaps nutrient levels in streams could be monitored so that farmers could better manage their application of fertiliser, particularly in times of heavy rainfall.

Evaluate and create

4 What do you see as some of the barriers to ICZM principles being adopted in Bangladesh?
5 What do you see as some of the advantages in managing coastal changes using this approach?

3.11 ICZM in the Netherlands

The province of Zeeland in the Netherlands is a large agricultural area that is home to more than 380 000 people (Source 3). Much of the region lies below sea level. The land has been drained and reclaimed, creating new islands that are linked by bridges and tunnels. The area has an intricate series of levees (known as dykes) and dams that hold back the waters of the North Sea and regulate the flow of the rivers to the sea. The province also supports a large fishing industry and is home to the largest national park in the Netherlands.

In Zeeland, ICZM is used to reduce flooding from storm surges. The largest of the flood protection dams, the 9-kilometre-long Oosterscheldekering, links two of the largest islands in Zeeland. The 62 steel doors that make up the barrier can be lowered or raised in response to tides, storms and other sea level changes (see Source 1). For most of the year, seawater can flow freely beneath the dam so that marine ecosystems in the bays and estuaries of the delta can be maintained.

The dam, which was opened in 1986, has been declared one of the Seven Wonders of the Modern World and bears a plaque with the words, 'Here the tide is ruled by the wind, the moon and us (the Dutch).' Any long-term changes in sea level due to climate change will place greater pressure on this region and on these amazing engineering works.

The series of dams, storm surge barriers and bridges have provided many benefits for the people of the Zeeland region. As well as protecting them from storm surges and flooding, large areas of former saltwater estuaries have been converted into freshwater lakes creating a reliable supply of water. The dams and bridges also link together island communities that had been isolated for hundreds of years and the calmer waters of the river mouths and estuaries are safe for shipping and recreational boating.

Source 1 The Oosterscheldekering storm surge barrier in Zeeland

Source 2 An aerial photograph of Zeeland showing a number of dams and storm surge barriers (including Oosterscheldekering)

ZEELAND: TOPOGRAPHIC MAP

Source 3 Source: Oxford University Press

Check your learning 3.11

Remember and understand

1 Why was the Oosterscheldekering constructed?

2 Locate the province of Zeeland in an atlas and describe its location.

Apply and analyse

3 Use the eight key principles of ICZM (see Source 1 on page XX) to comment on the flood protection provided by Oosterscheldekering. For example, how does this barrier take local conditions into account?

4 Examine Sources 2 and 3.

- **a** What factors do you think may be responsible for the large sandbanks forming in the Oosterschelde?
- **b** Identify the different land uses on the island of Schouwen-Duiveland.
- **c** Describe the relief of the island using the contour lines on the map.
- **d** Describe the southern shore of the island.

Evaluate and create

5 Draw a sketch map of the vertical aerial photograph in Source 2. On your map label the key natural and human features of the landscape.

6 The Oosterscheldekering is only one part of a much larger flood protection scheme. Use Google Earth to examine the region and find other examples of flood protection.

3.12 Protecting the coast

An effective way to manage and protect natural environments such as coasts is to give them legal protection. This helps ensure that harmful activities are banned or limited. In Australia, this is achieved mainly through a system of national parks (on land) and marine reserves (in the surrounding seas and oceans).

National parks

Each state and territory of Australia has a large number of special places, both coastal and inland, that the government has decided to protect. These might be as small as a single historic house or beach, or as large as a wilderness or national park. Despite the name, virtually all of Australia's more than 550 national parks are the responsibility of the individual state and territory governments.

Although management strategies differ between states, the common ideals are that the land, plants and animals within the parks have protection from activities that threaten their existence and that people should be able to visit these special places. This can lead to problems, as visitors who come to see these areas in their natural beauty may threaten the very environment they are visiting. The managers of the national parks have the task of controlling what visitors do in each park by limiting or restricting certain activities in sensitive areas.

Marine reserves

While national parks protect special places on land, Australia's diverse marine environments also need to be protected. In 2012, the Australian government announced the creation of one of the world's largest marine reserve networks. Around 3.1 million square kilometres of our oceans are now managed mainly for the purposes of biodiversity conservation. This is an area roughly equivalent to the land area of Queensland and the Northern Territory combined.

Managing a marine reserve is particularly challenging because, unlike national parks on land, fences and signs aren't easily erected to limit access to particularly sensitive areas. Instead, marine reserves are divided into zones, and certain activities are allowed, banned or limited in each zone. It is the responsibility of anyone who enters a marine reserve to be aware of the activities permitted within each zone.

Every marine reserve in Australia, except for the Great Barrier Reef which is recognised as a special case, has been assigned a particular management category (see Source 2). These are the same as those adopted in other countries and have been developed by the International Union for the Conservation of Nature (IUCN).

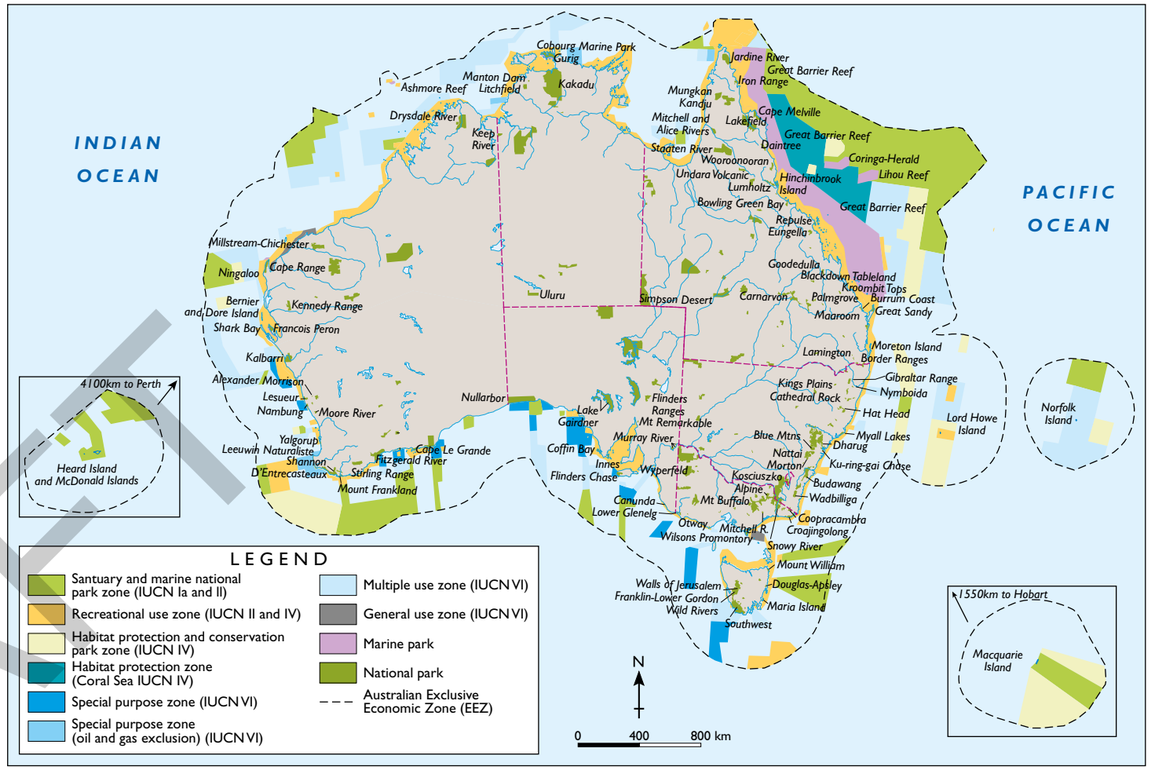
Source 1 Royal National Park is Australia's oldest. Established in 1879, it protects large areas of coastal rainforest and ancient sand dunes.

Source 2 The IUCN management categories for the conservation of marine reserves

IUCN number	Name of reserve type	Purpose of the reserve
Ia	Strict nature reserve	Managed primarily for scientific research or environmental monitoring
II	National park	Protected and managed to preserve its natural condition
IV	Habitat/species management area	Managed primarily to ensure the maintenance of habitats or to meet the requirements of specific species
VI	Managed resource protected area	Managed to ensure long-term protection and maintenance of biological diversity with a sustainable flow of natural products and services to meet community needs

Source 3 Freycinet Marine Reserve on Tasmania's east coast includes large areas designated as strict nature reserves due to the biodiversity of the coast's offshore seamounts (undersea mountains) and bird populations.

AUSTRALIA: NATIONAL PARKS AND MARINE RESERVES, 2012



Source 4

Source: Oxford University Press

Check your learning 3.12

Remember and understand

1 In what ways are natural environments protected in Australia?

2 What are the ideals behind the management strategies implemented in national parks?

Apply and analyse

3 Examine Source 4.
- **a** Where are Australia's largest marine reserves located?
- **b** Describe the location of marine reserves in the state in which you live.

4 Examine Sources 1 and 2, showing people in two protected coastal areas. Describe what they are doing and how this may impact on the natural environment. How could park managers in these areas limit these impacts?

Evaluate and create

5 There were many objections to the Australian Government announcement in 2012 that millions of square kilometres of ocean were to become marine reserves. In small groups consider which Australian groups would be likely to support this announcement and who would be likely to oppose it. Brainstorm the arguments that each of these groups would use to support their points of view.

6 Source 4 shows the extent of Australia's Exclusive Economic Zone (EEZ). Research this area and find out the benefits for Australia in having such a large EEZ. You may also like to find out about the Timor Gap and how this was created.

3.13 Reducing the impacts of coastal tourism

Tourism is the world's largest industry. It generates more than $US8 trillion a year in income and employs about 220 million people worldwide. Tourism in coastal areas has experienced a surge in recent years, and for many coastal communities it has become the largest contributor to their economy. While tourism has the potential to alleviate poverty and bring better infrastructure such as new roads and public services, it also has the potential to bring about major environmental degradation.

Tourism not only attracts visitors to coastal areas but also locals, who move to the coast for work, providing the goods and services tourists require. Tourism also brings developments such as hotels, jetties, roads, airports and shopping strips, often with minimal or hurried planning. The result is that many coastal tourism hubs are under significant environmental pressure.

The potential negative environmental impacts of tourism are many. Greater numbers of people bring increased pollution and landfill (see Source 1). As ecosystems such as mangroves, wetlands and reefs are removed to make way for hotel developments, there is a subsequent decline in biodiversity and an increased risk of beach loss from erosion and natural disasters. In addition, an increased demand for fresh water, food (especially seafood), energy and sanitation make tourism a huge consumer of natural resources.

Ecotourism: a way forward?

Ecotourism is one option that coastal tourism operators are using to make their industry more sustainable. It is also a strong marketing tool, appealing to tourists who want more environmentally friendly travel. The International Ecotourism Society (TIES) defines ecotourism as 'responsible travel to natural areas that conserves the environment and improves the wellbeing of local people'. TIES believes that those who implement and participate in ecotourism activities should:

- minimise environmental impacts
- build environmental and cultural awareness and respect
- provide positive experiences for both visitors and hosts
- provide direct financial support for conservation
- provide financial benefits and empowerment for local people
- ensure sensitivity to the host country's political, environmental and social climate.

Source 1 Cruise ships that carry up to 4000 passengers each contribute to the 70000 tonnes of waste generated annually from tourism in the Caribbean region.

key concept: sustainability

The Penguin Parade

One of Victoria's most popular tourist attractions is the nightly arrival of hundreds of Little Penguins at Summerlands Beach on Phillip Island. This natural event attracts around 1 million visitors per year, more than half of whom are from overseas. As well as a tourist attraction, the Penguin Parade is also an example of minimal impact ecotourism and conservation.

As a non-profit organisation, the Phillip Island Nature Park uses the income generated from the parade to protect, conserve and restore the natural environment of the region. The organisation has become a world expert on the Little Penguins as well as carrying out vital research on seals and seabirds. In order to protect the penguins, rangers undertake large- and small-scale revegetation and habitat restoration programs. As a result, the penguin population climbed from 19000 in the 1980s to 32000 in 2013.

Much of the restoration and revegetation work is on the site of a former housing estate located adjacent to the Penguin Parade. Between 1985 and 2010, the Victorian Government purchased and removed hundreds of holiday homes, as well as the roads, gardens, power cables and septic tanks that made up the Summerlands Estate. The area is now prime habitat for the penguins. Future plans include moving the visitor centre and car parks so that the land on which they now sit can also be restored to natural habitat.

For more information on the key concept of sustainability, refer to page XX of 'The geography toolkit'.

Source 2 Raised boardwalks and viewing platforms minimise the environmental impact of visitors to the Penguin Parade and allow penguins to move freely from the ocean to their burrows every evening.

Check your learning 3.13

Remember and understand

1 What is ecotourism?
2 In what ways can the Penguin Parade on Phillip Island be considered to be an example of ecotourism?

Apply and analyse

3 Source 1 shows a cruise ship docking at a Caribbean port. Describe the changes that have been made to the coast as a result of tourism that can be seen in this photo.
4 Compare these changes to those that have occurred at the Penguin Parade.

Evaluate and create

5 Imagine that an international tourism operator has proposed to build a port for cruise ships at Rainbow Beach (see Source 1 on page XX) and that that you have been appointed the company's environmental consultant. Brainstorm the impacts of this development on the natural environment. Use the ecotourism principles provided to make recommendations that minimise these impacts. Prepare a report for the tourism operator with your recommendations. You may like to include a map and sketches in your report.

3.14 Indigenous management of the coast

Prior to European colonisation in 1788, the coastal areas of Australia supported large numbers of Aboriginal and Torres Strait Islander peoples. The coasts provided a reliable source of food both from the sea and the surrounding land.

Today, nearly half of all Indigenous Australians live near the coast. Many maintain a close association with the coast through cultural and historic connections, through continued use of coastal resources and by law. In the Northern Territory, for example, Aboriginal communities own and manage approximately 85 per cent of the coastal land.

Coastal places with special significance to Indigenous Australians are under the same environmental threats as other coastal places: from population and economic growth, land use changes, climate change and the arrival of invasive species. Indigenous communities are now working with government to restore lands that are important to them. This joint approach means that factors of Indigenous heritage are taken into account when decisions are made about the use and restoration of degraded areas.

Source 1 An oblique aerial photograph of the Coorong, Lower Lakes (including Lake Alexandrina and Lake Albert) and Murray Mouth region of South Australia

Case study: Indigenous management of the Coorong

> The land and waters is a living body. We the Ngarrindjeri people are a part of its existence. The land and waters must be healthy for the Ngarrindjeri people to be healthy. We are hurting for our Country. The Land is dying, the River is dying, the Kurangk (Coorong) is dying and the Murray Mouth is closing. What does the future hold for us?
>
> Tom Trevorrow, Ngarrindjeri Elder, Camp Coorong, 2002

The region known as the Coorong, where the Murray River reaches the sea, covers an area of 14000 square kilometres. The Coorong was recognised as a Wetland of International Importance and as a breeding ground for many bird and fish species by the Ramsar Convention on Wetlands in 1985. Due to a combination of factors, including water extraction in the Murray–Darling Basin, drought and barrages (dams) built across the Murray to hold back sea water, the region has become severely degraded. In particular, the waters of the Coorong Lagoon and lakes have become saltier than the sea, wetlands have dried out and acidic soils have become exposed. Another cause of this degradation has been the building of dams that collect water during wet seasons and then release this water during dry seasons. This has disrupted the natural cycle of the Murray River of floods and droughts and had a dramatic effect on the natural ecosystems of the river, particularly at its mouth. In some years, so little water flows through the mouth that it closes, cutting off the lakes of the region from the sea.

The traditional owners of the region, the Ngarrindjeri people, maintain a strong connection with the lands and water of the Coorong. They believe that the health of their nation is closely linked to the environmental health of the region, and that a freshwater flow that allows plants and animals to thrive must be maintained.

The Ngarrindjeri community through the Ngarrindjeri Regional Authority (NRA) has formed a close relationship with the South Australian Department of Environment, Water and Natural Resources (DEWNR) to deal with short-term crises in the region and to plan for a sustainable future. This has resulted in the adoption of a long-term plan which aims to secure a future for the region as a 'healthy, productive and resilient wetland system that maintains its international importance.' The plan includes a number of specific goals:

- to protect and restore natural habitats
- to restore viable populations of native bird, fish and other animal species. Restoring the natural flow of fresh water to the Coorong and Lower Lakes are seen as a key component of this goal.
- to improve water quality and increase flows through the wetlands. It is proposed, for example, that very salty water be pumped out of the lagoon to the sea.
- to recognise the Ngarrindjeri community's association with the area.

Large areas of dunes, wetlands and farmland have already been replanted using native plant species as the first step in this plan to restore the Coorong area.

COORONG: INDIGENOUS LANDS AND NATIONAL PARKS

Source 2 Source: Oxford University Press

Source 3 South Australian Environment Minister Paul Caica and NRA chairman Tom Trevorrow meet at the Coorong in 2012 to sign a new management agreement for the region.

Check your learning 3.14

Remember and understand

1. Why did many Aboriginal and Torres Strait Islander peoples live near the coast in the past?
2. Why are the Ngarrindjeri people particularly concerned about the health of the Coorong ecosystems?

Apply and analyse

3. Use Source 1 to describe the natural environment of the Coorong and Lower Lakes. Include the water and land features that you can identify.
4. Examine Source 2.
   a. Describe and account for the location of Indigenous lands.
   b. Describe the locations of the barrages. Why have the barrages been built in these places? How would they change the natural environment of Lake Alexandrina and the Coorong?

Evaluate and create

5. Use the eight key Integrated Coastal Zone Management principles shown in Source 1 on page XX to devise a strategy to improve the health of the Coorong ecosystem.
6. Research which other wetlands in Australia are listed in the Ramsar Convention.

3B rich task

Ningaloo Coast

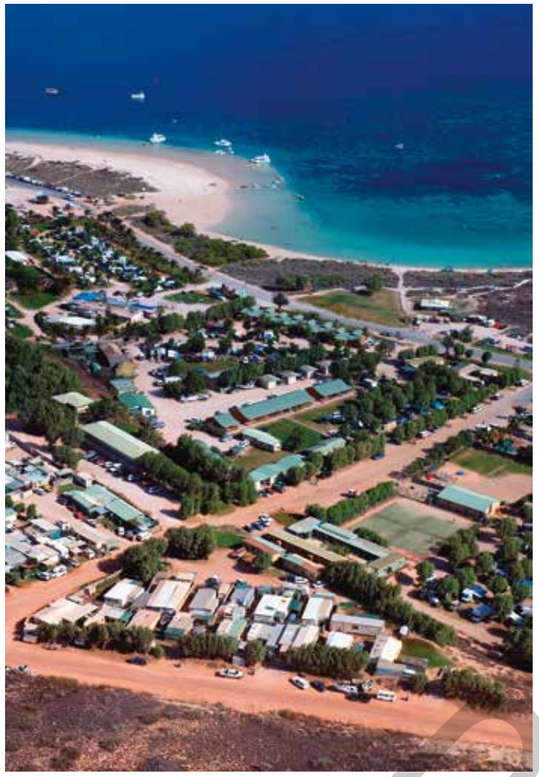
On the north-west tip of Western Australia is one of the world's most spectacular coastal environments. Long white beaches run along the shore, and visitors can swim out from the beach to Australia's longest fringing reef (a reef that lies extremely close to shore). The region has about 300 000 visitors a year, many of them arriving between April and July for a chance to snorkel with whale sharks. The region is also home to dugongs and visited by humpback whales and greenback turtles.

Much of the region is under some form of legal protection as part of the Ningaloo Marine Reserve and Cape Range National Park. It is also Australia's newest World Heritage site, having been added to the World Heritage List in 2011.

Though a remote and relatively pristine area, the Ningaloo Coast faces a number of potential environmental threats. These include:

- oil and gas exploration off the coast
- damage to coral reefs from boat owners anchoring in the fragile reef areas
- illegal fishing
- plastic bags killing turtles and whales by intestinal blockage
- damage to vegetation from off-road driving
- waste disposal and pollution
- increasing level of water consumption
- potential for bushfires
- invasive species (foxes, goats, cats) destroying or attacking native plants and animals.

Other potential issues in the area include a RAAF bombing range south of Cape Range National Park, which may threaten important limestone caves and sinkholes, and livestock from local farms that could damage vegetation if they are not appropriately managed. In addition, the development of oil and gas reserves in offshore basins and shelves could present a future threat to the coast and reef.



Source 1 The small town of Coral Bay is used as a launching point for whale watching and fishing boats.

skill**drill:** data and information

Analysing complex maps

Complex maps contain more than one set of information. Geographers use complex maps to analyse different features, reveal patterns and explain links between features in a given area. You can analyse a complex map by following these steps.

Step 1 Look carefully at the map and read its title to make sure you understand what is being shown.

Step 2 Examine the map's legend. Complex maps can have more than one part to a legend, and these parts will be represented on the map in different ways. For example, in Source 2 areas of colour are used to show the location of recreational use zones and state marine reserves. Different symbols are also used, to show roads and coastal water boundaries.

Step 3 Train your eyes to look for one set of information at a time. For example, look at solid blocks of colour on the map and work out what they tell you.

Step 4 Move to a different set of information by selecting another symbol or block of colour from the legend. Examine the map to identify this symbol or area of colour.

Step 5 Look for concentrations of the same symbol in areas to see if patterns exist.

Step 6 Note any patterns you can find on the map between different features and locations.

Step 7 Describe the degree to which patterns are connected.

Step 8 Try to suggest reasons for the connection between the two patterns.

Apply the skill

Look at the map of Ningaloo Marine Reserve (Source 2).

1 Find the symbol for multiple use marine zones in the legend then locate these areas on the map. Describe the concentration of these areas.

2 What relationship is there between the multiple use marine zones and the location of recreational use areas?

3 Describe the location of the Ningaloo World Heritage area.

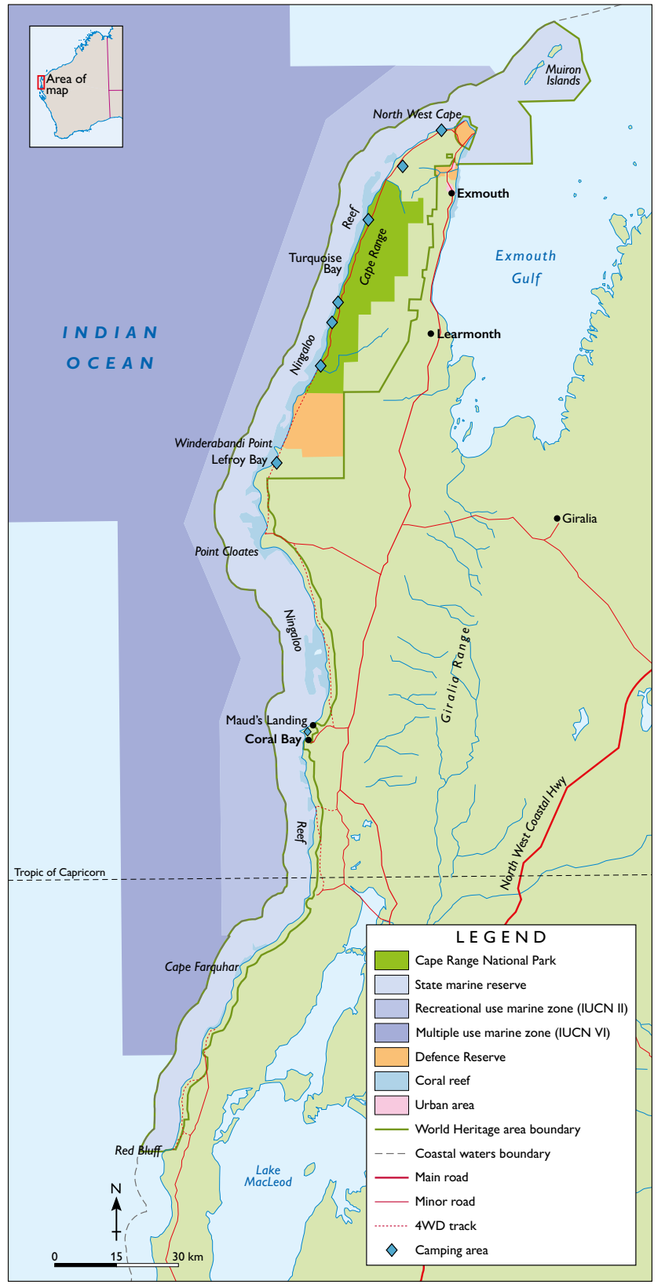
Extend your understanding

Do some further reading on the Internet to complete the following tasks.

1 Research Ningaloo's World Heritage listing.
   - **a** What does World Heritage mean?
   - **b** Why are sites placed on this list?
   - **c** Why was the Ningaloo Coast added to the list?

2 In the early 2000s, a large resort and marina called Coral Coast Resort was planned for the coastal area to the north of Coral Bay known as Maud's Landing. Find out about these plans and why the resort was not built.

NINGALOO MARINE RESERVE AREAS



Source 2 Source: Oxford University Press

3.15 The role of geographers in managing environmental change

Geographers have an important role to play in the management of environmental change. Because geographers draw on knowledge and skills from the natural sciences (such as geology, biology, chemistry and physics), the social sciences (such as psychology, history and economics) and humanities (such as philosophy) they are uniquely placed to see the 'whole picture' when examining environmental change. Geographers can, for example, consider the reasons why people act in a certain way and consider the impacts of these actions on the environment. They can also help to explain why people respond to change in different ways and, most importantly, recommend a course of action that is beneficial to both the natural environment and people.

Fieldwork case study

When examining environmental change such as coastal erosion, geographers often begin by developing a set of geographical questions. The geographer then sets out to answer these questions using a range of geographic tools. One of the most useful tools is fieldwork – visiting the environment being studied and observing it firsthand.

When exploring changes at the coast, geographers use a range of specific techniques. These include constructing cross-sections of dunes, cliffs and other landforms, photographing evidence of change and measuring **longshore drift**. By visiting the same site at regular intervals (for example, once a year) geographers can also observe changes that have occurred between their visits. It may be important to visit the site at different times of the year to observe seasonal changes such as the effects of storm waves during winter or the impacts of holiday-makers during summer. The following case study is an example of the sort of environmental issues that might be explored by a geographer completing fieldwork.

Case study: Coastal issues at Old Bar, New South Wales

The small coastal town of Old Bar, located on the mid-north coast of New South Wales, faces a range of environmental changes. The town is located on a dune system within a river delta and is home to around 4000 permanent residents. It also has a large number of visitors, particularly during holiday times. The dunes are eroding rapidly at a rate of up to 1 metre per year and this is threatening homes and infrastructure. Studies have found that the dunes in this area have experienced periods of erosion in the past but that rising sea levels are making the current situation more severe.

Local residents are worried that trail-bike riders on the dunes are causing more damage and that the old site of a sand-mining business, which operated back in the 1980s, is an erosion hot spot. Some are also concerned that a proposed 10-hectare housing estate south of the town will further damage the dunes. Many residents believe that building two artificial reefs at the cost of $10 million would protect the coast from further erosion. However, an expert study recommended that a managed retreat coupled with a sloping sea wall of sand-filled bags and regular beach nourishment was a better option.

Source 1 An oblique aerial photograph of Old Bar showing the location of a proposed real estate development.

Photographs from fieldwork at Old Bar

Source 3 Dune erosion has destroyed some homes and is threatening others.

Source 2 In some places the beach is composed of pebbles as well as sand.

Source 4 Evidence of erosion includes a large Norfolk pine tree which has fallen onto the beach.

Check your learning 3.15

Remember and understand

1 Why is fieldwork an essential tool for geographers?
2 Why are geographers uniquely placed to help describe and manage environmental change?

Apply and analyse

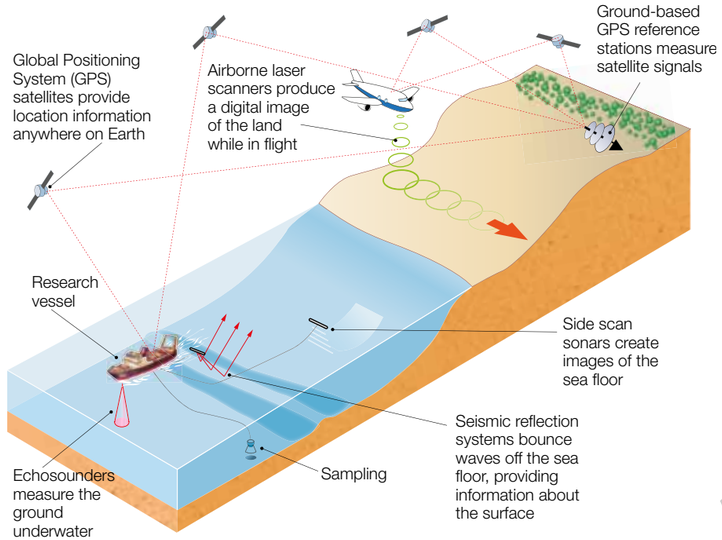
3 Look carefully at the photographs on these pages. Create a series of geographical questions that could be used as the basis of a field trip to Old Bar. You may like to begin your questions with the words 'what', 'where', 'how', 'why', 'what impact' and 'what should'. Share your questions with a partner and then with the class.
4 Why would many residents prefer artificial reefs to be constructed rather than implementing the soft engineering approach of managed retreat?
5 What would be the advantages and disadvantages of sea walls and beach nourishment at Old Bar?

Evaluate and create

6 Read page XX of 'The geography toolkit' and use the tip on conducting successful fieldwork to design your own fieldwork investigation of Old Bar. Outline the five stages of your inquiry, making sure that you investigate:
   a the causes of coastal erosion
   b the effects of coastal erosion
   c the responses to coastal erosion.

3.16 Using spatial technologies

Geographers use a range of tools to describe and predict environmental change. These tools may be as simple as direct observation or involve measuring and recording the changing width of a beach with a tape measure. Increasingly, however, digital tools are being used to measure change and to help manage dynamic environments such as coasts, forests and farms (see Source 1). These tools rely on the collection of data from sources such as the **global positioning system (GPS)**, aerial photographs, ships and tide meters. The data collected is then analysed by computer programs and made available for use by **geographic information systems (GIS)** and **digital terrain modelling (DTM)** as well as other applications.

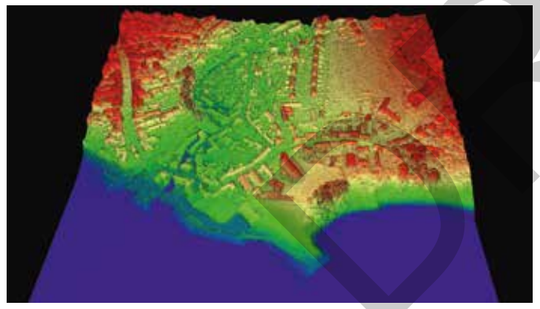


Source 1 Geographers use a range of digital data collection methods.

As more and more coastal communities become concerned about the impacts of rising sea levels due to climate change, there is a greater demand for more advanced methods of monitoring the coastline. This is driving a boom in coastline monitoring through spatial technologies and is making more data and information about coastal changes available to geographers than ever before.

Digital terrain models (DTMs)

A DTM shows the relief (or shape) of the land in three dimensions (see Sources 2 and 3). Much of the data needed to create a DTM is collected from special sensors on satellites. This data is represented as a raster (grid of squares) and manipulated by technicians to form a model of the Earth's surface. These models can help geographers 'see through' features of the environment such as coastal waters and forests to examine the terrain below. They can be used to predict areas at risk from erosion and other hazards, such as coastal flooding. This information can then be used to help manage the environment to limit the effects of these potential hazards and disasters.



Source 2 In this DTM, the height of the land and the depth of the sea are represented by changes in colour.

Source 3 The same data used to create the first DTM has been combined with an aerial photograph to create a more realistic digital representation of the landscape.

key concept: interconnection

Geographic Information Systems (GIS)

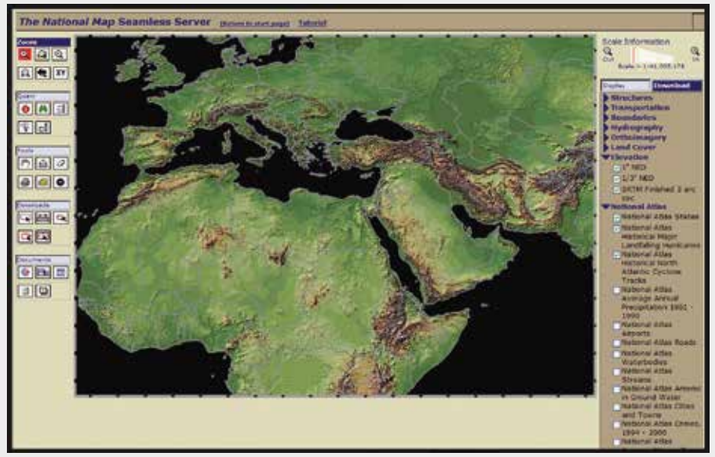
GIS uses digital data to create a series of maps of a particular landscape. Each map focuses on a different aspect of the environment, such as the ocean depth, salinity, roads, settlements and relief. Using a GIS program, the maps are presented as a series of layers which can be switched on and off. This enables geographers to compare different aspects of the environment and look for interconnections between them.

GIS is particularly useful in examining and managing change in coastal environments. It allows geographers to isolate different and competing land uses, to see beyond political and physical boundaries and to measure change over time.

The Netherlands provides a good example of the use of this technology. Every year, the entire 350-kilometre-long Dutch coastline is digitally mapped and measured using methods similar to those shown in Source 1.

The maps and cross-sections produced in this annual survey are compared to the first survey of this kind, undertaken in 1990. Areas of coastal erosion and accretion (growth) are clearly displayed on GIS maps and are used by coastal managers to make changes in coastal defence strategies such as beach nourishment and sea walls.

For more information on the key concept of interconnection, refer to page XX of 'The geography toolkit'.



Source 4 A GIS map of North Africa and Europe. A range of GIS tools are shown in the left-hand margin and the map layers available in the right-hand margin. By manipulating these tools and layers, geographers can create their own maps and examine regions in great detail.

Check your learning 3.16

Remember and understand

1 Why do geographers use digital tools?
2 How is data collected to create GIS and DTMs?

Apply and analyse

3 Examine Sources 2.55 and 2.56.
  a What evidence is there that this coastline is under threat of erosion?
  b Which of these DTMs would be most useful to an engineer planning the placement of new groynes? Give some reasons for your answer.
  c Who would find these models useful?

Evaluate and create

4 Examine Source 1 on page XX showing the proposed real estate development site at Old Bar in New South Wales before completing the following tasks.
  a Imagine that the developer at Old Bar has asked you to suggest a range of digital data collection methods to create a GIS that will assist them with their planning. Describe the most relevant data collection methods to use.
  b Now sketch the map layers that you think the developer would most like to see included in the program.

3.17 Understanding spatial variations

Each place on the Earth's surface is unique. In the same way that no two people are exactly alike, natural environments such as forests, glaciers and coasts all differ. The reasons for these variations may be complex, but recognising them is a critical part of understanding why different places have different problems. Geographers examine these differences (also known as **spatial variations**) and use what they find to propose solutions and responses to environmental change and/or issues. It is important to remember that these solutions and responses need to be site-specific. They may work in one place but not work in another. Some environments are also more resilient to change than others.

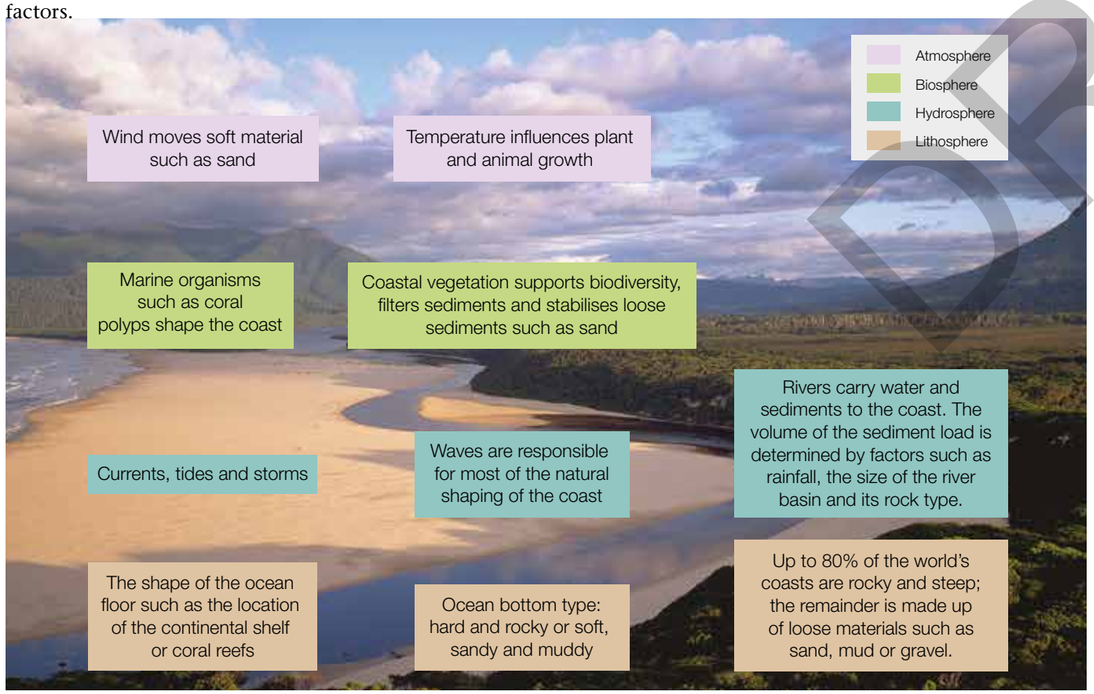
The factors that need to be looked at when considering spatial variations in environments can be divided into two groups – natural factors and human factors.

Natural factors

Geographers often use models to help them understand processes that take place in the natural world. One of these models (known as the four spheres model) is particularly useful when investigating the natural factors that influence spatial variations. The four spheres that interact to form unique landscapes include:

1. the **atmosphere** – all of the gases that surround the Earth
2. the **biosphere** – all living things on Earth (i.e. plants, animals, humans and other organisms)
3. the **hydrosphere** – all of the water on Earth (i.e. in solid, liquid and gaseous forms)
4. the **lithosphere** – the outer rocky layer of Earth (i.e. crust).

Source 1 provides an example of how the four spheres model can be used to investigate and describe how natural factors interact to shape coastal environments.



Source 1 An analysis of an Australian coastal environment using the four spheres model

Source 2 The Gold Coast in Queensland is an example of an anthropogenic coast.

Human factors

People have always been drawn to the coast. Coastal environments provide us with many ecosystem services that we need to live and thrive such as food, shelter, transport, recreation and flat land for building. Areas near the mouths of rivers also provide fresh water and fertile soil. Human influence tends to be concentrated in certain places on the coast where these ecosystem services are most available. In these places, the coastlines are now so altered by human activities that some geographers refer to them as anthropogenic coasts (see Source 3), meaning humans have become the dominant force in these environments.

Source 3

Features of an anthropogenic coast
• Coastal protection constructions such as sea walls
• Cleared vegetation
• Dredged shipping channels
• Mining operations including sand mining and oil drilling
• Fishing and aquaculture
• Coastal agriculture
• Forestry
• Shipbuilding and other industries
• Shipping and port facilities
• Dammed rivers for hydroelectric power generation
• Naval and other defence operations
• Tourism and recreation
• Roads
• Draining coastal wetlands and salt marshes
• Land reclamation
• Cities

Check your learning 3.17

Remember and understand

1. Name the four interconnected spheres that make up the Earth.
2. List four ecosystem services that the coast provides us with.

Apply and analyse

3. Would rocky coasts be more resilient to change than sandy coasts? Give some reasons for your answer.
4. Choose a section of coastline you have visited or know well and describe the natural and human processes that have shaped it.

Evaluate and create

5. In the same way that natural factors can be classified, so too can human factors. One method is to classify them as social, historic, environmental, economic, political or technological (making the acronym SHEEPT). Use this method to classify the human factors listed in Source 3. For more information on the SHEEPT method, refer to page XX of 'The geography toolkit'.

3.18 Assessing environmental change

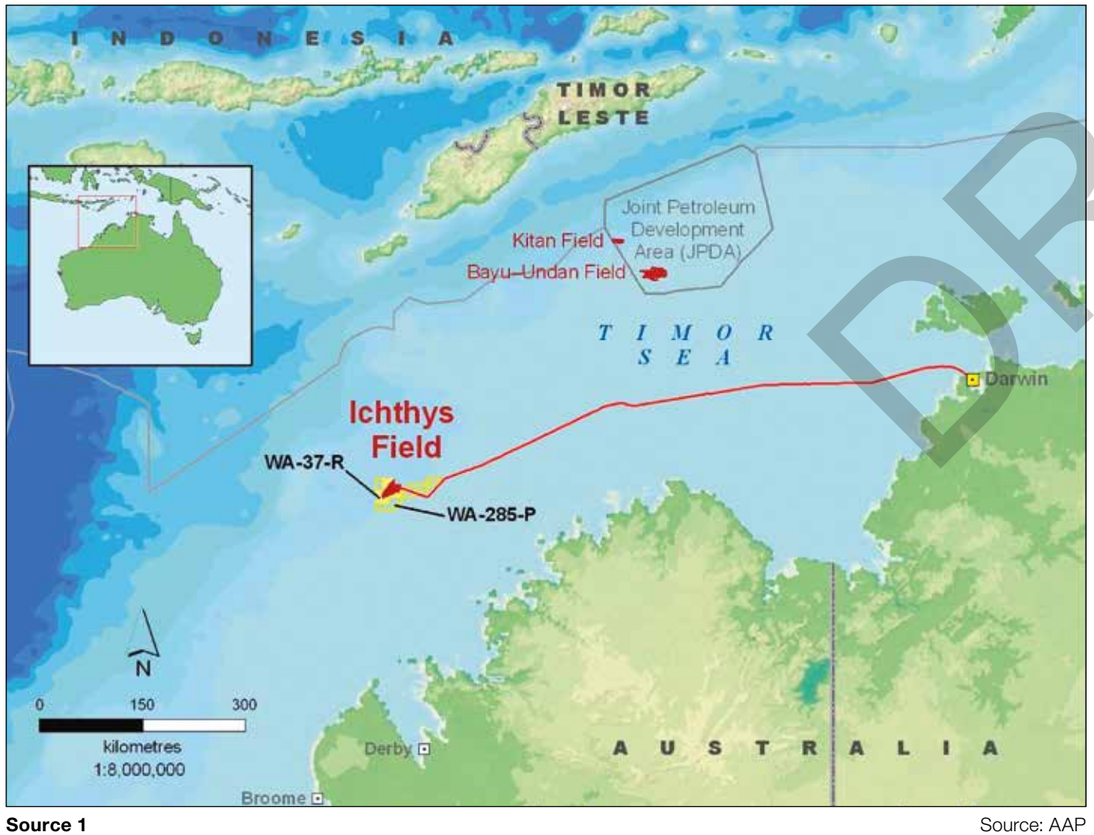
In Australia, and in many other countries, building projects that are likely to impact on the natural environment must go through a process of environmental assessment. This involves a study of the likely impacts of the proposed project on the environment. The resulting document is called an Environmental Impact Statement (EIS) and is generally prepared by a geographer with specialised training.

When completed, the EIS is submitted to the relevant authority, for example the state planning ministry. The state planning ministry then has the authority to stop the project if they feel it has too much impact on the environment. Alternatively, they may request changes to aspects of the project in order to minimise the environmental impacts.

Case study: The Ichthys Project

The Ichthys Project (named after the classical Greek word for 'fish') is the largest oil and gas mining project to be undertaken in the Northern Territory. It is being built by INPEX, a worldwide gas exploration company, and its partners, with construction in the Timor Sea and Darwin. Natural gas, an extremely valuable energy source, will be extracted from beneath the Timor Sea and then transported to Darwin through a pipeline that will be laid on the seabed.

ICHTHYS PROJECT: LOCATION OF THE PROPOSED OFFSHORE WELLS, PIPELINE AND ONSHORE PLANT



Source 1 Source: AAP

The massive project is set to deliver significant social and economic benefits to Australia, bringing jobs, training, business opportunities, and advancement for the energy industry.

The three stages of the project – the offshore wells, the pipeline and the onshore facilities at Darwin – were all assessed for their environmental impacts before the project was allowed to proceed.

The onshore processing plant is being constructed on Middle Arm Peninsula to the south of Darwin and close to an existing natural gas plant. The following factors were studied as part of the three-year environmental assessment of the project:

- The impact of dredging parts of the harbour and the disposal of the dredged material on corals, sea grass and marine animals such as dolphins, dugongs and turtles. Dredging involves the removal of a large rock shoal by methods such as using explosives (three explosions per day for 57 weeks) or specialised dredges.
- An increase in underwater noise and the impact of this on dolphins which use sound to navigate.
- Impacts on shore birds and wading birds, particularly from the loss of mudflat habitat and the potential of oil spills.
- Impacts on fish species including the commercially important barramundi and on crustaceans, especially mud crabs.
- The removal of areas of mangrove forest, including plants listed as vulnerable to extinction, and the possible impacts of increased sedimentation on other areas of mangrove.
- Disposal of waste water, including sewage from the plant and the village built to house up to 3500 construction workers.
- Air and noise pollution and the effects of these on Darwin residents.
- Greenhouse gas emissions. The project, when completed, will be the largest emitter of greenhouse gases in the Northern Territory and one of the largest in Australia.

Based on their assessment of the impacts and potential benefits of the project the Northern Territory government allowed it to go ahead, as long as the company made a number of changes to reduce the potential environmental impact and agreed to a range of recommendations. These included:

- monitoring and researching the health of Darwin Harbour for 40 years
- long-term research of coastal dolphins to assist with their conservation
- a $3 million donation to Charles Darwin University to assist in oil and gas research
- an extensive mapping project covering the natural habitats of the Darwin region.

Source 2 A computer-generated image of the completed onshore processing plant near Darwin

Check your learning 3.18

Remember and understand

1 What is an Environmental Impact Statement (EIS) used for?
2 List the potential benefits as well as potential negative impacts of the Ichthys Project.

Apply and analyse

3 Examine Source 1.
  a Estimate the total length of the pipeline.
  b What are some of the potential impacts of the pipeline?
4 Examine Source 2. Describe the changes to the natural environment as shown in this computer-generated image.
5 Why would INPEX agree to the range of recommendations put forward by the Northern Territory government?

Evaluate and create

6 Explain the importance of each of the Northern Territory government's recommendations for the natural environment.
7 Brainstorm with your classmates what cultural, economic and environmental factors a government would need to consider when deciding whether or not to approve a project such as the Ichthys Project.

3.19 Developing responses to environmental issues

<< A very full spread. If Source 2 needs to be large please cut a para of text or trim title. >>

Once an environmental issue has been identified and assessed, it is often necessary to come up with a suitable response. Remembering that each environmental issue is unique, the environmental response must also be individually designed for that particular environment. Management responses that are effective in one place may be ineffective or even damaging in other places.

When considering a suitable response to environmental issues, important questions to ask include:

- Does the response deal with the causes of the issue as well as its effects?
- Is the response affordable, both in the short and long term?
- Is the response beneficial to all natural environments, or does it just move the problem and perhaps result in greater environmental changes in another place?
- Is the response fair to all of the relevant stakeholders?

Case study: Sierra Leone's disappearing beaches

Sand mining is having a serious environmental impact on the coastal environment in the African nation of Sierra Leone.

The capital city, Freetown, is experiencing a population and building boom. The population is growing by about 70000 people per year and there is a growing demand for new housing as well as commercial and industrial buildings. Many of these buildings are made from concrete which requires vast quantities of cheap, good quality sand. Sand-mining operations can involve up to 40 trucks at a time, each with a team of diggers, who shovel sand from a beach. This process is creating changes in both the natural environment, as the sea is able to penetrate further inland, and the human environment. Local residents are being affected as the remaining dunes are eroding rapidly and houses are falling into the sea.

Possible responses

Sierra Leone is trying to build a viable tourism industry to boost the nation's economy but tourist resorts are

Source 1 Sand mining on Hamilton Beach, Freetown, Sierra Leone

in danger of losing their beaches and their potential customers. A possible response to this problem would be to declare sand mining illegal and arrest those who continue to take sand from the beaches. Another possible response to this problem would be the importation of sand from other places.

Some of the factors that would need to be considered when planning a response to the issue of sand mining in Sierra Leone are:

- Sierra Leone is one of the world's poorest countries. Many people struggle to earn enough money to provide adequate food, shelter and water for their families. Sand mining provides a source of income for hundreds of men and their families.
- As a developing country, levels of technology in industries such as transport and mining are low.
- Coastal areas are often heavily used for many purposes: fishing, residences, tourism, recreation and a source of building materials.
- As dunes disappear, coastal erosion is accelerating and is now up to 6 metres per year in some places.
- Global climate change is expected to raise sea levels on this coast and to increase the number and severity of storms generating large, destructive waves.
- Sierra Leone's police force has not enforced previous bans on sand mining.
- Corrupt local officials accept payments from the construction companies to continue the sand mining.
- The main sources of sand, Hamilton and Lakka beaches, are located within Freetown's urban sprawl (see Source 2).

Source 2 Hamilton and Lakka beaches shown on the edge of Freetown's urban sprawl

skill**drill:** place, space and interconnection

Evaluating possible responses to environmental issues

Complex environmental issues often require complex responses. Geographers can propose possible responses or assess the environmental, economic and social sustainability of responses proposed by governments. Geographers can evaluate possible responses against a set of criteria. For example, the issue of sand mining in Sierra Leone requires an urgent response. If the situation continues, hundreds of people will lose their homes, the tourist industry will collapse and many people will lose their jobs. The area around Freetown will also lose many ecosystem services such as storm protection.

When evaluating possible responses to environmental issues such as the one in Sierra Leone, follow these steps:

Step 1 Read all of the background information carefully and make sure that you understand it well. You may also like to conduct some additional research on the issue if anything is unclear.

Step 2 In some cases, you may be required to suggest your own responses to environmental issues. In other cases, you will evaluate responses that have been suggested by others. For example, in the case of Sierra Leone:

- Response 1 – Declare sand mining illegal and arrest those who continue to take sand from beaches
- Response 2 – Import sand from other places.

Step 3 Develop a set of criteria to evaluate each of the suggested responses. These criteria should consider all sides of the issue, for example economic viability, environmental sustainability and social justice.

Step 4 Create a table to evaluate each response against each criterion. You may like to use symbols such as:

√ – criterion met % – criterion partly met
× – criterion not met ? – unsure.

Step 5 Use the data in your table to select the best response to the issue. You may need to reconsider particular aspects of the response (and make modifications) to come up with the best response. In other cases, you may need to combine aspects of more than one response to come up with the best solution.

Step 6 Based on your evaluation, present your final recommendation. Include maps and diagrams to help describe the proposal and the intended benefits.

Apply the skill

1 Follow the steps to develop a sustainable response to beach sand mining in Sierra Leone.

Check your learning **3.19**

Remember and understand

1 Why is beach sand mining a problem?
2 Why doesn't the Sierra Leone government just ban beach sand mining?

Apply and analyse

3 List the effects of illegal sand mining and rank them from the most to least significant in terms of the severity of environmental impact.

Evaluate and create

4 Beach sand mining also occurs in other countries including Liberia, Morocco, India, Jamaica and New Zealand. Research beach sand mining in one of these places and make a list of the underlying reasons for the practice.
5 Using Source 3 on page XX, identify the human factors that are shaping the coastline of Sierra Leone. How do these differ from those shaping the coastline at Old Bar (see pp. XX)?

<< Intro para could be one line smaller to reduce the cramped vibe >>>>

<< Also is this a 4 page rich task? >>

3C rich task

Gulf of Mexico oil spill

The Gulf of Mexico lies between the United States, Mexico and Cuba and contains one of the world's busiest oilfields. There are almost 4000 active oil wells in the Gulf along with a further 27 000 abandoned wells.

In April 2010, an active oil well operated by British Petroleum (BP), known as the Deepwater Horizon, exploded and sank to the sea floor, 1500 metres below the surface. Oil gushed from the well for three months while BP and American authorities tried desperately to plug the hole. The results were catastrophic. An oil slick covering 1500 square kilometres started moving towards the American coastline. Thousands of sea birds, fish, dolphins and turtles were covered in oil and died. Other animals along the shoreline such as crabs and molluscs were also badly affected. Local industries such as fishing and tourism collapsed, and many people lost their livelihoods.

skill**drill:** data and information

Analysing environmental accidents using complex maps

In the case of an environmental accident, the impacts of the accident usually have multiple causes. Geographers try to go beyond the obvious cause (the oil well blew up) to explore other factors that have influenced the course and extent of the impacts. These are generally a combination of natural processes and human activities. Complex maps contain more than one set of information. Geographers use complex maps to analyse different features, reveal patterns and explain links between features in a given area. You can analyse a complex map by following these steps.

Step 1 Look carefully at the map and read its title to make sure you understand what is being shown.

Step 2 Examine the map's legend. Complex maps can have more than one part to a legend, and these parts will be represented on the map in different ways. For example, in Source 1 natural environments are shown using a range of colours and towns and cities with a range of symbols.

Step 3 Train your eyes to look for one set of information at a time. For example, look at solid blocks of colour on the map and work out what they tell you.

Step 4 Move to a different set of information by selecting another symbol or block of colour from the legend. Examine the map to identify the symbol or areas of colour.

Step 5 Look for concentrations of the same symbol in areas to see if patterns exist.

Step 6 Note any patterns you can find on the map between different features and locations.

Step 7 Describe the degree to which patterns are connected.

Step 8 Try to suggest reasons for the connection between the two patterns.

Apply the skill

1 Using Source 3.65, analyse the causes and effects of the Gulf of Mexico oil spill. Once you have completed your analysis, fill in the table below as a way of organising your results. An example has been done for you.

Geographic factor	Possible contributing feature	Description of feature
Physical environment	Shape of the coastline	The Gulf of Mexico is an extensive broad bay which opens to the Atlantic Ocean and Caribbean Sea in the east.
	Features of the seabed	
	Location of coastal marshes	
Natural processes	Ocean currents in the Gulf	
Demographics	Distribution of towns and cities	
	Location of oil refineries and oil rigs	

GULF OF MEXICO: EXTENT OF OIL SPILL FROM DEEPWATER HORIZON, 2010

Source 1 Source: Oxford University Press

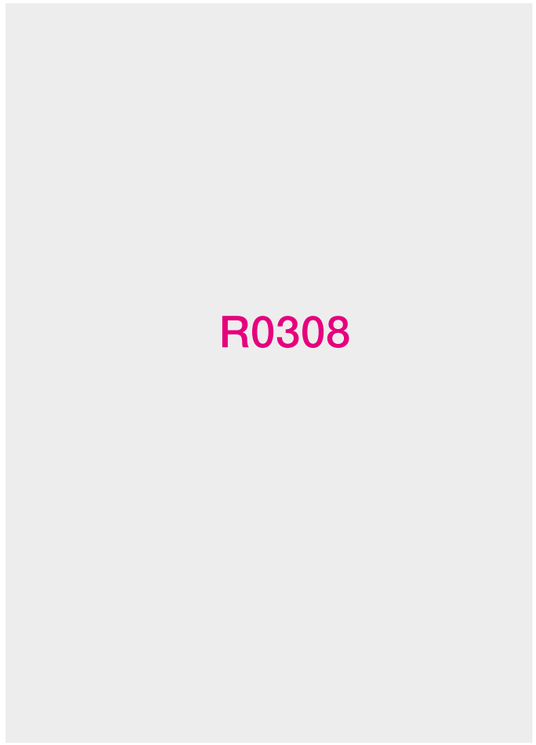
Extend your understanding

In addition to complex maps, geographers use information from a range of additional sources to explain how the impacts of the accident progressed and to look at the longer-term impacts on the environment. Research the Gulf of Mexico oil spill on the Internet before answering the following questions.

1 Can you identify any contributing factors to the accident that are not shown on Source 2 (for example any economic or technological factors). What was their role in the accident? Add these factors to the table provided.

Contributing factors	Possible contributing feature	Description of feature
Economic factors	Level of development of USA	
	Importance of oil in USA economy	
	Tourism and fishing industries	
Technological factors	Operation of oil refineries and oil rigs	
	Technical failure of oil rig	

2 Since 2000 more oil wells have been drilled in much deeper water than in the past. Some experts believe that this was an important factor in this disaster. Why do you think wells are now being drilled in much deeper water?



Source 2 The fire on the Deepwater Horizon oil platform

Source 3 Marine animal populations in the Gulf of Mexico were devastated by the oil spill in 2010. In total, around 750 million litres of crude oil was released into the gulf affecting fish, dolphins, whales, sea turtles and birds, as well as molluscs across the sea bed.

3 Sources 4 and 5 show some of the community responses and protests to the Gulf of Mexico oil spill. Shortly after the incident in 2010, civil and criminal charges were brought against BP in the American courts.

Conduct research to answer the following questions:

- **a** What kinds of charges were brought against BP in the aftermath of the Gulf of Mexico oil spill in 2010? Who brought these charges against BP?
- **b** How did BP plead in the case?
- **c** How was the case resolved? How was BP penalised and how much did they have to pay?
- **d** Do you consider this amount to be appropriate? Give reasons for your answer.

Source 4 Consumer advocate Barbara Holzer pours chocolate syrup over a model duck while demonstrating with about 50 others in front of the Washington offices of oil giant BP to protest the company's handling of the Deepwater Horizon oil spill June 4, 2010. Representatives of Greenpeace, Public Citizen, Energy Action Coalition, Chesapeake Climate Action Network and others tried to carry out a 'mock citizen's arrest' of BP CEO Tony Hayward but were turned away at the building's doors.

Source 5 Activists hold signs during a protest in front of the Hale Boggs Federal Building on the first day of the trial over the Deep Water Horizon oil rig spill on February 25, 2013 in New Orleans, Louisiana.