Unit 1 Landscapes and landforms

Coastal landscapes

Coasts are very dynamic places – they are constantly changing. Crashing waves, strong currents, tidal waters and hazards (such as tsunamis) all transform coastal landscapes. Along the east coast of England and Scotland the coast is under constant attack from the sea. In some places large waves wear away the coast at the rate of about 2 metres every year. Roads, buildings and farms tumble slowly into the sea and many villages dating as far back as ancient Roman times have disappeared.

People, too, bring about changes to coastal landscapes. These changes range from small human activities, such as walking across a sand dune, to large activities, such as building ports and sea walls.

chapter 4

Source 1 A section of road on the Holderness coast in Yorkshire, England, shows the devastating effect that coastal erosion can have on communities. Many villages in this region have already been lost to the sea.

4A

How are coastal landscapes formed?

1. What evidence is there in Source 1 that this coast is changing?
2. What changes do you think will take place here over the next 20 years?

4B

How are coastal landscapes used and managed?

1. How is this coast being used by people?
2. What could be done to control this erosion to protect these homes?

4C

Are coastal landscapes hazardous places?

1. How could people be injured or killed by coastal erosion in this place?
2. What other natural hazards are present in coastal areas?

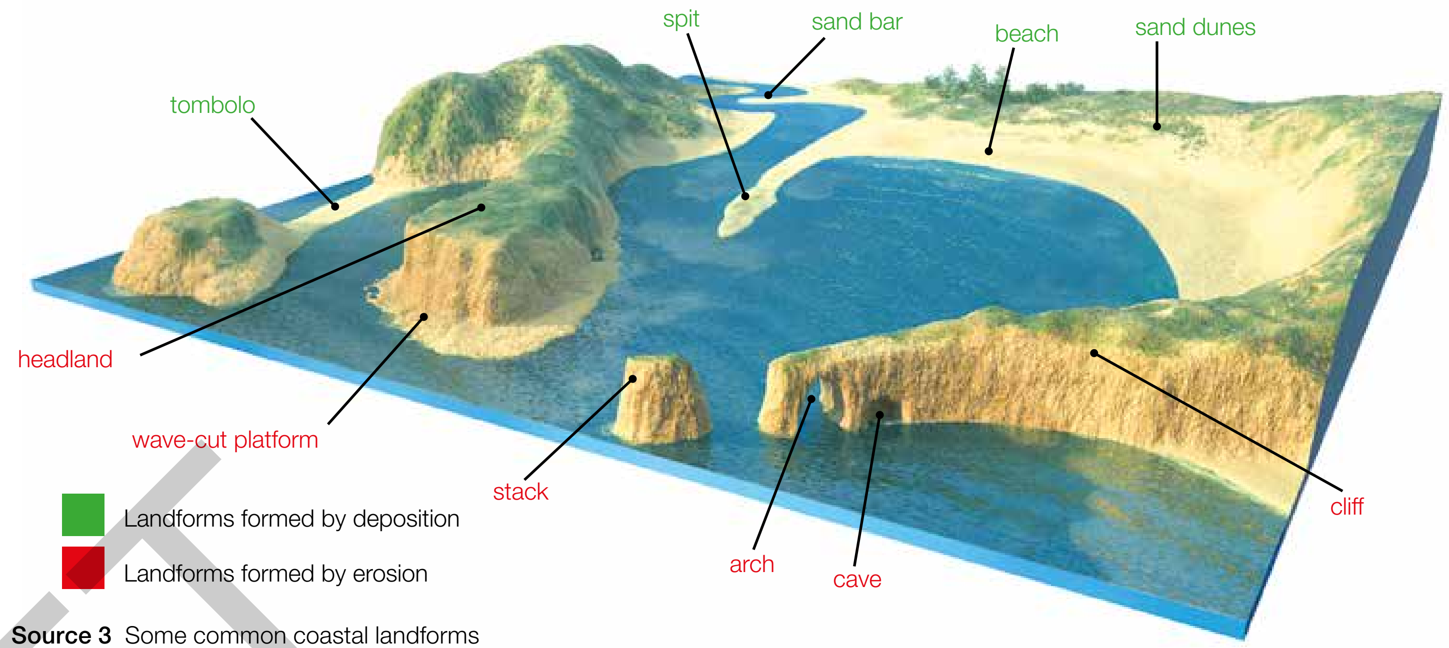
4.1 Coastal landforms

Constant movements of water and wind carve coastal landscapes into an amazing variety of shapes. Geographers, who refer to these shapes as landforms, are particularly interested in exploring the forces that create them. To begin your own investigation into coastal landscapes, you should start by finding out the names of the most common landforms, shown in Source 3. Some of them you may have heard before but others may be new to you.

Coastal landforms can be formed in two different ways, either by erosion (the wearing away of land by waves and wind) or by deposition (the building up of land through deposits of sand and other materials). Because of these processes, there is no 'typical' or 'average' coastal landform: every **arch**, **stack**, **cave** or **headland** will be unique. There are, however, common features for each type of landform. Geographers examine and describe the similarities and differences of these features and use them to explain how they were formed. For example, Sources 1 and 2 show two Australian coastal landforms. Geographers would describe both of these landforms as headlands, despite the fact that they look quite different.

Source 2 A headland at South West Cape, Tasmania

Source 1 Headlands at Port Campbell, Victoria



Source 3 Some common coastal landforms

keyconcept: Change

A day at the beach

Like all landscapes, coasts are constantly changing. During a five-hour visit to a beach, about 2500 waves hit the shore. Each wave picked up millions of grains of sand and moved them. Some grains were moved further inland, some along the beach, some out to sea, and some were picked up and put back in the same place. The wind picked up millions of particles of dry sand and blew them onto the dunes. People walked through the dunes, trampling the plants and creating a wind tunnel that sped up erosion. In the course of the day, the sea level rose and fell about 2 metres as the Moon's gravity pulled the oceans towards shore and away from it, creating tides.

Source 4 Bondi Beach in Sydney is located between two headlands.

What makes beaches perfect for geographers to study is the rapid rate of change that takes place there. This is mainly because:

- one wave crashes about every 8 to 10 seconds and each of them changes the coast
- sand is easily eroded and deposited
- people use the coast in many ways, constantly changing it.

For more information on the key concept of change, refer to page 12 of 'The geography toolkit'.

Check your learning 4.1

Remember and understand

1 How do beaches change?
2 What natural forces are working continuously on the coast carving new landforms?

Apply and analyse

3 Describe a stack. How do you think stacks are formed?

Evaluate and create

4 How have people used the headland in the foreground of Source 4? Why might this be a hazardous place to live?
5 Each of the three photographs in this section shows headlands. Examine each of these photographs.
   a Based on these photographs, give a definition of a headland.
   b What features does each share?
   c In what ways is each unique?
   d In pairs, discuss some geographical questions you would ask to explore why the headlands are different.
   e Where would you find some answers to the geographical questions you have discussed?

4.2 The power of waves

Waves are the main force that shape coastal landscapes. Waves begin at sea when the wind blows across the surface of the water. The water surface rises along with the wind, but then is pulled back down by the power of gravity. This tug-of-war between the drag of the wind and the pull of gravity creates an **orbit** – a circular movement of water (see Source 2) beneath the surface. This orbit creates what we see as a wave.

As waves move into the shallower waters near the coast, the bottom of the orbit comes into contact with the sea bed. Friction generated on the sea bed slows the bottom of the wave more quickly than the top. The top (or crest) of the wave continues moving and finally falls forward onto the shore (much as a person can stumble and fall over, head first). The water that falls forward and moves up the shore is called the **swash**. The **backwash** is the water that runs back to the ocean.

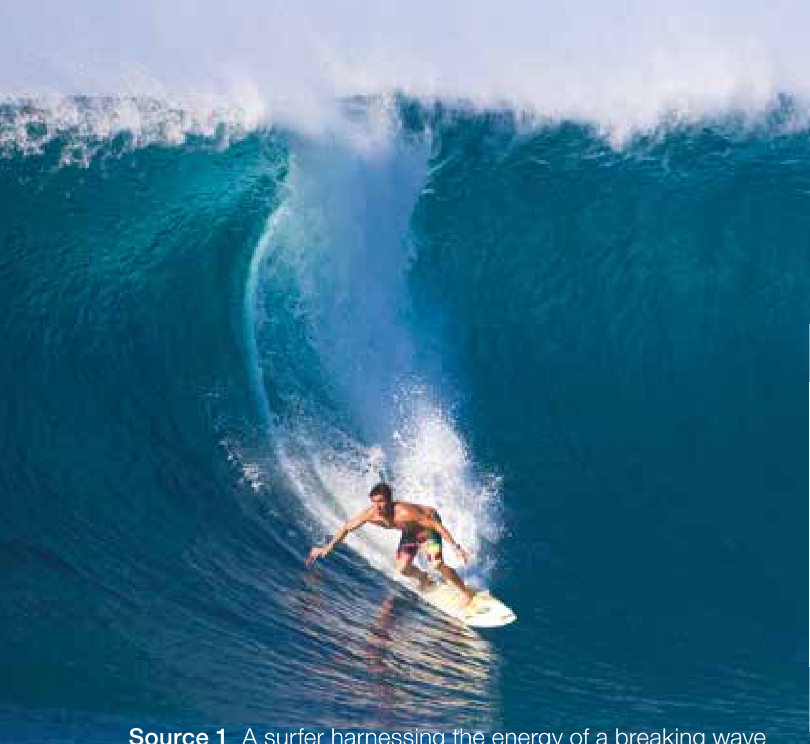
The energy in waves can travel thousands of kilometres before it is released on the coast. This energy then changes the coast in three important ways. Firstly, it erodes the coast by breaking down the rocks of cliffs and headlands into small pieces of stone or sand, eventually forming a beach. Secondly, along with tides and currents, the wave energy transports the sand out to sea and along the coast. Thirdly, the waves deposit the sand in new places, forming new beaches, spits and sand bars.

Longshore drift

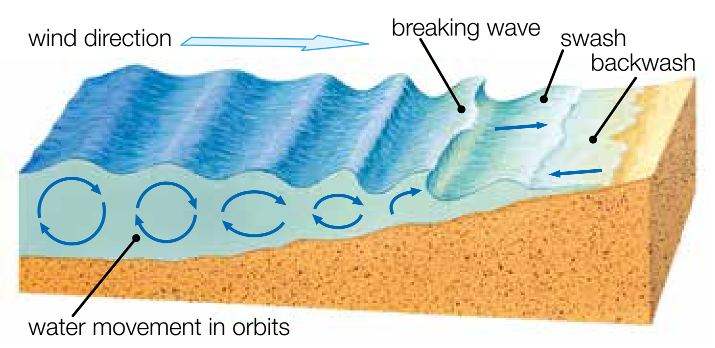
Although some waves can hit directly onto a shoreline, most waves hit the coast at an angle. This occurs because of the varied shape of the land and the varying direction of the wind that produces the waves. When the waves hit the coast at an angle, the swash picks up the sand and carries it along the beach rather than just dumping it directly forward onto the shore. The next wave that comes along will also move the sand along the beach until eventually, after hundreds of small zigzags, many grains of sand are moved to one end of the beach. They may pile up to form long deposits of material, such as **spits** and **tombolos** (see Source 3 on page 97), or the wind may change direction, causing new waves to carry sand back in the opposite direction. This movement of sand along a coast is called **longshore drift**. It is a major contributor to the shape of the coastline.

Longshore drift is also responsible for many problems faced by those people who live along the coast. The movement of sand can clog harbours and river mouths. Many coastal communities in Australia spend millions of dollars a year digging up the sand moved by longshore drift and putting it back on the beaches where local residents want it.

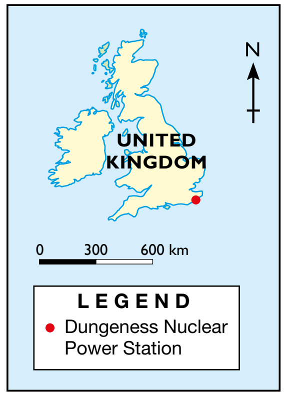
One of the most dramatic examples of problems caused by longshore drift can be found on England's south-eastern tip, in a town called Dungeness. Here, a nuclear power station has been built near the coast on an ancient and very large spit made of small stones called shingle. For centuries, this shingle has been shifting back and forth along the southern coast. Currently, huge amounts of the small shingle stones have to be moved to prevent the shingle from eroding. Erosion would threaten the station itself, potentially causing sea water to enter the reactor and bring about a nuclear meltdown. A meltdown would result in radioactive contamination – a disaster with devastating effects that could last thousands and thousands of years.

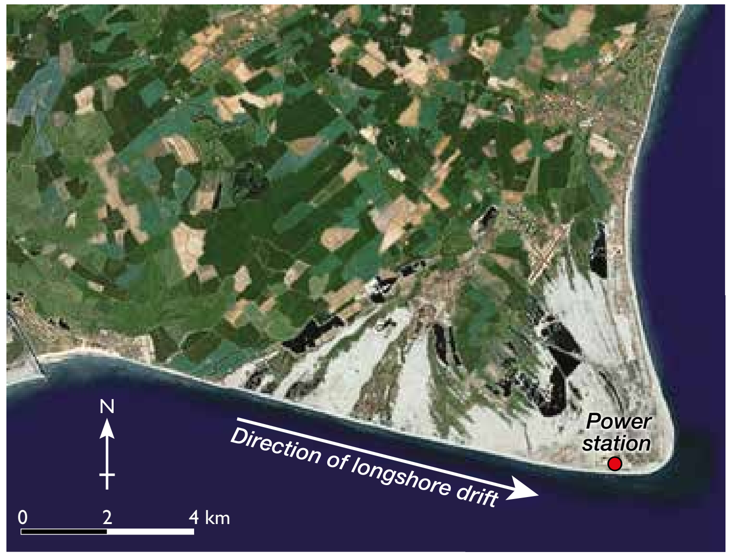


Source 1 A surfer harnessing the energy of a breaking wave

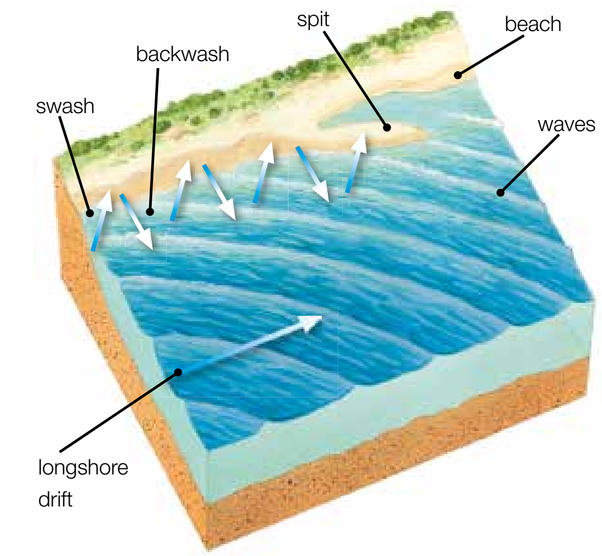


Source 2 Formation of waves





Source 3 Longshore drift is threatening Dungeness Nuclear Power Station



Source 4 Longshore drift

Check your learning 4.2

Remember and understand

1 What is the difference between swash and backwash?
2 How do waves begin?
3 Why do waves break?

Apply and analyse

4 How do waves change the coast?
5 What do you think happens to sand on a beach where the waves strike directly onto the beach rather than on an angle?

Evaluate and create

6 Describe the journey of a grain of sand on a beach where the waves strike at an angle.
7 Like many beaches around the world, Dungeness is being changed by longshore drift.
   a What are the local authorities doing about this?
   b Why is this particularly serious at Dungeness?
   c Discuss with a partner some other possible solutions. Decide on your best solution and then sketch it so that you can present it to the class.
   d When you have heard all the possible solutions from your classmates, decide on the one you consider to be the most likely to succeed. Explain why you think this would work.

4.3 Erosional landforms

Coastal landforms are created in two main ways. This is due to the fact that when waves hit the shoreline their effects can be varied. They can help to create landforms that allow plants and animals to live and thrive, or they can destroy landforms, killing plants and animals or driving them away.

The types of waves that erode and destroy sections of coast are known as **destructive waves**. Destructive waves are tall and frequent, which means they crash into the shoreline, digging out large chunks of land and eroding the beach. Their swash is weaker than their backwash, causing soil and nutrients to be drawn back into the sea rather than deposited on land.

Destructive waves begin in a large, stormy ocean. The waves travel thousands of kilometres, building up energy that is unleashed onto the rocks and sands of the coast. These waves carve the coastline into amazing shapes in much the same way that a sculptor carves shapes from a piece of marble. This process of wearing away is known as erosion, and the landforms created this way are known as erosional landforms.

A stretch of coastline close to the town of Port Campbell in southern Victoria (Source 1) provides a good example of erosional landforms. This part of Australia's coast is constantly being battered by waves from the Southern Ocean. As a result, the limestone cliffs in the area are being slowly chipped away, creating an ever-changing coast.

1 Cliff
Cliffs along coasts are formed by the action of waves on rock. The power of the waves erodes softer rock, leaving the more durable rock behind.

3 Gorge
Some caves can be hundreds of metres long. Waves entering long caves can wear away the roof, causing it to collapse and forming a deep gorge.

4 Arch
As waves erode the back of a cave they may penetrate right through the headland and produce an arch. Waves may pass through the arch, eroding the sides and top. The arch here (inset) has recently eroded and fallen into the sea creating two stacks (main image).

5 Headland
Some sections of the coastline are made up of harder rock than other sections. These can resist the energy of the destructive waves longer than the softer parts and remain as headlands – high, rocky outcrops of land.

Source 1 A section of coastline near the town of Port Campbell in Victoria

2 Cave
As waves approach the coast they tend to bend around headlands and islands and attack them from the side in a process known as **refraction**. When waves encounter a weak spot in the cliff (such as a section of soft limestone) they wear away the rock. They create a small opening, which is soon enlarged into a cave. The waves can now enter the cave and erode the sides and top.

6 Bay
The softer parts of a coastline wear away more quickly than headlands and become bays.

7 Stack
As the soft rock of arches is eroded by the destructive waves, the rock above the arches eventually falls into the sea leaving behind stacks – vertical columns – of rock.

Check your learning 4.3

Remember and understand

1 Describe what a destructive wave is, in your own words.
2 Why do some rocks erode more quickly than others?

Apply and analyse

3 Study Source 1.
   a How many caves, arches and stacks can you identify?
   b Describe the waves in this landscape. What evidence is there that they are destructive waves?

Evaluate and create

4 Predict what changes might occur in the next few thousand years in the landscape shown in Source 1. On a sketch or copy of the photograph, sketch and label the following features of a future landscape:
   - a collapsed stack
   - a new arch
   - a new stack
   - the shape of the new coastline
   - a new gorge.
5 This coastline is moving inland at the rate of about 2 centimetres a year. The Great Ocean Road, which you can see in the background, is about 200 metres from the coast at present.
   a Estimate the date at which it will fall into the sea.
   b What other features of the human environment in this region will also change by then?

4.4 Depositional landforms

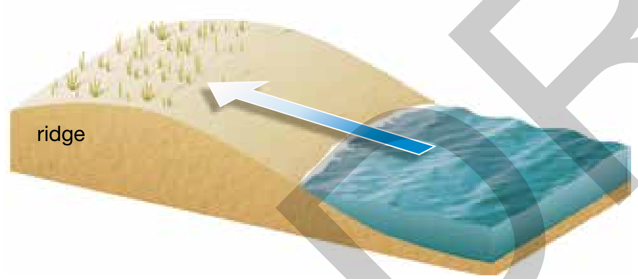
Unlike destructive waves, **constructive waves** have characteristics that help to create landforms that allow plants and animals to live and thrive. Constructive waves are long and low which means they begin far out at sea and gently roll onto the shore, allowing for a smooth and gentle landing. In this way, soil and plants are deposited onto the shore. The swash of these waves is slow and strong, which means that materials from the sea can be brought further inland. The backwash, in contrast, is very weak, which means materials are not dragged back into the sea. In this way, a wide, gently sloping beach is formed. Plants can grow and thrive, and the animals that feed on them will settle there.

When waves are small and gentle, they do not generate enough energy to erode the land or cause great and sudden destruction. This is generally the case in bays and harbours that are sheltered from strong winds, such as Port Phillip Bay in Melbourne and Sydney Harbour. Sandy soil is moved from the base of cliffs and from the mouths of rivers by the action of the water. It is carried by constructive waves to new sites along the shore and gently deposited there. Whereas erosional landforms are the result of the removal of material from the shoreline, depositional landforms are the result of this addition of material. Constructive waves and the shapes they create are called depositional landforms.

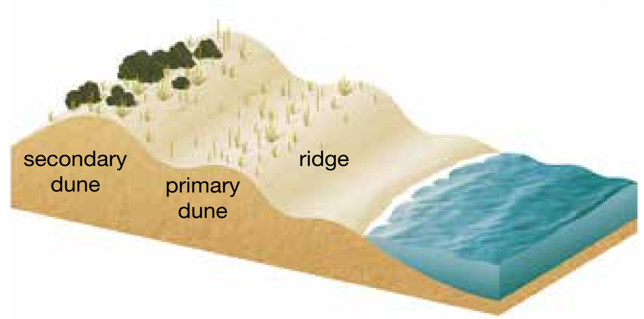
The most common depositional landforms are beaches. A beach is formed when constructive waves carry sand, pebbles and broken coral or shells in their swash and deposit them on the shore (see Source 2). These small waves do not have enough energy in their backwash to take the sand back to sea, so it remains as a beach. Storms may bring destructive waves several times a year and wash away parts of the beach, but the slow, gradual process of beach building repairs this damage.

As the tide goes out, the sand dries out and the wind can then pick up individual grains and blow them inland. As the grains move, they may be trapped by an obstruction, such as plants, or they may collect in areas sheltered from the wind. As the sand piles higher it forms **sand dunes** (see Source 3). Plants grow on these dunes and hold them together, which allows even larger plants to take root and grow. But if the plants are removed,

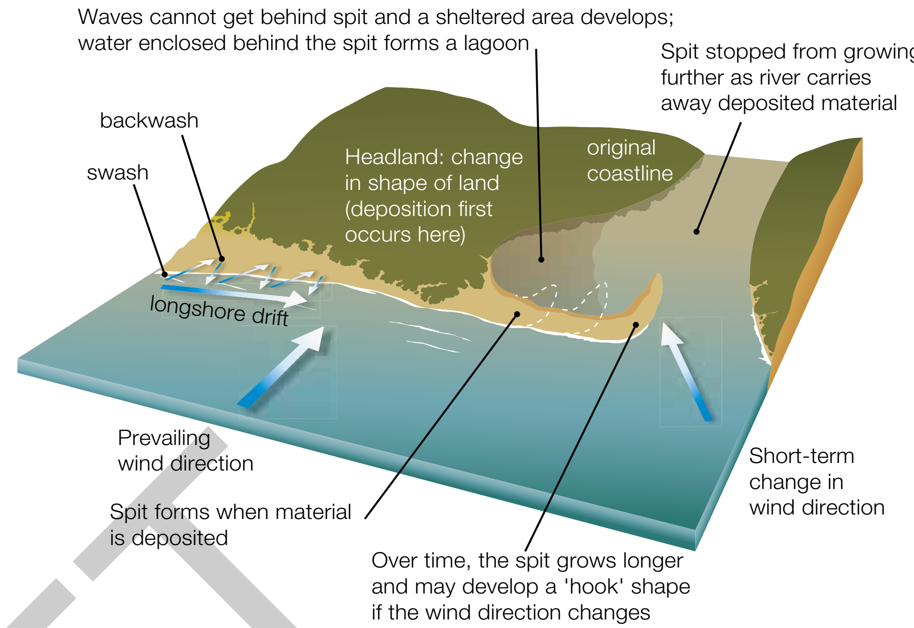
Source 1 Whitehaven Beach, Queensland, is an example of a depositional landform.



Source 2 Constructive waves carry sand onto the shore where it collects and forms a beach. Wind picks up dry sand and blows it inland.



Source 3 Sand is trapped by plants and collects in dunes. Over time larger plants grow over the dunes, holding them together and making them stable.



Source 4 How spits form

entire dunes can gradually move further inland, covering roads, car parks, paddocks and plants. These are called **blowout dunes** (see Source 5).

As well as moving inland, sand moves along the coast as a result of longshore drift. As sand is deposited along coasts, other landforms can be created by the forces of water and wind.

A spit is a long, curved landform that is built up at the mouth of a river, which is where the river widens and ends. A river carries soil and rocks from upstream in its swiftly moving water. This material is dumped at the river mouth, forming a spit. Over time further soil and rocks collect at the river mouth, making the spit larger and more secure. This more stable environment encourages the growth of plants, which, in turn, provide habitats for animals.

Some spits grow so large that a river may be forced to change its course to reach the sea. Over thousands of years, the river mouth may move hundreds of metres along the coast and a stretch of calm water behind the spit, known as a **lagoon**, is formed. These are often home to communities of plants and wading birds, such as herons and egrets.

A tombolo is formed when waves curve around an island close to shore and deposit a bar of sand or other sediment on the lee side of the island (the side closest to the mainland). Eventually, enough material builds up on the leeward side that a permanent connection, or tombolo, is made between the island and the mainland (see Source 3 on page 97).

Source 5 A massive blowout dune inches its way across Fraser Island away from the beach.

Check your learning 4.4

Remember and understand

1. Why do constructive waves tend to add sand to a beach rather than take it away?
2. What role does the wind play in the formation of sand dunes?
3. What is a lagoon and how does it form?

Apply and analyse

4. Why are waves important to the formation of a tombolo?
5. Is the dune in the photograph of Fraser Island (Source 5) advancing towards the camera or away from it? How can you tell?
6. Describe three key steps in the formation of a spit.

Evaluate and create

7. Draw a sketch map of Whitehaven Beach (Source 1) showing the locations of sand, sea, rivers and forest. (For more information on sketch maps refer to page 39 of 'The geography toolkit'.) Remember that a map is a view from above, not on an angle as in the photograph. On your sketch map, use arrows to show the movement of sand.

4A rich task

Mandurah, Western Australia

The city of Mandurah, south of Perth in Western Australia, is typical of many Australian coastal communities; it has a growing population, with thousands of people flocking to its beach in summer. However, the beaches at Mandurah have a problem – the sand there just will not stay put! For much of the year, winds approaching the coast from the south-west cause waves to strike the coast at an angle. These waves move sand northwards along the beach in the process known as longshore drift. At other times, winds from the north-west move sand away from Mandurah in a southwards direction.

Source 1 The fieldwork site at Silver Sands beach, Mandurah

skill**drill:** Data and information

Measuring longshore drift

The coast is a popular place for geography field trips because it is possible to see and measure many of the changes that are taking place there. There are several ways to measure the forces responsible for longshore drift. You will need some equipment to do this and you will need to record your findings carefully so you can process the data back in the classroom and present your findings.

Step 1 Measuring wind direction. Stand on the beach and feel the wind. Use a magnetic compass oriented to north (see Source 2) to determine the direction from which the wind is blowing. You may need to drop a few grains of dry sand to help you establish the wind direction. Try to establish the wind's 'average' direction. Draw a line in the sand showing this direction.

Source 2 A magnetic compass oriented to north

Source 3 This boy is measuring wind speed with a hand-held anemometer

Step 2 Measuring wind speed. The device for measuring wind speed is called an anemometer. Your school's sports department may have an anemometer, as they are sometimes used to measure wind speed at athletic events. Set up the anemometer and take regular readings of the wind speed every 5 minutes over a 20-minute period. This will allow you to work out the average wind speed.

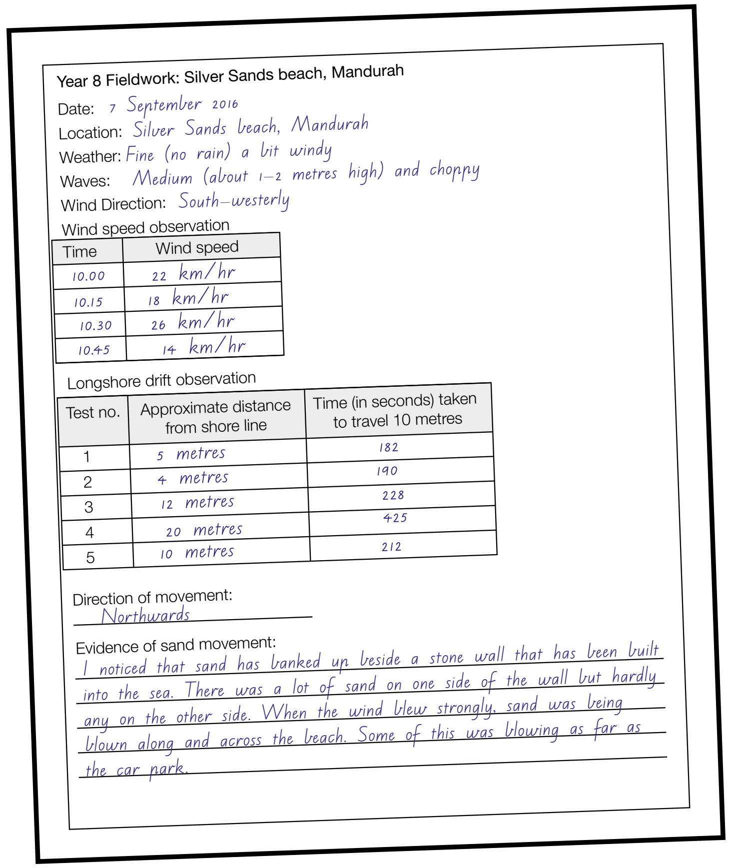
Step 3 Measuring longshore drift. Measure and mark out a set distance of 10 metres on the beach near the water's edge. Stand at the upwind end of your marked-out area and throw an orange out into the water directly from that point. Record the time taken in seconds for the orange to move 10 metres along the coast. Divide this number by 10 to find out the rate of longshore drift in metres per second. Try this at a few different places along the beach and a few different distances from the shoreline in order to work out the average speed of longshore drift. Use your magnetic compass to work out the direction of this drift.

Apply the skill

1 List the equipment you would need to complete the fieldwork activities described.

2 Why is measuring wind direction important in understanding longshore drift?

3 Source 5 shows a student's notes from a field trip to Silver Sands beach at Mandurah (Source 1). Read them carefully and answer the questions that follow.
   a Calculate the average wind speed by adding together all the recorded speeds and dividing the total by four.
   b What other evidence was provided that it was windy on the day of the field trip?
   c Calculate the average rate of longshore drift. Add together the five observations and then divide the total by five.
   d Why was the sand moving northwards on the day of the field trip?
   e What other trend is apparent in the measurements of the longshore drift?



Year 8 Fieldwork: Silver Sands beach, Mandurah

Date: 7 September 2016
Location: Silver Sands beach, Mandurah
Weather: Fine (no rain) a bit windy
Waves: Medium (about 1–2 metres high) and choppy
Wind Direction: South–westerly

Wind speed observation

Time	Wind speed
10.00	22 km/hr
10.15	18 km/hr
10.30	26 km/hr
10.45	14 km/hr

Longshore drift observation

Test no.	Approximate distance from shore line	Time (in seconds) taken to travel 10 metres
1	5 metres	182
2	4 metres	190
3	12 metres	228
4	20 metres	425
5	10 metres	212

Direction of movement:
Northwards

Evidence of sand movement:
I noticed that sand has banked up beside a stone wall that has been built into the sea. There was a lot of sand on one side of the wall but hardly any on the other side. When the wind blew strongly, sand was being blown along and across the beach. Some of this was blowing as far as the car park.

Source 5 Student fieldwork recorded at the fieldwork site at Silver Sands beach, Mandurah (Source 1)

Source 4 Mandurah, Western Australia

Extend your understanding

1 Is Silver Sands beach being changed mainly by constructive waves or destructive waves? Give two reasons for your answer.

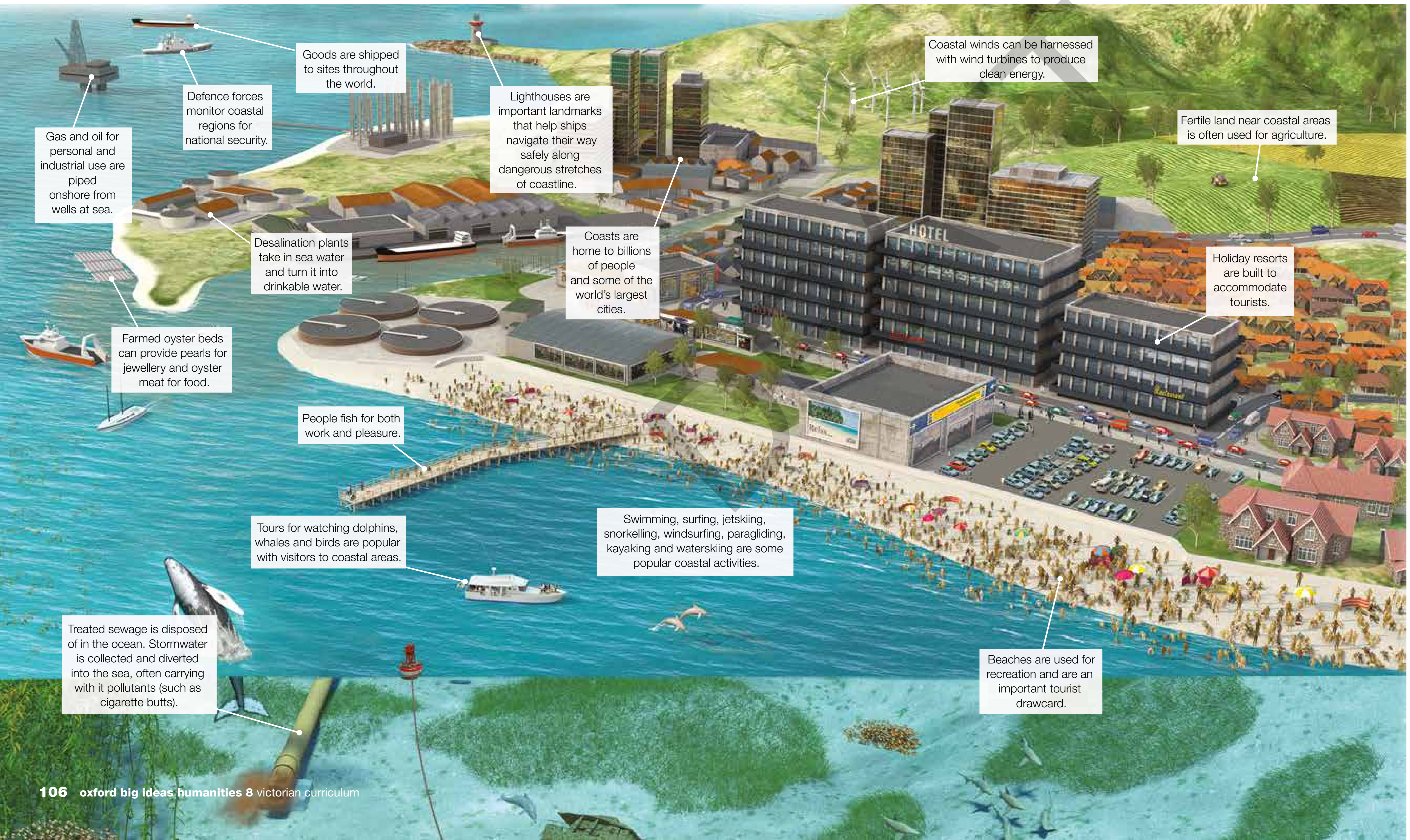
2 Look carefully at the oblique aerial photograph in Source 4.
   a In which direction is longshore drift moving sand at Mandurah beach in this photograph? Give some evidence from the photograph for your answer.
   b How might longshore drift affect the opening of the river in the centre of the photograph?
   c What evidence is there of measures taken to try to limit and control longshore drift?

4.5 One landscape, many uses

Coastal landscapes are some of the most highly populated areas on Earth. About 3.5 billion people – more than 50 per cent of the world's population – live on or near a coast. Some geographers estimate that this number will double over the next 15 years.

In Australia, this figure is already much higher – 85 per cent of us live within 50 kilometres of the sea. Many coastal towns and cities are currently experiencing rapid population growth, increasing this figure even more.

Coastal areas are used for much more than places to live. Source 1 shows some of these uses and their impacts on the environment.



Source 1 How and why people use coastlines

Check your learning 4.5

Remember and understand

1 Name two ways in which ships and boats are used in a coastal landscape.
2 Which parts of the coastal landscape in Source 1 have attracted the most people? What are these people doing?

Apply and analyse

3 How do you use the coast? Which of the labels on Source 1 describe ways you use the coast?
4 Has the artist chosen to show a coast shaped by destructive or constructive waves? How can you tell?
5 How does tourism change coastal areas?
6 Why do you think so many people live near the coast?

Evaluate and create

7 Can you think of any uses of the coast not shown in Source 1?
8 Which activities shown in Source 1 would have no or very little impact on the natural environment? Which three would have the greatest impact?
9 Identify one activity shown in Source 1 that you believe has the greatest impact on the environment. Work with a partner to discuss some ways in which people could reduce the impact of this activity on the environment.
10 Use a street directory (or Google Maps) to examine a coastal city in Australia. Carefully examine the coastline of this city and list all the ways in which the people of the city have changed the coast or used it in some way. What are some common changes or uses and what are some surprising ones?

4.6 Managing coastal landscapes

The forces of nature are constantly changing coastal landscapes around the world. The shapes of beaches are changed; spits are formed; harbours fill with sand; and waves erode the coast, causing houses, roads and other structures to collapse into the sea. Cities and towns built in coastal areas are often affected by these natural processes.

The residents of coastal cities and towns around the world have responded by trying to control or manage the natural processes. Their responses differ depending on the types of forces being dealt with. For example, along depositional coastlines responses are designed to combat the presence of too much sand, while along erosional coastlines the responses are designed to combat the wearing away of the land.

Coastal management for depositional coasts

The main issue confronting communities along depositional coasts is sand movement. For example, the sand that makes up Adelaide's beaches is gradually moving northwards under the influence of longshore drift. This is causing the beaches in some areas to become narrower, leading to waves eroding land close to roads and houses. In other areas, sand is being deposited in river mouths, blocking boat access to the sea. In Australia, the Department of Sustainability, Environment, Water, Population and Communities is trying a number of measures to address this problem.

Constructing sea walls from large rocks, concrete blocks or sandbags can slow or even stop the movement of sand along the coast. **Groynes** – walls that jut out from a beach into the sea – prevent erosion of a beach by stopping waves from pounding onto the shore, and by directing them away from specific areas of the beach (see Source 1). **Training walls** – walls on either side of the mouth of a river – are built to prevent sand from blocking a harbour or river mouth (see Source 2).

Source 1 These groynes near Brighton Beach in Adelaide were built to protect the millions of cubic metres of sand pumped onto this beach in the 1990s.

Source 2 Two training walls and a breakwater have helped to trap sand at the mouth of Glenelg Harbour in Adelaide.

Another method to prevent the erosion of beaches is to move sand from one place to another. This method, known as beach nourishment (or beach replenishment), may involve moving thousands of truckloads of sand every year to reverse the effects of longshore drift. In Adelaide, millions of cubic metres of sand have been dredged from the sea floor or taken from dunes in other places and trucked onto the eroding beaches.

Coastal management for erosional coasts

In places where destructive waves are eroding the coast, communities have responded by building barriers, parallel to the coast, to prevent waves from reaching the coastline. These barriers are usually made of concrete or piles of rocks or rubble. Walls that are built out in the sea are called **breakwaters**. Walls that are built close to the coast are called **seawalls**. These barriers are designed to direct the water's force at the solid walls made of hard materials rather than the soft and easily moved sands and dunes.

While these walls may help in the short term, they can often create new problems. The energy of the wave may be deflected downwards, for example, eroding the front of the wall, weakening it until it eventually collapses into the sea. The shoreline is then left unprotected.

Source 3 Lakes Entrance on Victoria's east coast

Check your learning 4.6

Remember and understand

1 What are groynes and why have they been built in Adelaide?

2 Have the structures built at Glenelg Harbour (see Source 2) been successful in controlling the movement of sand? Give some evidence for your answer.

Apply and analyse

3 Examine Source 3 carefully.
   a Is this an erosional or depositional coast? What is your evidence for your answer?
   b What is the groyne designed to do? Is it working?
   c What is the training wall designed to do? Is it working?

Evaluate and create

4 There is a large build-up of sand in the river channel at site A in Source 3. Over time it may build up further and become a danger to small boats using the river.
   a What does this build-up of sand tell you about the river?
   b What would you do to try to control this sand build-up? You may like to sketch your solution onto a copy of the photograph.

5 Draw a sketch map of a coastline that includes a groyne, training walls, seawalls and a breakwater. (For information on drawing sketch maps refer to page 39 of 'The geography toolkit'.) Show these features in your map legend.

4.7 The impacts of gas exploration on coastal landscapes

In many coastal areas, human activities impact on natural processes and environments. An example of this is the development of a natural gas plant on Curtis Island off the coast of Queensland near the town of Gladstone. The plant being built will allow liquefied natural gas (LNG) to be stored and loaded onto ships for transportation. LNG is gas that has been compressed into liquid form to make it easier to transport and store. The gas is extracted from onshore coal seams before being piped to the island. Ships then transport the gas to ports around the world, particularly in Asia.

The facility will allow the company building it and the 520-kilometre pipeline that brings the gas to the port to sell the gas and make a profit. The company argues that building the facility also creates thousands of jobs and boosts the economy of the region.

Gladstone is the largest port in central Queensland with over 1500 large ships using the port facilities every year. Large quantities of coal, petroleum and cement are already moved through the port. When the plant is completed, each week two to three specially designed ships will carry LNG from Curtis Island to export markets. Other companies are also interested in building LNG plants on the island.

Source 1 A typical LNG ship is 300 metres long, 45 metres wide and needs a channel at least 12 metres deep.

Source 2 An oblique view of the construction site at Laird Point on Curtis Island

Gladstone port and Curtis Island are located beside the Great Barrier Reef. The reef is the largest in the world and is considered one of the world's great natural wonders. It is also included on the UN World Heritage list. Curtis Island sits within the Great Barrier Reef World Heritage area, so the companies building the plant have had to ensure that they follow strict guidelines about changes to the environment.

Some people remain concerned that the new gas facility will endanger the natural environment, including the reef. In particular, they are worried about the following:

- To allow large LNG ships to reach the gas plant 8 million cubic metres of sand and mud need to be dredged from the channel between Curtis Island and the mainland. This environment is home to marine life, such as turtles and dugongs.
- Dredged material will be dumped near the reef.
- The LNG plant requires a reliable supply of fresh water so a desalination plant is being built as part of the facility. This takes water from the sea, removes the salt and pumps the salt back into the sea.
- The movement of ships through the reef means there is the potential for a shipping accident that may damage the reef.

NATURAL GAS PLANT DEVELOPMENT AREA

Source 3 Source: Oxford University Press

Check your learning 4.7

Remember and understand

1 What changes are taking place on Curtis Island? Why are these changes taking place?

Apply and analyse

2 Construct a table with two columns: 'Arguments for the new LNG plant' and 'Arguments against the new LNG plant'. List the various arguments in the correct columns.

3 Imagine that you are a representative of the World Heritage committee that has come to Curtis Island to find out whether the LNG plant is going to affect the Great Barrier Reef. Make a list of the questions you would ask in your investigation. Discuss these with a partner before sharing them with the class.

4 Carefully examine the map showing the natural environments in this region (Source 3).

   a Describe the natural environment in which the LNG plant is being developed. In your description include details about vegetation as well as birds and animals.

   b Dugongs are marine mammals that feed on seagrass on the sea floor. How might dredging affect these animals?

Evaluate and create

5 Design and produce a poster either supporting or opposing the expansion of the Curtis Island plant for display in the Gladstone town hall.

6 Debate the topic, 'While the development might have some impact on the environment, Australia's prosperity is more important.'

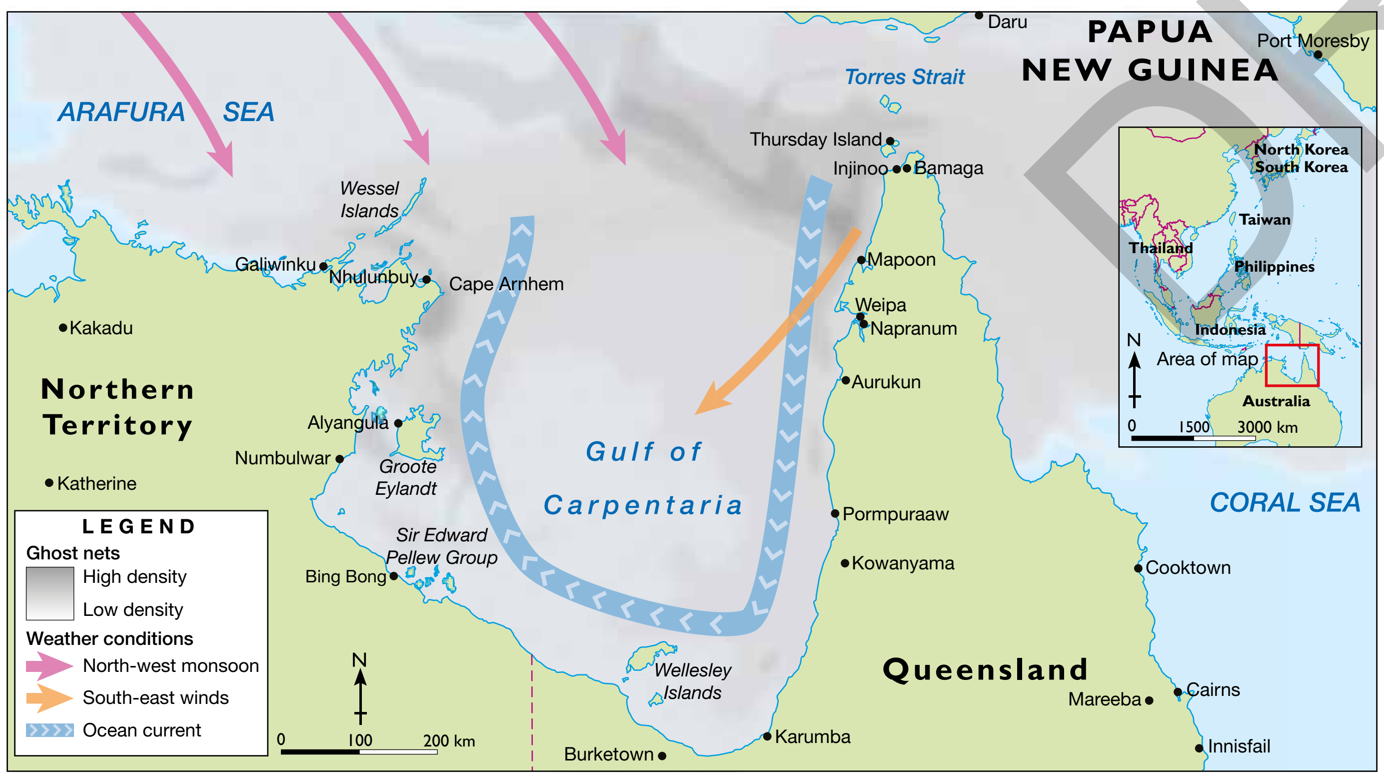
4.8 The impacts of fishing on coastal landscapes – ghost nets

Every year, about 6.4 million tonnes of fishing gear (nets and tackle) is lost in the world's oceans. Most of this is made up of abandoned fishing nets that have drifted free from boats in extreme weather conditions or have been cut free because they became entangled. In many cases it is cheaper and easier for fishermen working in waters to the north of Australia to cut these tangled nets free than to haul them in and untangle them. The nets, still afloat because they are plastic, are carried south on ocean currents and continue to entangle fish and other marine species, such as turtles, dugongs and even crocodiles. They are referred to as **ghost nets** and at any one time there are thousands of them in the ocean.

About 100 000 marine mammals are killed by ghost nets every year. This includes endangered animals, such as whales, Australian sea lions and turtles. In northern Australia, ocean currents and winds carry ghost nets into the Gulf of Carpentaria where they can remain for years, trapped by circulating currents (see Source 2). Tides and storms wash them onto the shore and then drag them back to sea or bury them in the sand.

Source 1 Yirralka Laynlapuy rangers remove a ghost net from a beach in Eastern Arnhem Land.

THE GULF OF CARPENTERIA: WEATHER PATTERNS AND DENSITY OF GHOST NETS



Source 2 Source: Oxford University Press

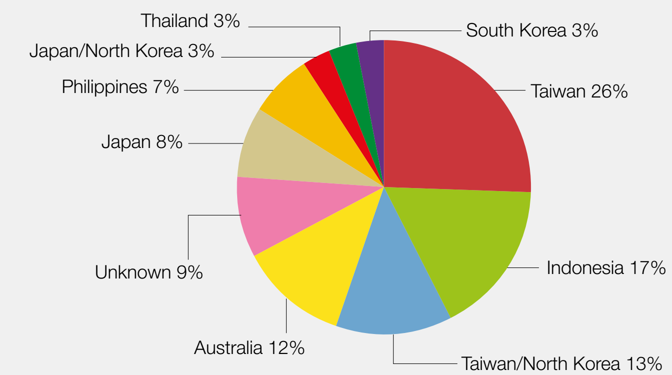
In response to this issue, GhostNets Australia, an organisation dedicated to removing ghost nets from the waters and beaches of northern Australia, was formed in 2004. It is an alliance of coastal Indigenous communities from Queensland, the Northern Territory and Western Australia. Since GhostNets Australia was formed its rangers have retrieved about 12 000 nets from Australian waters. This represents about 90 kilometres of netting. As well as removing the nets, these rangers also free trapped wildlife, map the location of the nets using GPS systems, and try to identify the origin of the nets using resources supplied by the World Wildlife Fund.

key**concept:** Interconnection

Where do the ghost nets come from?

Although some environments are unique, no environment exists in isolation from others. There are links between places, and by exploring these links we can develop a better understanding of the ways in which networks and systems work. This may help us to solve problems such as marine and coastal pollution. In the case of the ghost nets of the Gulf of Carpentaria, geographers examine the winds and currents of the area to help explain why nets collect in this region. By examining the data collected by the GhostNets Australia rangers and other researchers we can also find out the origin of the nets (see Source 3).

For more information on the concept of interconnection, refer to page 9 of the 'The geography toolkit'.



Source 3 Origin of nets found at Cape Arnhem, Northern Territory

Check your learning 4.8

Remember and understand

1 What are ghost nets?
2 Why do ghost nets create problems for the natural environment?
3 Describe the work done by the GhostNets Australia rangers.

Apply and analyse

4 Examine Source 2. How do ocean currents and winds affect the movement of ghost nets. Refer to specific winds and places in your answer.
5 Why do you think most GhostNets rangers are Indigenous Australians?

Evaluate and create

6 On an outline map of the Asia–Pacific region, locate and label the countries of origin of fishing nets found at Cape Arnhem (see Source 3).
   a Shade in each of these countries using darker shades for countries that have contributed many nets and lighter colours for those with fewer nets. For example, you may use red for countries with more than 15 per cent, orange for those with 5 to 15 per cent, and yellow for those with less than 5 per cent.
   b Describe the pattern shown on your map.
   c Use arrows to show the paths that may have been taken by these nets to reach Cape Arnhem.
   d Use BOLTSS to finish your map.
   e How far have the Japanese nets travelled to reach the Gulf of Carpentaria? Why is this hard to estimate correctly?
   f Why are rangers and researchers interested in the origins of the nets?
7 What do you think should be done to reduce the number of ghost nets in the oceans? Why do you think this is such a difficult problem to solve?

4B rich task

Gold Coast Seaway, Queensland

A good example of coastal management in action can be seen on Queensland's Gold Coast. Northward sand movement over centuries has caused the mouth of the Nerang River to be pushed north along the coast. This created a long spit sheltering a lagoon (known as The Broadwater). Although this is a natural process, it created several problems in the region. The southern tip of South Stradbroke Island was being eroded by the waters emerging from the mouth of the Nerang River, the spit was unstable and large amounts of moving sand in the mouth of the Nerang River made boating hazardous.

The solution was to build training walls at the mouth of the Nerang River to stabilise the sand and to direct the river flow away from the southern end of South Stradbroke Island. This structure became known as the Gold Coast Seaway. To move the drifting sand from one side of the seaway to the other, a 490-metre-long sand-collection jetty was built. Beneath the jetty are 10 pumps that collect the sand and pipe it to South Stradbroke Island. This sand-bypass system, which can move 500 cubic metres of sand an hour, was the only one in the world when it was completed in 1986.

skill**drill:** Data and information

Drawing sketch maps

One of the most useful skills a geographer can master is the drawing of sketch maps. Sketch maps show the main features of the landscape that you are studying, but do not contain the details you would be expected to include on a formal map. While conducting fieldwork you will probably start with a basic outline map of the main features of the location you are studying, such as a coastline. The steps listed here are for a sketch map that you would complete as part of your fieldwork.

Step 1 Look closely at the outline map you have been given to see if you can recognise some of the features around you. Orient your map by turning it around so that it is facing the right way.

Step 2 Decide on the focus of your fieldwork. If you are studying the ways in which people have managed a coastal landscape, for example, you will mark on your map features such as training walls and a sand collection jetty.

Step 3 Label the features that you recognise. Keep your writing neat and level across the page.

Step 4 Look around the area you are studying in your fieldwork and find other examples of ways in which people have managed the coast. Locate and label these on your sketch map. You may find it best to shade large areas, such as the training walls, and to add a legend to show the shading and any other symbols you use.

Step 5 Add carefully labelled arrows to show examples of movement. For example, in the sketch map of the Gold Coast Seaway (Source 4), an arrow shows the direction in which sand is moving. Other examples may include the movement of people, cars and water.

Step 6 Add any examples you can find of change over time. A build-up of sand on one side of a groyne, for example, shows that sand is moving along a beach. A collapsed stack or a pile of rocks at the base of a cliff is evidence of erosion.

Step 7 Add a title that includes the date, and a north arrow. (You may need to use a compass.)

Apply the skill

1 Create a sketch map of the area shown in Source 4. Remember that all maps show a view from directly above. On your sketch map, show how people have managed this coast.

Extend your understanding

1 Why were training walls built at the mouth of the Nerang River?

2 What effect did the training walls have on the direction of water from the Nerang River?

3 Name the coastal process that the training walls are designed to manage.

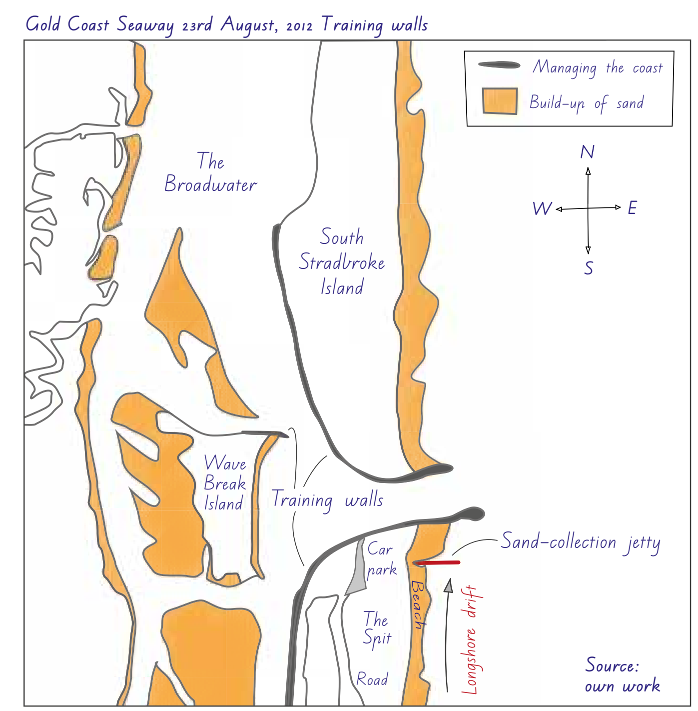
4 How successful have the structures been? Give some evidence from the vertical aerial photograph (Source 3) for your answer.

5 What evidence is there in the photograph (Source 2) that sand is moving down the Nerang River?

Source 1 Aerial photograph of the Nerang River entrance, 1984. You can see how the southern tip of South Stradbroke Island has been eroded by the waters flowing out of the river.

Source 2 An aerial photograph of the Nerang River entrance, 1985, at the beginning of the construction of the Gold Coast Seaway.

Source 3 An aerial photograph of the Gold Coast Seaway, 2002. You can see how South Stradbroke Island has built up and become stabilised with natural vegetation.



Source 4 A sketch map

4.9 Coastal erosion

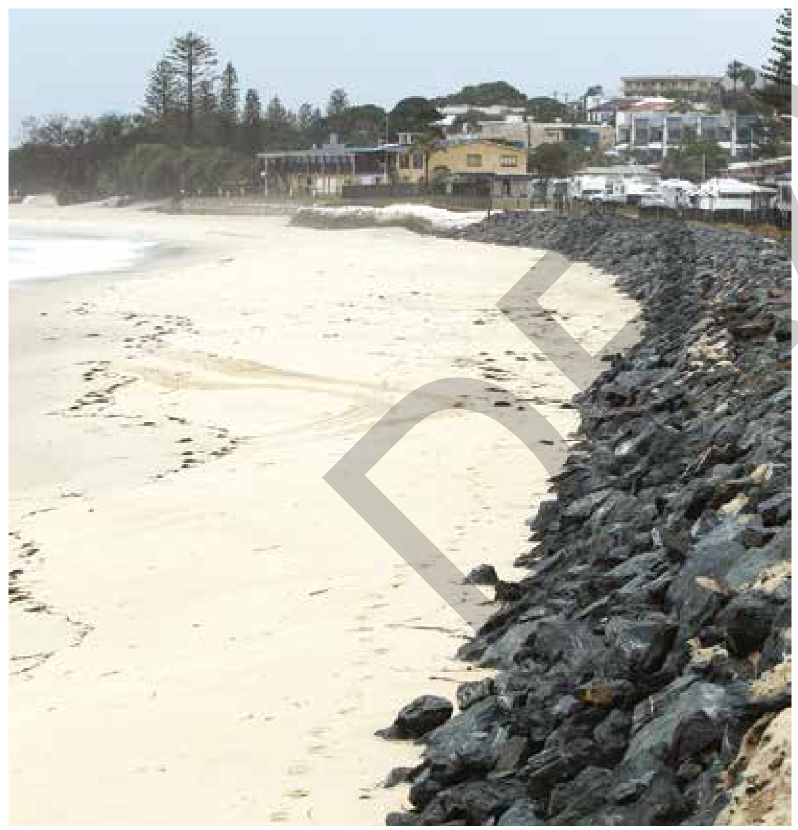
Waves and currents are constantly changing coastal landscapes. In some places, wave action erodes beaches and cliffs, which can create many problems for people who live in coastal communities. Many built features (such as caravan park facilities, roads, houses, walls and playgrounds) on or near an eroding coastline face the constant threat of collapsing into the sea. Most at risk are communities built on sandy coastlines, as these landforms can change very rapidly – with devastating consequences.

Case study: Kingscliff, New South Wales

A community affected by coastal erosion is Kingscliff in northern New South Wales. At times, a wide beach, popular with holiday-makers, extends in front of the town. Structures such as a bowling club and surf life saving club have been built beside the beach. Roads, paths and car parks have also been built along the coast. However, storm waves occasionally batter the beach and scour out huge quantities of sand. The beach can disappear overnight and waves then directly erode the base of the buildings and roads.

The local community has responded to this changing coastal landscape in a number of ways. A training wall and groyne have been built at the mouth of the river that flows into the sea. This controls flooding and has helped to secure the southern end of the beach. Trees have been planted to help hold the larger dunes in place and a seawall has been built in front of some of the buildings, including the bowling and surf clubs. Storm waves have, however, at times eroded the base of this wall, and large textile bags filled with sand have had to be piled in front to help protect the wall from wave erosion.

Source 1 In 2010, storm waves in Kingscliff caused a road to fall into the sea (foreground) and threatened the local surf life saving club (background).



Source 2 Kingscliff beach in July 2012 showing a seawall that has been built to protect homes and businesses along the coast.

keyconcept: Change

Future changes at Kingscliff

A study of the Kingscliff coastline has found that a strip of land 40 metres wide is vulnerable to strong storms and could be eroded to the point where it disappears entirely. This includes much of the caravan park and surf club and the entire bowling club. More alarmingly, the study found that a combination of rising sea levels due to climate change and the natural process of erosion will threaten much greater areas around Kingscliff in the future. The authors of the study estimated the rate of erosion in this area as about 20 centimetres a year. On the satellite image (Source 3), lines have been drawn that show areas at immediate risk in a storm, areas at risk in 40 years and areas at risk in 90 years.

For more information on the key concept of change, refer to page 12 of 'The geography toolkit'.

Source 3 A satellite image of Kingscliff showing areas at risk of coastal erosion

Check your learning 4.9

Remember and understand

1 Why are some coastal communities more at risk from coastal erosion than others?

2 How has the Kingscliff community responded to coastal erosion?

DESIGNER NOTE: PLEASE CUT ONE WORD FROM QUESTIONS 5 AND 6

Apply and analyse

3 Examine Sources 1 and 2 showing Kingscliff beach severely affected by erosion.
   a List any changes as a result of erosion that you can identify in these sources.
   b Use your understanding of the way in which sand moves to explain these changes.
   c How might these changes affect local residents and holiday-makers in the region?

Evaluate and create

4 Examine Source 3 showing predicted changes over the next 90 years.
   a Describe the area at immediate risk from coastal erosion.
   b Use the scale to estimate the distance the coastline is predicted to move inland in the next 90 years.
   c Describe the changes to this area if this prediction is correct.
   d What natural processes may occur in the next 90 years that will make this prediction incorrect?

5 Based on the evidence that you can see in these images, has the local community been successful in controlling coastal erosion? Use the evidence in your answer.

6 Imagine that you have been asked by the Kingscliff community to help protect their coast from further erosion by storms. They also want their beach to be attractive to tourists. What advice would you give them?

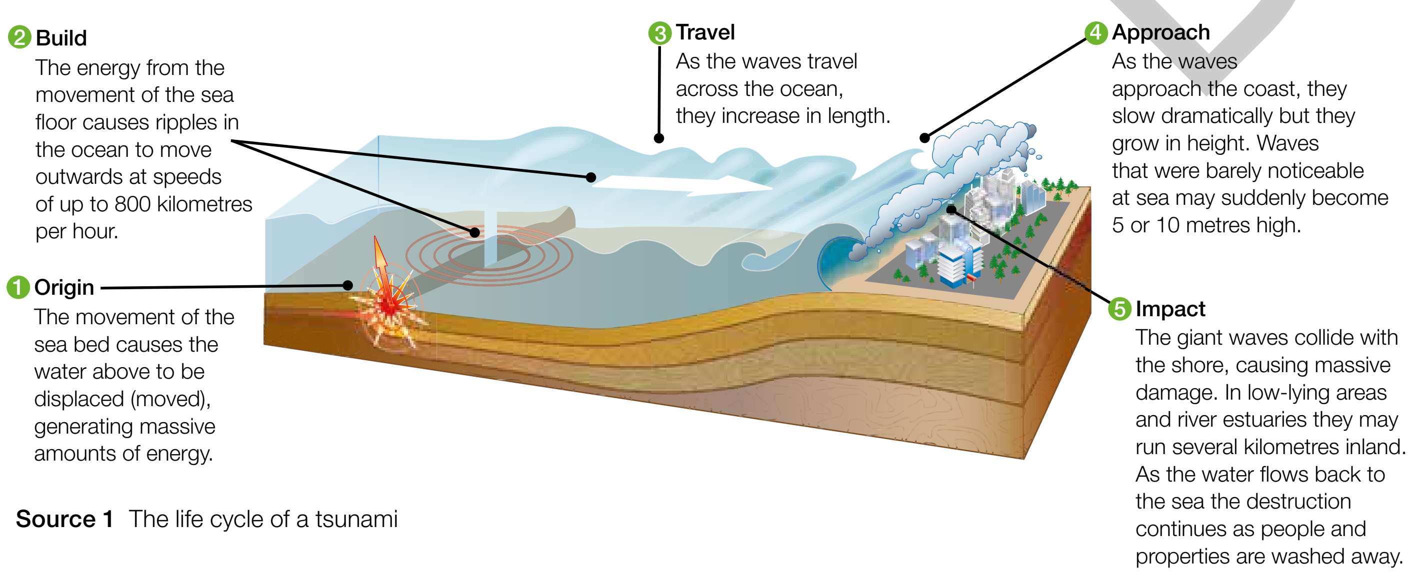
4.10 Tsunamis

Giant waves called tsunamis (a Japanese word meaning 'harbour wave') are perhaps the most terrifying coastal hazard. A tsunami is created when natural events move a huge amount of water in a short period of time. The largest and most common tsunamis are created when the sea floor moves upwards during an earthquake. This causes a series of high, very broad waves to be generated. Other events that can cause tsunamis include underwater volcanic eruptions and landslides. Smaller tsunamis can be created when a large landslide reaches the sea or when large sheets of ice break off glaciers.

Indian Ocean earthquake and tsunami (2004)

On Boxing Day 2004, a natural disaster of epic scale and force struck many of the countries surrounding the Indian Ocean. A huge earthquake near the southern coast of the Indonesian island of Sumatra triggered massive, broad waves of water that slammed into nearby coastal towns and cities, such as Banda Aceh in Indonesia. The tsunami then travelled across the Indian Ocean, sending huge amounts of water inland with tremendous force wherever it encountered low-lying coastal areas. Indonesia, Sri Lanka, India and Thailand were most affected, but deaths were recorded as far away as Somalia, Tanzania and even South Africa. By the time the tsunami had run its course, much of coastal Asia lay in ruins.

Source 2 Banda Aceh, Indonesia, before and after the tsunami struck – 23 June 2004 (top) and 28 December 2004 (bottom)



Source 1 The life cycle of a tsunami

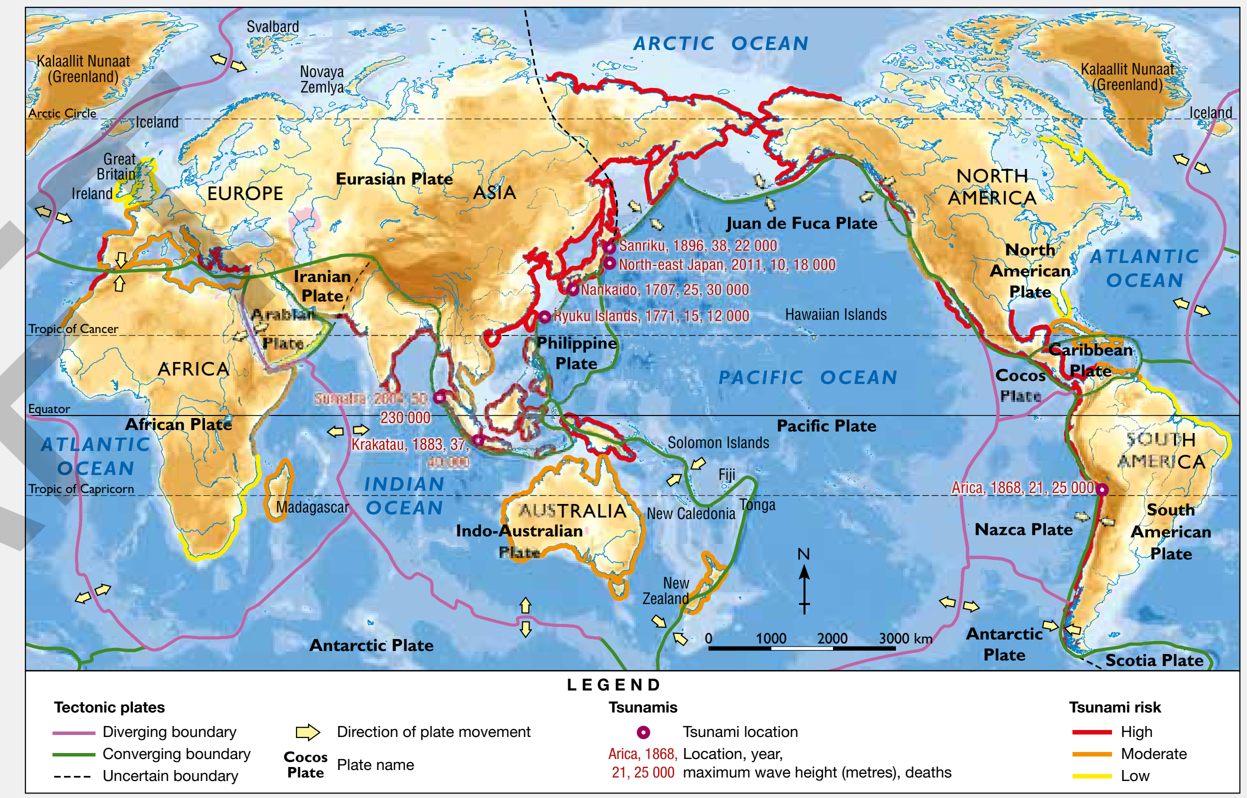
keyconcept: Space

Where do tsunamis occur?

Geographers have noticed that some coastal areas are much more at risk from tsunamis than others. By comparing the distribution of tectonic plate boundaries, earthquakes and tsunamis, they found that coastal areas facing a region where undersea earthquakes occur are most at risk from tsunamis. Japan is the world's most earthquake-prone country, as its east coast lies within 100 kilometres of a very active plate boundary.

For more information on the key concept of space, refer to page 7 of 'The geography toolkit'.

WORLD: TSUNAMI THREAT AND OCCURRENCE



Source 3 Source: Oxford University Press

Check your learning 4.10

Remember and understand

1 What are some of the causes of tsunamis?

2 In 2004, which countries were worst hit by the Indian Ocean earthquake and tsunami?

3 Describe how a tsunami wave changes as it approaches the coast. How do these changes make it more dangerous?

Apply and analyse

4 Study the map (Source 3). Describe the distribution of the most tsunami-prone regions of the world.

5 Describe the relationship between plate boundaries and the level of tsunami threat as shown on the map. Give the names of specific places and plates in your answer.

Evaluate and create

6 Sketch the outline of the Banda Aceh coast as shown in the June 2004 satellite image (Source 2, top). On your sketch label five changes caused by the 2004 tsunami.

7 While the 2004 tsunami caused immediate damage to Banda Aceh, some of its effects will be felt for years. In a small group, discuss how tsunamis affect people.

4.11 Japan earthquake and tsunami (2011)

The world's largest tectonic plate, the Pacific Plate, is moving slowly westwards towards Japan at the rate of about 80 millimetres a year (see Source 3 on page 119). This movement causes many earthquakes and makes Japan the tsunami capital of the world. Because of the danger, many Japanese towns and cities are protected from tsunamis by high seawalls. There are also many tsunami evacuation centres built on higher ground across Japan. Japanese people, aware of the threat, are educated about ways to prepare for a tsunami event.

On 11 March 2011, all these preparations were put to the test when one of the largest earthquakes ever recorded sent massive tsunami waves racing towards Japan and eastward across the Pacific Ocean. Within an hour, tsunami waves up to 7 metres high reached Japan's east coast and caused immediate devastation.

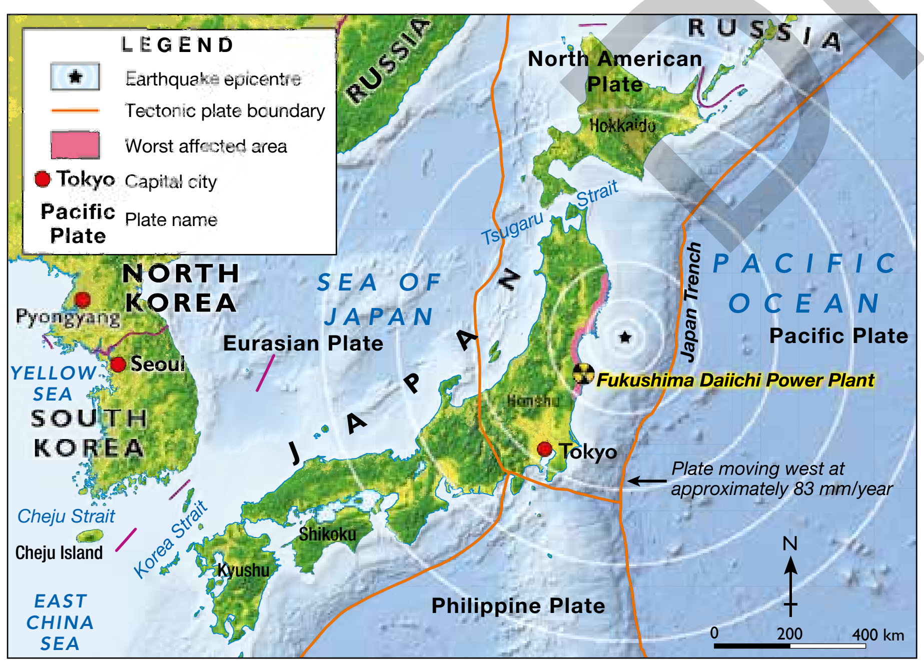
The waves in some places pushed several kilometres inland. The water cascaded over the tsunami walls and washed away buildings, cars, roads and people. The damage was worst in areas close to the epicentre of the earthquake; in these areas entire towns were destroyed or entirely washed away. The movement of the tsunami waves was strongly influenced by the shape of the land, as the water tended to be funnelled into estuaries and bays. In one location, researchers found fishing equipment that had been carried 30 metres up a cliff face, making these waves among the highest ever recorded in Japan.

In some places, the earthquake caused land to sink (subside) and this allowed the waves to travel even further inland. Almost 300 000 buildings were completely destroyed and more than 1 million were damaged. Four large shipping ports were destroyed and a further 300 fishing ports were damaged. Damage to power stations and electricity lines left more than 4 million homes without electricity. An estimated 25 million tonnes of debris was created in the earthquake and tsunami, 5 million tonnes of which was washed into the Pacific Ocean. Items such as boats and soccer balls began washing onto the west coast of North America about a year after the disaster.

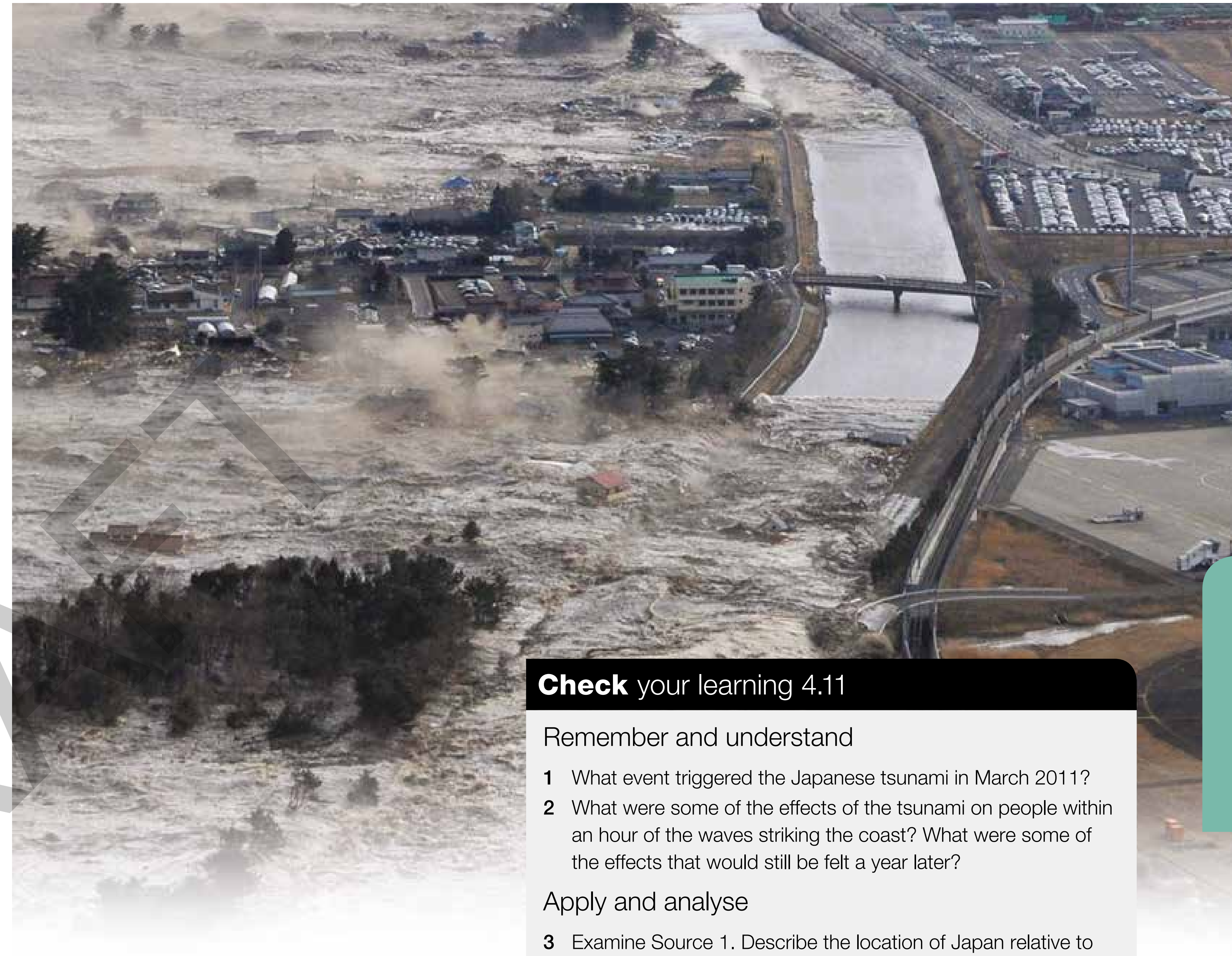
Eleven nuclear reactors that supplied electricity in Japan were immediately shut down after the initial earthquake, but the safety systems of several of these plants were destroyed in the tsunami that followed.

This caused three of the nuclear reactors at the Fukushima Daiichi Power Plant to overheat and go into meltdown, releasing high levels of radiation into the atmosphere. In response to the disaster, all people living within 20 kilometres of the damaged power plant were ordered to evacuate their homes.

JAPAN: 2011 EARTHQUAKE AND TSUNAMI



Source 1 Source: Oxford University Press



Source 2 The 2011 Japanese tsunami destroyed everything in its path as it moved inland (from left to right).

The final death toll may never be known but authorities estimate that nearly 16 000 people were killed by the earthquake and tsunami and more than 6000 were seriously injured. More than 12 months after the disaster, more than 3000 people were still listed as missing.

Check your learning 4.11

Remember and understand

1 What event triggered the Japanese tsunami in March 2011?
2 What were some of the effects of the tsunami on people within an hour of the waves striking the coast? What were some of the effects that would still be felt a year later?

Apply and analyse

3 Examine Source 1. Describe the location of Japan relative to tectonic plate boundaries. How does this location make the country the 'tsunami capital of the world'?
4 The centre of the earthquake was about 70 kilometres from the coast of Japan. How soon did the tsunami waves reach Japan's east coast? How fast were they travelling? At this speed, how long would they take to reach California, 7800 kilometres away?

Evaluate and create

5 In the photograph (Source 2), the first tsunami wave can be seen as it moves from left to right. Describe what you think will happen in this place in the 15 minutes after this photograph was taken.
6 Japanese children are taught what to do if a tsunami wave is approaching. What do you think they are told to do?

4C rich task

The Twelve Apostles

Victoria's south-western coastline is under constant attack from the water. Large, destructive waves from the Southern Ocean are eroding the soft limestone. Softer rocks are being eroded more quickly, while harder rocks are withstanding the attack a little longer. These harder rocks remain as stacks, arches and headlands, producing one of the world's most spectacular coasts. More than 1 million visitors a year are drawn to the Port Campbell coast, many of whom are secondary-school students who come to see and study coastal erosion in action.

skill**drill**

Creating a field sketch

Field sketching is an important skill for all geographers. Field sketching is used to show the different geographic features of a landscape in a simple visual form. Being able to sketch the features of an environment is useful as it can provide the geographer with a visual record of their observations while in the field. Outlines, shading and annotations and labels are all used by the geographer to capture all relevant details of the environment being observed in their sketch.

For example, imagine that you are standing on the viewing platform looking at the Twelve Apostles while on a geography field trip. You have been asked to complete a field sketch with a focus on the ways in which this coast is changing. Sources 2 to 4 demonstrate how to build up a field sketch. Here are the steps to take when completing a field sketch.

Source 1 The Twelve Apostles seen from the visitor's viewing platform

Step 1 Establish the boundaries of your landscape and draw a border of the correct shape.

Step 2 With a pencil, lightly sketch the main landscape lines. If there is a horizon in the scene put this about one-third from the top of the frame.

Step 3 Keeping in mind the features that you want to focus on, add detail to your sketch.

Step 4 Add shading. Shading helps to establish depth in your sketch and also helps to show the shape of objects.

Step 5 Add some colour if you wish. Don't try to copy every subtle colour of nature; just give a hint of the right colour. Label those parts of the scene that you consider most important.

Step 6 Label your sketch with the location and date.

Apply the skill

1 Complete a field sketch of Bondi Beach using Source 1 on page xx. On your sketch label the following features:
- rocks
- beach
- swimmers
- rip currents.

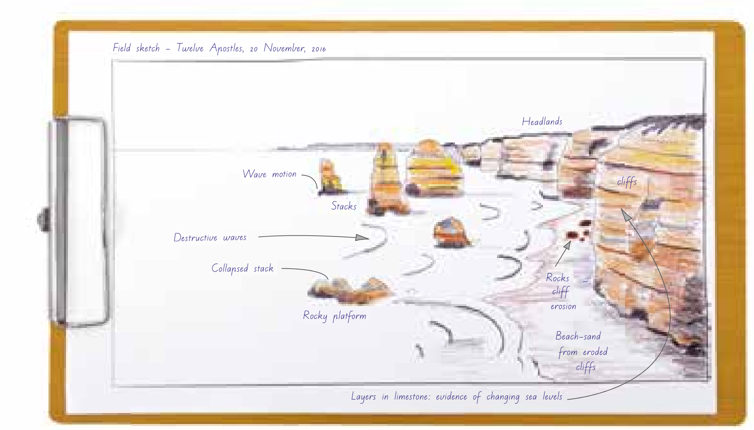
Use arrows to show the movement of water towards and away from the beach.

Extend your understanding

1 What evidence is there in the photograph that this coast is changing over time? Give some reasons for your answer.
2 What natural forces are bringing about these changes?
3 What hazards exist in this place for visitors?
4 How could these hazards be minimised?
5 If you were visiting a depositional coast on a field trip what could you sketch to show how the coast is changing?

Source 2 Stage 1 in completing a field sketch of the Twelve Apostles

Source 3 Stage 2 in completing a field sketch of the Twelve Apostles



Source 4 Stage 3 in completing a field sketch of the Twelve Apostles