8.1 What happens when waves reach the coastline? (2)

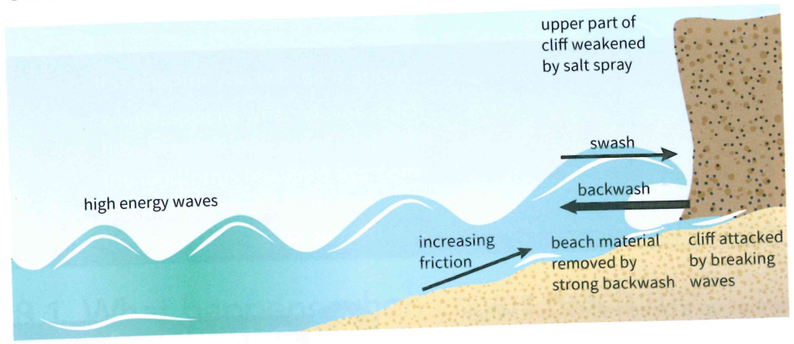

Figure 8.5 Destructive waves (also called plunging waves).

Figure 8.6 A beach affected by destructive waves.

Beaches created by constructive waves

As waves approach the coast they pick up sediment and when waves break the sediment is deposited. Constructive waves deposit more sediment than they remove, creating wide, gently sloping beaches (Figure 8.4). There are two main types of beach created by constructive waves: swash aligned beaches and drift aligned beaches.

Swash aligned beaches

Swash aligned beaches are formed when waves approach the coastline parallel to the beach. The swash and backwash moves sediment up and down the beach creating a wide beach with an even profile.

Drift aligned beaches

Drift aligned beaches are formed when waves approach the beach at an oblique angle to the coastline. The energy of the swash moves the sediment up the beach at the same angle, while the backwash moves the sediment back down

the beach in a straight line, under the force of gravity (Figure 8.7). In this way sediment is moved along the beach by a process called longshore drift, creating a beach with an uneven profile. On some beaches groynes are built to slow down the movement of sediment along the beach.

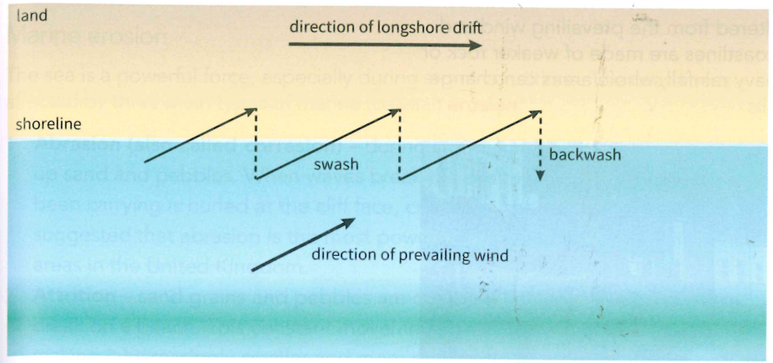

Figure 8.7 Longshore drift.

Figure 8.8 A constructive, drift aligned beach.

ACTIVITY 8.1

1 Explain how waves break.
2 Examine the relationship between wind speed and wave energy.
3 Use annotated diagrams to describe:
   a constructive waves
   b destructive waves.
4 Use Figure 8.7 and Figure 8.8 to describe the characteristics of beaches created by constructive waves.

8.2 How do physical processes affect the coast?

The coastline is the frontier between land and sea (Figure 8.9) and is being constantly reshaped by the action of waves and the weather. Where coastlines are made of more resistant rocks, or are sheltered from the prevailing wind and storm waves, changes occur slowly. Where coastlines are made of weaker rock or open to the full force of storm waves and heavy rainfall, whole areas can change in minutes as a result of landslides or rock falls.

Figure 8.9 Waves battering the coast at Porthleven, Cornwall.

The coastal system

The shoreline acts like a giant conveyer belt (Figure 8.10): rocks are broken down and worn away in some places. The resulting sediment is transported by waves and wind and deposited in other places.

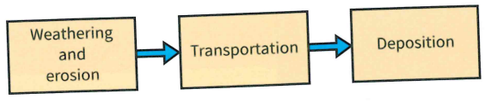

Figure 8.10 The coastal conveyer belt.

Weathering in coastal areas

Coastal areas are mainly affected by two types of **weathering**.

Mechanical weathering

Rocks are broken down without any change in their chemical composition. Examples found in coastal areas are:

1 **Wetting and drying** – softer rocks such as clays and shales are affected by water. These rocks expand and contract as they become wet and then dry out. As they dry out, cracks develop so rainfall and sea spray can more easily penetrate the rock, making them unstable. This can lead to landslides.
2 **Freeze-thaw** – moisture in rock surfaces freezes and expands at night and thaws during the day. In cold coastal areas the constant expansion and contraction weakens the rock surface until it begins to crumble.

Key term

weathering: the breaking up of rocks that occurs *in situ* (the same place) with no major movement taking place

Did you know?

The increasing use of coastal areas for recreation can put pressure on the coastal environment. The over-use of clifftop footpaths can weaken the rock structure and the removal of vegetation can leave clifftops more vulnerable to weathering and erosion.

Chemical weathering

Water reacts with the minerals in the rock to change its structure. The main type of chemical weathering found in coastal areas is solution. Carbon dioxide in the air dissolves in water, making the water slightly acidic. This weak acidic solution is able to dissolve some types of rock, especially limestone.

Marine erosion

The sea is a powerful force, especially during storm conditions. The coastline is affected by three main types of marine (coastal) **erosion**.

1 **Abrasion (also called corrasion)** – during storm conditions waves pick up sand and pebbles. When waves break the sediment that they have been carrying is hurled at the cliff face, creating a sandblasting effect. It is suggested that abrasion is the most powerful type of erosion affecting coastal areas in the United Kingdom.
2 **Attrition** – sand grains and pebbles are constantly being moved as waves break on a beach. This constant movement wears away the beach material, making it increasingly smaller and more rounded.
3 **Hydraulic power** – the sheer force of waves breaking against a cliff will cause parts of the cliff to break away. As waves hit a cliff face air is compressed in cracks in the rocks, 'blasting' away small fragments of material. During storms, hydraulic power can remove enough rock at the base of a cliff to make the cliff face unstable, resulting in a rock fall (Figure 8.11).

Figure 8.11 Rock fall on a chalk cliff.

ACTIVITY 8.2

1 Explain what is meant by the 'coastal system'.
2 Construct a table with the heading, 'How physical processes affect the coast'.
   a List the processes of weathering and erosion down the left hand side of your table.
   b Write a brief definition of each type of weathering and erosion.
3 Explain how weathering and erosion helps to 'reshape' the coast.
4 Suggest three factors that might affect the rate of erosion.
5 When walking along a shingle beach in front of a cliff, what evidence might you look for to identify the different physical processes taking place?

Key term

erosion: the breaking up of rocks that is the result of movement

Tip

Remember that coastlines are affected by both **weathering** and **erosion**. Weathering weakens and breaks rocks down which means they are then more easily attacked by the forces of erosion.

Did you know?

During storms, breaking waves can exert force of up to 50 tonnes per square metre on a cliff face.

Download Worksheet 8.1 from Cambridge Elevate for help with Activity 8.2, question 2.

8.3 What landforms are associated with coastal erosion?

The influence of geology on coastal landforms

Rock type and structure can have a significant influence on coastal landforms. Rocks that have a stronger structure, such as chalk and limestone, erode more slowly and often produce spectacular cliff and **headland** features. When chalk cliffs are undercut by erosion, caves are formed but the cliff does not easily collapse because of the strength and structure of the rock. Weaker rocks, such as clays and sands, have less structural strength and are more easily affected by weathering and erosion, resulting in slumping and landslides.

Landforms associated with headland erosion

Many coastlines are made up of headlands and bays. Because headlands are made of more resistant rock they erode more slowly and often form spectacular scenery. This can be clearly seen on chalk headlands where wave action produces a number of distinctive landforms. Figure 8.12 shows how these features are formed.

Tip

When describing the formation of coastal landforms, remember the sequence of their formation. Use geographical terms to identify processes and individual features.

Key term

headland: a narrow piece of land extending out into the sea, sometimes called a promontory

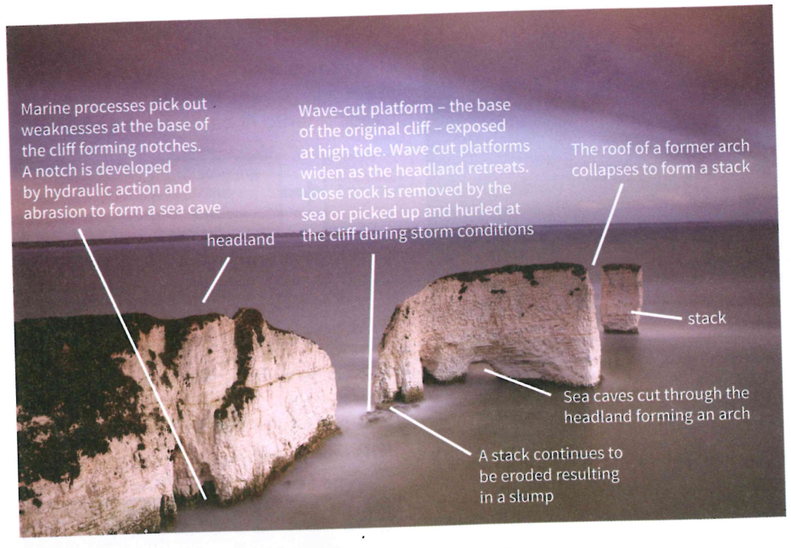

Figure 8.12 Annotated photograph showing chalk headland features.

Mass movement in coastal areas

Mass movement is the downhill movement of material caused by gravity. Weathering and erosion weakens cliffs and they become increasingly unstable, resulting in a mass movement event. Examples of types of mass movement include:

- **Landslides** – where a mass of unconsolidated material moves down a slope, often after a period of rainfall.
- **Slumping** – where a section of cliff drops down along a line of weakness (Figure 8.13).
- **Rock fall** – where material falls from a cliff face and lands at the base of a cliff. This is often seen on chalk cliffs.

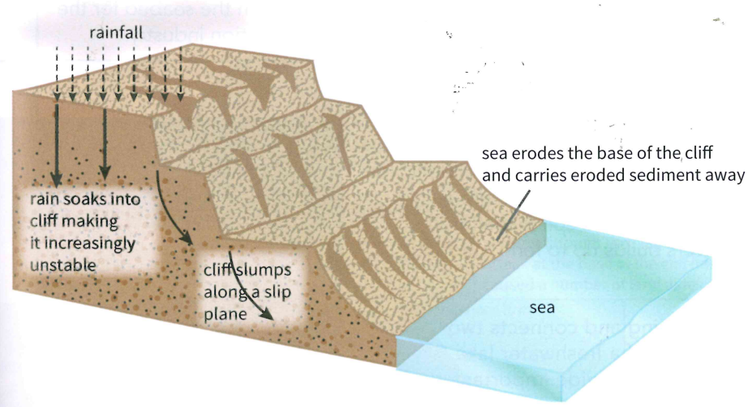

Figure 8.13 Diagram showing rotational slumping.

Watch an animation on Cambridge Elevate about how erosion affects coastal headlands.

ACTIVITY 8.3

1 How does rock type affect rates of erosion?
2 Explain the processes that lead to rotational slumping.

8.4 What landforms are created by coastal deposition?

Beaches

As waves approach the coast they pick up sediment and carry it towards the beach. In some coastal areas, especially where there are sheltered bays or the slope of the seabed is gentle, wave energy is reduced. In these areas more sediment is deposited than is transported away from the coast, so wide, gently sloping beaches are created (refer back to Figure 8.4).

Sand dunes

Sand dunes are formed when strong onshore winds blow sand from the beach inland. The sand forms into mounds, held together by long rooted grasses such as marram (Figure 8.14). Where no vegetation is present the sand will continue to be blown inland. In some places grasses are planted or fences built in an attempt to stabilise the dunes.

Spits and bars

Spits and bars are ridges of sand or shingle that has been transported along the coast by longshore drift (refer back to Figure 8.7). Where the coastline changes direction sediment continues to be transported in the same direction of the original coastline, eventually being deposited to form a ridge of sediment sticking out into the sea. The seaward end of the spit is usually shaped into a curve by wave action and ocean currents. The area behind the spit is sheltered from wave action so mud and **silt** deposited by rivers builds up to form **mudflats** and **salt marshes** (Figure 8.15).

A bar is formed when a spit extends across an opening and connects two areas of coastline. This often results in the formation of a freshwater lake or lagoon behind the bar. Areas behind spits and bars provide important habitats for plants and animals and are often considered to have high environmental value. They are often protected by being designated as Nature Reserves or Areas of Outstanding Natural Beauty (AONB). Many environmentally protected coastal areas are used by the public for recreational and educational activities.

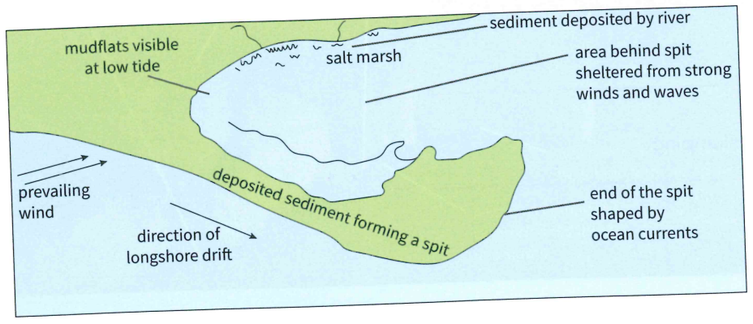

Figure 8.15 The formation and features of a spit.

Did you know?

Millions of tonnes of sand and gravel are dredged each year from the seabed for the construction industry.

Figure 8.14 Marram grass helps stabilise sand dunes.

Key terms

silt: very fine material deposited by water

mudflats: a stretch of muddy land which is uncovered at low tide

salt marsh: an area of coastal grassland regularly flooded by seawater

Example

The Holderness coast, Yorkshire

The Holderness area on the Yorkshire coast has a mixture of hard and soft rocks, resulting in a range of spectacular coastal landforms (Figure 8.16).

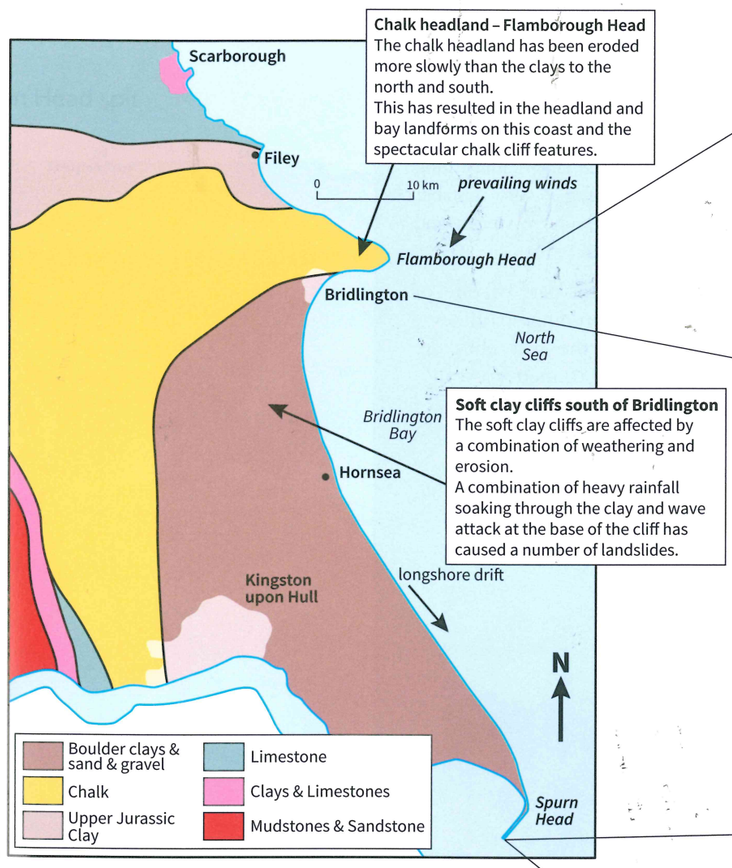

Figure 8.16 Simplified geological map of the Holderness coast, Yorkshire

Spurn Point is a curved spit created by deposited sediment transported south along the Holderness coast. It is approximately 6 km in length but only 50 m wide in places. It is made of sand and shingle, held together by marram grass. Mudflats and salt marshes have developed behind the spit, creating an ideal habitat for wildlife.

Figure 8.17 Flamborough Head.

Figure 8.18 Slumping at Bridlington.

Figure 8.19 Spurn Point.

Example

The Holderness coast, Yorkshire (continued)

The following example shows a landslide that occurred to the south of Scarborough.

The vanishing coastline

Guests at the Holbeck Hall hotel in Scarborough woke up to find cracks in their bedroom walls and part of the hotel garden missing. Guests were quickly evacuated as it became clear that a landslide was likely to occur. Over the next 48 hours about a million tonnes of clay and gravel slid into the sea, taking much of the hotel with it.

The landslide followed a period of heavy rainfall which meant that the cliff had become increasingly unstable. A local geologist said, 'After a long dry period there were a number of deep cracks in the clay. Heavy rainfall then penetrated the cracks, lubricating the clay and making it very unstable. Eventually the pressure of weight and gravity did the rest!'

Scarborough is on part of one of Europe's fastest eroding coastlines – in some places the soft cliffs are retreating at over 10 metres a year.

Figure 8.20 Holbeck Hall landslide – 3 June 1993.

Find out more about hard and soft coastlines at the **Channel Coastal Observatory website** (www.cambridge.org/links/gase40062)

Find out more about Spurn Head at:

- **BBC – Seven Wonders – Spurn Head** (www.cambridge.org/links/gase40059)
- **The Yorkshire Wildlife Trust** (www.cambridge.org/links/gase40060)
- **Spurn Bird** (www.cambridge.org/links/gase40061)

Spurn Head spit

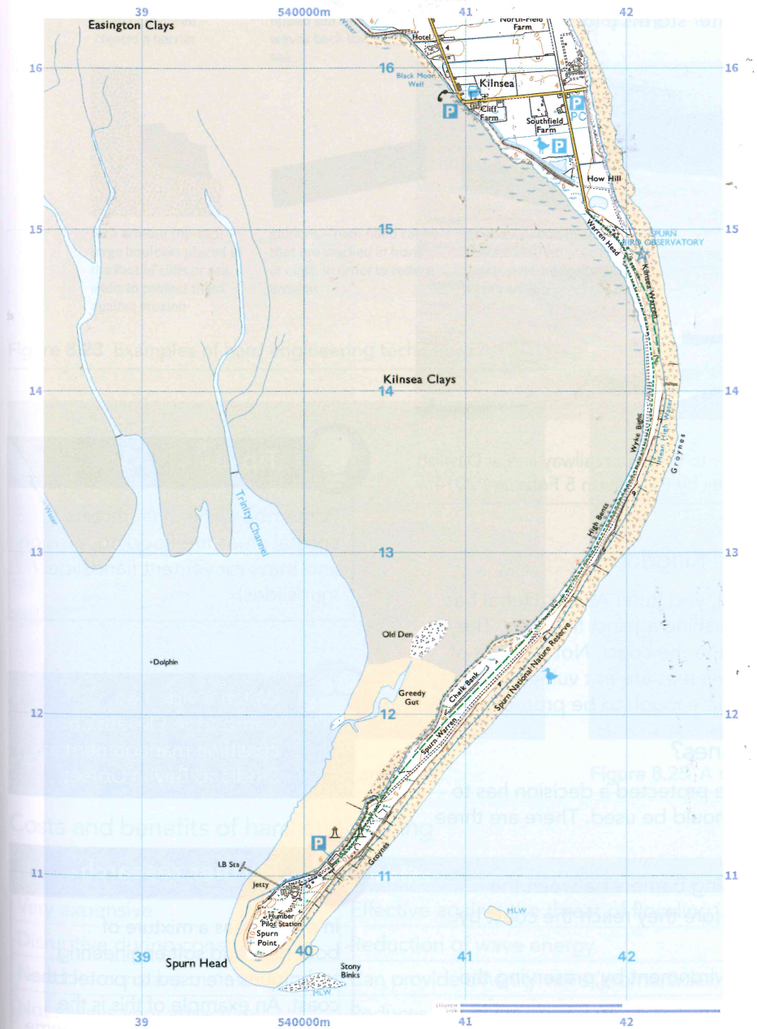

Figure 8.21 OS 1:25 000 map of Spurn Head.

Skills link

See 19.9 Cartographic skills – coordinates, to remind yourself about grid references and other map skills.

ACTIVITY 8.4

Using Figure 8.21:

1 Give the six-figure grid reference for:
   a Spurn Bird Observatory
   b the southernmost point on Spurn Head spit
2 What is the direct distance, to the nearest kilometre, from Spurn Bird Observatory to the southernmost point on Spurn Head spit?
3 What is the direction of longshore drift in grid squares 4115/4116?
4 Why have mudflats and salt marshes formed behind the spit?
5 Why have sand dunes formed on the spit?
6 Using evidence from Figure 8.19 to help you, explain why coastal spits are valuable environmental and recreational areas.

8.5 Protecting coastlines from the effects of physical processes

Why is there a need to protect coastal areas from the effects of physical processes?

The increasing use of coastal areas, both as places for industrial development and places to live, has meant that a growing number of people are at risk from coastal erosion and flooding. The cost, both in terms of risk to life and property loss, of coastal flooding and mass movement events can be significant. There has always been a need to protect vulnerable coastal areas from the elements, but this need is likely to increase in the future as climate change brings about rising sea levels and an increasing number of winter storms (Figure 8.22).

Figure 8.22 Railway workers inspecting the main Exeter to Plymouth railway line at Dawlish which was closed due to parts of it being washed away by the sea on 5 February 2014.

How are coastlines managed in the United Kingdom?

In the UK the Department for Environment, Food, and Rural Affairs (Defra) has overall responsibility for the protection of the coastline against flooding. They work with local councils and landowners to manage the coast. Not all parts of the coastline need to be protected. Some coastal areas are not vulnerable to erosion or flooding or are not considered valuable enough to be protected.

What methods are used to protect coastlines?

If it is decided that an area of coastline should be protected a decision has to be made about the management strategy that should be used. There are three main strategies of coastal protection.

1. **Hard engineering** – controls the sea by building barriers between the sea and the land, or forces waves to break before they reach the coast by building offshore breakwaters.
2. **Soft engineering** – works with the natural environment by preserving the beach. A wide, gently sloping beach absorbs wave energy, reducing the threat of erosion and flooding.
3. **Managed retreat (coastal realignment)** – involves allowing the sea to flood land up to a new line of defence further inland. Salt marshes are then developed on the newly flooded land, providing a natural barrier against storm tides.

Tip

Remember: The main threats to coastal areas are flooding, erosion and mass movement (landslides/mudslides).

Watch a video on Cambridge Elevate about coastline management at Studland Bay in Dorset.

Further research

In many areas a mixture of both hard and soft engineering techniques are used to protect the coast. An example of this is the West Bay Coastal Defence Scheme in Dorset. Find out more at the **Dorset County Council website** (www.cambridge.org/links/gase40063)

Hard engineering

Hard engineering attempts to control the power of the sea by using artificial structures. These structures are designed to reduce wave energy or simply create a barrier between the land and the sea so that the storm waves cannot reach cliffs or flood low-lying coastal areas (Figures 8.23 and 8.24).

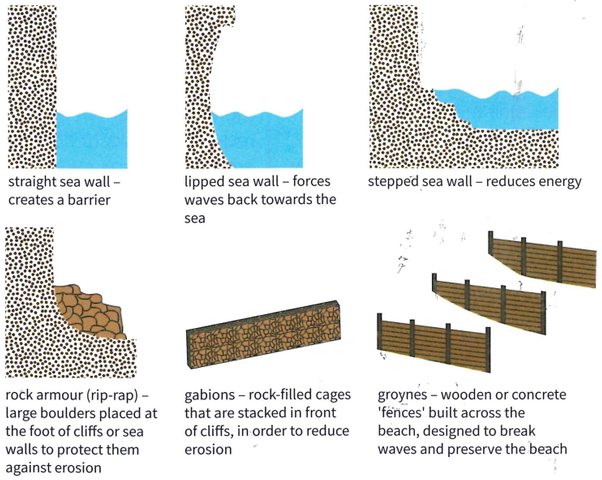

Figure 8.23 Examples of hard engineering techniques.

ACTIVITY 8.5

1. What factors might be taken into account when a decision is made about whether a coastal area should be protected or not?
2. Why are the terms 'hard' and 'soft' engineering used to describe those two methods of coastal protection?
3. Explain how hard engineering techniques protect coastal areas from physical processes.
4. Using Figures 8.24 and 8.25:
   a. Describe the hard engineering methods used at Cleveleys.
   b. Suggest why hard engineering was used at Cleveleys.

Figure 8.24 Sea defences at Cleveleys, Lancashire.

Figure 8.25 A storm at Cleveleys.

Costs and benefits of hard engineering

Costs	Benefits
Very expensive	Effective against the threat of flooding
Disruptive during construction	Reduction of wave energy
Need for constant maintenance	Can provide amenity valve (promenades)
Not always very attractive	Reduces risk of damage, making residents and local business feel more secure
May disturb/damage wildlife habitats	

Table 8.1 The costs and benefits of hard engineering.

8.6 Protecting coastlines from the effects of physical processes – soft engineering

What is beach nourishment?

Beach nourishment is a method of adding sediment to a beach so that it acts as a natural defence against storm waves (Figure 8.26). A wide and gently sloping beach acts as a natural defence because it is able to absorb wave energy and prevent waves from moving inland. It is used to reduce the flood risk in low-lying areas.

Beach nourishment is an example of '**soft engineering**' because it provides a natural defence against the sea without having to build large, artificial structures. Consequently it is seen as environmentally friendly and more suitable in sensitive environments. The following example, at Pevensey Bay in East Sussex, describes how soft engineering techniques have been used to reduce the risk of flooding.

Why was coastal management needed at Pevensey Bay?

Pevensey Bay is a low-lying coastal area which has a history of flooding and faces increasing flood risk as sea levels rise. Just inland are the Pevensey levels, a low-lying freshwater environment which would be significantly damaged by saltwater flooding. The coastal area is home to about 1000 people and there are a number of local tourism related businesses. The main road and rail links are close to the coastline.

There are four main coastal management techniques being used at Pevensey Bay:

- **Beach nourishment** – replacing beach material lost during storms and as a result of longshore drift. Sand and gravel is taken from the seabed and sprayed back onto the beach using a specially adapted ship (Figure 8.26).
- **Beach recycling** – longshore drift carries beach material from west to east (25 000 m^3 a year). Lorries are used to move the material back to its original position, making sure that the width of the beach remains the same along its length (Figure 8.27).
- **Beach reprofiling** – during storms beach material is moved towards the sea by the strong backwash, creating a beach with an uneven profile. This can leave the upper parts of the beach very low. Bulldozers push the material back up the beach, creating an even profile (Figure 8.28).
- **Technology** – global positioning systems (GPS) are used to track the movement of the beach material and identify areas where replenishment is required.

Dune regeneration

Dune regeneration is another type of soft engineering. It is used in areas where there are sandy beaches and strong on-shore winds which can blow the fine sand inland. In order to preserve the beach and stabilise the sand dunes, the area is planted with marram grass and fencing is used to trap the sand, creating a natural barrier between the land and the sea. In some areas boardwalks or coconut matting is used to protect the sand dunes from erosion caused by walkers and bike riders.

Managed retreat (coastal realignment)

Managed retreat is where low-lying areas are allowed to flood up to a new line of defence. This creates an area where salt marshes can be developed. When the salt marshes are fully developed they absorb wave energy during storms and therefore act as a natural defence. The area of salt marsh also allows rising tides to spread out, reducing the flood risk on surrounding coastal areas. The newly formed salt marshes provide an ideal habitat for wildlife and are often designated as **nature reserves**.

Managed retreat is often called coastal realignment because a new coastline is formed inland, so the coastline is 'realigned'.

Key term

soft engineering: working with the environment in order to reduce the risks of flooding and erosion

Figure 8.26 Beach nourishment.

Figure 8.27 Beach recycling.

Figure 8.28 Beach after reprofiling.

Costs and benefits of soft engineering

Costs	Benefits
Requires regular maintenance	Has a more natural appearance
Not very effective against storm waves	A wide, gently sloping beach reduces wave energy
Removes sand from elsewhere	Uses natural materials
Can be expensive to set up	Creates a wide beach with high amenity value

Table 8.2 The costs and benefits of soft engineering.

Costs and benefits of managed retreat (coastal realignment)

Costs	Benefits
Can be very expensive to set up	Creates a natural barrier against storm waves, reducing flood risks
Causes the loss of land and amenities	Develops an **intertidal habitat** (salt marsh)
Cost of relocating infrastructure	New habitat encourages wildlife
Conflict with local landowners	Nature reserves create environmental and social opportunities

Table 8.3 The costs and benefits of managed retreat (coastal realignment).

Find out more on the **RSPB website** (see www.cambridge.org/links/gase40065) or the **SCOPAC website** (see www.cambridge.org/links/gase40066)

Assess to progress

1 Name and describe two types of coastal erosion. 4 MARKS
2 Suggest how geology influences coastal landforms. 4 MARKS
3 Explain the formation of a coastal spit. You may use a diagram. 6 MARKS
4 Describe the features of erosion and deposition in a section of UK coastline you have studied. 6 MARKS
5 Using an example you have studied, describe the features of a coastal management scheme and explain why management was required. 9 MARKS

Further research

Find out more at the **Pevensey Bay website** (see www.cambridge.org/links/gase40064)

Think about:
- why soft engineering was used in this area
- how successful the scheme has been.

Key terms

nature reserve: a conservation area which is set aside to preserve plants and animals

intertidal habitat: land exposed at low title and covered at high tide

ACTIVITY 8.6

1 Explain why a beach is a good defence against storm waves.
2 Explain why Pevensey Bay required three types of beach management techniques (nourishment/recycling/reprofiling).
3 Why would hard engineering not be appropriate at Pevensey Bay?
4 Why was Medmerry a suitable area for a managed retreat scheme?
5 Why is the Medmerry managed retreat scheme described as a 'sustainable way to manage this coastal area'?

Example

Coastal management scheme, Ventnor to Bonchurch, Isle of Wight

The coastline between St Catherine's Point and Bonchurch, on the south coast of the Isle of Wight lies within an area known as the Undercliff. The **geology** of this area is a complicated mixture of clay, sands and chalk and it is one of the most unstable coastal areas in the whole of Europe. Because of this, the area has a long history of landslides and rock falls, especially after heavy rainfall and major storms (Figure 8.29).

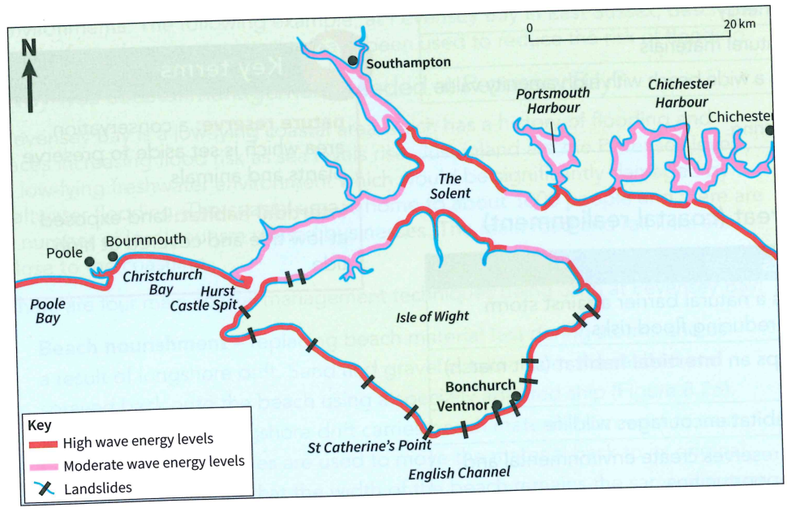

Figure 8.29 The Isle of Wight.

Why is coastal management needed in this area?

There are a number of physical and economic reasons why this area needed coastal protection. The following statement describes some of these reasons.

'This is a high energy coast which is affected by powerful winter storms. Along most of the coast there is no real beach to break the energy of the waves. The cliffs are very unstable and the area has a long history of landslides, some of which have caused significant property damage. Increasingly wet winters have increased the risk of ground movement. The area is both a holiday resort and a residential area with millions of pounds' worth of property. The main east–west road link runs close to the coast and all the main services run underground. A major landslide event in the area would have serious economic and social consequences.'

What type of hard engineering techniques have been used in this area?

This area has been protected from the effects of erosion and weathering for many years but historically coastal defences were built along short parts of the coast as a response to a particular storm or landslide event. However, over the last 40 years there has been a coordinated plan to use hard engineering techniques to protect the whole of the coastline between Ventnor and Bonchurch (Figures 8.31 and 8.32).

Did you know?

If there was no coastal management in this area it is estimated that the **cliff retreat** would be 48–160 m over the next 100 years.

Key terms

geology: study of the Earth, especially rocks

cliff retreat: cliff eroding away and the position of the coastline moving back

sub-aerial processes: processes that affect the face and top of cliffs

Further research

Investigate the recent landslips in the Undercliff area to the west of Ventnor to see the impacts of major ground movement. Search the web with terms such as, recent landslide, Undercliff, Isle of Wight.

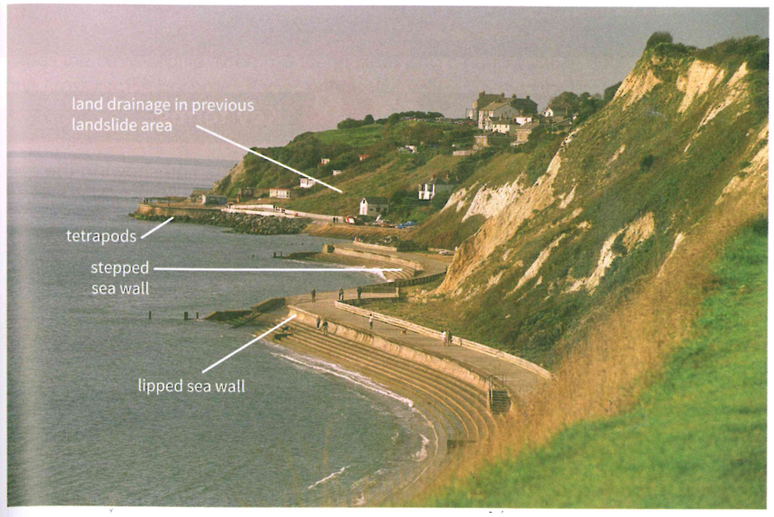

Figure 8.30 Coastal management between Ventnor and Bonchurch.

Figure 8.31 Hard engineering techniques – Ventnor to Bonchurch. The photo on the left shows tetrapods; the photo on the right shows rock armour (rip-rap).

The plan aims to:

- protect the cliffs from the effects of storm waves and **sub-aerial processes**
- stabilise the areas where there are risks of landslides.

Has coastal management been successful in this area?

The two key aims of coastal management were to protect the area from the effects of erosion and to reduce the risks from landslides. In terms of these aims the scheme has been successful. There are no areas where the sea can now directly attack the cliff and the area has seen no major landslides for the last 20 years. Sections of coast to the east and west of this area, which are not protected, have had major landslide events. The cliffs are still affected by weathering and there are minor rock falls occasionally, but these are not significant. Despite the success of coastal management in this area, there are conflicting views about it. Some of these are shown below.

'It has reduced the risk of landslides and included a wonderful promenade where you can walk right along the coast.'

'All the concrete has spoilt the look of the area and it needs to be repaired after every winter.'

'It may not look nice but it is very effective and was really the only option for the area.'

'It may have affected wildlife habitats and has made the area less attractive for visitors.'

'Without the scheme there would be a massive risk of erosion and landslides, with a loss of homes and business. Now it is stable people are more likely to set up new businesses in the area.'

ACTIVITY 8.7

1 What is meant by a 'high energy coast'?
2 Explain why coastal management was needed in this area.
3 a Describe the hard engineering techniques used on the Ventnor–Bonchurch coast.
  b Explain how the techniques reduce the risks of erosion and landslides.
4 Why do some people think that hard engineering is not a very environmentally friendly way to manage the coast?
5 a Do you think that coastal management has been successful in this area?
  b What other evidence might you collect in order to make a more detailed judgement about the effectiveness of coastal management in this area?