3 Sediment sources, cells and budgets

In this section you will learn about sediment sources, cells and budgets in coastal systems

Sources of sediment

Globally, most beach sediment comes from rivers, streams and coastal erosion. However, there are considerable local variations. The main sediment sources are as follows:

- Rivers – sediment that is transported in rivers often accounts for the vast majority of coastal sediment, especially in high-rainfall environments where active river erosion occurs. This sediment will be deposited in river mouths and estuaries where it will be reworked by waves, tides and currents.
- Cliff erosion – this can be extremely important locally in areas of relatively soft or unconsolidated rocks. The extensive till cliffs along the Holderness coast in Lincolnshire comprise sand and clay and rates of erosion can be as high as 10 m a year (Figure **1**). This contrasts with the tough, igneous granites in Cornwall that erode at very slow rates.
- Longshore drift – sediment is transported from one stretch of coastline (as an output) to another stretch of coastline (as an input).
- Wind – in glacial or hot arid environments, wind-blown sand can be deposited in coastal regions. Sand dunes are semi-dynamic features at the coast that represent both accumulations (sinks) of sand and potential sources.
- Glaciers – in some parts of the world, such as Alaska, Greenland and Antarctica, ice shelves *calve* (chunks of ice breaking off a glacier or ice sheet) into the sea, depositing sediment trapped within the ice (Figure **2**).
- Offshore – sediment from offshore can be transferred into the coastal (littoral) zone by waves, tides and currents. In the UK, sea levels rose at the end of the last glacial period, resulting in a considerable amount of coarse sediment being bulldozed onto the south coast of England to form landforms such as barrier beaches (e.g. Start Bay in Devon and Chesil Beach in Dorset). Storm surges associated with tropical cyclones and tsunami waves can also be responsible for inputs of sediment into the coastal system.

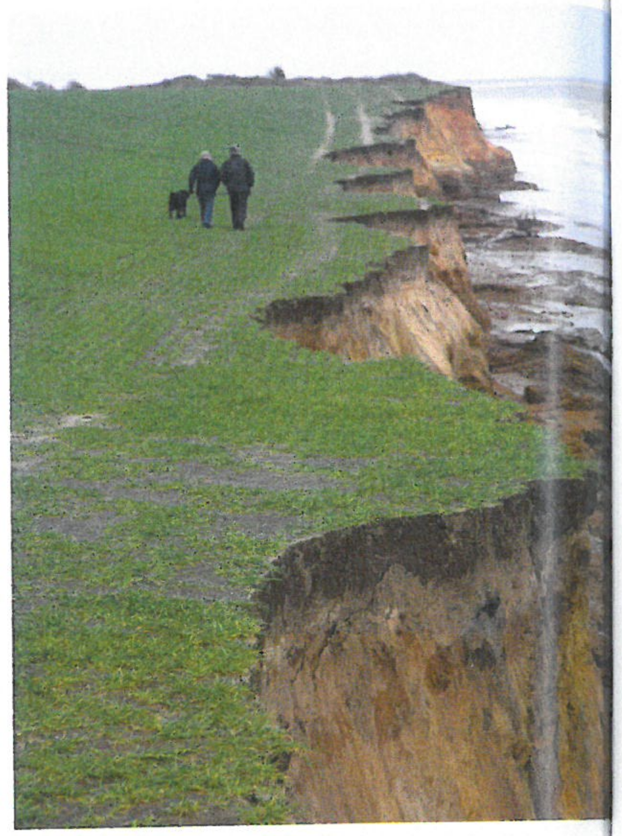


Figure 1 *Rapidly eroding Holderness coast*

Sediment cells

A *sediment cell* is a stretch of coastline, usually bordered by two prominent headlands, where the movement of sediment is more or less contained. Figure **3** shows the sediment cell in the form of a conceptual systems diagram, with inputs (sources), transfers (flows) and stores (sinks).

- Inputs (sources) – these are primarily derived from the river, coastal erosion and offshore sources, such as bars or banks.
- Transfers (flows) – these involve longshore (littoral) drift together with onshore and offshore processes such as rip currents.
- Stores (sinks) – these include the beach, sand dunes and offshore deposits (bands and bars).

Figure 2 *Ice calving at Alaska Bay, Alaska, USA*

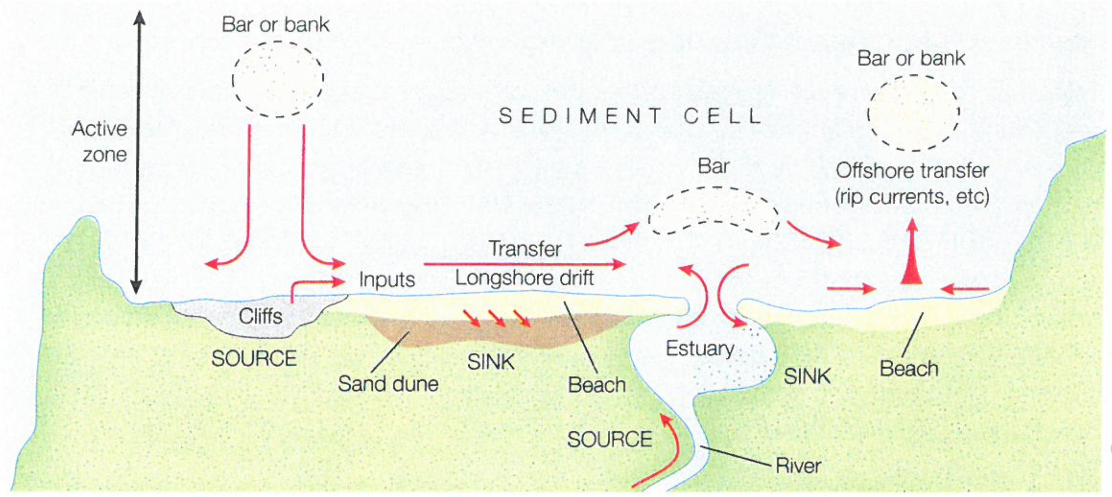


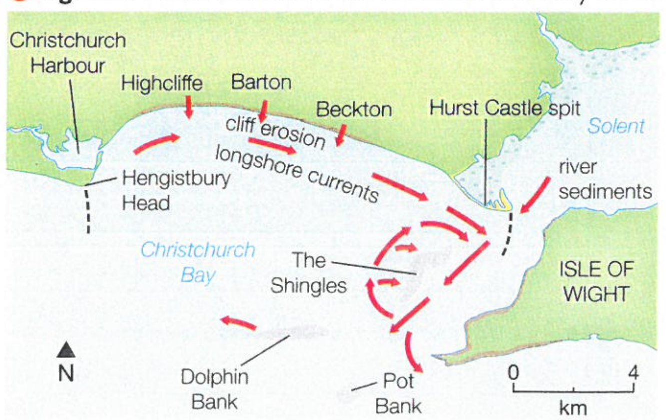
Figure 3 *The sediment cell system*

Some material within the cell may be swept out to sea to act as an output from the system. This may occur as a result of a severe storm event. The temporal nature of the sediment stores is interesting to consider; just how permanent are they? It is all a matter of time scale, as even long-term stores such as sand dunes, sandbanks and beaches may be destroyed by severe storms or long-term sea level rise associated with climate change. In terms of energy, the primary source of energy is the Sun, converted into wave energy by the wind. Tectonic energy is another source of energy in that it will generate tsunami waves.

Sediment cells in England and Wales

Each of the eleven major cells in England and Wales (Figure **2**, 3.1) can be divided into several smaller subcells. One of these subcells lies in Christchurch Bay in Dorset (Figure **4**). Within the Christchurch Bay subcell, the interlinking marine processes of erosion, transportation and deposition can be mapped. It is possible to identify sediment sources (inputs) such as the cliffs to the west of Barton, areas of deposition (stores or sinks) such as The Shingles, and transfer mechanisms, such as longshore drift operating from west to east.

Figure 4 *Sediment movement in the Christchurch Bay subcell*



Sediment budgets

Material in a sediment cell can be considered in the form of a *sediment budget*, with losses and gains. Losses from the system involve deposition in sediment sinks, whereas gains tend to involve coastal erosion or sediment brought into the system by rivers or from offshore sources. In principle, the sediment budget seeks to achieve a state of *dynamic equilibrium* where erosion and deposition are balanced. This balance can be upset by events, such as a surge in river discharge following floods introducing vast amounts of sediment into the system. This, in turn, leads to deposition in the river estuary. A severe storm might also upset the balance by eroding a beach and transferring sediment outside the system.

Figure **5** shows the main inputs from coastal erosion together with the transfers along the coast in East Anglia. By comparing the values of sediment movement, it is possible to identify losses and gains at points around the coast and to make assertions about the location of sediment sinks or alternative sources of sediment. This diagram illustrates the difficulty in obtaining data for all components of a sediment cell.

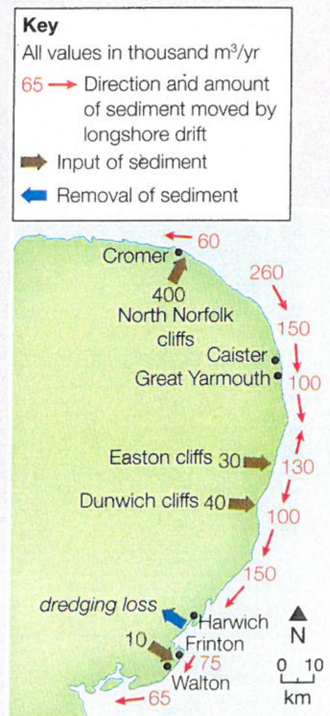


Figure 5 *Coastal sediment budget for East Anglia*

The South Carolina, USA, Coastal Erosion Study

The US Geological Survey (USGS) conducts regional studies of coastal erosion to provide impartial scientific information necessary for the protection and management of valuable coastal resources. One such study involved the north-east coast of South Carolina. The main objective of the study was to determine the geologic and oceanographic processes that control sediment movement along the region's shoreline, thereby improving projections of coastal change, in particular increased coastal erosion resulting from climate change.

The research involved dredging and beach profiling together with the use of secondary data. Figure **6** shows the main components of the sediment budget and Figure **7** lists the results of the research. These results show that, in order to account for the losses as measured directly by dredging of sediment sinks, a huge amount of erosion is taking place, particularly in the inner shelf. Interestingly, relatively small amounts of sediment are gained from river deposition.

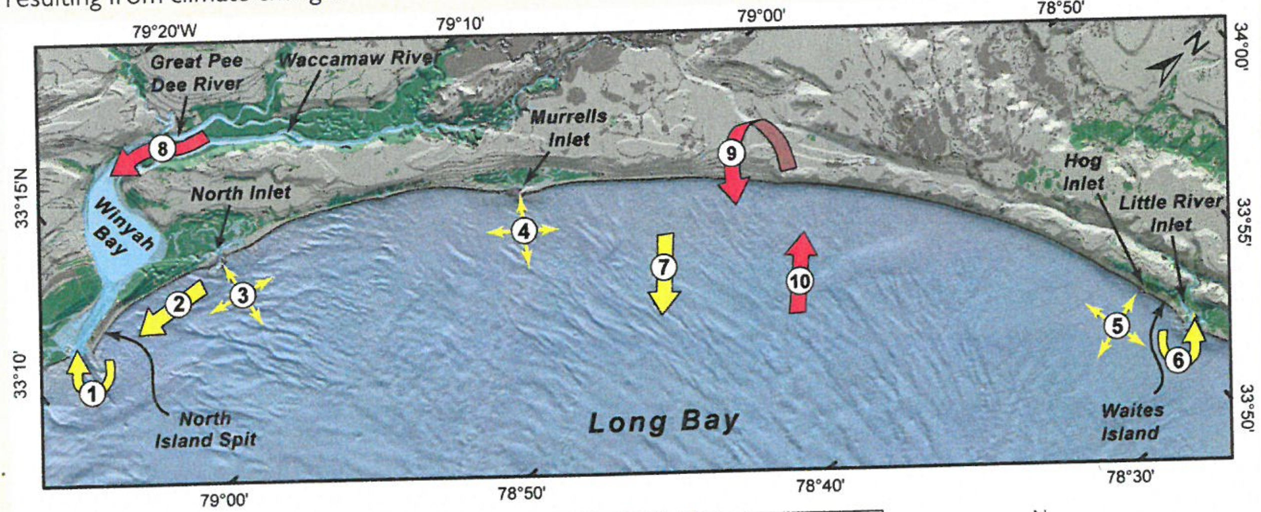


Figure 6 *The components of a conceptual long-term sediment budget for the Grand Strand region (modified from Gayes and others, 2003)*

Sediment sinks (losses)	Volume (m³/yr)	Basis of estimate
1. Winyah Bay	284 000+	1994–2002 dredging records
2. North Island Spit	79 000	Historic spit growth
3. North Inlet	unknown	
4. Murrells Inlet	75 000	1974–1978 dredging records
5. Hog Inlet	unknown	
6. Little River Inlet	57 000	1982–1995 dredging records
7. Loss offshore	unknown	
Total Sinks	**495 000**	
Sediment sources (gains)	**Volume (m³/yr)**	**Basis of estimate**
8. Rivers	very small	Patchineelam and others (1999)
9. Beach and shoreface erosion	104 000	Beach profile migration based on the long-term average erosion rate
10. Inner shelf erosion	391 000	Difference between total sinks (1–7) and gains from other sources (8 and 9)
Total Sources	**495 000**	

Figure 7 *Estimated volumes of mobile sediment annually lost to sinks and gained from different sources (modified from Gayes and others, 2003)*

The impact of coastal protection on sediment budgets and the sediment cell

Figure **8** shows a stretch of coastline before and after coastal protection. Notice that the coastal protection measures have the potential to significantly disrupt the operation of the sediment cell and affect the sediment budget (also see Figure **6**, 3.5).

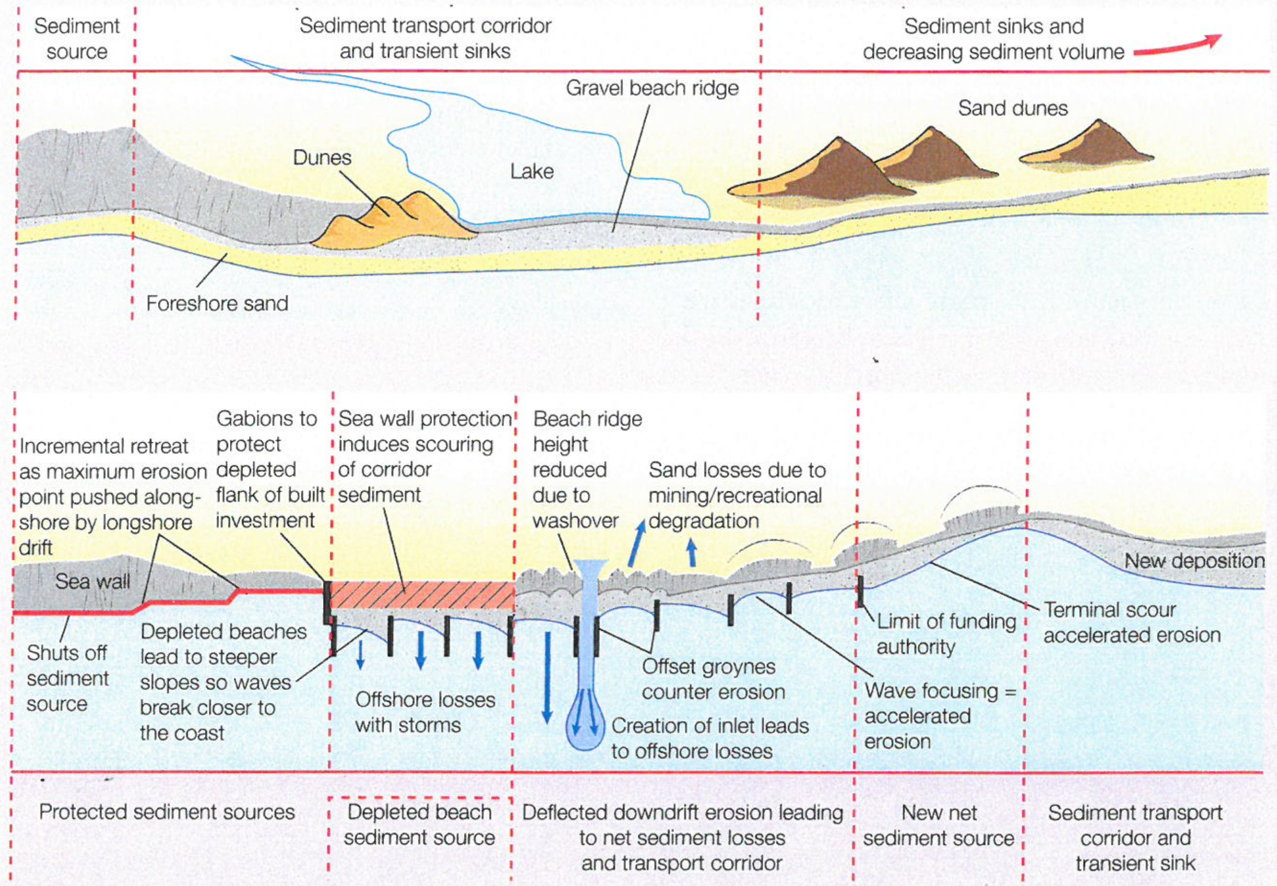


Figure 8 *Distortion of sediment cell by coastal protection measures*

ACTIVITIES

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1 Draw a large conceptual diagram to show the various sources of sediment. Use the internet to expand your annotations and consider using a selection of photos to illustrate your diagram.

2 Make a careful copy of Figure **4** and use labels and/or symbols explained in a key to identify the inputs (sources), transfers (flows) and stores (sinks). Suggest energy flows and consider whether any feedback loops can be identified. Use Figure **2**, 3.1 to help you.

3 Study Figure **5**. Write a short discussion paper using the data to enable you to make assertions about the type and location of additional sediment sources and sediment sinks on this stretch of coastline. Include a simple sketch to support your discussion.

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4 Write a brief report on the South Carolina coastal research project based on the stretch of coast at Grand Strand (Figures **6** and **7**). Your report should identify the purpose of the study, the sediment system in Long Bay, the results of the research and discussion of the implications for the future management of the coastline. Use an appropriate graph or diagram to present the data in Figure **7**. For additional information, access the website at http://pubs.usgs.gov/of/2008/1206/index.html

5 Study Figure **8**. To what extent can coastal protection measures disrupt the operation of a sediment cell and affect its budget?