SPEY BAY

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OS Grid Reference: NJ264688–NJ388642

Introduction

Spey Bay (see Figure 6.2 for general location) is one of the most important gravel coastal geomorphology sites in Great Britain for several reasons. The extensive and well-developed gravel ridge complex is recognized as the finest in Scotland, providing examples of dynamic coastal processes and active fluvial supply of gravels that are unparalleled in the British context (Comber *et al*., 1994; Gemmell, 2000; Gemmell *et al*., 2001a, 2001b). In addition, the active coastal margin is backed by a magnificent emerged strandplain of Holocene gravel ridges that record the progressive history of coastal development and sea-level fall in this part of Scotland over the last 10 000 years (Ogilvie, 1923; Steers, 1973). The Speymouth delta and related forms have a complex and well-documented history of dramatic change (Grove, 1955) and provide an excellent example of the fluvial-coastal interaction and sediment interchange of an actively braided gravel-bed river entering a high-energy coastal environment (Gemmell *et al*., 2001a, 2001b). Indeed, the lower River Spey has also been selected as a GCR site in its own right on account of its unique fluvial geomorphology (see GCR site report in the GCR volume Fluvial Geomorphology of Great Britain (Gregory, 1997)). Nowhere else in the UK is there such a dynamic example of an actively braiding gravel-bed river delivering sand and gravel to a wide coastal gravel beach and backed by a suite of emerged gravel shorelines (Figure 6.32). The wealth and scale of juxtaposed features provide a unique insight into the Holocene development of this part of the Scottish coastline.

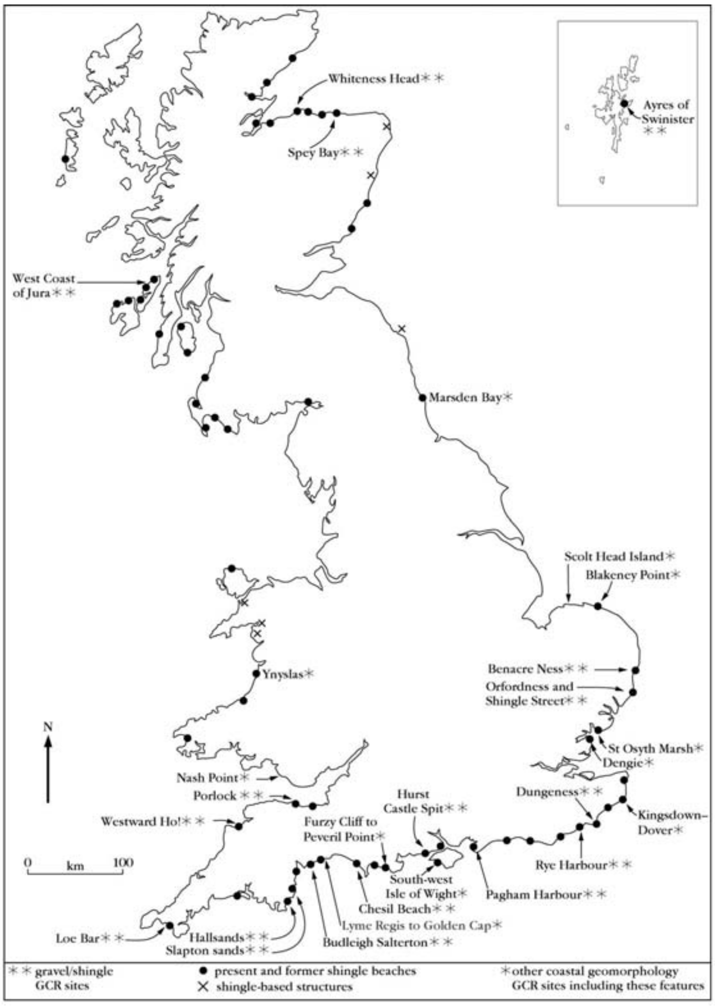

Figure 6.2: Coastal shingle and gravel structures around Britain, showing the location of the sites selected for the GCR specifically for gravel/shingle coast features, and some of the other larger gravel structures.

Figure 6.32: The extensive gravel ridges and emerged coastal and fluvial terraces of the Spey mouth in 1963. At this time, the river was diverted west by over 1 km, threatening the village of Kingston in the right centre of the view. (Photo from Gemmell et al., 2001b)

The GCR boundary follows the Spey Bay SSSI boundary along mean low-water springs (Figure 6.33) for 13 km from Porttannachy (Portgordon) in the east to 2.5 km east of Lossiemouth in the west, and is paralleled by a landward boundary along tracks and fencelines up to 250 m inland from MLWS. The site is selected for its gravel features and although the western limit is located some 2.5 km east of Lossiemouth, the ongoing migration of gravels beyond this boundary is set to continue. As a result, the obvious geomorphological boundaries of this stretch of coast lie at the rocky headlands at Porttannachy (Portgordon) and Lossiemouth.

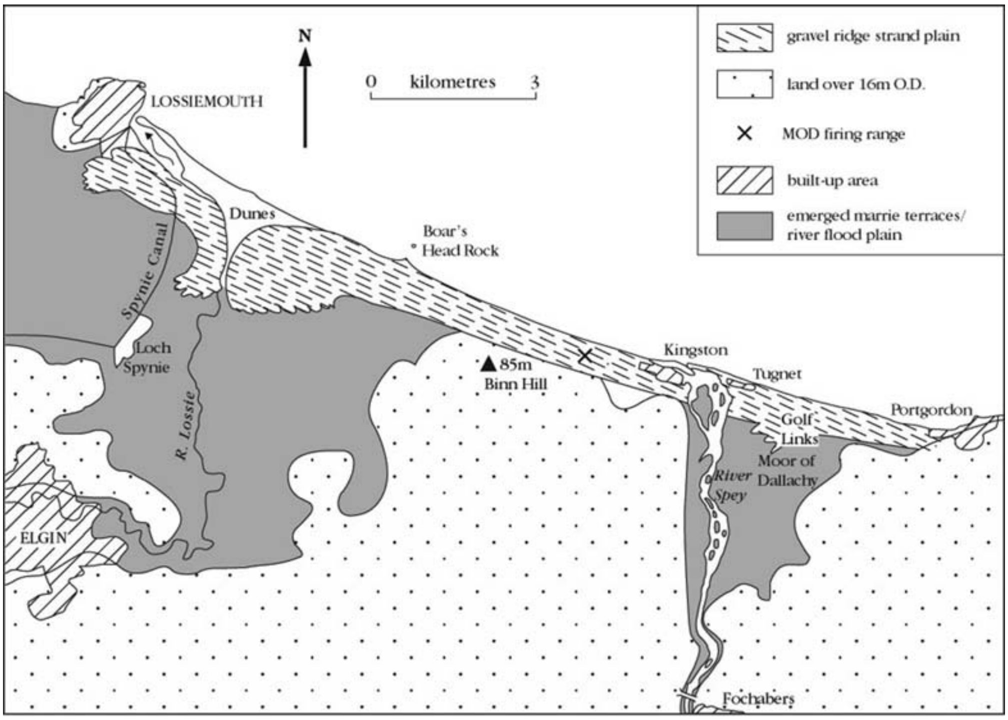

Figure 6.33: Spey Bay showing coastal gravel strandplain backed by emerged marine (and fluvial) terraces. Land over 16 m is mainly glaciofluvial sands and gravels. MoD is a Ministry of Defence weapons testing range. (After Ritchie, 1983.) Westerly extension of the active gravel beach (West Spey Bay). (From Gemmell et al., 2001b.)

Description

As already noted in the description of the Whiteness Head GCR site above, the Moray Firth is landlocked except between north and east and so north-easterly waves dominate and their oblique incidence produces a westerly movement of sediments. Erosion of the coast is at its most severe under northerly and north-easterly storms. For further details on waves, tides and general sea-level changes, see site GCR report for Whiteness Head (present chapter).

Spey Bay lies on the southern shore of the Moray Firth and extends for a distance of *c*. 16 km between rock headlands at Lossiemouth in the west and Porttannachy/Portgordon in the east (Figure 6.33). The present-day coastline trends WNW–ESE and is juxtaposed against a magnificent emerged strandplain of gravel ridges (Figure 6.34) which have isolated a series of glaciogenic deposits, glacio-fluvial and recent river terraces and residual pockets of low marshy ground (Ritchie, 1983). The contemporary gravel beach extends for *c*. 13 km from Porttannachy/ Portgordon in the east to about 2.5 km east of Lossiemouth, where an abrupt transition occurs to a low-angled sand beach backed by sand dunes. The gravel beach is punctuated between Tugnet and Kingston by a complex of gravel ridges that mark the delta of the River Spey (Figure 6.32). Along much of Spey Bay, the average altitude of the main gravel ridge crest is *c*. 6 m OD, although this varies considerably. Crestal overtopping of the gravel storm ridge is common along much of the coastline, particularly west of Porttannachy/ Portgordon and west of Kingston, and coastal recession is a constant concern. The width of the gravel beach varies considerably, from *c*. 10–15 m immediately west of Kingston, to up to 70 m wide, west of Boar's Head Rock.

Figure 6.34: The emerged gravel ridges of Spey Bay descend in a 'staircase' from 9–10 m OD to the present-day beach. The greatest extent of the unvegetated gravel occurs to the west of Kingston (see Figure 6.35), where this picture was taken. (Photo: J.D. Hansom.)

West of the Speymouth delta, close to the Ministry of Defence firing range, several low altitude vegetated ridges are truncated by the present gravel beach, and curve gently landwards. These low altitude recurves occur continuously from this point to the westward extent of the gravel beach beyond Boar's Head Rock and become higher and more prominent westwards. West of Boar's Head Rock up to five well-defined gravel ridges curve gently landwards from the rear of the present-day active ridge. In the west, the ridges reach *c*. 6 m and stand up to 2 m above the adjacent intervening troughs. To landward, the ridges are sparsely vegetated by mosses and grasses and are eventually buried by high sand dunes and forest. The full landward extent of ridges is known to be substantial, continuing into the Spynie area to the south of Lossiemouth and as far west as Burghead Bay (Gemmell *et al*., 2001a, 2001b). Within Spey Bay, the junction between these younger, more recently deposited ridges and the ridges of the emerged gravel strandplain, is marked by a 1–2 m rise in altitude and a distinct break in slope, best seen 2–3 km east of Kingston.

On the seaward face of the gravel beaches, cusp forms of different wavelengths are well developed, the size and spacing of these ephemeral features altering in response to short-term processes that vary with wave and tidal conditions. Beach-face slope angles, the degree of sediment sorting and crest elevations also alter in response to wave and tidal conditions. Sediment sorting is well developed down the beach face, with finer-grained, well-sorted gravel lying in the intertidal zone whereas larger calibre, but more poorly sorted, gravel, occurs at or above high-water mark or in the horns of the cusps. However, there is no obvious alongshore trend in beach sediment size, until the abrupt transition from gravel to sand close to Lossiemouth. The median grain size of the gravel varies from 30 mm to 50 mm along the beach, whereas the sand has a median grain size of 0.22 mm (Gemmell, 2000; Gemmell *et al*., 2001b).

Along much of its length, the gravel ridge is subject to washover during storms and at several places washover throats occur in the main gravel ridge that allow coarse gravel lobes to accumulate landwards of the main ridge. This roll-over effect is widespread along the coast. Gravel is also being moved westwards under the influence of westerly waves. According to Grove (1955) 'the most recent gravel bank on the west side [of Spey Bay] appears to have grown steadily along the beach towards Lossiemouth over a distance of one and half miles (2.4 km) since 1870' at an average rate of westerly extension comparable with that of the gravel spits that grow across Spey mouth (Grove, 1955). Using map and field evidence the total westerly extension of the gravel beach was 4.2 km between 1870 and 1995, an average annual extension rate of 33.6 m a^{-1} (Gemmell *et al*., 2001a, 2001b; Table 6.3). Where there was no gravel present in 1903, today there is a 60 m-wide gravel beach, consisting of an active beach ridge of *c*. 4 m OD behind which lie several landward-recurving ridges at about the same altitude.

Changes in the position of mean high-water springs (MHWS) and MLWS at Spey Bay between the first (1870) and the latest current Ordnance Survey (1970) reveal that the eastern side of Spey Bay has been eroded over the intervening 100-year period. This erosional trend declines to the west beyond the Spey delta until it gives way to accretion *c*. 4 km west of the delta (Gemmell *et al*., 2001a, 2001b). Recession rates since 1975 of 1–1.5 m a^{-1} have been recorded both east and west of the river exit (Riddell and Fuller, 1995). The replacement of sand by gravel, discussed above, is reflected by accretion over the 1870–1970 period in the west of Spey Bay along a 4 km stretch in the vicinity of Boar's Head Rock. Farther west, the sandy beach and dunes at Lossiemouth are wholly erosional over the map period, a trend which continues today (Gemmell *et al*., 2001a).

At the mouth of the Spey, complex fluvial and coastal processes interact to create a dynamic and highly active system (Figure 6.35). Historical records (Grove, 1955) suggest that:

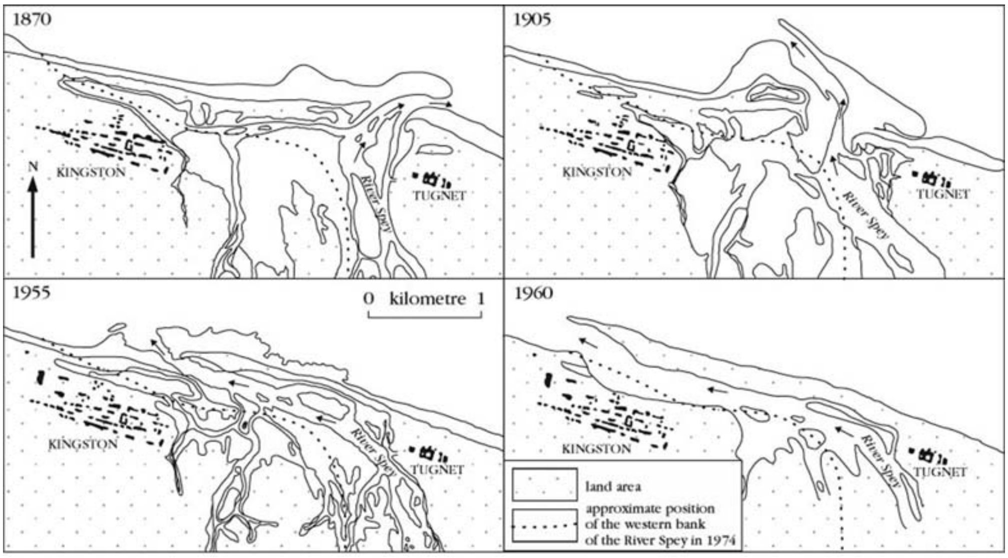

Figure 6.35: Movement of the River Spey mouth between 1870 and 1960. (After Grove, 1955 and Gemmell et al., 2001a.)

'the mouth of the Spey alters more rapidly from year to year than almost any other section of the coastline of Britain and ... the position of the mouth of the Spey has fluctuated violently throughout the last two centuries'.

Changes in the position of the river mouth between 1726 and 1995, documented in Gemmell *et al*. (2001a, 2001b) show a natural tendency for the river mouth to shift westwards towards Kingston, driven by the wave-driven westward migration of the spit across the mouth. If this natural process is uninterrupted, the mouth migrates by up to 1.2 km west of its 'central' (c. 200 m west of Tugnet) position. According to local tradition the Speymouth spit was *c*. 5 km long in 1798 (Hamilton, 1965). The river has always returned to a central location through natural breaches of the gravel spit, as recorded in 1829 and 1981 (Riddell and Fuller, 1995), but recent breaches have been artificially engineered to a 'central' location in order to reduce the threat of flooding and erosion at Kingston. In spite of this, there are also several documented examples (e.g. 1870, 1989 and 1995) of temporary easterly drift at Speymouth, which, although generally short-lived, demonstrate the sensitivity of the longshore drift system to local variations in the wind and wave climate. A complex suite of gravel ridges is present both to the east and west of the Spey outlet, enclosing tidal lagoons. The orientations and recurves of these ridges relate to the interaction of coastal and fluvial processes during the varying positions of the river over time, allowing former positions of the Spey mouth to be identified.

As a result of the erosional nature of much of Spey Bay protection measures have been implemented, mainly in the east. A vertical sea-wall fronts the village of Porttannachy/Portgordon in the east, a 400 m-long section of rip-rap backs the beach immediately to the east of the river mouth at Tugnet and a programme of beach replenishment using gravel excavated from the ridges at the delta mouth has recently been implemented along a 2 km stretch at Kingston (Gemmell *et al.*, 2001a, 2001b).

Interpretation

The contemporary coastal development of Spey Bay is juxtaposed against a fine suite of older emerged Holocene landforms and provides a unique site for the study of former sea levels and how these relate to both past and contemporary sediment budgets. In the UK context, Spey Bay also provides a unique insight into the underresearched area of deltaic processes that occur as a large gravel-bed river exits into a highly dynamic open coast situation.

Ogilvie (1923) provided the first interpretation of the gravel strandplain of Spey Bay in its wider regional and Holocene context, although the most recent and detailed work is that of Riddell and Fuller (1995), Gemmell (2000), and Gemmell *et al.* (2001a, 2001b). Initial emplacement of the Spey Bay ridges against the foot of the Holocene cliff probably began before the peak of the Holocene Transgression (c. 6500 years BP), when rising sea levels delivered large quantities of offshore material to the coast. Together with River Spey gravels, this material infilled the low and flooded areas south of the present-day coast in the area of the Moor of Dallachy, almost as far as Fochabers upriver and to the south of Kingston along the foot of Binn Hill (Gemmell *et al.*, 2001a, 2001b; Figure 6.33). Along its entire length, the Holocene coastline was marked by a very prominent cliff, last occupied *c.* 6500 years BP, and now fronted by a seawards-falling staircase of younger emerged beaches (Figure 6.34). Progressively, the bay of the lower Spey was closed off by gravel storm ridges across the mouth between Porttannachy/Portgordon and Kingston and infilled by fluvial accretion behind. Extending westwards from Kingston, gravel ridge accretion extended beyond the lower Lossie–Spynie area, which was an inlet of the sea, as far as Burghead Bay and the Findhorn area. However gravel accretion and sea-level fall progressively cut off the inlet of the Spynie area and River Lossie from the open sea. Eventually an 800 m-wide swathe of ridges developed to separate Binn Hill from the sea. Altitudes of the ridges suggest that the majority of the sequence was deposited after the peak of the Holocene transgression, with levelled transects displaying a stable and then rapidly falling trend in altitude (Comber, 1993; Gemmell *et al.*, 2001a, 2001b).

There remains great potential for further research at this site and elsewhere on the Moray Firth to produce a quantified Holocene sediment budget for the Firth. For example, research at Culbin *c.* 40 km west of the Spey (see GCR site report for Culbin, Chapter 10) recognized the Holocene contribution of sediment from the River Spey and Findhorn to the development of the large gravel ridge strandplain at Culbin (Comber, 1993).

Contemporary coastal processes and landforms are dominated by a strong westerly movement of gravels and truncation of the gravel recurves in west Spey Bay by the present-day beach suggests that the preceding generations of gravel ridges were subject to similar driving forces. However, since the older ridges were probably deposited along a coastline that trended along a west–east axis, rather than the present-day WNW–ESE, there is a strong suggestion of long-term erosion and planimetric re-adjustment of this part of Spey Bay (Hansom and Black, 1996). These recurves were also noted by Ritchie (1983) who posed the question of '...whether or not the present beach ridge is another gravel beach ridge that continues the pattern of progradational ridges or, as is more likely, it is largely a product of the reworking of the front of one of the ridges of the emerged gravel foreland'. The suggestion from both Ritchie (1983) and Hansom and Black (1996) is that while the eastern part of Spey Bay is eroded and rotates landwards, it fuels a seawards rotation of the west Spey Bay gravel ridges.

Gemmell (2000) and Gemmell *et al.* (2001a, 2001b) produced a preliminary contemporary sediment budget for Spey Bay (Figure 6.36), using a combination of map and field evidence and results from published computer modelling. Sediment input into the contemporary system derives from updrift erosion of the present-day beach and from the River Spey itself, which from modelling studies contributes an estimated 8000 m^3 a^{-1} to the coast (Riddell and Fuller, 1995). These input sediments contain approximately 80% gravel and 20% sand, and so the annual input of gravel into the system from the river is *c*. 6400 m^3 (Figure 6.36). When added to the amount contributed by recession of the adjacent shore (9496 m^3), some 15 900 m^3 of gravel is input to the Spey system annually. However, the annual accretion of gravel in the ridges at Boar's Head Rock and beyond only accounts for approximately 5600 m^3 and so there is an apparent annual net loss of 10 316 m^3 of gravel from the Spey system. This apparent loss may be a function of error in the amount and periodicity of material delivered or in the estimate of gravels held at Boar's Head Rock. If losses are occurring then the final destination of the gravels is unknown. There is also an apparent annual net loss of sand from the Spey Bay system that amounts to 8864 m^3. The final destination of the sand is probably to sand dune accretion behind the beach and infill of the Lossie saltings, however an unknown amount is almost certainly lost to the offshore zone and may bypass the local sediment cell boundary (Ramsay and Brampton, 2000c) at Lossiemouth.

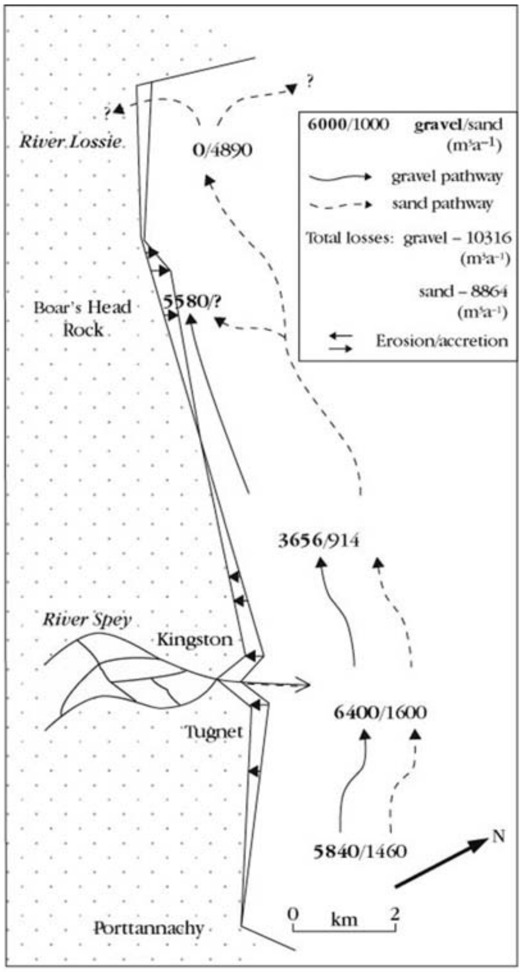

Fig 05.39

Figure 6.36: Diagrammatic representation of the Spey Bay sediment budget. Scale approximate. (After Gemmell et al., 2001a.)

The above sediment budget, although preliminary and under revision, is instructive because it supports the geomorphological evidence and indicates that the entire length of Spey Bay functions as a discrete sedimentary unit, with erosion of one section influencing accretion at another. However, the supply of gravel alongshore is not constant and is subject to pulsing depending upon fluvial supply and storm events (Gemmell *et al*., 2001a). Further, since sediment supply from the offshore to Scottish coasts is now much diminished, the supply to the Spey system is no longer added areally to the shoreface as before. Instead, reduced volumes of sediment are now added mainly as point sources at the Spey delta and at erosional sites

(Hansom, 2001). The result is that periodic alongshore re-distribution of discrete plugs of gravel occurs, and this may give rise to local areas of gravel surplus and deficit.

It follows that interference in the natural transit of gravels will inevitably affect the geomorphological evolution of the Spey system. For example, the hard coastal defences at Porttannachy/Portgordon already interrupt sediment transport and effectively starve the downdrift beach of feeder sediment, thus contributing to accelerated erosion. As a result, proposals to erect coastal defence structures in mid-Spey Bay and protect Kingston are likely to impact negatively on the downdrift beaches of west Spey Bay. Work by Gemmell*et al*. (Gemmell *et al*., 2001a) has also shown that increasing fluvial protection of the banks of the River Spey over the last century has probably reduced the amount of sediment entering Spey Bay and may now be beginning to affect the natural geomorphological evolution of the coastal system.

Conclusions

Spey Bay is an important site for coastal geomorphology and of particular interest because the large input of fluvial gravels is unusual in a UK context. The active gravel storm ridges of the present-day coast are some of the finest in Scotland and their constant adjustment to waves in Spey Bay demonstrates both short- and medium-term dynamic coastal processes. The active coastal margin is juxtaposed against a magnificent emerged strandplain, with a suite of gravel shorelines relating to the progressive history of coastal development within the Moray Firth as adjustments took place in Holocene sea levels. Additionally, the site is important on account of the unique fluvial–coastal interaction displayed at Speymouth, where the coarse sediments of the dynamic and actively braided River Spey enter a high-energy, open-coast gravel beach.

At Spey Bay, there is great scope to provide more accurate contemporary and Holocene sediment budgets for the river and coast. In addition, the contemporary development of Spey Bay has three unique features, all of which have great potential for future study: the loss of the sand beach at Lossiemouth and the progressive replacement by the westerly accretion of gravel; the gradual change in coastal orientation of Spey Bay, as updrift erosion in east Spey Bay fuels downdrift accretion; and the dynamics of fluvial-coastal interaction and periodic release of gravels at Speymouth.

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