Solway Firth (North Shore), Dumfries and Galloway

[NY 003 668]–[NY 118 652]

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Introduction

In spite of work by Marshall (1960, 1962), Steers (1973), Mather (1979) and Bridson (1980), the only recent detailed geomorphological research on the Solway (north shore) saltmarshes has concerned the inter-relationship between forms, sediments and radionuclides by Allan (1993), Harvey and Allan (1998) and Harvey (2000). Extensive saltmarshes occur adjacent to the River Nith that warrant detailed research, particularly concerning the recycling of eroded sediment in the developing marsh. Radionuclide-polluted sediment provides a useful method of quantifying such erosion and deposition.

Caerlaverock saltmarsh has been designated a Special Area of Conservation (SAC), a Special Protection Area (SPA), a National Nature Reserve (NNR) and it is part of the Nith Estuary National Scenic Area.

Description

The north Solway saltmarshes extend from the Nith estuary [NY 003 668] eastwards through the Caerlaverock National Nature Reserve across the mouth of Lochar Water to its exit at Priestside Merse (Figure 10.12). The intertidal sandflat in this area exceeds 10 km in width. Within the Nith estuary and the inner Solway, the active marshes are terraced with as many as four levels separated by unvegetated terrace edges. Flanking the west shore of the Nith, Kirkconnell Merse extends to 208 ha, much of this a *Puccinellia–Festuca* (common saltmarsh-grass–fescue) sward (Burd, 1989) (Figure 10.13). At its landward edge, the merse is entirely enclosed by earth banks, and the river edge is marked by a prominent terrace, which runs almost exactly north—south. The merse reaches 1 km at its widest to the west of Glencaple on the east bank of the Nith, but narrows southwards to disappear at Airds Point (Figure 10.13). Northwards, the merse narrows before widening and merging with Green Merse near Kelton. The marsh surface is traversed by a dense dendritic network of shallow creeks, with saltpans virtually absent other than in a narrow zone along the middle and rear of the marsh. Other than north of Kelton, where it reaches 200 m wide and is traversed by deep creeks, the saltmarsh on the east side of the Nith is narrow, intermittent and limited by the proximity of the channel of the Nith and by rising ground behind.

Caerlaverock Merse, including the 77 ha of Priestside Bank at its eastern end, extends to a total of 560 ha and is dominated by a mainly *Puccinellia–Festuca–Glaux* sward with small stands of reeds *Phragmites* (Burd, 1989; (Figure 10.14)). Common saltmarsh-grass *Puccinellia* and samphire *Salicornia* occur in the creeks. Caerlaverock is about 8 km long and widens from less than 100 m wide at the Nith mouth in the west, to almost 1 km wide at the Lochar Water in the east. The marsh sediments are formed almost entirely of fine-grained sand (0.2–0.002 mm in diameter) with some fine-grained silt and day (Harvey, 2000). The landward boundary of Caerlaverock is marked by an earth bank, which extends for some distance inland along the Lochar Water. Landwards of the earth bank, a well-defined emerged beach occurs that shows two distinct surface levels at +8 m and +6.5 m OD (Steers, 1973). Using aerial photographs, Marshall (1962) indicated that these emerged beach surfaces were traversed by drainage channels that resembled old creeks and suggested that the surfaces represented emerged former saltmarshes.

The surface of Caerlaverock Merse is cut by several deeply incised creeks that run southwards to the marsh edge. However, the creeks are infrequent except in the vicinity of the Lochar Water, where a well-developed creek system exists draining eastwards. Elsewhere, the creeks are short and fed by small and infrequent surface streams. Saltpans are infrequent and tend to be located towards the rear of the salt-marsh surface. In the west of the saltmarsh, substantial lengths of the seaward edge are subject to erosion and are marked by a *c.* 1.5-m high, vertical, or in places stepped, terrace edge (see (Figure 10.15)). In places, the top surface of this terrace also shows extensive damage to the vegetation and surface sediment with vegetation having been stripped off for distances of up to 10 m inland. Lying below these stripped and eroded edges, and often masking the junction between terrace and sandflat below, lie numerous blocks of eroded saltmarsh sediment. The prominence and height of the terrace edge reduces to the east and is replaced by a low-angled and largely accreting foreshore. The amount of accretion increases towards the Lochar Water and this extremity of Caerlaverock is actively extending eastward, an extension favoured by the migration of the channel of the Lochar Water towards its eastern bank at Priestside.

Priestside Merse is situated on the east bank of the Lochar Water and comprises an area of grazed saltmarsh fronted by sandflat. Perkins (1973) reported that a wide saltmarsh with an erosional terrace at its front edge was present in 1964 but that by 1968 accretion was taking place at the front edge. Firth *et al.* (2000) observed a low 20–30 cm-high erosional bluff along this edge, fronted by a 5–10 m-wide zone of slumped material and turf blocks. Eastwards, the marsh widens to 400 m before narrowing to a thin strip of Puccinellia-dominated sward at Powfoot (Mather, 1979). At Powfoot the saltmarsh is reduced to an area of 30 cm-high small hummocks capped by *Puccinellia,* locally known as 'dabs', the seaward side of which is marked by an abrupt boundary with the intertidal sandflat.

Although lying in the west, between Balcary Point and Southerness, and thus outwith the Solway Firth (North Shore) GCR site boundary, substantial saltmarshes have developed at the head of the major embayments of Auchencairn Bay, Orchardton Bay and Rough Firth and along the tidal channel of Southwick Water (Figure 10.12) as well at the head of some of the more sheltered small bays (e.g. Balcary Bay). These saltmarshes have developed in sheltered locations where extensive sandflats occur. A relatively extensive, but in the Solway context, rare, area of mudflat also occurs in Rough Firth. Many of the more extensive and mature saltmarshes, such as at Southwick, are dissected by a complex series of deep creek channels and tend to change abruptly from low marsh and pioneer communities such as samphire *Salicornia,* along the channel edges into areas of mature high marsh immediately above. At Orchardton, a substantial area of Spartina-dominated marsh has developed since the 1960s following the introduction of *S. anglica.* However, there are indications that this rapid accretion has been recently replaced by erosion, possibly associated with *Spartina* die-back (Harvey, 2000).

Interpretation

It is clear that the development of saltmarshes on the North Shore of the Solway is not a recent phenomenon and substantial evidence exists to indicate long-lived deposition related to shoreline emergence over the Holocene Epoch. For example, extensive level areas on either side of the Nith, and along the valley floor of its west bank tributaries, represent the emerged remnants of the Main Postglacial Shoreline and its intertidal estuarine flats (Firth *et al.,* 2000). At Barnkirk Point, the flat nature of the land immediately inland of the coastal edge is typical of emerged beaches and has been shown to include sedimentary evidence for Holocene sea-level change (Jardine, 1975). Along the Southwick section of the coast, modern saltmarsh and sandflat are backed by relict cliffs 45–50 m high whose foot is adorned with emerged natural arches and stacks (e.g. at Needle's Eye and Lot's Wife). At the head of Auchencairn Bay, emerged estuarine flats up to 1 km wide lie at 8–9 m OD, and similar features lie at similar altitudes along the banks of the Urr Water as far north as Dalbeattie and make up much of the peat-covered surface behind the Mersehead Sands dune ridge. The uppermost of these surfaces at about 9 m OD and most likely date from the rise in relative sea level that occurred up to the peak of the Holocene transgression at about 6500 years BP The lower sur faces relate to deposition that occurred on its subsequent fall (Haggart, 1989). 'The detailed position of terrace extent and edge location relates to the former routes of the main river channels and saltmarsh creek positions.

Such a process of adjustment to sea level and to the shifting positions of streams continues today and controls the way in which the salt-marsh and its feeder sandflats react to changing conditions. Within the Nith estuary and the inner Solway, the active marshes are terraced with as many as four levels, which Marshall (1962) suggests reflect periodic shifts and meandering of channels in the marshland or periods of increased tidal scour when high tides coincide with severe storms during periods of strong winds. However, it is also known that the moat of Caerlaverock Castle was filled by seawater in the 13th and 14th centuries, and this led Steers (1973) to suggest that there was very little marsh around it at that time. As a result, not all of the terraces may be related to sea-level changes and it is important to distinguish between the significance of the variations in altitude of the marshes and the presence of the terrace edges. The upper marshes appear likely to have been constructed at a higher relative sea level than today, but the terrace edges that separate them may not themselves represent a distinct change of sea level.

The development of most of the Solway marshes indicate that they undergo phases of erosion and deposition. For example at Caerlaverock the entire marsh seaward of the lower emerged beach seems to have developed in three phases between 1820 and 1962 (Steers, 1973). Prior to 1856 accretion had occurred in the lee of Saltcot Hill, although the site of accretion shifted to Bowhouse Scar between 1856 and 1898. Between 1898 and the 1920s, most accretion occurred west of Bowhouse Scar (Bridson, 1980). At present the oldest marsh occurs at the eastern end and is higher in altitude than the other parts. Accretion since the early 19th century was replaced by erosion during the 1920s, possibly because the piers of the Bowness to Annan viaduct, built in 1864, acted as groynes and accelerated accretion on their western side (Marshall, 1962). The rapid extension of Caerlaverock Merse and the eastern part of Kirckonnell Merse was probably related to attempts to improve the Nith river channel for navigation (Steers, 1973).

Between 1946 and 1955 erosion at Bowhouse, south-west of Caerlaverock Castle, totalled 38.1 m a^{-1} and the annual rate between 1955 and 1976 was *c.* 7.6 m (Bridson, 1980). Over similar timescales, the annual vertical accretion rate declined with altitude from 30 mm at +5 m OD, to 10 nun at +5.1 m and to very small amounts at +5.2 m (Steers, 1973). Between July 1959 and March 1961, common saltmarsh-grass *Puccinellia* marsh extended seawards by 4.9 m. However, individual events are also important, and the saltmarsh edge near Caerlaverock Castle was cut back by 3.3 m during a single storm between 30 October and 11 November 1960. Marshall concluded that generally erosion was exceeding accretion and this is borne out by saltmarsh-edge mapping conducted by Rowe (1978) (Figure 10.14) that shows the marsh edge at Caerlaverock to have retreated substantially over most of its western part while accreting in the east in the period 1946–1973. More recent work by Pye and French (1993), Hawker (1999) and Harvey (2000) show the process of erosion in the west and accretion in the east at the Lochar Water to be continuing.

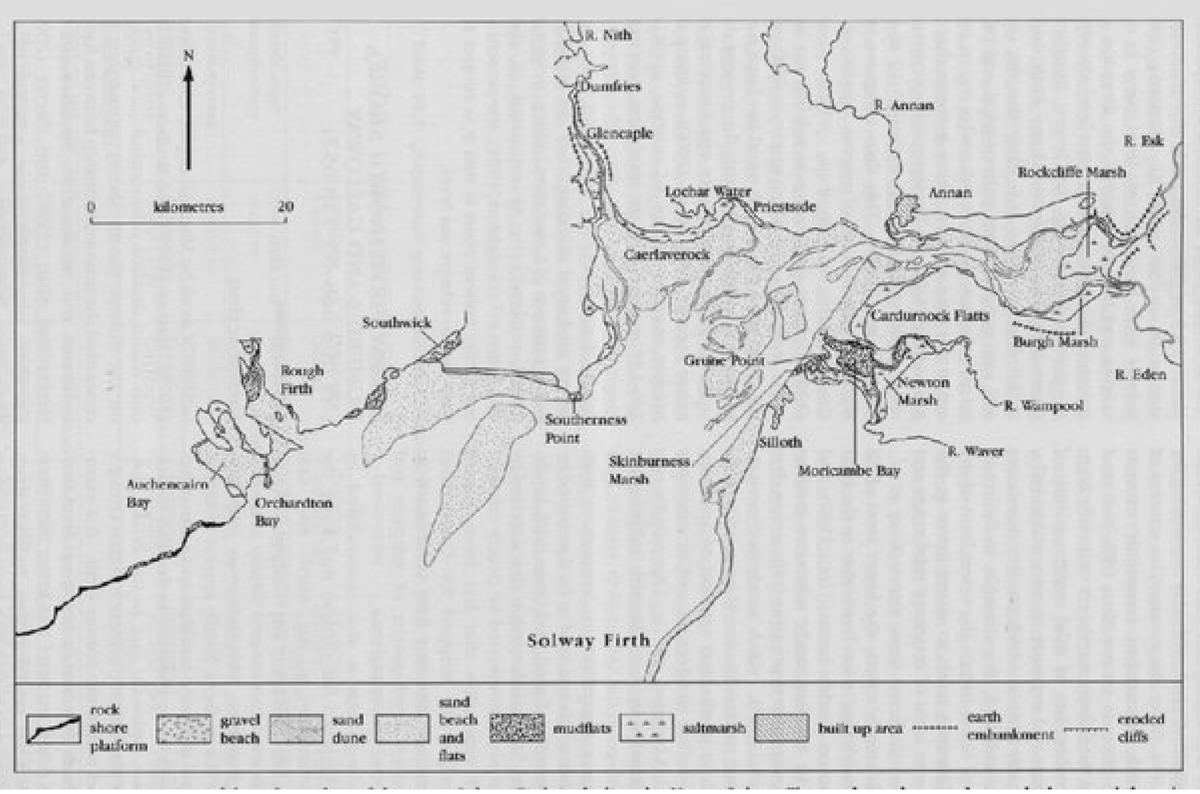
The switch from deposition to erosion that has characterized the western part of (5) Caerlaverock may be attributed to a number of factors.

1. Changes in the position of the main channel of the Nith indicate a progressive easterly migration, accelerated by dredging related to navigational improvements and the dumping of the spoil on the west bank.
2. The western side of the estuary is also more sheltered than the east side and Kirkconnell Merse showed a net increase of 51 ha between 1946–1973 (Rowe, 1978), a rate of about 2 ha per year. Over the same period, the west of Caerlaverock has undergone edge erosion via toppling failure of large blocks of saltmarsh sediment by undercutting at high tide during storm conditions. Even in this relatively sheltered part of the Solway, the short and steep waves that impinge on the saltmarsh edge are capable of significant erosion of unconsolidated sediments, and the stripping of layers of sediment and vegetation from the top surface of the terrace.
3. The front edge of the saltmarsh at Caerlaverock is penetrated by a number of large creeks and within-creek erosion occurs through headward extension of the creek inland and vertical incision, forming a narrow channel. Loading pressures from overlying sediments may lead to the deformation of the lowermost saturated horizons of silty sand into the creek and Firth *et al.* (2000) suggest that the process may lead to localized lowering of the surface along the creek margins (and presumably the seaward edge) and the development of a noticeable tilt, or camber, towards the creek.
4. It is also possible that the annual heavy grazing and trampling of the site by large numbers of wintering wildfowl (e.g. 13 000 barnacle geese), which locally damages the vegetation cover, may lower the resistance of the marsh surface to wave erosion. In this context much of the Solway saltmarsh is characterized by a lawn-like sward dominated by closely cropped graminoid vegetation. The grazing levels by cattle were recorded by Marshall (1962) as the highest on any British saltmarshes with 1 stock unit to 0.8–1.0 ha.
5. The apparent present trend towards erosion of the saltmarsh edge may be controlled by the present rise in global sea level of about 1–2.5 mm a^{-1} (Houghton, 1994). Since the best estimates of actual rates of isostatic uplift in the Upper Solway lie in the range 0.4–0.56 mm a^{-1} (Firth *et al.,* 2000), the Upper Solway may be presently subject to a slow rise in sea level; the pattern of more widespread marsh-edge erosion, and more limited and local areas of saltmarsh accretion, is set to continue.

Work on the Solway by Harvey and Allan (1998) and Harvey (2000) relates to the way in which saltmarsh sedimentation can be informed by the inter-relationship between forms, sediments and radionuclides. The onshore movement of fine-grained sediments brings with it significant levels of radionuclides attached to the particles. These radionuclides are almost exclusively derived from the Sellafield Nuclear Fuel Reprocessing Plant in Cumbria and result in varying concentrations with depth in the salt-marsh (Figure 10.16). Coring of the saltmarsh shows that the depths of different peaks in radionuclide concentration varies spatially over the saltmarsh and so provide marker horizons from which sedimentation rates can be calculated over the time-span represented by the core length. Since erosion of older parts of the salt-marsh is ongoing then re-release of radionuclide-contaminated sediment may ultimately provide a method to estimate the relative contributions of old versus newly arrived sediment to accreting areas of the saltmarsh.

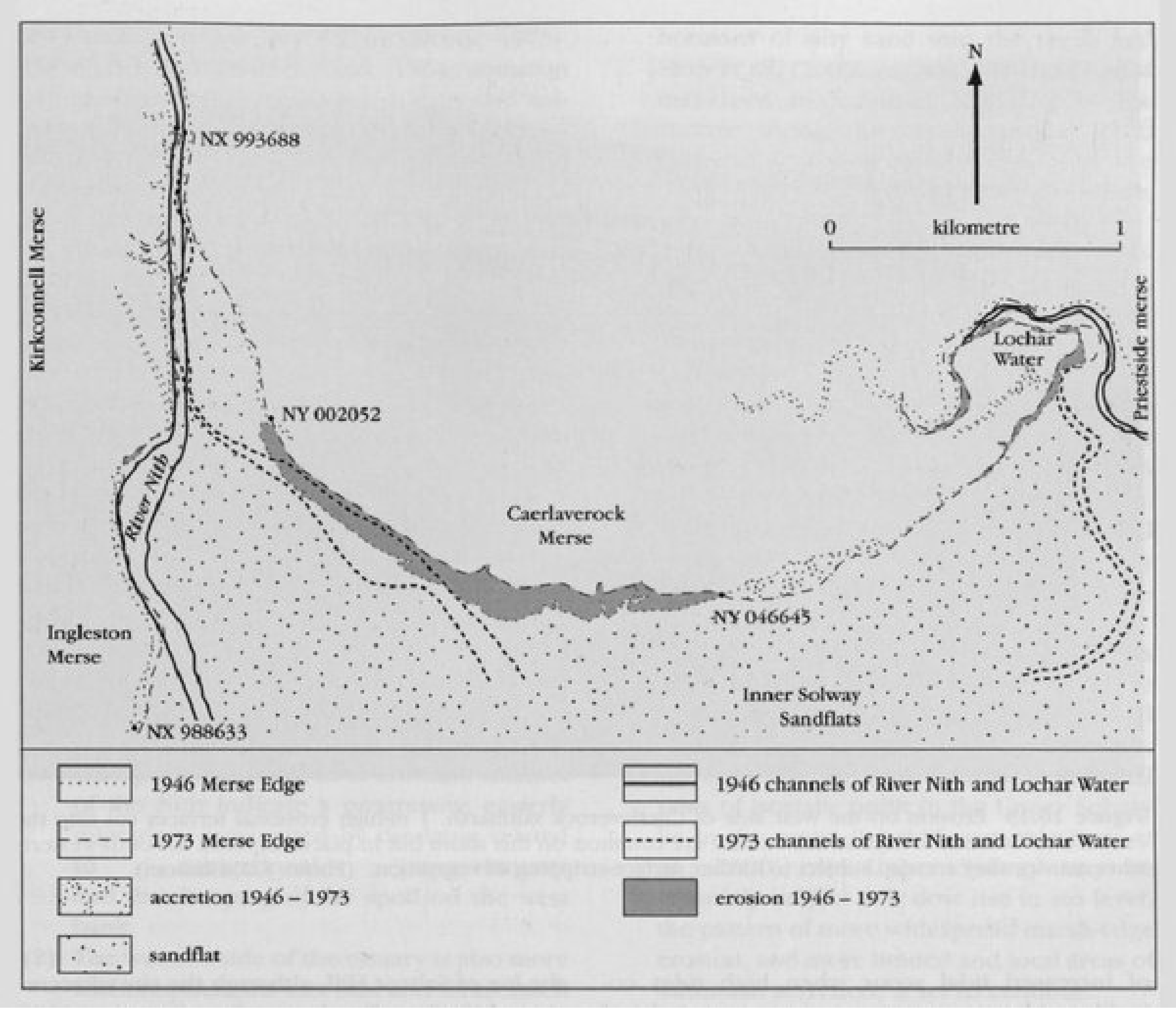
Conclusions

The saltmarshes of the Solway Firth north shore are nationally important because both their geomorphology, and that of their emerged counterparts, show evidence of past and present responses to isostatic uplift, changing sea levels and channel migration patterns. In addition, the top surface of the prominent marsh cliff that occurs along the seaward edge of the marsh has in exposed sites been subject to distinctive stripping of the vegetation cover during storm conditions. The old creek patterns that can be traced on the emerged marine surfaces landward of the present marshes represent evidence for the existence of higher and more extensive saltmarshes in the past, and radionuclides provide an additional means to estimate rates of sedimentation and thus age. Nationally, the marshes of the Solway north shore are key sites for the study of saltmarsh processes, morphology and evolution.



(Figure 10.12) Location of the saltmarshes of the inner Solway Firth including the Upper Solway Flats and marshes on the south shore and the saltmarshes of the Solway Firth (north shore). The 2842 ha of saltmarsh found at these sites comprises 79% of all the saltmarsh in the Solway and 8% of all British saltmarshes. (After Pye and French, 1993.)

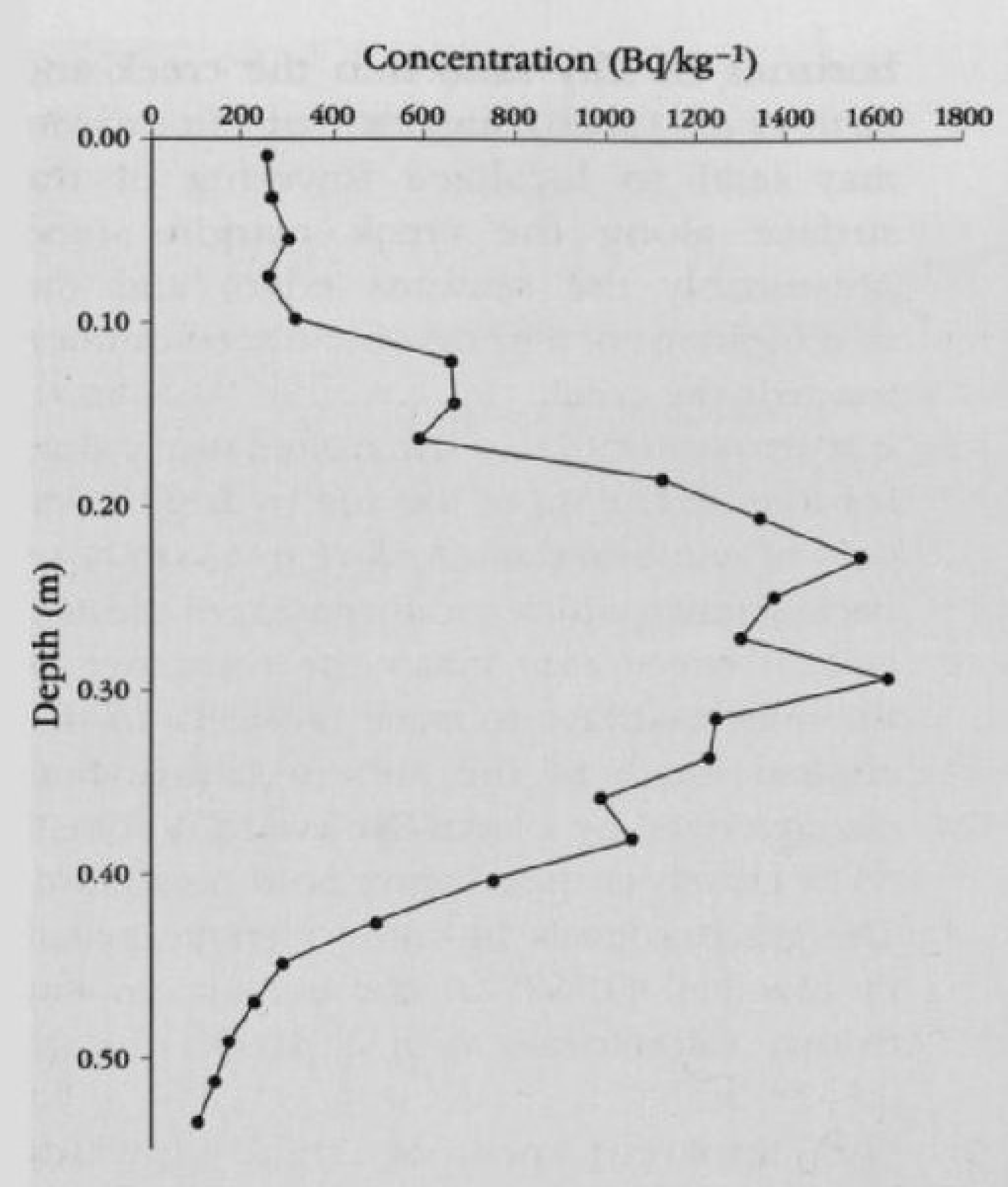
(Figure 10.13) A view looking south over Kirkconnell Merse on the west side of the River Nith towards Airds Point in the middle distance and Southerness beyond. The saltmarsh is grazed and is crossed by many well-developed creeks that drain to a prominent terrace along the Nith. Part of the saltmarsh of Caerlaverock can be seen on the east side of the river and to the south lie extensive sandflats. (Photo: P and A. Macdonald/SNH).



(Figure 10.14) Erosion and accretion of the Caerlaverock saltmarsh edge between 1946 and 1973. Eastward migration of the main channel of the Nith resulted in erosion of the western side of Caerlaverock. Between 1973 and 1999, the

channel had migrated back to the west of the bay and approximately occupied its 1946 route. In spite of this, Harvey (2000) has shown that erosion continues to dominate the west side of the salt-marsh (see Figure 10.15). In the east, close to the exit of the Lochar Water, accretion is the long-term trend. (After Rowe, 1978.)

(Figure 10.15) Erosion on the west side of Caerlaverock saltmarsh. 1 m-high erosional terraces cut into the Puccinellia-dominated high-marsh surface are common on this shore but in places exposed to south-westerly wave activity, they are also subject to further surface-stripping of vegetation. (Photo: J.D. Hansom).



(Figure 10.16) Elevated concentrations of the radionuclide ^{137}Cs occur at varying depths beneath the saltmarsh surfaces of all of the Scottish Solway saltmarshes, including at Caerlaverock. The time-integrated profile of Sellafield discharges shown here, comes from nearby Southwick saltmarsh, and shows peak concentrations at 0.30 m depth below the high-marsh surface, which represent input of sediments from the outer firth that peaked in 1978 and have declined since. These data can be used to calculate a sedimentation rate over time that can be compared with direct measurements using sedimentation plates or pins. (After Harvey, 2000.)