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Sustainable estuary management for the 21st century

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Abstract

In England, many estuaries have been effectively canalised, or so constrained that natural energy attenuation provided by saltmarsh and mudflat has been severely impaired. In this paper, it is argued that there is a need for a change in the management of estuary form, flood defence design and the maintenance of other coastal structures that influence morphological evolution. This needs a radical departure from popular thinking that existing structures should be maintained in situ. Such an approach, whilst defying the popular view of flood and coastal management, is likely to lead to sustainable form, and lower maintenance and capital investment costs in the long-term. In many cases, positive measures to widen the mouth of many estuaries will be needed and reversal of canalisation should be an objective where saltmarsh extent is too limited for effective sustainable flood management.

Keywords: Sea level rise; Coastal squeeze; Morphological evolution; Flood and ebb dominance; Estuary mouth; Canalisation; Saltmarshes; Sandflats; Mudflats; Sustainability.

Introduction

The English coastline is very varied, reflecting the wide age range of bedrocks, with older harder rocks to the west and north, and softer sands and clays to the south and east. This, together with the distribution of periglacial material strongly influences the form and function of many estuaries. For example, the estuaries of south-western England such as the Fal and Helford (Cornwall) and Tamar (Devon) are deep, relatively sediment free and form natural deepwater harbours. In the north-west, estuaries such as the Solway and Duddon (Cumbria) have wide mouths, extensive sandflats and saltmarshes, and are shallow with shifting sandbanks. In southern and eastern England, much of the sediment is derived from eroding clay and sand cliffs and leads to the formation of muddy estuaries such as the Humber (East Yorkshire/Lincolnshire), Stour-Orwell (Essex/Suffolk) and Blackwater (Essex).

A brief evaluation of English sites designated for their nature conservation importance shows that a high proportion of our coastline is designated under UK and international legislation. Foremost amongst such designated sites are our estuaries. At a rough glance at least 48 English estuaries are designated, most of which have European designations in addition to domestic status as Sites of Scientific Interest (SSSI). This level of protection reflects the importance of English estuaries as wildlife sites, especially as overwintering grounds for migratory waterfowl and as breeding sites for an array of birds including marsh harrier *Circus aeruginosus*, bittern *Botaurus stellaris*, bearded tit *Panugus biarmicus*, wildfowl and waders. Habitats of importance associated with estuaries include saltmarshes (Atlantic salt meadows), mudflats and sandflats, subtidal sandflats, *Zostera* beds, biogenic and rocky reefs. Estuaries are the conduit for migratory fish, especially salmonids, lampreys and shads, whilst mudflats and saltmarshes are important nursery grounds for fish such as bass *Dicentrarchus labrax.* Behind sea walls, saline lagoons and brackish grazing marshes are particularly important for their invertebrate assemblages (Drake, 2004).

Historic influences on estuary morphology

Where estuaries support extensive saltmarshes there has been an historic tendency to build counter-walls to limit the degree to which the land was flooded. Such walls would have been sufficient to allow grazing by livestock, but more recent designs have changed. There are two obvious drivers for the change in sea wall design. Firstly the great storm of 1953 led to widespread flooding and fatalities in eastern England (and the Netherlands etc.): it changed for ever the public perception of flood defence. The public memory is long, and the perceived solution is to build bigger armoured walls. Secondly, agriculture behind the flood defences has changed. Post-1945, the political direction for agriculture centred upon self-sufficiency for our food supply. This combined with the UK's entry into the Common Market and more effective mechanisation led to a major shift from coastal grazing marshes to arable prairies. As a consequence, some 85% of coastal grazing marshes in the Thames Estuary were converted to arable (Thornton and Kite, 1990), the value of which was considered much greater in relation to cost-benefit analysis. In the north-west, however, coastal marshes continue to be grazed and are not subjected to the same agricultural pressures.

A further factor behind the construction of sea walls and the canalisation of some estuaries was the nature of coastal shipping and the location of ports. Historically, commercial navigation went many miles inland, linking up with the canal system and carrying goods to and from a final destination far inland. This meant that some estuaries were much-modified to allow favourable navigation conditions, minimise the costs of maintenance of the navigation channel and to deliver particular economic benefits to communities that were to a large extent self-contained.

Today, coastal shipping has changed dramatically, with bigger ships calling at fewer ports. In addition, road and rail transport have led to the gradual loss of inland water-borne transport and the fracturing of communities that are now pleasant dormitories rather than the focus for local commerce. The past infrastructure has slipped into disuse and decay. In places, former floodbanks and training walls have breached (often as a result of the 1953 flood) leading to unusual estuary forms with narrow, hardened entrances and extensive inland mudflats. Classic examples include the Blythe and Alde Estuaries in Suffolk, but others with close similarities include the Crouch and Roach in Essex and the Deben in Suffolk.

In some parts of England, the morphological evolution of estuaries has led to the development of bars or spits that have subsequently been consolidated by hard defences and structures such as quays or hard-standing that make natural evolution in response to changing tidal prisms difficult. Extreme examples include Portsmouth Harbour (Hampshire) and the Mersey (Lancashire) but there are many variants ranging from the Deben (Suffolk) to the Medina (Isle of Wight) and Langstone Harbour (Hampshire). In some cases the scale of infrastructure investment is such that it is inconceivable that changes can be made to the mouth (*e.g.* Portsmouth harbour, the Medina and Mersey Estuaries), but in others the cost/benefit in the long-term may favour such an approach.

Prior to the 1980's, saltmarshes and mudflats were seen as a resource, as new agricultural land and of course for commercial development. This became more pronounced as land prices rose, and development land became more expensive. Thus, the principal ingredients for coast squeeze were in place, but their effects had yet to be recognised. However, by the late 1980's it became apparent that there was a developing problem as east-coast saltmarshes showed signs of erosion (Burd, 1992). More recent studies have confirmed these findings and for example show net losses of nearly 30% of saltmarsh in Hamford Water, and nearly 80% loss in the Stour Estuary between 1973 and 1998 (Coastal Geomorphology Partnership, 2000). Flood defences have become more exposed, requiring strengthening, raising and the placing of energy absorbing rock-armour (also to protect the exposed toes of sea walls). The natural energy attenuation provided by saltmarshes has been substantially lost and engineering solutions have been sought.

The reasons for the accelerating saltmarsh loss first recognised in the late 1980's (Burd, 1992) arise from a number of combined factors. Two of these are largely beyond our control in the immediate future. Firstly, isostatic adjustment whereby south-eastern England is gradually sinking as the north-west rises in response to the loss of the ice-sheet that covered much of the UK during the last glaciation. Secondly, the rising spectre of climate change accompanied by sea level rise and increased storminess. In an unmodified environment these twin factors would simply mean that saltmarshes, reedbeds and mudflats migrated inland, but where there are hard defences this is not possible and the only part of the process that can progress is the erosion of the outermost mudflats and saltmarshes.

The width of the estuary channel along its length, but perhaps especially at its mouth, is particularly important in the process of morphological evolution and responses to sea level rise. O'Brien (1931, 1969) argued that there was a close relationship between the width of the mouth of an estuary and the tidal prism, whereby the mouth width would adjust in accordance with increasing or decreasing flow arising from volumes of water moving in and out of the estuary. Above a particular threshold, the mouth would narrow and below that threshold the mouth would tend to widen. Similar responses can be modelled along the length of an estuary, so a pinch-point within an estuary may lead to localised or more extensive changes to the flood-ebb regime accompanied by erosion or accretion. This relationship has since been refined and forms the basis for much of the top-down and hybrid modelling for estuary form and function including Regime Theory (Pethick and Lowe, 2000) and Dronkers gamma asymmetry ratio (Dronkers, 1969).

These various influences set the scene for today's estuary management issues and possibly offer clues as to how solutions could be delivered. To recap, the problems of sea level rise, erosion of natural energy attenuation features, long-term flood management economics have got to be addressed regardless of other important drivers. For English Nature a major driver is the need to ensure that nature conservation is properly accommodated within the equation. England's estuaries offer some of the best wildlife and wilderness experiences. Many estuaries, including all those quoted above are designated for their international wildlife interest: migratory and breeding birds under the Birds Directive (EEC, 1979), habitats and species under the Habitats Directive (EEC, 1992) and for other wetland communities under the Ramsar Convention (UNESCO, 1994). Sea level rise, coastal squeeze and accompanying loss of intertidal habitat have profound implications for the maintenance of these sites in favourable condition and as a consequence there are huge implications for the coherence of the Natura 2000 series. Unfortunately, the solutions are not simple, and may in themselves involve a degree of loss of existing habitat to create functionally sustainable estuaries.

The nature conservation and flood management dilemma

In many estuaries, nature conservation interest lies both to the front of, and behind sea walls or coastal structures. Since 1945, once extensive grazing marshes with networks of freshwater and brackish ditches favoured by specialist plants and invertebrates, and open grassland supporting breeding and roosting waterfowl, have been reduced to a fraction of their pre-war extent. Saline lagoons, naturally rare habitats that are in many cases transitory in a dynamic coastal environment, are often represented by artificial structures behind sea walls, or are squeezed between mobile barrier beaches and hard defences to their rear. In addition, upstream reedbeds and wetlands that represent natural transitions between the open coast and fluvial systems are non-existent in many estuaries as a result of widespread land-claim and drainage. These, combined with cases where active habitat creation and management has led to important wildlife resources in pools and wetlands behind flood defences, mean that we have a multitude of problems that require innovative solutions.

In the past ten years, there have been important changes in flood management policy, and in the process of planning for future flood management programmes. Morphological evaluation drawing on a variety of top-down and bottom-up models now features prominently in the development of estuary-wide flood management strategies in the UK. However, there are significant obstacles to the delivery of sustainable estuary form that delivers improved flood management standards utilising natural energy attenuation and reversing past intervention that prevents the development of sustainable form. Inevitably, the most challenging problem is that of public opinion and the ways in which local communities wish to maintain the status-quo. This can often lead to the flood management authorities and their consultants concluding that the most appropriate way of addressing sea level rise is to prioritise realignments of flood banks to new defendable locations, and to target nature conservation sites for such realignment in the first instance.

Whilst it is accepted that there will be a need for realignment over some nature conservation sites, such as grazing marsh and lagoons behind sea walls, there is a problem in so far as their loss needs to be accompanied by compensatory habitat creation. That in turn arouses concern amongst the public and flood managers; firstly because it often involves reversion of agricultural land and secondly because it is costly. Delays arising are frequently blamed on nature conservation being unreasonable and on the Habitats Directive being too restrictive.

Case studies

The Blyth Estuary

The Blyth Estuary (Fig. 1) in Suffolk was once canalised along its entire length. Today, there are extensive mudflats upstream as a result of breaches during the 1953 flood, but the mouth extends inland as a canal. This leads to a highly ebb dominant system that does not allow the import of sediment to feed mudflats and sandbanks, and means that flood banks are left in an unsound condition through erosion and foreshore lowering. A major proportion of the flood banks defends arable or nature conservation sites and could be retreated by adopting to high ground or to localised new defences to form new intertidal; but this would further push the estuary into ebb dominance. Meanwhile, the canalised mouth of the estuary is such that navigation is extremely difficult and existing structures will require major investment to maintain further.

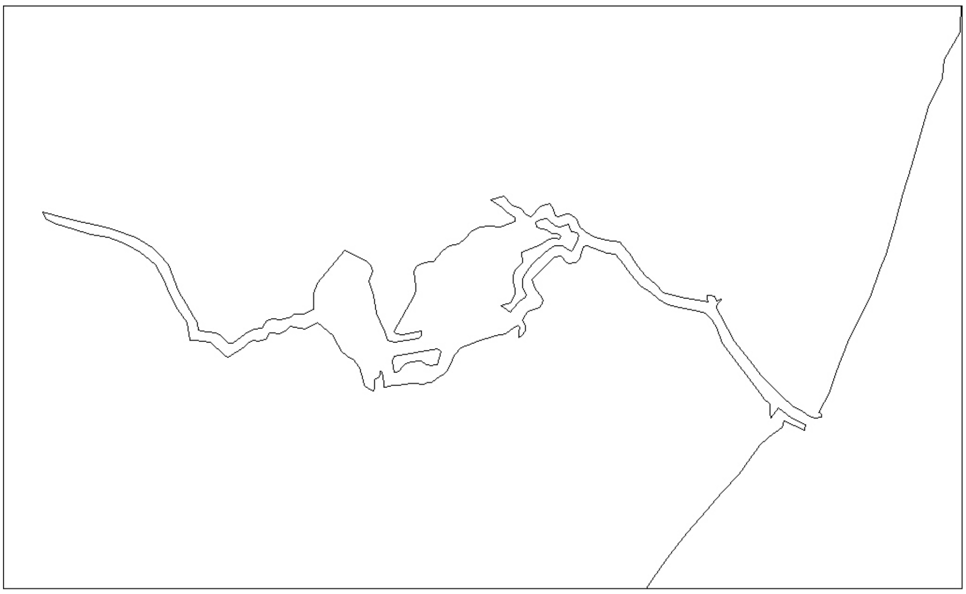

Fig. 1. The Blyth Estuary, Suffolk, UK.

The Alde-Ore Estuary

The Alde-Ore Estuary (Fig. 2) cSAC. SPA and Ramsar Site lies behind the spit of shingle forming the Orfordness to Shingle Street cSAC. Again, it is highly canalised for much of its length, with open mudflats upstream as a result of breaches in the 1953 flood. There have been ongoing possibilities of a breach forming at the northern end of Orfordness (towards Aldborough) in keeping with the overall evolution of such shingle structures exhibited by, for example, the cuspate foreland at Dungeness. In the face of sea level rise and increased storminess, such a breach is probably inevitable, especially as bathymetric data indicate that the foreshore is steepening. There is therefore an argument in favour of managing the change rather than trying to maintain the existing state for as long as possible. Morphologically, a breach would have important implications for the flood/ebb regime on the estuary and modelling suggests that this would push the estuary into ebb dominance rather than mild flood dominance in its current state. As a consequence additional morphological changes would be needed to widen the currently canalised sections of the Alde Estuary northwards.

Fig. 2. The Alde-Ore Estuary, Suffolk, UK.

The Crouch and Roach Estuary

The Crouch and Roach Estuary (Fig. 3) SPA and Ramsar Site (part of the Essex Estuaries cSAC) is effectively canalised for much of its length, with few natural locations for evolution of saltmarsh and mudflats. In this case, there are a number of pinch-points that affect the ability of flood managers to deliver a sustainable estuary form based on natural energy attenuation of mudflat and saltmarsh. Without widening of these pinch-points, it is unlikely that additional measures can be widely undertaken to create new saltmarsh and mudflats other than in some restricted areas.

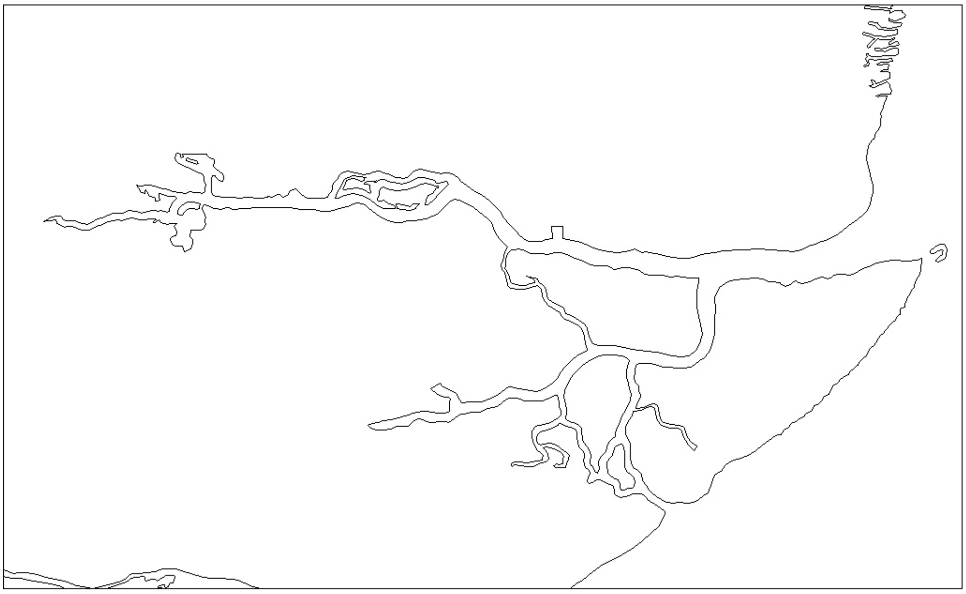

Fig. 3. The Crouch and Roach Estuary, Essex, UK.

Some wider considerations

In many estuaries, the natural transition from saline to freshwater through various levels of brackishness has been lost or confined to a narrow channel constrained by flood banks. Reed-swamp and brackish swamps have to a large extent been lost completely, and the plants and animals they formerly supported are now confined to artificial habitats such as ditches, borrow-dykes and fleets in grazing marshes. The ability of these assemblages to move, adjust to losses or to colonise newly created habitat is poorly understood; this needs much further investigation if we are to ensure that losses associated with the development of a strategic approach to flood management can be compensated for elsewhere.

Plants and invertebrates are relatively obscure, however, and do not evoke the emotions that are expressed over the loss of bird habitat. Therefore much recent debate has centred on the ways in which compensatory habitat for breeding birds can be secured. Such habitat does not necessarily require a coastal location but a whole-estuary approach to flood management, compensatory habitat creation and sustainable use of the tidally influenced environment therefore seems to offer a solution.

A sustainable solution

Sustainable management of our coasts and estuaries relies on the adoption of a long-term vision that provides sufficient time for adaptation and evolution. In particular, it is important to undertake cost-benefit analysis over a sufficient time-frame to recognise the real costs of holding the line, or to realise the front-loaded costs of implementing radical change. The processes of defining a way forward must be founded on sound morphological principles in relation to the effects of sea level rise and increased storminess. There are a number of obvious components, largely associated with the natural environment:

- Sea level rise will inevitably lead to increased tidal prisms, which will push many estuaries closer to or deeper into ebb dominance, whereby the currents on the ebb tide are of greater strength than the shear-stress of newly accreted sediment. In these circumstances, ebb dominance for fine sediments will affect the ability of an estuary to accrete sediment and for saltmarshes and mudflats to keep pace with sea level rise.

- Estuary sensitivity to change is a key driver to find a more stable morphological solution. Removal of pinch-points along the length of the estuary wherever possible will be necessary if soft engineering techniques such as realignment are to be used. Erosion of soft sediments at the estuary mouth must be expected as a natural component of stratigraphic rollover in which erosion at the mouth of an estuary is countered by upstream transgression of tidal influence accompanied by sediment deposition further upstream (Allen, 1990).

- The importance of eroding soft coastlines as a sediment resource must be safeguarded. This is highlighted in the final report of the Eurosion Project (2004). In broader terms, sediment such as material removed through maintenance dredging must be seen as a resource and not as a waste product. Even when disposed of at sea, it forms part of the background of suspended marine sediment.

- In defining programmes for sustainable flood management within estuaries, there is a need to give serious consideration to the removal of structures that currently constrain the mouths of estuaries or which canalise sections and make them morphologically incapable of accommodating realignment to create sustainable soft defences.

- Managed realignment should not be confined to the wholly saline end of an estuary. There is a need for programmes of realignment to take place as far upstream as possible within the tidal influence. This way, it should be possible to create sustainable freshwater and brackish habitats to offset losses where grazing marshes have to be sacrificed in the best interests of a sustainable estuarine form and to accommodate stratigraphic rollover.

- There is a need to embark on a programme of grazing marsh re-creation based on prior research into the mobility and restoration potential of brackish water invertebrate and plant communities.

Our vision for English estuaries is the restoration of a morphologically functional system capable of accommodating stratigraphic rollover, and exhibiting all of the features that would normally be associated with such a system including brackish-freshwater transitions to the limits of the saline wedge and beyond. Such a vision is unlikely to be achieved completely in many estuaries, but there are a number where such aspirations could be met.

Estuary sustainability in a human and economic context

Radical changes to flood management provisions inevitably provoke the expression of many concerns by the communities they serve. Inevitably there is a tendency to resist change and to argue in favour of further investment in existing defences. In one important case, a small group of residents adjacent to the Cuckmere Estuary (Sussex) have applied for consent to reinforce flood defences on land owned by third parties who are in favour of realignment. In another, the scale of public opposition to a major realignment scheme was such that it had to be dropped; and in further cases there have been objections from other parts of the nature conservation movement to the loss of freshwater habitat and to realignments that in any way change the current form of an estuary! There is no consensus.

So far, the messages over managed realignment and sustainable estuary form have been championed by the nature conservation community, especially by English Nature. As a consequence, sustainable flood management is largely perceived as a nature conservation management tool. In England, there have been a relatively small number of realignments to date; nearly all of which have been promoted largely for nature conservation benefits. Some examples include Orplands, Old Hall Farm, Northey Island and Tollesbury (Essex), North Sea Camp (South Lincolnshire) and Paull Holme Strays and Alkborough (Humberside). All of these have joint flood management and nature conservation benefits, either as trials for the technique or as measures to offset flood management works elsewhere. In reality, there is a need for a shift towards sustainable flood management based on sustainable estuarine morphology to deliver a social benefit in the first instance and wider nature conservation benefits as an ancillary outcome. That shift can only be achieved by the emphasis on some key messages:

- Flood management costs will spiral in the next 100 years and will not be affordable in the light of demographic changes leading to increased pressure on social welfare budgets such as old age pensions.

- The technical feasibility of maintaining the existing line of defence will diminish as foreshores steepen and wave exposure increases. The longer the delay, the more costly the solution; especially as improved defences encourage inappropriate development that makes longer-term options less practicable.

- Evaluation of possible uses of newly created intertidal habitats that would positively add to the rural economy. For example it would not be an impossibility to allocate some new intertidal as moorings or even as more formal marina facilities. Samphire *Salicornia* harvesting is another obvious possibility that has been undertaken on one realignment site. The key issue is to manage change and to look for opportunities that replace lost employment or perceived attractions.

- There must be a shift towards flood management programmes taking forward realignment projects without nature conservation benefits as a principal objective: such soft engineering is needed for very real flood management and social benefits and needs to be promoted as such.

Conclusions

Climate change and accompanying sea level rise sit towards the top of the issues that will most profoundly affect the human and natural environments in forthcoming years. Continuation of current flood management practices does not appear to be sustainable in the long-term, and there is an urgent need for flood management planning to adopt radical new approaches. Without such approaches, the risks and costs for coastal communities will rise as foreshores steepen, mudflats and saltmarshes erode, and natural wave energy attenuation declines.

The solutions need to be radical, and require a degree of foresight and bravery as decisions may have to be made in the face of serious local opposition. To make such decisions more socially and economically viable, solutions must not focus solely on nature conservation outcomes, but must seek to deliver the most morphologically sustainable form from the mouth of the estuary to the tidal limits and beyond. This may mean that some estuaries will look very different in years to come.

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