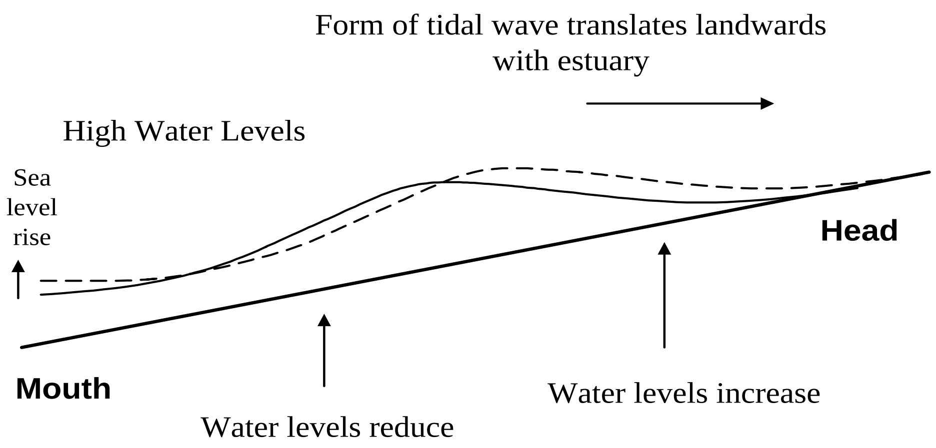
ESTUARY TRANSLATION (ROLLOVER)

It has been suggested that an estuary will maintain its position relative to the tidal frame in response to sea level rise (Allen, 1990; Pethick, 1996). To do this the estuary form must move landwards and upwards. This "rollback" of the system as a whole has been observed in the Severn Estuary and the Blackwater, Essex (*op.cit.*). In some cases, a further consequence of such landward movement is that, at any particular location on the estuary, the magnitude of sea level rise may be masked. This is because the tidal wave also translates landwards, as shown in the sketch below. Depending on the degree of amplification of the tidal wave as it propagates up the estuary, it is possible for levels to increase more or less than any rise in the mean sea level along the length of the estuary. The occurrence of this particular phenomenon does however depend on the degree of tidal amplification within the estuary and the rate of landward translation (it does not occur in estuaries with more or less constant high water levels). This is determined by the relative magnitude of the overtide as governed by the M2 and M4 tidal constituents (Friedrichs & Aubrey, 1988) and the shape of the estuary (Prandle, 1985).



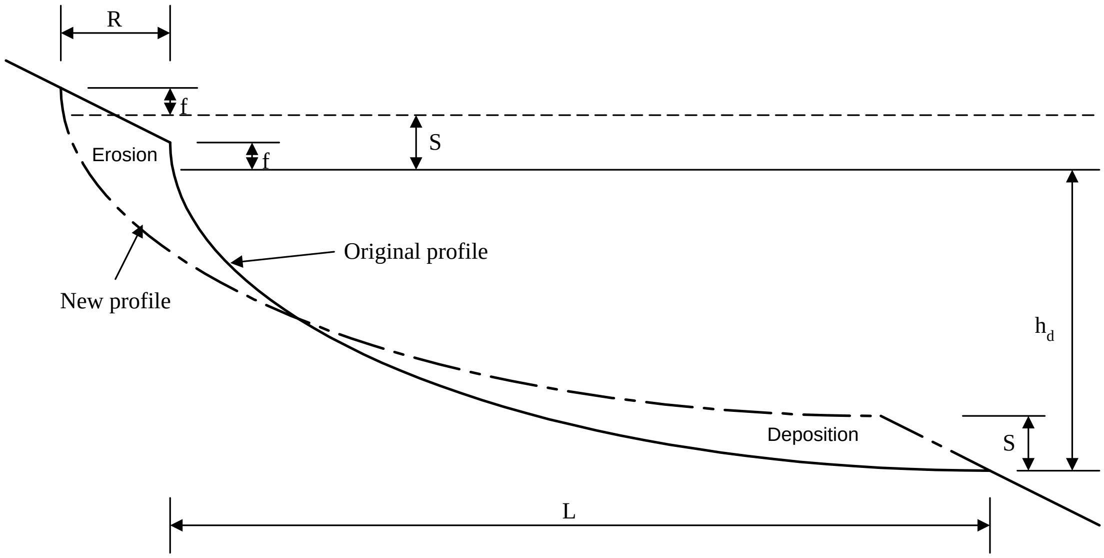
As yet however there is no theoretical model to represent such translation from a top-down perspective (i.e. looking at a parameterisation of the gross changes rather than some form of detailed process modelling to derive a bottom-up prediction of the system response to sea level rise). This note outlines a hypothesis for such a top-down approach (Pethick and Townend, 1998).

Rollover on Beaches

A similar concept has long been established for beaches. Known as the 'Bruun Rule', it describes the cross-shore response of a beach to sea level rise. The basis of the approach is that, within the closure zone of the beach (defined by the boundary between the beach face and the adjacent shelf - typically the limit of significant wave-driven sediment transport), the beach will adjust to maintain its profile relative to still water level. This can be achieved by translating landwards and upwards, with the erosion at the landward end of the profile supplying the material to raise the lower portion of the profile (see sketch below). Overall the approach assumes a net sediment balance, so that simple geometry gives the landward translation, R as:

$$R = \frac{S * L}{h_d + f}$$

where S is the amount of sea level rise, L is the active length of the profile, h_d is the closure depth and f is the freeboard. First proposed by (Bruun, 1962), the concept has been extensively explored for beaches around the world ((Fisher, 1980; Everts, 1985; Bruun, 1980; Townend, 1994)). Much of this work relates to sand beaches, whereas within estuaries we are potentially interested in more cohesive sediments. This is now beginning to be addressed with a number of recent studies examining the hypsometry of intertidal mudflats (Lee & Mehta, 1997; Friedrichs, 1993). Using these forms to describe the intertidal profiles of muddy shores, an equivalent to the Bruun Rule has been proposed (Kirby, 1998), which acknowledges the greater variability in profiles between concave and convex forms.



It is important to recognise that the Bruun Rule applies in a 2-D sense to the cross-shore profile and takes no account of 3-D effects such as longshore transport, although the relative importance of such effects has been considered (Bruun, 1980). There is also very little field validation of the concept as applied to muddy shores.

Rollover of a Creek or Estuary

The concept of rollover within a creek or estuary has been formulated based on the combination of the model of translation proposed by Bruun and the 3-D form model (*E*st*F*orm see Form analysis). By translating the form landwards and upwards, some areas will erode providing sediment for other areas to accrete. The 3-D form is moved up by the amount of sea level rise and moved landwards along the line of the thalweg by a distance that results in a sediment balance (equal amounts of erosion and accretion). The hydraulic form is maintained. Consequently the hydraulic regime, whether in equilibrium or not, is conserved. An initial estimate of the amount of landward translation for sediment balance is given simply by:

$$R = \frac{S.L}{d_m}$$

where as before S is the amount of sea level rise, L is now the length of the estuary and d_m is the depth at the mouth.

In isolation this model could potentially rise above the surrounding land, in cases where the catchment is low lying towards the estuary mouth. Consequently it is necessary to include a mechanism for warping up low-lying land immediately adjacent to the estuary. This has been included as a saltmarsh width, which is warped up to keep pace with sea levels, so creating a further sediment demand. The basis of this component is based on the field observations and laboratory experiments on sediment propagation over saltmarshes (Pethick *et al*. 1990). The additional translation can be approximately estimated based on the following adjustment to the above equation:

$$R = \frac{S.L}{d_m}.\left(1 + \frac{2.b_{sm}}{bm_{hw}}\right)$$

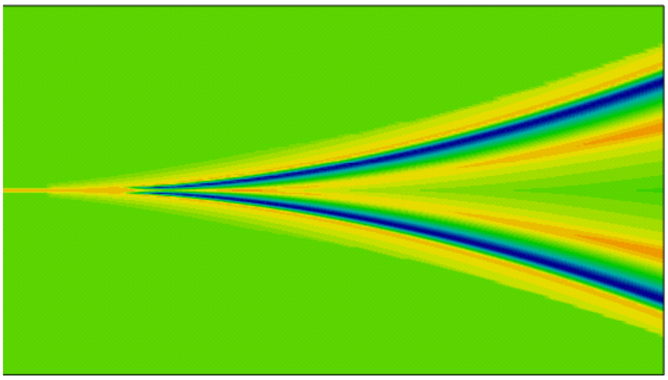
where b_{sm} is the saltmarsh width and bm_{hw} is the high water width at the mouth. There is, in addition, some variation as a result of the specific form of the estuary or creek. At present this is not included in the model and is provided for by a simple correction factor in order to ensure the distance equates to a sediment balance.

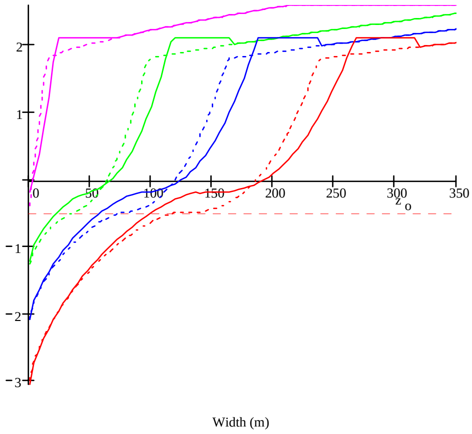
Finally there is provision in the model to incorporate features that do not translate, such as geological hard points, sea walls, bridge structures, etc. Dredge channels can also be included and for the present these are also treated as “fixed” physical forms.

The *E*st*F*orm model is able to consider the range possible responses to sea level rise, from zero lateral translation as the system warps up based on a supply of sediment, through translation to give sediment balance, on to the even greater translations which give rise to a net export of sediment. For each potential outcome, the sediment supply or demand is estimated and in all cases the current hydraulic regime is maintained. The actual outcome will depend on the available sediment supply/demand, ongoing anthropogenic activity (e.g. dredging to maintain channel depths) and any changes that may be induced in the prevailing hydraulic/morphological regime. As illustrated in Figure 1, the estuary or creek form is also a significant influence in determining the distribution of erosion and deposition when this type of translations takes place. On the assumption that the system has the ability to be self-sustaining, estimates of the translation distance that results in a sediment balance, provides a useful initial estimate of the potential translation (see also Townend & Pethick, 2002; Townend *et al*. 2004).

Figure 1 - Erosion/accretion patterns for rollover in different shaped inlets

(a) Funnel shaped inlet

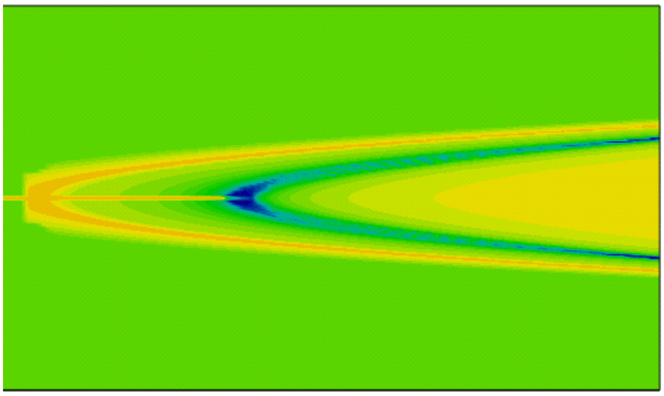


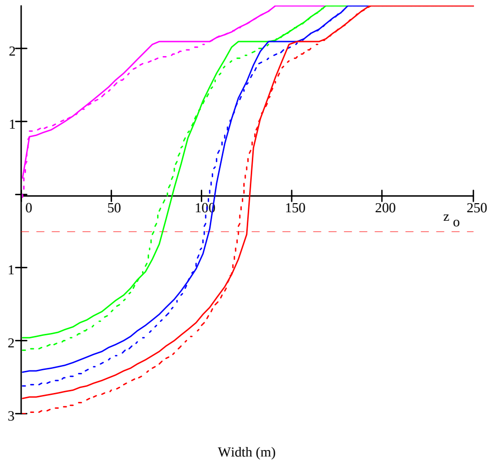


Contour plot of changes in depth. Blues represent erosion, yellows accretion. Accretion above and outside the initial bank represents warping-up of the saltmarsh/ backshore area.

Half sections taken at intervals along length of channel. Solid lines represent post-sea level rise section, dashed lines represent pre-sea level rise sections

(b) Bell shaped inlet





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