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Sedimentation in the inner estuary of the Thames, and its relation to the regional subsidence

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The Inner Thames Estuary is defined as that part of the estuary which lies above the point of widening at Southend and the tidal limit at Teddington Weir (figure 1). In respect of sedimentation it may be divided into three zones. From Teddington to below Tower Bridge the river carries mainly land-derived sediment; suspension load is low, and deposition on the bed and banks is slight. From Woolwich Reach to Gravesend Reach is a zone of high suspended load

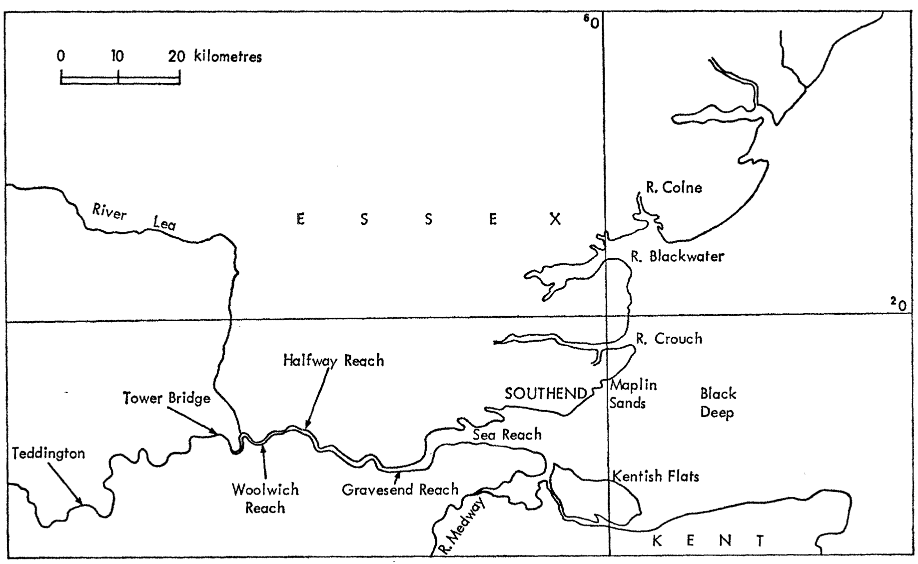

Figure 1. Location map of Thames Estuary.

and much sedimentation – these are the 'Mud Reaches'. Below that, down to Sea Reach, sedimentation is dominated by bed-load transport from the sea. The sedimentation pattern of the Mud Reaches is related to the position of the salt-water–freshwater mixing zone, and so is most sensitive to relative changes of sea level. In point of fact the constitution of this 'mud' is widely variable, varying from 80 down to 10% of clay, while still retaining its fluid and mobile character. This fluidity appears to be due largely to the loose packing of the flocculated clay particles which it contains, although the relatively high organic content of the mud undoubtedly plays a part. It would, however, be wrong to attribute the peculiar problem associated with the accumulation of fluid mud in the Thames to the organic pollution of the river, for similar deposits are shown in many less-polluted estuaries, e.g. the Taw-Torridge, the Gironde, etc. Moreover, the known improvement in pollution conditions which has taken place over recent years (Townsend 1967) has had no very obvious effect upon the conditions of sedimentation. If a reason has to be sought for the size of the problem in the Thames it is probably the ready availability of the London Clay, whose erosion and reworking since the late Tertiary has

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probably provided the bulk of the raw material, and the confining, due to regional subsidence, of a tidal influx into a fluvially created, and artificially maintained, river channel.

Except for a small part of the north Kent coast the whole of the outer estuary is underlain and bordered by London Clay. During the last glacial phases of southeastern England the melt-waters of the retreating ice-sheets ran over the London Clay lowlands of Essex to join a proto-Thames estuary situated far below the present. As the sea level rose, more and more of this flat London Clay plain became submerged, and the estuary widened, so that marine erosion was able to flood the Kentish Flats, and to attack the low cliffs of, for instance, the north Kent coast. Thus clay-grade sediment was readily available even at this early stage of development.

At the present time the Mud Reaches receive sediment from the higher reaches of the Thames. This consists very largely of finely divided clay sediment carried in suspension, and the presence of 'hard-bottom' in many places above London Bridge indicates that most of it is carried through. On meeting the saline waters, however, flocculation takes place, and the larger particles which result are less capable of transport.

The Mud Reaches also receive some sediment from tributaries (e.g. Rivers Lea and Roding) though in many cases the flow is in reality derived from the sewage works discharging into them. Studies of suspended and bottom sediment in the River Lea indicate that the sediment transported lies almost entirely within the clay-grade.

Long-term observations suggest that much of the sediment deposited on the banks of the river is eventually returned to circulation. The thin veneer of mud deposited during one stage of a tidal cycle can be observed to be scoured off during another stage. In many places there is a slow accretion of mud beween low- and high-water mark, which eventually becomes unstable, and then slides into deeper water, where it is taken up into suspension again. Even the small-scale waves generated by winds and the wash of passing vessels are capable of resuspending this very mobile material.

Inglis & Allen (1957) suggested that there was a net landward drift of bottom sediment from the sea to the lower end of Woolwich Reach. Studies of the heavy minerals (Beg 1967) and of the distribution of ostracode carapaces (Kilenyi 1970) indicate that some outer estuary material reaches higher than this. Thus the traction load of the flood tide flow is itself a source of clastic material.

The process of sedimentation in the Mud Reaches has been described by Dobson & Prentice (1967). The movement of the tides causes most of the fine grained and some of the coarse grained sediment to remain in suspension, but as current velocities slacken so there is a steady progressive fall of the clay-grade and silt particles towards the bottom, so that the water body shows a transition zone almost clear at the top to a dense, thick suspension at the base. Sediment concentrations of up to 94000 parts/10^6 have been recorded from the lower levels. At stages of slack water the dense lower levels can become a discrete and independent layer, the top of which is sufficiently well defined to be recorded on an echo-trace. When the tidal movement begins again, the identity of the layer is lost, and as the tidal velocity increases the sediment becomes suspended through the water column once again. If, however, the fluid mud layer has accumulated in a position protected from the tidal flow it may remain there, lose its water, and become a relatively permanent deposit.

Studies of the siltation conditions in Dagenham Reach have shown that a sharp line can be drawn between the places along the bank at which deposition occurred, and those sites at which there was no deposition. A study of current velocities in the two types of area was made.

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It is seen that the critical factor was probably the length of time available for the fluid mud layer to remain undisturbed. From the particle size distribution of the sediment, and calculating from the curves of Hjulstrom (1935), it was concluded that the erosion velocity was likely to be *ca.* 0.5 m/s. It is observed that in the site of deposition the current velocity is below this figure for more than half the tidal cycle, whereas at the erosional site current velocities are greater than this for more than half the cycle.

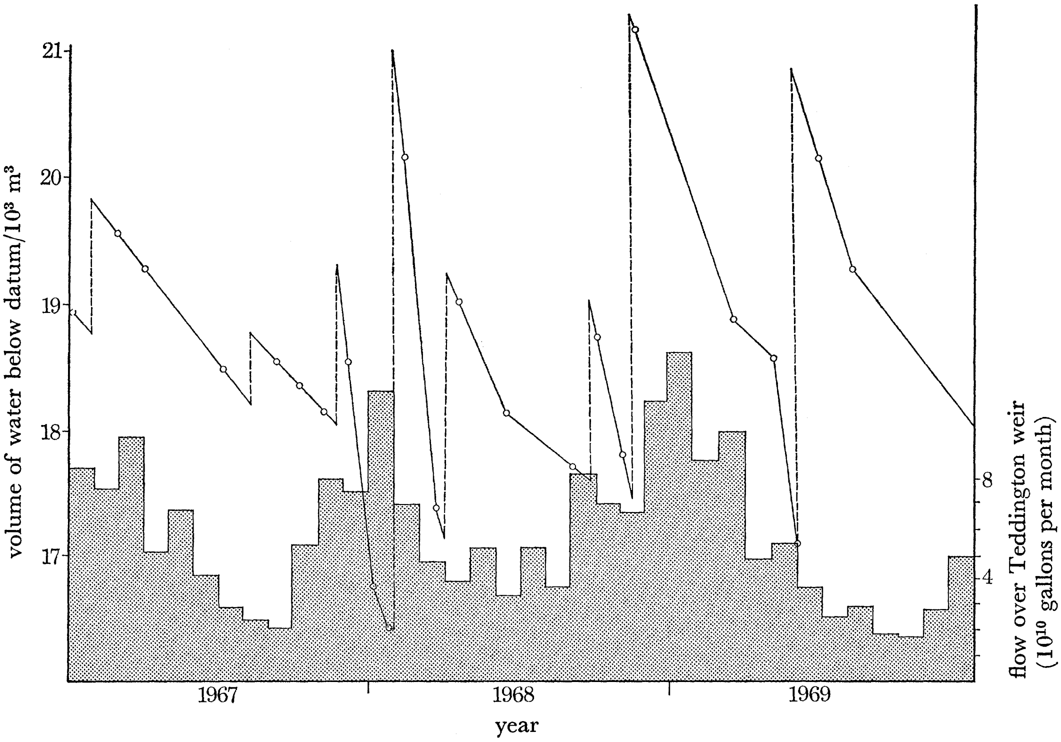

FIGURE 2. Progressive siltation of Tanker Berth, Halfway Reach. The graph records the volume of water in the berth, as recorded by repeated sonar surveys (open circles). Vertical dashed lines indicate dredging. The histogram records the monthly flow of fresh water over Teddington Weir (Thames Conservancy records).

An attempt has been made to quantify the rate of siltation at selected sites in the river. A regular series of surveys made by Messrs Samuel Williams & Sons in Halfway Reach has enabled the author to construct the diagram shown in figure 3. A particular tanker berth, known to be subject to heavy siltation, was selected, and the quantity of water below low-water datum in the berth was measured. During the period of observation dredging operations were carried out repeatedly, as is indicated by the vertical lines of the graph. The graph (figure 3, top) shows clearly that rate of siltation is much more rapid in the winter months. The histogram (figure 3, base) indicates the monthly flow of fresh water over Teddington Weir, and the correlation of the high flow phases there with the phases of rapid siltation at Halfway Reach is remarkable. Although precise information is not yet available, there is an impression gained from studies of berths upstream that in the middle of the Mud Reaches siltation is more evenly distributed throughout the year, whereas in the higher parts of the reaches it is concentrated in the summer. The pattern appears to be one in which the zone of deposition moves up and down the river in response to the changes of fresh-water flow.

Conversely, in the seaward zone below the Mud Reaches maximum deposition in sheltered sites occurs in the summer. In this zone deposition is mainly from a traction carpet brought from

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the seaward end, and is dependent upon the balance between upstream transport on the flood tide and scour downstream by the ebb. Thus the reduced ebb flows produced by dry weather will favour accretion, while the higher ebb flows of winter will produce a net loss of sediment.

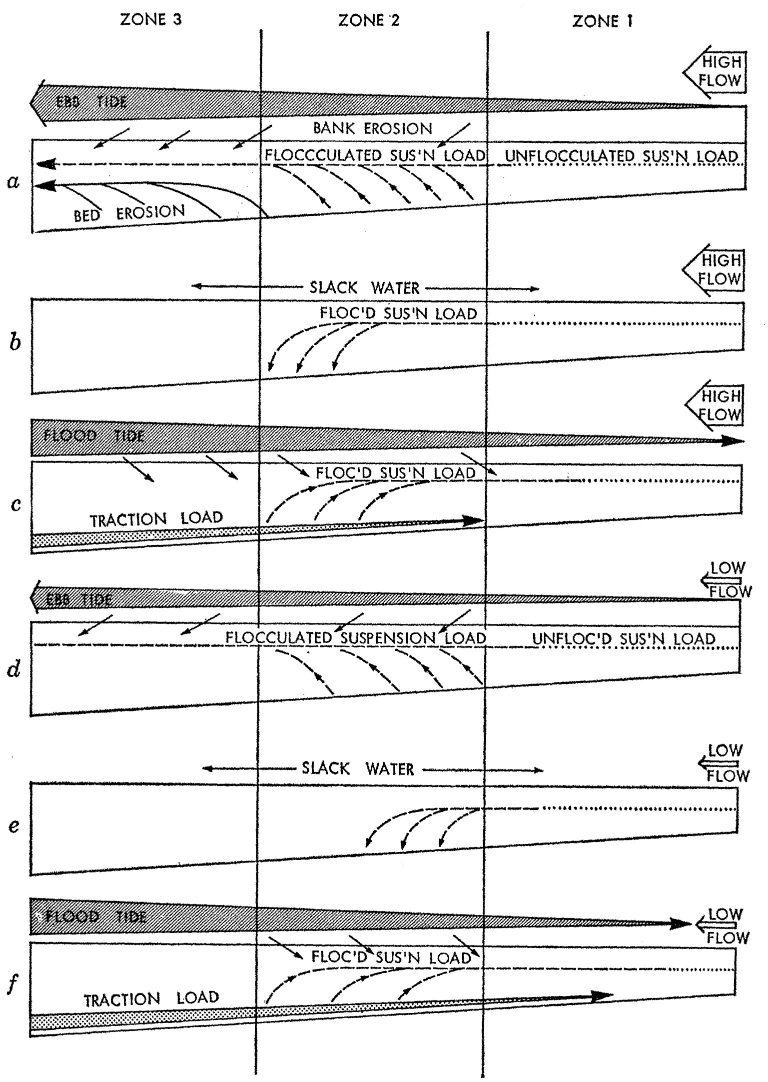

FIGURE 3. Diagrammatic representation of erosion and deposition conditions along the River Thames at various states of tide and freshwater flow. Zone 1, Teddington Weir to Tower Bridge; zone 2, Tower Bridge to Halfway Reach; zone 3, Halfway Reach to Sea Reach. (*a*) high fresh-water flow and ebb tide; extensive erosion of the banks and bed in zones 2 and 3, and rapid influx of suspension load through zone 1. (*b*) Slack water causes deposition of flocculated suspension load at lower end of zone 2. (*c*) Flood tide with high fresh-water flow moves traction load upstream, and causes resuspension of some of the recently deposited bed and bank material; (*d*) Low freshwater flow on the ebb tide causes only a moderate resuspension erosion. (*e*) Slackwater in low flow conditions causes deposition of flocculated suspension load in higher reaches of zone 2. (*f*) Flood tide with low freshwater flow moves traction load high upriver and resuspends bed and bank material.

RELATION TO SUBSIDENCE

Since deposition of the suspended load, and arrest of movement of the traction carpet, are both very temporary and mobile phases, it is hardly to be expected that they will leave much permanent record within the sediment body. Borings in the Black Deep area (Maddrell & Prentice 1967) and in the Maplin Sands show that the buried channels of the estuary are in the

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main filled at their base with shelly gravel, which rapidly fines upwards into the well-sorted fine sand which forms the bulk of the sediment body of the Thames estuary (Prentice *et al.* 1968). If subsidence of the region and the consequent flooding of the Thames river system with sea water was perfectly even, it is to be expected that the mobile muddy phases would simply move upstream. Preservation of these phases is then likely to reflect changes of rate of subsidence – either a slowing down which allows time for the mud to consolidate, or an acceleration producing a rapid influx of marine sand which then overtakes the muddy sediment within it. One such level is found at 20 to 22 m below ordnance datum in boreholes in the Black Deep area, while clays at –30 m O.D. in the Maplin Sands may represent a similar phase.

Conclusions

The studies so far completed of the sedimentation processes in the inner Thames estuary suggest that the zone is a sediment trap in which the limits are set in the upstream direction by the salinity gradient, and in the downstream direction by the point at which loss of muddy sediment exceeds the supply. Within the estuary two zones are recognizable, an upper zone dominated by deposition from fluid mud, and a lower in which bed-traction is the predominant agent.

It is clear that the phases are highly mobile, and subject to seasonal shift. The effect of continued subsidence is likely to be the increase of salt-water penetration and the movement of the whole zone upstream. Any restriction of salt-water penetration of engineering works in the Sea Reach and its approaches, such as those proposed in connexion with reclamation schemes for the outer estuary, will tend to move the zones downstream; any restriction of freshwater flow such as might be imposed by any barrier, will tend to condense the zones in an upstream direction.

References (Prentice)

Beg, I. R. 1967 Petrological and environmental aspects of the sediments of the Thames estuary. Ph.D. thesis, University of London.

Dobson, M. R. & Prentice, J. E. 1967 Sedimentation in Halfway Reach, River Thames, England. *Abstr. Proc. 7th Inst. Sediment. Congr. Gt. Br.* (1967).

Hjulström, F. 1935 Studies on the morphological activity of rivers as illustrated by the River Fyris. *Bull. Geol. Instn Univ. Uppsala* **25**, 221–522.

Inglis, C. C. & Allen, F. H. 1957 The regime of the Thames estuary as affected by currents, salinities and river flow. *Proc. Instn civ. Engrs* **7**, 827–878.

Kilenyi, T. I. 1970 The problems of ostracod ecology in the Thames estuary. *Symp. Morph. Taxon. Ecol. Recent Ostracoda* (Edinburgh 1968).

Maddrell, R. J. & Prentice, J. E. 1967 The Black Deep – a critical area of the Thames estuary. *Proc. Conf. Technol. of the Sea and Sea-bed*, pp. 581–593. London: A.E.R.E.

Prentice, J. E. *et al.* 1968 Sediment transport in estuarine areas. *Nature, Lond.* **218**, 1207–1210.

Townsend, C. E. C. 1967 *The cleaner Thames* 1966. Port of London Authority,