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Contemporary and Holocene Sediment Dynamics of the Walton Backwaters

Preliminary Report

Contemporary and Holocene Sediment Dynamics of The Walton Backwaters North East Essex

Preliminary report and review of progress

by

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Abstract

The Walton Backwaters is a shallow mesotidal embayment on the north-east Essex coast consisting predominantly of saltmarsh and intertidal mudflats. It is currently the subject of much interest due to an apparent long-term breakdown and erosion of the saltmarsh. This preliminary report introduces the site and describes the aim of the present investigation, reviews relevant literature, looks briefly at data collected during the course of the year, and outlines a proposed course of study for the next two years. The predominant finding so far is a large tidal asymmetry: ebb velocities appear to be of far greater magnitude than the flood suggesting a net ebb sediment transport. Saltmarsh monitoring transects have been established over a limited area to assess the rate of change but results show no significant trends so far. In the light of preliminary results on sediment transport, the intentions for the next year are firstly, to verify the sediment transport regime, and secondly, to expand the study of the spatial and temporal patterns of sedimentation in the system through the Holocene, and identify the major controls on these patterns.

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1. Introduction

1.1 Geographical Setting

The Walton Backwaters[1] is a small, shallow mesotidal embayment (average tidal range: 3.8m on springs and 2.3m on neaps) situated on the north-east Essex coast between the port of Harwich to the north and Walton-on-the-Naze to the south (Fig. 1.1 (a) & 1.1 (b)). Its maximum depth is 6.8m (below extreme low water) in the main channel of Hamford Water and a similar depth adjacent to Stone Point in Walton Channel. The entrance is partially restricted by shoal water and there is a negligible freshwater input, being enclosed to the north, south and west by a small semi-circular catchment area (approximately 40 km^2). The main entrance channel, Pye Channel, running south-west from Pye End Buoy is only 200m wide at extreme low water but swells to 2 km at high water. The interior of the Backwaters opens out into a complex network of creeks, islands, saltmarsh and mudflats some 2,300ha in area. At low tide the Backwaters are practically devoid of water, apart from the main channels of Hamford Water, Walton Channel and Kirby Creek, and large expanses of mud and saltmarsh are exposed. The largest area of intertidal mud is the Wade, about 2.4 km^2 in area. The present shape of the Backwaters has resulted from a long history of reclamations, discussed briefly in section 2.5.2, and the remaining saltmarsh and mudflats are now almost entirely bounded by a seawall backed by drainage ditches which empty through conduits into the saltmarsh.

In a review of British estuaries, Davidson *et al.* (1991) describe the Backwaters as an embayment-type estuary: mudbanks dominate the inner, sheltered regions, where the finest suspended sediments are deposited. At the mouth, main outflow channel and

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[1]The Walton Backwaters is classified by English Nature as Hamford Water (Davidson *et al.*, 1991). For the purposes of this investigation, however, the site is referred to as The Walton Backwaters, or the Backwaters, since Hamford Water also refers to the name of the main east-west tidal channel and therefore a separate feature within the site.

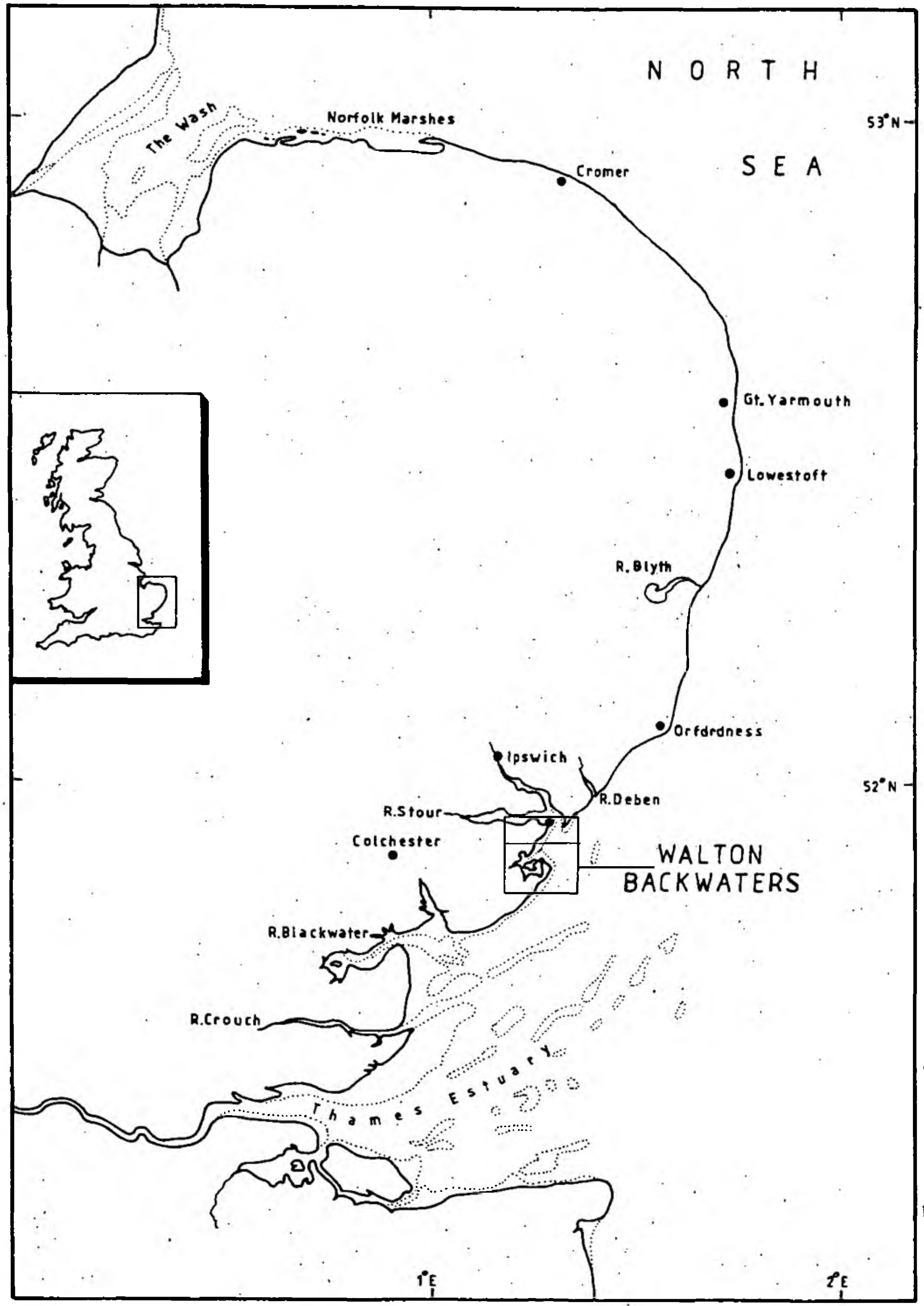
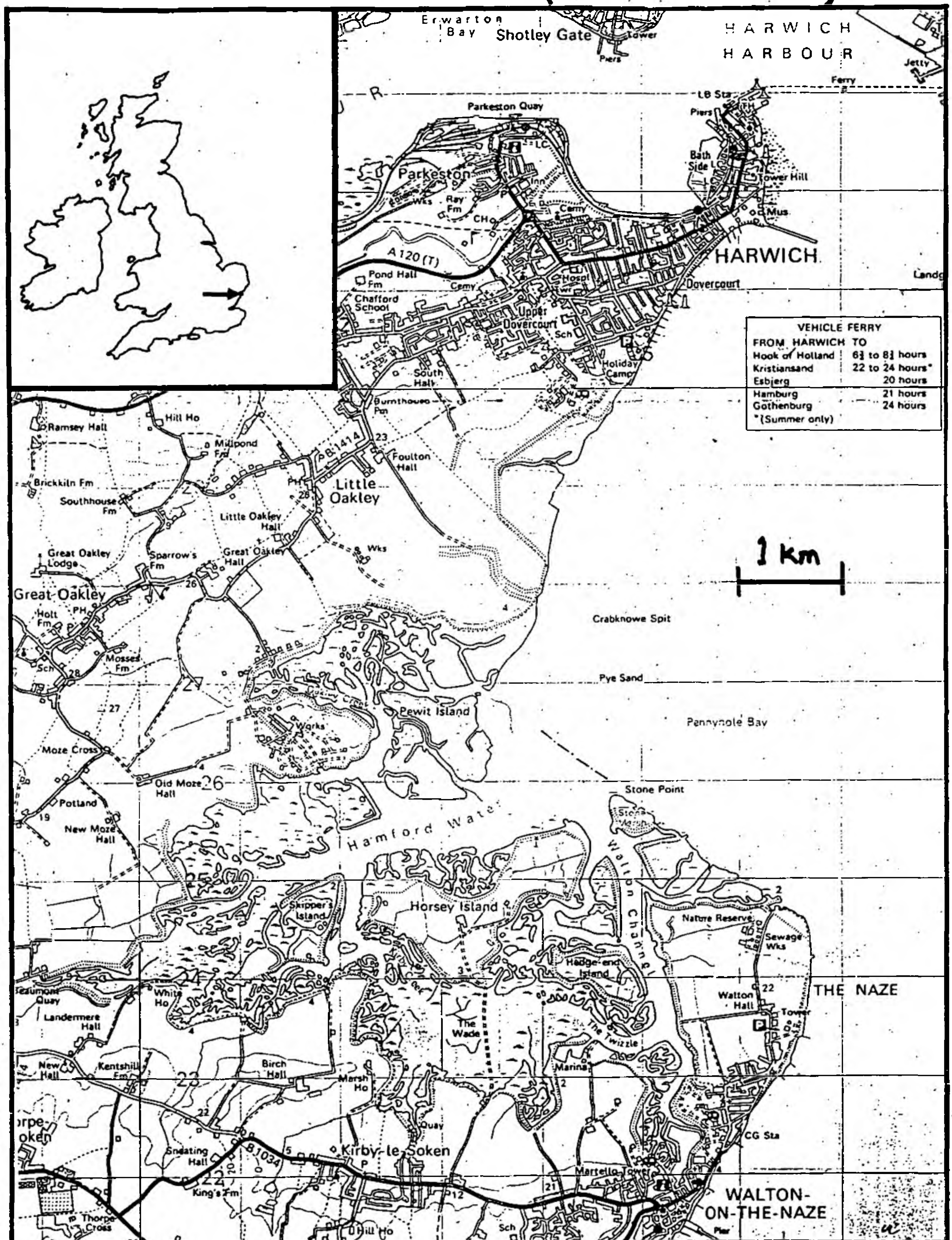


Figure 1.1(a) -
The Walton Backwaters and East Anglia.

Fig. 1.1 (b)

WALTON BACKWATERS (HAMFORD WATER)



on the exposed shore of Pye sand, wave energy and/or faster tidal currents keep fine sediments in suspension and hence only the coarser sediments are deposited. The Walton Backwaters is also unique in that it is characterised by a complex morphology and has a negligible freshwater input, unlike the more typical estuarine environments of neighbouring Deben, Orwell and Stour, which have sizable rivers flowing into them (Fig. 1.). Of the total area of 2,377 ha, 1,570 ha (66%) is intertidal, the shoreline covers a distance of 54.0km and the tidal channels 8.3km. (Davidson *et al.* 1991).

1.2 Aims of the Investigation

The Walton Backwaters has recently become the subject of considerable attention as regards coastal management and conservation[2] . Concern over the extent and rate of erosion of the saltmarsh in particular has stimulated much debate and numerous reports and proposals on coastal management schemes (Dixon, 1989; HR Wallingford, 1990; Dixon 1990; Burd, 1992; Dixon, 1992; Unicomarine, 1992; Posford Duvivier, 1993; WS Atkins Ltd. 1993; ICES, 1993). It is generally accepted that saltmarsh constitutes an important part of sea defence; the greatest significance being its ability to dissipate wave energy to such an extent that very little reaches the landward limit (Brampton, 1992). However, continuing problems of erosion of saltmarsh are resulting in destabilisation of sea defence, requiring increased expenditure on upgrade and maintenance. Thus much importance has been attached to saltmarhes as illustrated by the research the National Rivers Authority, Anglian Region (NRA) has coordinated since 1986 and as summarised in a report prepared for the NRA by the Institute of Estuarine and Coastal Studies (IECS), University of Hull (NRA, 1993).

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[2]The site is of international conservation importance for example, for breeding *Sterna albifrons* (Little terns) and wintering *Branta bernicla* (Dark-bellied Brent Geese), wildfowl and waders, and of national importance for many other bird species. It also supports communities of coastal plants which are rare or extremely local in Britain, including *Peucedaum officinale* (Hog's Fennel) which is found elsewhere only in Kent.

Despite this interest, and although considerable research has been carried out at the mouth of the Backwaters, insufficient data are available on the detailed complex dynamic behaviour of the intricate network of channels, creeks and saltmarsh within the Backwaters and especially how coastal management schemes may or may not affect the contemporary forces at work. Commonly recognised as a 'sediment sink' on the East Anglian coast (McCave, 1987), the reason, or reasons for an apparent disappearance of the saltmarsh in particular (Burd, 1992) requires further investigation. Informed decisions on possible management options require considerable baseline data on the current sedimentary dynamics of the area and the Holocene (last 10,000 years) context (Scourse, 1992). The principal objective of this project, therefore, is to provide such baseline data and provide a comprehensive appraisal of the development of the Hamford Water system through recent geological time to the present day. Particular emphasis is being placed on the spatial and temporal rates of sedimentation and erosion, and on the main sediment sources through time. The Holocene geological perspective will enable the evolution of the system prior to extensive anthropogenic impact to be compared with the present day situation in which anthropogenic influences are significant. Of particular interest is the impact of dredging at Harwich Harbour on the evolution of the system.

The specific aims of the investigation are therefore to:

a) establish the contemporary sedimentary regime in the Walton Backwaters system;

(b) establish the main sediment sources in the system, and to identify any significant changes in sediment source in the recent geological past;

(c) assess the relative significance of waves, current and tides in the contemporary sedimentary regime, and the significance and direction of longshore drift in the region; and,

(d) document the spatial and temporal patterns of sedimentation in the system through the Holocene, and to identify the major controls on these patterns (tectonic subsidence, sea-level change, sediment supply).

Work on the project started in January 1993 and to-date the following has been studied:

i. Review of literature (this report plus ongoing)
ii. Boundary layer conditions (Section 3.1.3)
iii. Hydrography (Section 3.2.2)
iv. Sediment sampling (Section 3.1.1)
v. Accretion/erosion monitoring (Section 3.1.5)
vii Cross-wall levelling (Section 2.5.2)

2. Holocene Evolution

2.1 Introduction

A study of the Holocene geological perspective enables the evolution of the system prior to extensive anthropogenic impact to be compared with the present day situation in which anthropogenic influences are significant. Work so far has been aimed at assessing the significance of our existing knowledge of geological, prehistorical and historical evolution of this site. This is an on-going aspect of the investigation and there is much material still to be considered.

2.2 Geology

There are no published one-inch or 1:50,000 scale geological maps covering the area, the most recent map being an old series quarter-inch map from which, and together with a variety of published literature on aspects of the geology of the surrounding area, a sufficiently comprehensive picture of the geological evolution can be pieced together. The area is described briefly in a geological memoir (Whitaker, 1877) and an old Geological Survey publication: London and Thames Valley (Sherlock, 1935). The stratigraphy can be reconstructed from borehole logs for water supply investigations (Whitaker and Thresh, 1916), NRA engineering sea defence work (NRA archives, Ipswich), a morphological study (Leeks, 1975), and various works on the geology and evolution of the surrounding area (for example: Markham, 1973; Jermyn, 1974; Funnell and Wilkes, 1976; Boyden, 1979; Leeks, 1979; UKEA, 1984; Allsop and Smith, 1988; Bridgland, 1988; Mathers and Zalasiewicz, 1988; Bridgland *et al.*, 1990; Whiteman, 1992; Whiteman and Rose, 1992; Bridgland *et al.*, 1993). The picture that emerges is illustrated in Figures 2.2.

As a broad generalisation the stratigraphy of the majority of the area consists of modern alluvium overlying Eocene London Clay, but flanked to the west, north-west and south-east by Pliocene

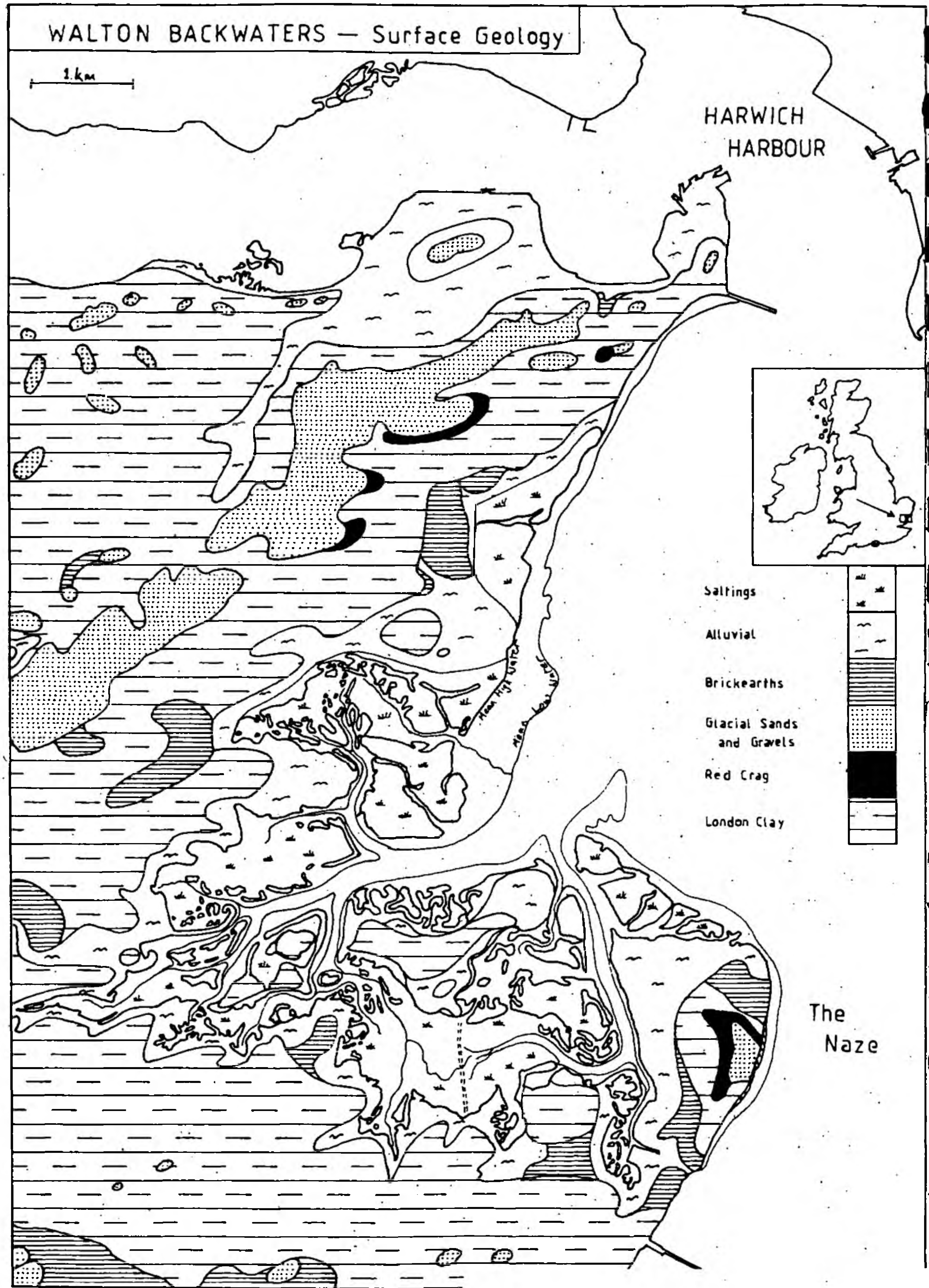


Figure 2.2 - The Walton Backwaters - Surface Geology.

Red Crag deposits capped by glacial sands and gravels. The London Clay makes up the islands of Horsey and Skipper's and outcrops extensively at the foot of the Naze. It is a stiff, dark or bluish-grey clay which weathers at outcrop to brown (Sherlock, 1935). The geological map shows that across the entrance to the Backwaters the London Clay is overlain by Recent clayey alluvium (not shown on Fig. 2.2), of an unknown origin and thickness, with sand/shingle banks on the seaward side. It is not certain whether the clayey alluvium at the entrance is merely recent Holocene mud, or glacial till.

The site also falls within an area of thin loess (Catt, 1978), a fine-grained Quaternary aeolian deposit, often having a high carbonate content, and frequently possessing a distinctive heavy mineral and clay mineral suite (Lowe and Walker, 1984). Almost all the loess was deposited during the later part of the Late Devensian (*c*.14,000 yrs bp), and often mixed by cryturbation with subjacent deposits. However, many of the deposits in the study area have been affected by the action of fluvial and colluvial processes, and are therefore frequently intermixed with other deposits to form what is referred to in south-east England, as brickearth, so called because of their value to the brick-making industry. As a result, the diagnostic physical and chemical properties are lost and recognition of the original wind blown nature of the sediments is difficult (Lowe and Walker, 1984).

2.2.1 Thames Drainage

The Pleistocene history of the landscape of the Walton Backwaters, and indeed the majority of the Essex countryside, is dominated by the movement of the Pre-glacial Thames. In Early and early Middle Pleistocene times the river flowed across the northern half of Essex and due to subsidence of the southern North Sea Basin, uniclinal shifting and diversion by the Anglian ice sheet, has gradually migrated south-eastward to its present position (Bridgland, 1988; Bridgeland *et al.*, 1992). It can be seen from Fig. 2.2.1 how the movement of the Thames/Medway may

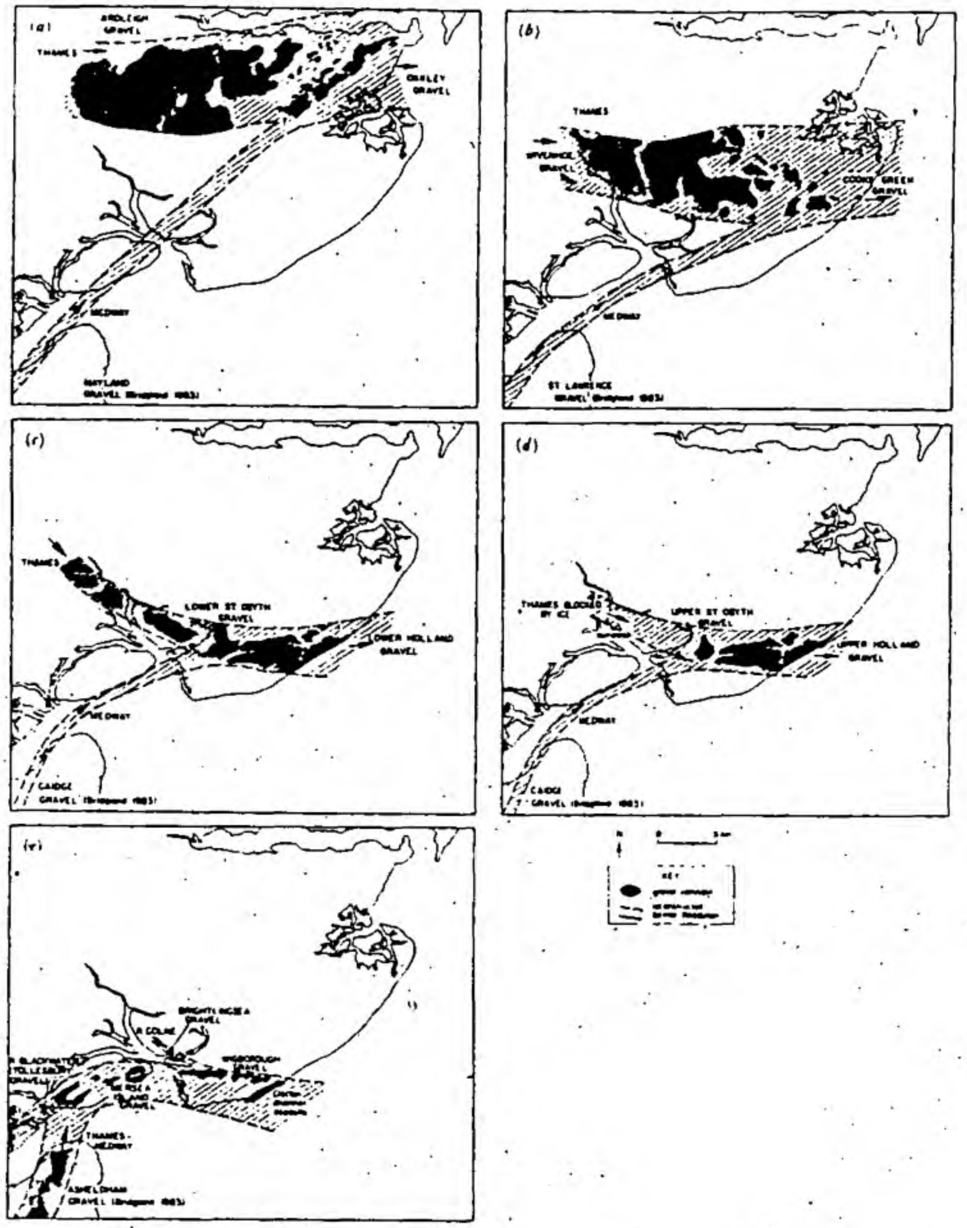


Figure 2.2.1 - Reconstruction of palaeodrainage in the region of the Tendring Plateau in (a) pre-Cromerian, (b) immediately post-Cromerian, (c) early Anglian, (d) Lowestoft Stadial, Anglian glacial maximum, and (e) late Anglian to early Wolstonian (reproduced from Bridgland, 1988).

have influenced the formation of the Backwaters. Given the position of the Backwaters, it may be envisaged as being at the head of a former tributary of the Stour/Orwell system which in turn joined the Thames and hence represent the final stages of the filling of a tributary of the former Thames valley.

2.3 Sea Level

A major aim of this investigation is the study of the Holocene estuarine sequences. Such studies invariably contribute to the understanding of sea level change. Sea level change not only influences the relative position of shorelines but also the character of coastal stratigraphic sequences (Kraft and Chrzastowski, 1985). It is by studying sequential variations in estuarine deposits around the coastline that a comprehensive picture of the nature of sea level change can be built up.

An important complicating factor in measuring changing sea-level is the change in the height of the land due to crustal movements (tectonic and/or isostatic change). Based on an analysis of over 400 sea level index points, Shennan (1989) has assessed crustal movement in Great Britain since 8,800 b.p. Current estimated rates of crustal movement confirm an overall pattern of differential movement involving relative uplift in highland Scotland and relative subsidence in southern England. The effect this crustal movement has on the observed relative change in sea level is further complicated by the natural availability of sediment, which can raise the shoreline in some areas at a rate at least equal to that of sea-level rise. The relatively recent enclosure of tidal land, building of sea defence and coast protection measures serves only to confuse the understanding of the precise relative rates of change as measured by tide gauges (Davidson *et al.*, 1991). Analyses of recent sea-level change derived from tide-gauge data have been made by Woodworth (1987) and Carter (1989). Carter splits the British Isles into two provinces, the south-east where the tendency is for sea-level rise and the north and north-west where sea-level is falling.

South-east England is of most concern when considering implications of sea-level rise. Land subsidence resulting from isostatic adjustments in this area reinforces the current rate of sea-level rise and results in overall relative rates of rise higher than can be attributed to eustatic change alone. It is generally believed that sea-level is rising in Essex at a rate of between 2 and 3mm/yr (Long and Mason, 1983; Clayton, 1990). South-east England is also an area that has seen particularly massive enclosure of tidal land to create agricultural land (see 2.5.2). The effects of these enclosures has been to reduce the extent of the intertidal and transitional zones. These would have formerly moved inland or seaward in response to changing patterns of tidal inundation, but are now restricted to a much narrower fringe around the coast. In areas such as the Walton Backwaters there is still some natural component to the sea defence capability of the coastline composed of mudflats backed by saltmarsh which directly abut the toe of the sea defence. However, a consequence of sea-level rise is the steepening of the foreshore which in turn is undermining the ability of fronting tidal flats and saltmarsh to dissipate wave energy.
There appear to be two underlying factors affecting these shoreline habitats: erosion pressure which affects both flats and saltmarshes, and decay of the saltmarsh itself (Davidson *et al.*, 1991).

2.4 Prehistorical

Of possible significance and requiring further investigation, is the prehistorical record and in particular the discovery, in 1910, of humanoid remains at the Naze , possibly of Neolithic age, but not certain (Warren, 1912). The find was located in clay beneath what is described as a layer of peat. The presence of peaty clay is also reported in NRA borehole records in the same general area, just west of the Naze, at depths of around -3m OD (NRA archives, Ipswich). The existence of peat in this area is significant, if it exists, in that it would contrast with the neighbouring Deben, Orwell and Stour estuaries which comprise a continuous estuarine clastic sequence without intercalated peat. However, to the north of the Deben, in particular, the Blyth and further north to the Broadlands, North Norfolk and the Fens, and also south to the Blackwater, Crouch and Thames, initiation and cessation dates of peat layers are reported (Brew et al. 1992). Unfortunately Warren's reference to 'peat' is probably used loosely and may simply refer to a peaty clay as described in borehole records. Leeks (1975), however, also reports a peat layer exposed on the north shore containing 'carbonized wood and root material', although he does not elaborate and such an outcrop has not been located. If such successions do exist, where peat is succeeded by marine deposits inferring a transgressive sequence, and the peat can be dated, it could contribute to our understanding of changing sea level in this area.

2.5 Historical

2.5.1 Coastline Changes

In order to appreciate the historical evolution of the coastline around the Backwaters, all known sources of maps and charts need to be considered, all varying in accuracy and detail. In addition, the history of neighbouring Harwich Harbour, which dates back to references in the Anglo-Saxon Chronicle for the year of 885 (Carlyon-Hughes, 1939), needs also to be considered as continuously having varying degrees of influence on coastal processes at the mouth of the Backwaters. Most Harwich Harbour surveys overlap the entrance to the Backwaters. These and all sources of Ordnance Survey maps, old Tithe maps and Admiralty surveys are currently being investigated.

Early maps concentrate on land usage and lack sufficient detail of the coastline to accurately record morphological changes. For instance, on most early land maps the saltmarsh in the Backwaters are not marked, merely termed "Sunken Marshes" (Gramolt, 1960). The earliest complete, detailed hydrographic survey of Hamford

Water was conducted in 1849 by the Admiralty (Figure 2.5.1). Compared with the most recent Admiralty survey of 1983 (Chart 2695 with amendments to 1992, not reproduced here due to its large size), the main changes are towards the entrance of Hamford Water. Although the drying line along the northern edge of Hamford Water/Pye Channel has altered little. Dugmore creek, originally depicted as a separate channel in 1849, is now a shoal area. The drying line on the south side of Pye Channel is shown 75m further south east, with the main channel 50-70m further south as well. On the south-eastern edge of Pye Sand, the drying line is similar to the present day, tending only to straighten as Stone Point apparently erodes. The Scarfe has migrated southwards with Stone Point, to form the present day Mussel Scarfe, which can now carry craft drawing up to 2m at High Water.

A significant observation made by The Admiralty (1983) is that Stone Point had retreated approximately 500m from its surveyed area position in 1849. This was also compared with a land survey of 1913 which revealed that the point had retreated approximately 200m. This would give a mean value of 3.0 metres erosion/year, together with the beach to seaward which had retreated 200-300m from its 1849 position. The Admiralty also points out that since the creek system of Hamford Water and Pye Sand region is based on a solid clay pavement, the channels are relatively permanent features of the area, and the gradual disappearance of Stone Point will probably alter the characteristics of discharge from the Hamford Water/Walton Channel entrance. With a greater area for the same discharge of water to flow out, the velocity of water flow should drop according to $Q = VA$, Q being discharge. This may cause suspended sediments to deposit out into Pye Channel as well as the Walton Channel entrance. Indications are given by the decrease in depths in Pye Channel and Walton Channel entrance since 1849. Soundings in the channels and creeks show a general agreement between the 1849 survey and 1983, showing approximately 1-2m greater depths than 1983, although it is pointed out that some of the difference is likely due to a

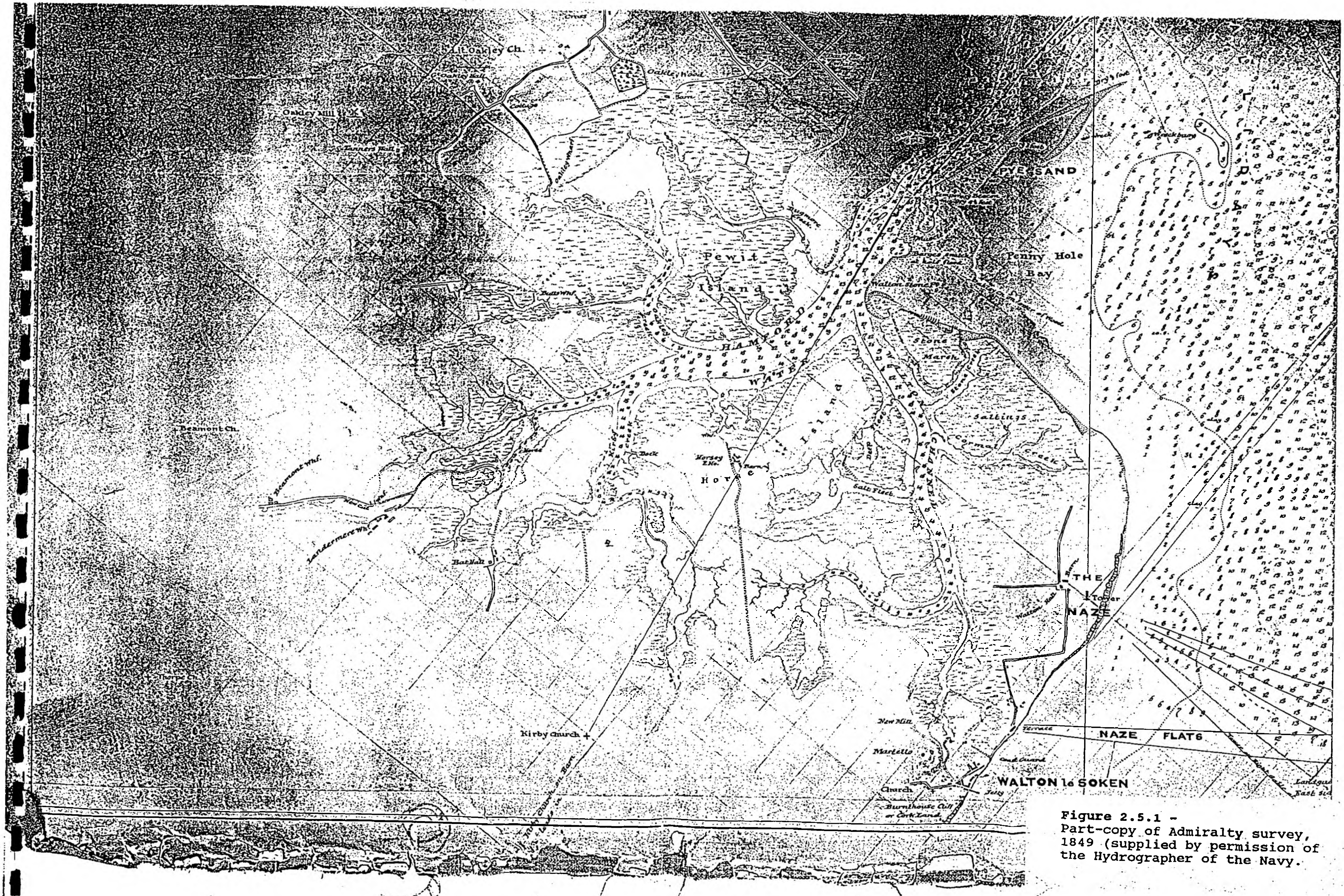


Figure 2.5.1 - Part-copy of Admiralty survey, 1849 (supplied by permission of the Hydrographer of the Navy.

difference in sounding datums. For the Walton Channel entrance west of Stone Point and for the Pye Channel the differences in soundings is more marked, with soundings greater in 1849 by up to 9m. The Walton Channel was a definite channel into Hamford Water and shows a depth of 8.2m compared to 2.5m in the same position in 1983. This extended to the main Pye Channel, with depths of 12-15m recorded, where the maximum depth is now 6.8m. The channel extended past Crab Knowle point with differences still around 6m greater for the older survey, out to Pye End, with depths recorded 2m more than 1983. The lie of the channel has not altered however. This decrease in depth cannot be attributed solely to chart or sounding datum differences and may be a result of infilling of the channel as Stone Point has eroded. It is perhaps conceivable that eventually another channel may be formed with the Pye Channel around the Cormorant Creek region taking most of the Walton Channel discharge with the Pye Sand region remaining near its present depth (Admiralty, 1983).

2.5.2 Reclamation and Sea Level

The present day boundary of the Walton Backwaters is much the result of reclamation and sea defence works, and very little of the Backwater has escaped the influence of such works. The most extensive documentation of the history of reclamation is by Gramolt (1960) who covered in considerable detail all known works carried out on the marshes of Essex including the Walton Backwaters. This was expanded by Leeks (1975), for this particular area, in an undergraduate study of the morphology of the Backwaters. It is the future intention of this investigation to consolidate Gramolt and Leeks' work and to expand the coverage to include recent studies and developments such as the erosional survey of Burd (1992) and the present work being carried out at Horsey Island, Foulton Hall Point and Stone Point.

The age of some of the earlier enclosures, for example the south shore of The Wade (pre-1774), has resulted in a considerable difference between the level of the land behind the seawall to that of the fronting saltmarsh due to subsidence. Pye (1992) suggests that assuming both active and reclaimed marshes are mature, i.e had achieved a constant elevation relative to the moving tidal frame, some indication of a rate of sea-level rise can be obtained. Pye's work was conducted on the North Norfolk marshes where it is pointed out that at the time of deposition, the sediment had a low bulk density (0.3-0.4 t m^{-3}) and a high organic carbon content (10-20% by dry weight). Over 50-100 years the bulk density increases to 1.2-1.6 t m^{-3} due to compaction, dewatering, degradation of organic matter and dissolution of calcium carbonate. The thickness of an annual accretion lamina may therefore be reduced to about 25% of its original value over a period of about 50 years.

As part of an initial reconnaissance of the area, a series of transects were levelled over the seawall from mature marsh to reclaimed land. Although yet to be fully evaluated, typical differences are between 800 and 1200mm, the present marsh surface being higher than the reclaimed land. Taking, as an example, the reclaimed field south of the Wade (reclaimed c.1740 (Gramolt, 1960)), where the difference is 1200mm, a relative sea rise, not allowing for the effects of compaction, of 4.7mm a^{-1} could be inferred on the assumption that marsh growth keeps pace with sea-level rise. Sheldon (1968) found that in the River Crouch under natural conditions sedimentation on the marshes keeps pace with subsidence, but where the land has been reclaimed and embanked, subsidence has continued with no compensating sedimentation. It is difficult in these circumstances to access the true level of both saltmarsh and reclaimed land; the former is generally badly fragmented where it fronts high seawall, and the latter usually consists of ploughed fields. The intention is to fully evaluate the results of the cross-wall levelling and their applicability to saltmarsh accretion and sea-level rise in this area.

3. Contemporary Processes

3.1 Sediment Dynamics - Introduction

A fundamental aim of this investigation has been to understand the sediment dynamics of the Walton Backwaters, in particular the sediment transport mechanisms operating within the main channels, creeks and over the saltmarsh surface, together with an understanding of the process of sedimentation on the saltmarsh and tidal flats. There are, however, many variables to be considered in such a study, mainly: sediment characteristics and flow characteristics and since sediment movement is driven by the near-bed flow, and the moving sediment itself affects this flow, attention has to be focused on the fluid forces and boundary layer flow (Dyer, 1986).

The initial intention for field work in 1993 was, therefore, to obtain some idea of the flow characteristics within the entrance of the Backwaters, analyze the overall grain size characteristics of the whole site, and begin monitoring the rate of saltmarsh and mudflat sedimentation. To this end the tidal flow characteristics were recorded over a limited number of tidal cycles, a representative amount of surficial sediment samples were collected, and various transects were established to monitor, chiefly, saltmarsh accretion and/or erosion. Unfortunately, the grain size characteristics have yet to be analyzed which has initially rendered the analysis of the boundary layer conditions somewhat academic since most computations rely on some idea of grain size. However, since the initial aim was to merely obtain some idea of direction of residual sediment transport, grain size data from HR Wallingford (1990) was considered adequate.

3.1.1 Sediment Characteristics

Although yet to be analyzed in detail, bottom sampling shows two distinct regimes. The area west of the Hamford Water/Walton

Channel entrance consists exclusively of fine silt and to the east sand. In the channels and on the mud flats this is often only to a depth of 10cm, below which is hard clay characteristic of the London clay. The channels appear to be stable features of the region, possibly relict channels cut into the London clay when sea-level was considerably lower. Pye Sand can be walked over at low water springs and consists of a thin layer of fine sand overlying the same clay in depths ranging from 0 to 60 cm and characterised by what are probably wave- and current-induced sand ripples. The sand is apparently moved by littoral drift southwards along the coast and over Pye Sand (Clayton *et al.* 1982; HR Wallingford, 1990). The sand fraction is evident on the seaward coastline from Harwich to the entrance of Dugmore Creek, where a bank of sand extends 150m out into the Hamford Water entrance, and then continues from Stone Point along the coast. The sand fraction stops abruptly at Stone Creek in the Walton Channel, suggesting, with the southward extending spit from Dugmore Creek, that sand migrates across the entrance to Hamford Water but does not move up the channels. This sand/mud line shows a possible clear distinction between the different energy regimes of a tide-dominated, estuarine Backwaters region and a wave-dominated Pye Sand region.

3.1.2 Tidal Regime

The tidal regime is classified as mesotidal (average tidal range: 3.8m on springs and 2.3m on neaps). Predicted tidal duration (to the nearest 5 minutes) of the flood is 6 hours 40 minutes during springs and 6 hours 30 minutes during neaps. Predicted ebb times are 5 hours 40 during springs and 5 hours 50 minutes during neaps. It is evident from observation and supplemented with limited current data, that the ebb and flood within the Backwaters is complex. From low water, the flood tide is initially confined to Pye Channel flows west up Hamford Water and south into Walton Channel. As Pye Sand covers, approximately 1½ hours after low water, the flow begins to converge bodily on the north-east point of Horsey Island. Flow around the existing wave break (consisting of sunken Thames lighters) at this convergence point is considerably turbulent. Within the Walton Backwaters the current regime is highly complex being affected by the flow on and off the tidal areas, flow around land masses, and the flow in the channels and labyrinth of tidal gullies.

The intention of recent fieldwork was to assess the direction of residual current. Leeks (1975) has looked briefly at currents in the small creeks and HR Wallingford (1990) has measured the flow north of Horsey Island and also analyzed OCSR data at four points outside the entrance to the Backwaters; and a limited amount of data was obtained for Walton Channel and Hamford Water from fieldwork in the summer of 1993. Measurements by HR Wallingford (1990) (Fig. 3.1.2 (g)) showed that the flood tide was of longer duration than the ebb and flow speeds were also higher and from this was inferred a flood residual. However, the latest measurements at Stone Point indicate a strong ebb residual. This concurs with results from Leeks (1975) from the entrance to Dugmore Creek (Fig. 3.1.2 (e) & (f)). In addition, to the north and just outside the Backwaters OCSR data indicates an ebb residual. Posford Duvivier (1993) conclude in their Environmental Impact Statement prepared for Harwich Haven that, at the interface between the Backwaters area and the open sea, residual currents tend to be directed seawards.

Tidal studies were carried out in the summer of 1993 and utilised an Eulerian sampling method; the vertical structure of the estuarine water body over a single tidal cycle in Hamford Water and in Walton Channel was investigated. The Braystoke CTD and flow meter array was used enabling a relatively rapid series of measurements to be made through the water column. It was rigged from a derrick over the port side of the survey vessel "Elizabeth Anne" (EA) and raising and lowering was via a hand-operated winch. EA was anchored as near as practicable to the main channel off Stone Point. Attempts to obtain CTD data for Hamford Water were thwarted on two previous occasions, the first due to severe weather and the second failure of the survey vessels main engine. Disappointingly, only one good data set from low water through high water to low water was obtained.

Simultaneous measurements of velocity, salinity and temperature were made at 30 minute intervals, at the surface, the bottom and at 0.5m intervals in between. Measurements were made continuously from low water through high water to the following low water. The state of the tidal cycle was 3 days after springs. The results of the survey are presented graphically in time-varying plots of velocity, salinity, temperature, and depth, and net vertical profiles of flood and ebb current velocity (Figs. 3.1.2 (a), (b), (c) & (d)).

Although generalizations about the Backwaters based on data from a single tidal cycle are not sufficient enough to justify any firm conclusions and eventual estuarine classification, several pertinent observations can be made from the available data:

a) The tidal cycle is clearly asymmetrical at this point: the ebb is stronger than the flood;

b) There is a noticeable shearing effect of the velocity profile: the surface and bottom velocity is considerably less than mid-depth.

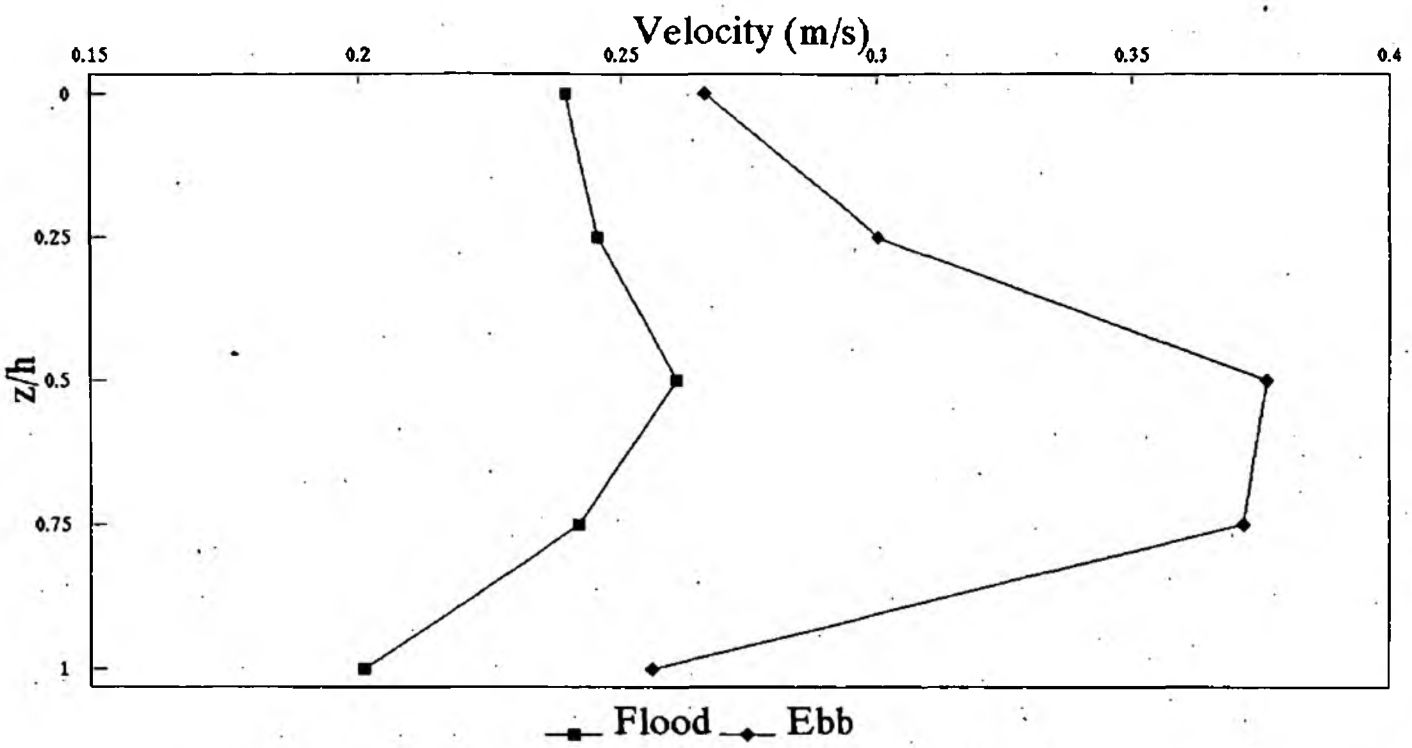
c) A short slack high water and rapid increase in velocity at the beginning of the ebb contrasts with a longer ebb slack water and long, gradual flood.

e) Salinity variation from low water to high water is negligible although when plotted on an expanded scale, there is a marginal drop in salinity at high water. Since these data are from mid-summer, it is reasonable to expect a slight increase in salinity due to evaporation within a small enclosed basin such as the Backwaters.

f) The same lack of variation in temperature is also displayed, merely showing a slight increase towards the end of the day indicating very little difference between temperatures inside and outside the Backwaters.

The CTD results, on their own, are fairly inconclusive and a more widespread assessment of the current flow is required. It would also be interesting to assess the circulation around Horsey

Island and how it may affect the duration and magnitude of ebb and flood in the vicinity of the wave break north of Horsey Island and how it contrasts with Stone Point in Walton Channel.



State of Tide: 2 day after springs.

Figure 3.1.2(a) Stone Point – Mean Flood and Ebb Velocity Profiles

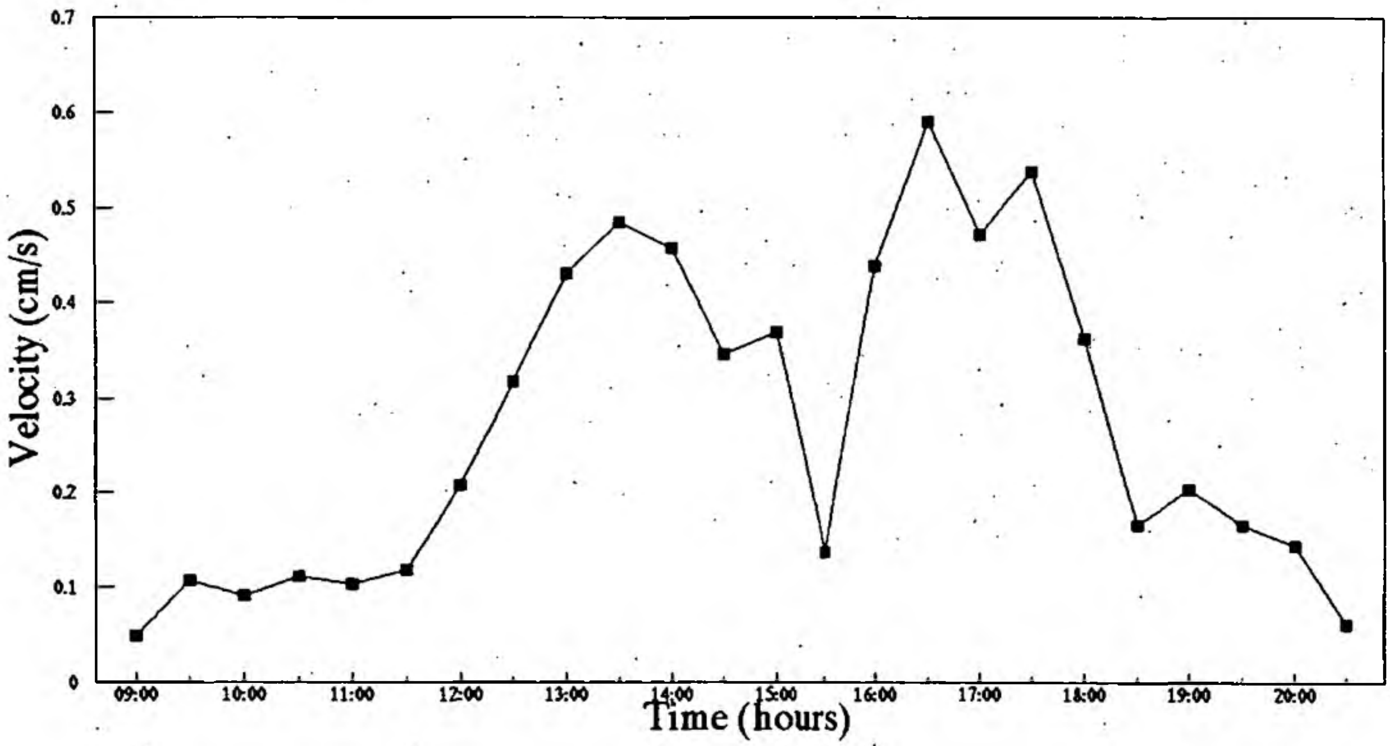


Figure 3.1.2(b) Stone Point – Depth Mean Velocity over half a tidal cycle – 7 August 1993

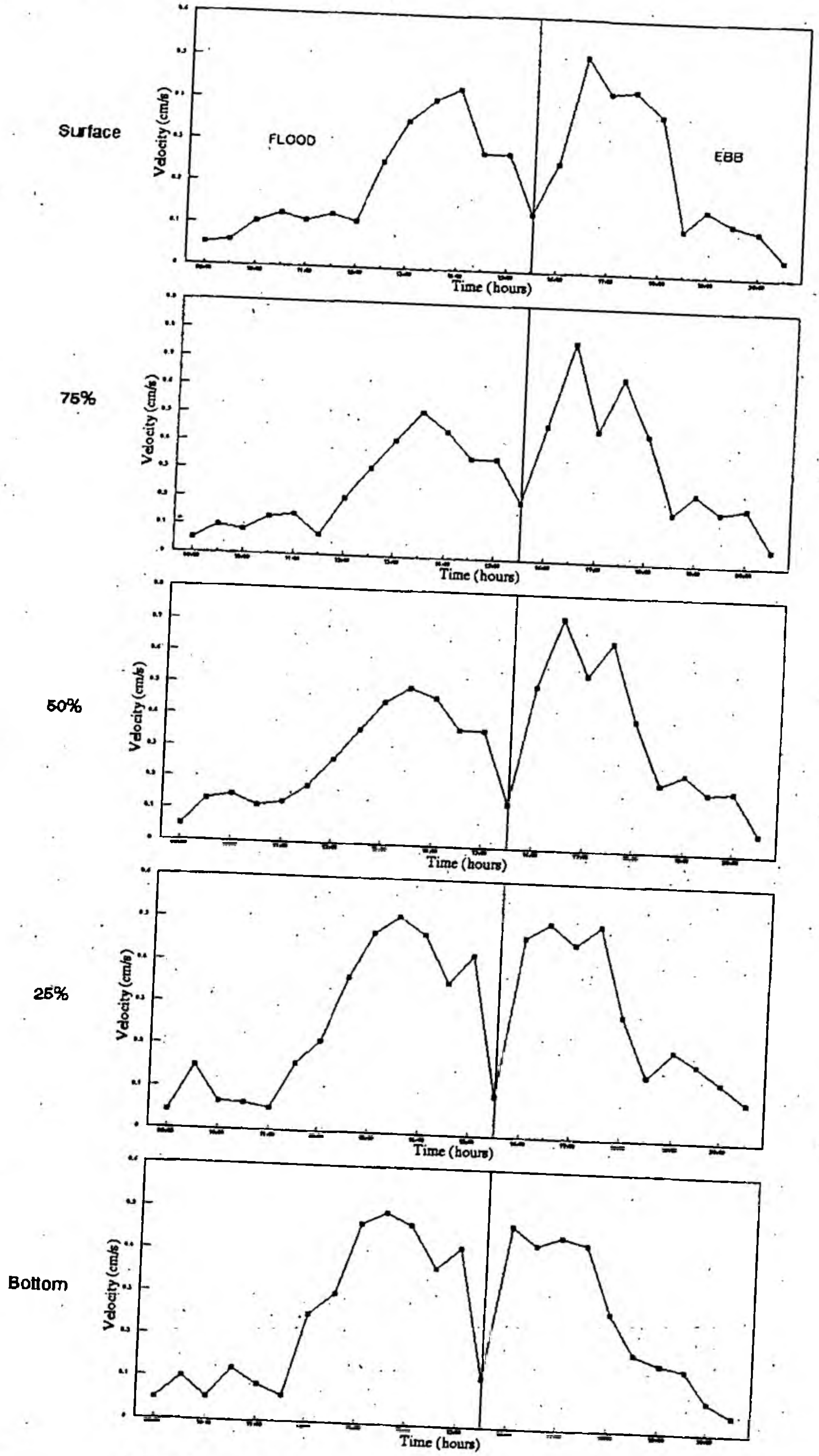


Figure 3.1.2(c) Stone Point – Depth Mean Velocities (cm/s) – 7 August 1993

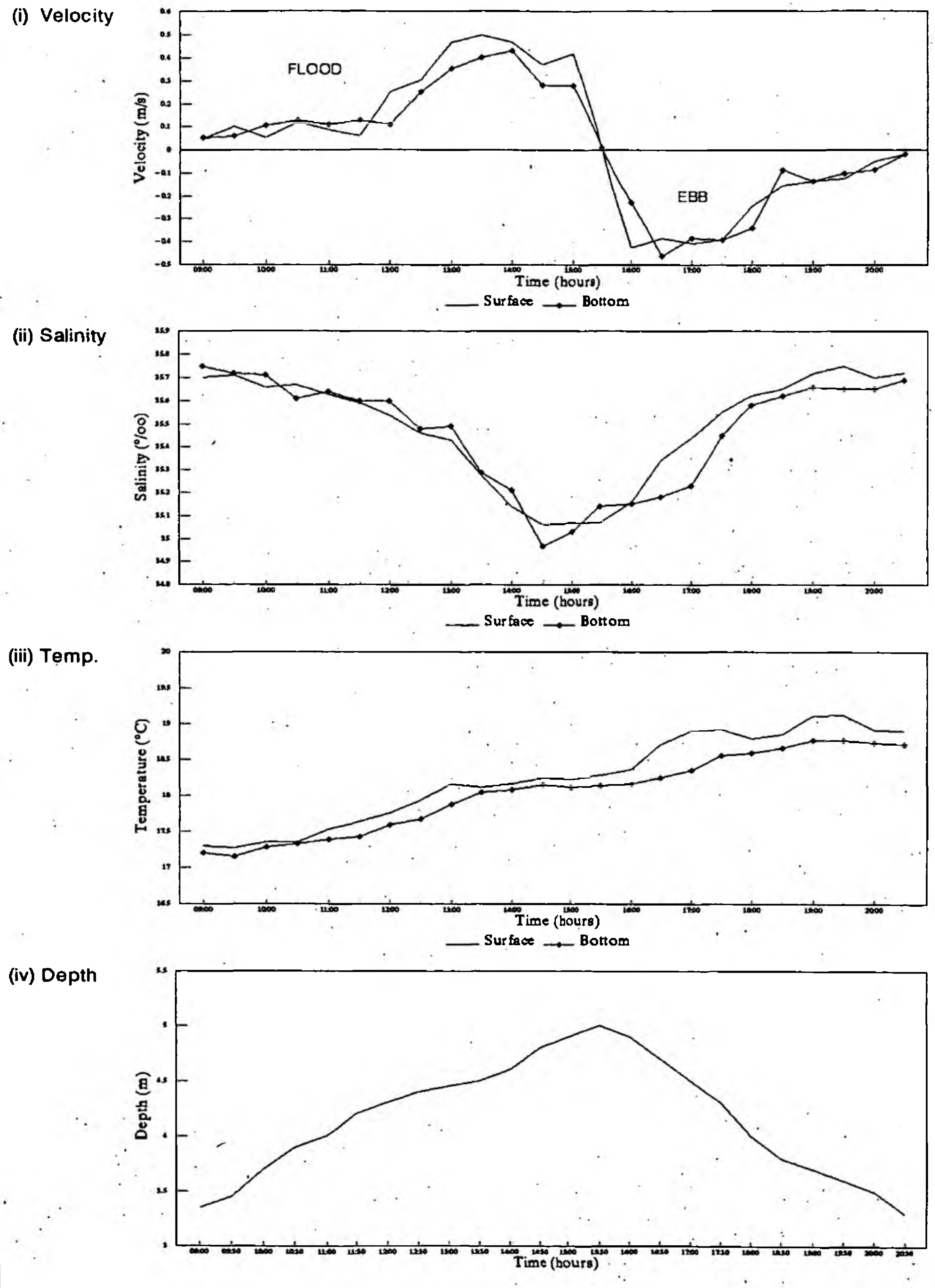


Figure 3.1.2 (d) Velocity, Salinity and Temperature variation – Stone Point – Spring tide.

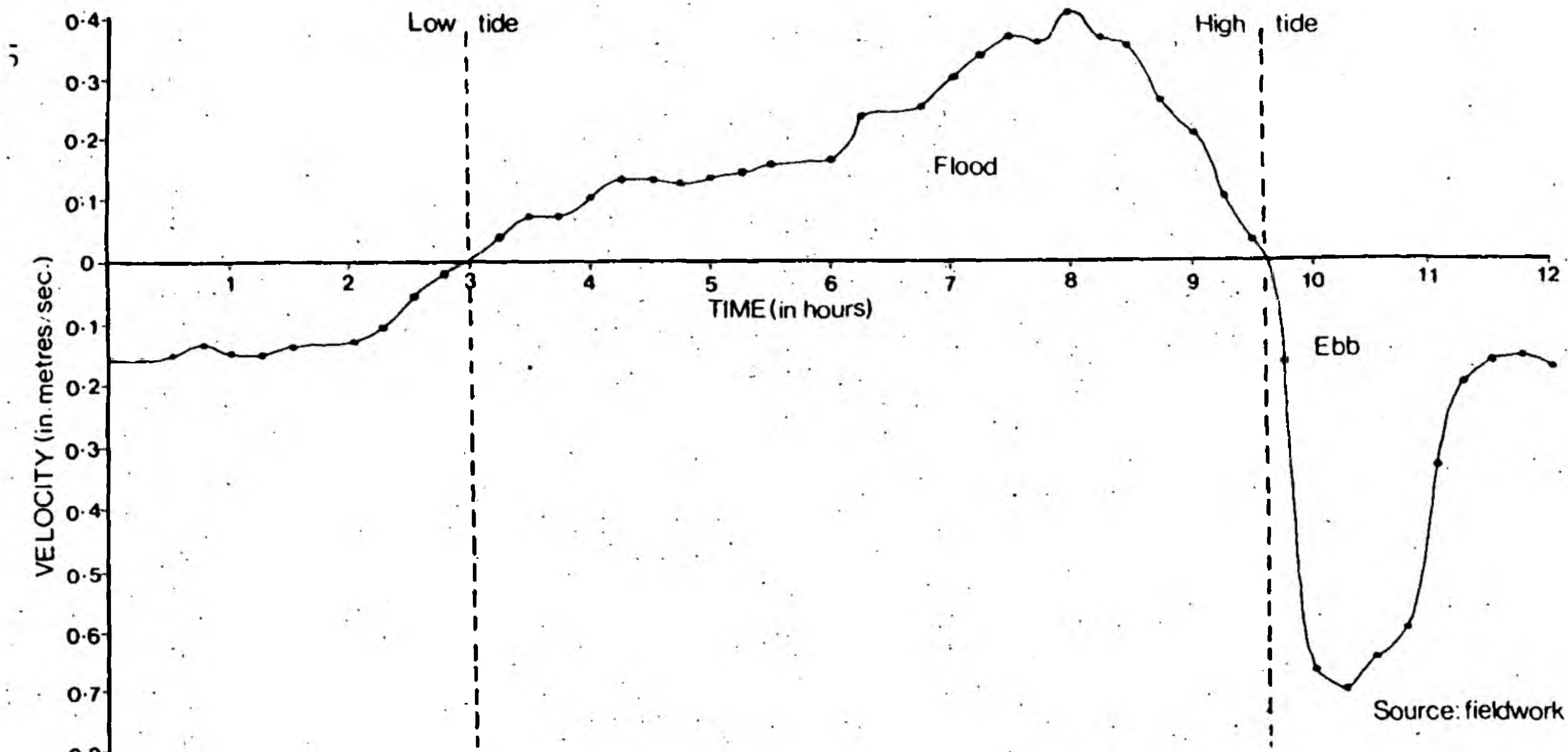


Figure 3.1.2(e) -
Surface flow velocities over a 12 hour period at the outlet of Dugmore Creek (from Leeks, 1975)..

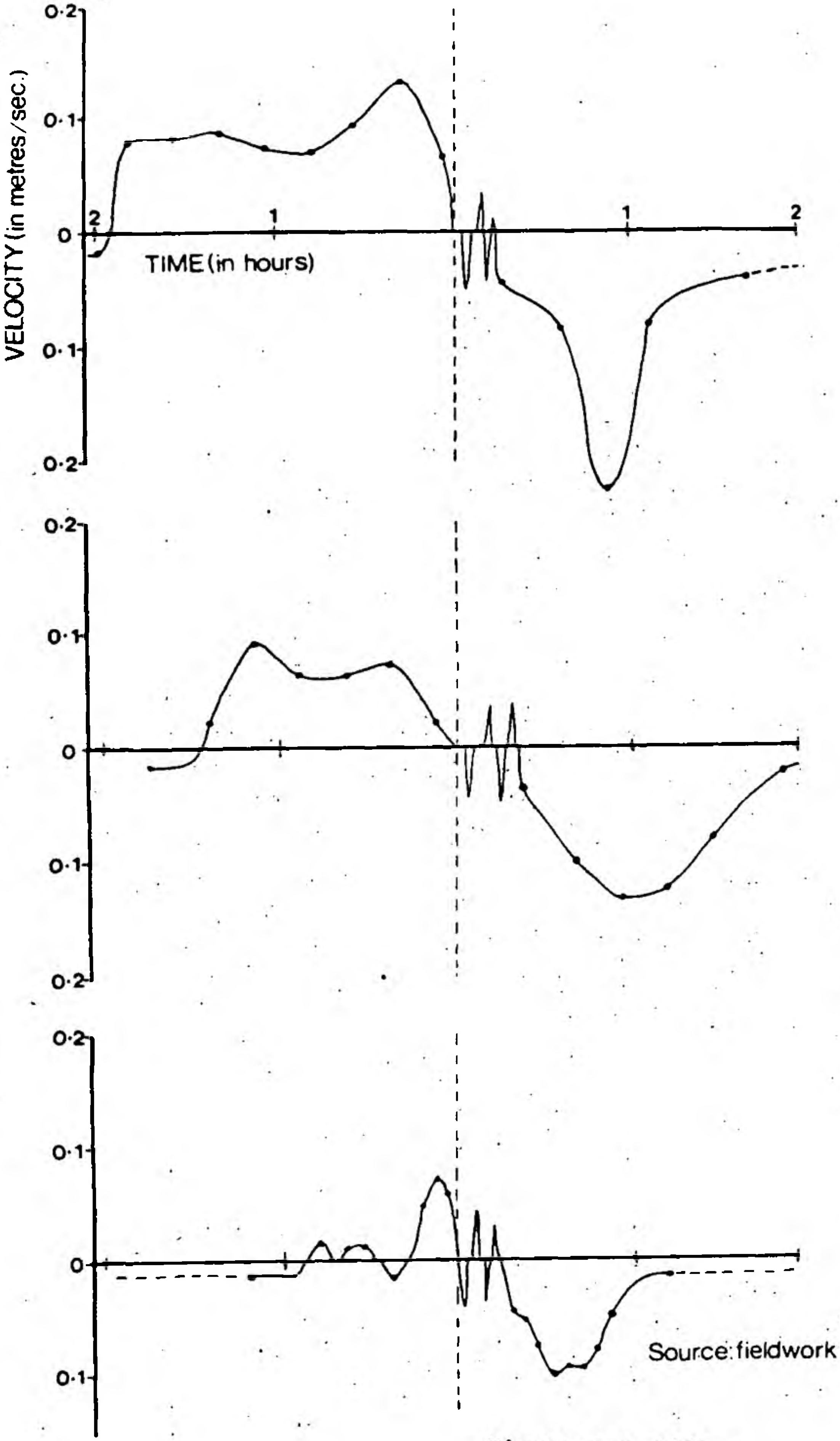


Figure 3.1.2(f) - Examples of surface flow velocities in the mature marsh area north of Hamford Water (from Leeks, 1975).

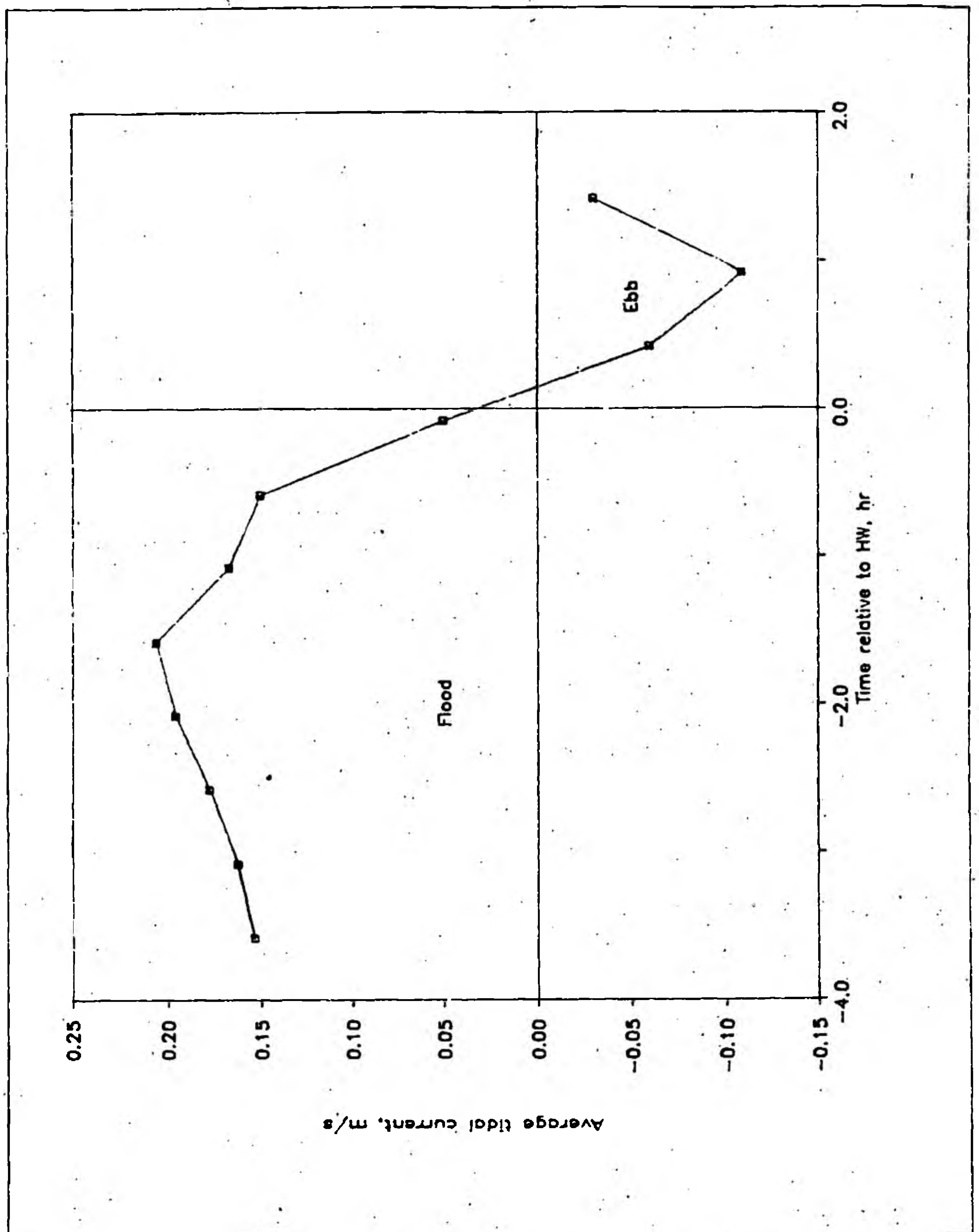


Figure 3.1.2(g) -
Tidal currents at Horsey Island
(from HR Wallingford, 1990).

3.1.3 Sediment Transport

A fundamental aim of this investigation is to establish the direction of sediment transport since the morphology of the Backwaters is to a large extent determined by the residual sediment transport pattern. However, the inverse statement is also true: residual sediment transport depends on differences in magnitude and duration between the ebb and flood (Dronkers, 1986). Tidal asymmetry has been studied in similar environments by Pethick (1980), Boon and Byrne (1981), and Dronkers (1986) and is essentially produced by distortion of the tidal wave propagating on the coastal shelf and entering the estuary. From these studies it is apparent that the most important cause of tidal asymmetry is an asymmetry in the tidal boundary conditions, and a variation in the basin geometry with water level (Dronkers, 1986). The most striking result from the Backwaters so far, is a large ebb/flood asymmetry (Figs. 3.1.3 (a), (b), (c) & (d)). These data were collected using a Velocity Gradient Unit which consists of an array of 10 OTT current meters rigged on a vertical mast firmly anchored to the seabed. Five current meters face the flood current and five the ebb. The meters were spaced at logarithmic intervals from the base to obtain as much detail of the boundary conditions as possible (Fig. 3.1.3(e)).

In order to understand the possible cause/effect of these results it is necessary to look at processes at work in such environments. The evolution of an environment such as the Walton Backwaters depends essentially on two processes (Dronkers, 1986; Dyer, 1986): firstly, the long-term averaged sediment supply, and direction and magnitude of the long-term averaged sediment transport; and secondly, any abrupt changes in the estuarine morphology caused by storms surges or by engineering works. The sediment supply and sediment transport pattern, in turn, depend on several factors: sediment characteristics; wind, waves and swell; current velocity distribution and in particular its variation during a tidal cycle; and, river inflow (although important in estuaries with considerable fresh water input, considered negligible in this case). Dronkers' work was devoted to the analysis of tidal wave deformation in shallow systems with a regular or a complex geometry, and its effect on the residual sediment flux. In conclusion, it was found that the main features of tidal wave distortion for residual sediment transport are, firstly, a difference between the slack water periods before ebb and flood, which affects the residual transport of the fine fraction of the suspended load, and secondly, a difference between the maximum velocity during ebb and flood, which affects the residual transport of the coarse fraction of the suspended load. The effects are different depending on the shape of the tidal basin. In regularly shaped basins (no important width variation with water-level) and in the absence of river inflow, the tidal wave tends to be distorted such that the maximum flood velocity is greater than the ebb and the slack water period before the ebb is greater than the flood. This distortion is manifest in the inner part of both long and short tidal basins (compared to the tidal wave length). The result is a sediment infilling of such estuaries in periods of low river discharge. Conversely, in irregularly shaped estuaries (meandering and braided channel system, tidal flats) the tidal current variation is influenced by the geometry, within which two types of geometry are distinguished: a) shallow channels and landward decreasing depth with tidal flats below mean sea level; and b) deep channels throughout with tidal flats above mean sea level. In the first case the slack water period before ebb will exceed the slack water period before flood and hence a residual import of fine sediment is favoured. In the second case the inverse situation occurs which very much appears to be the present situation in the Walton Backwaters. It has already been seen from the CTD data (Fig. 3.1.2 (a) to (d)), however limited it may be, that the flood is longer than the ebb and the period of slack high water is considerable shorter than slack low water. The results obtained using the VGU appear even more dramatic. Preliminary interpretation of VGU data centred around determining the direction of sediment transport and for this purpose use was made of the total load equation of Englehund and Hansen (1967) (as described by Asghar Ali, 1992). It is not the intention, at this stage, to assess the applicability of different methods of calculating sediment transport. The magnitude of the difference between the ebb and flood was considered sufficient and highlights this an area for further fieldwork.

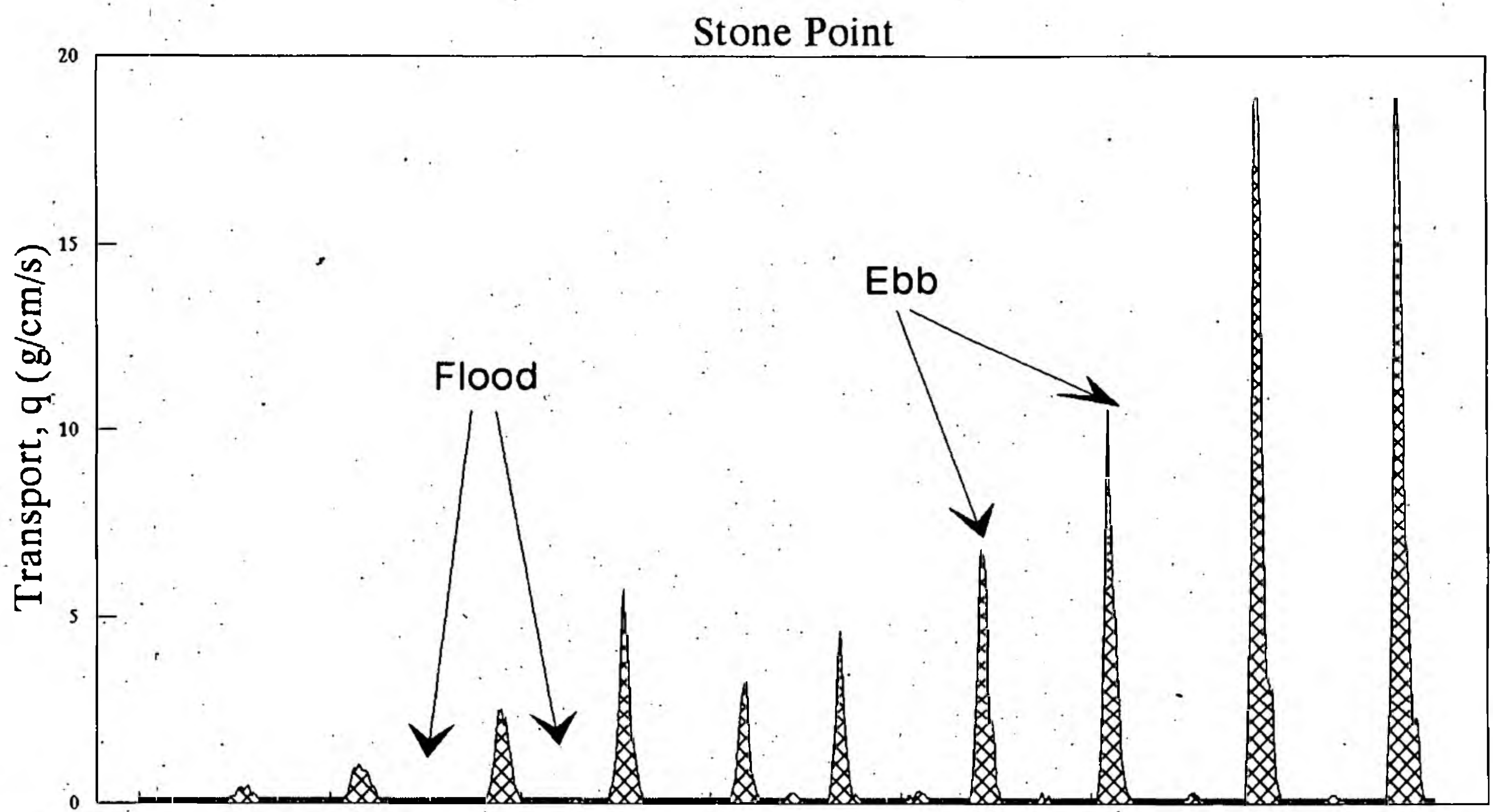


Figure 3.1.3(a) Total Transport, q (g/cm/s) over a 5 day cycle.
(Computed using total load equation of Engelhund and Hansen (1966).)

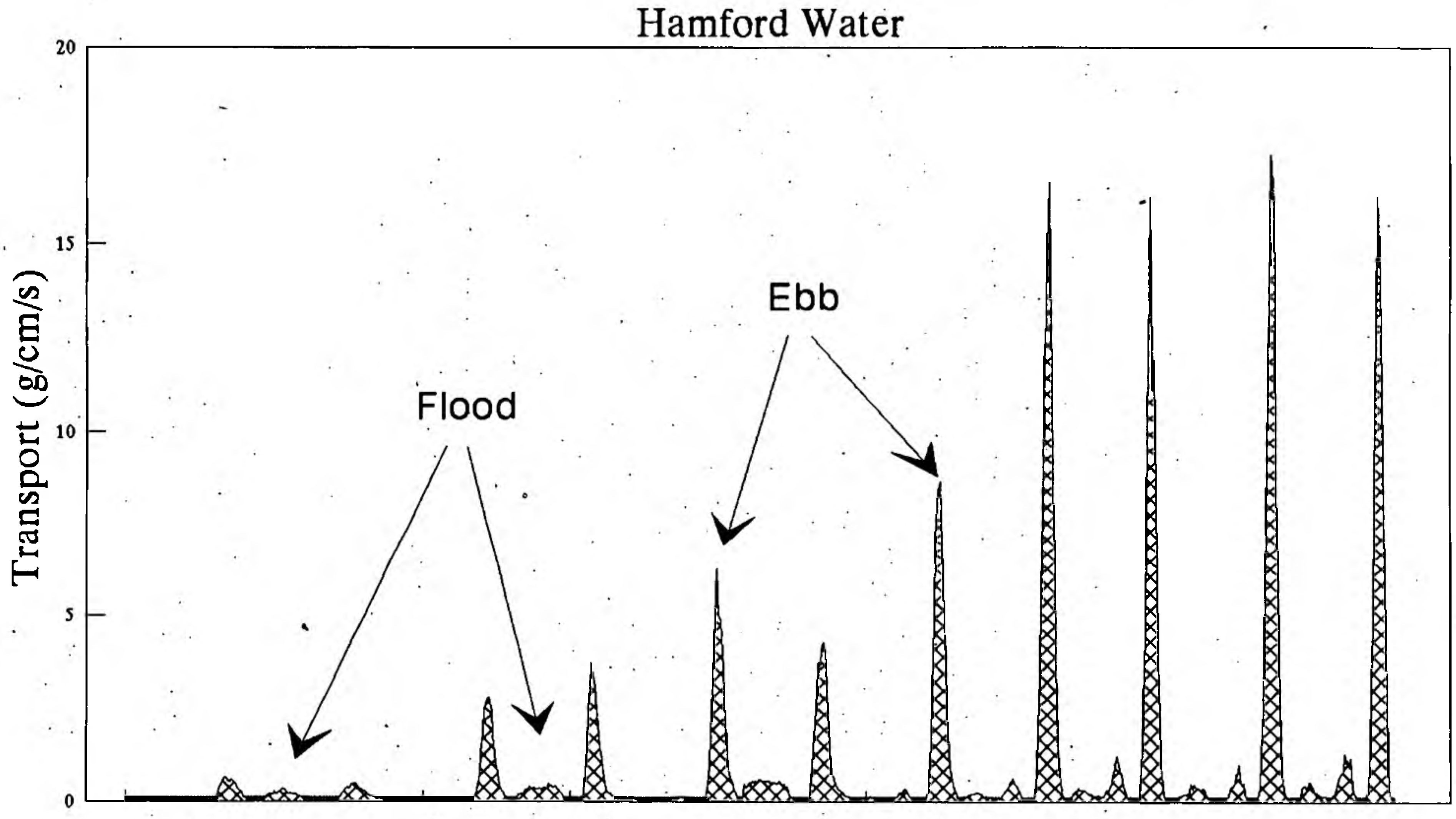


Figure 3.1.3(b) Total Transport, q (g/cm/s) over 5½ tidal cycles.
(Computed using total load equation of Engelhund and Hansen (1966).)

(i)

(ii)

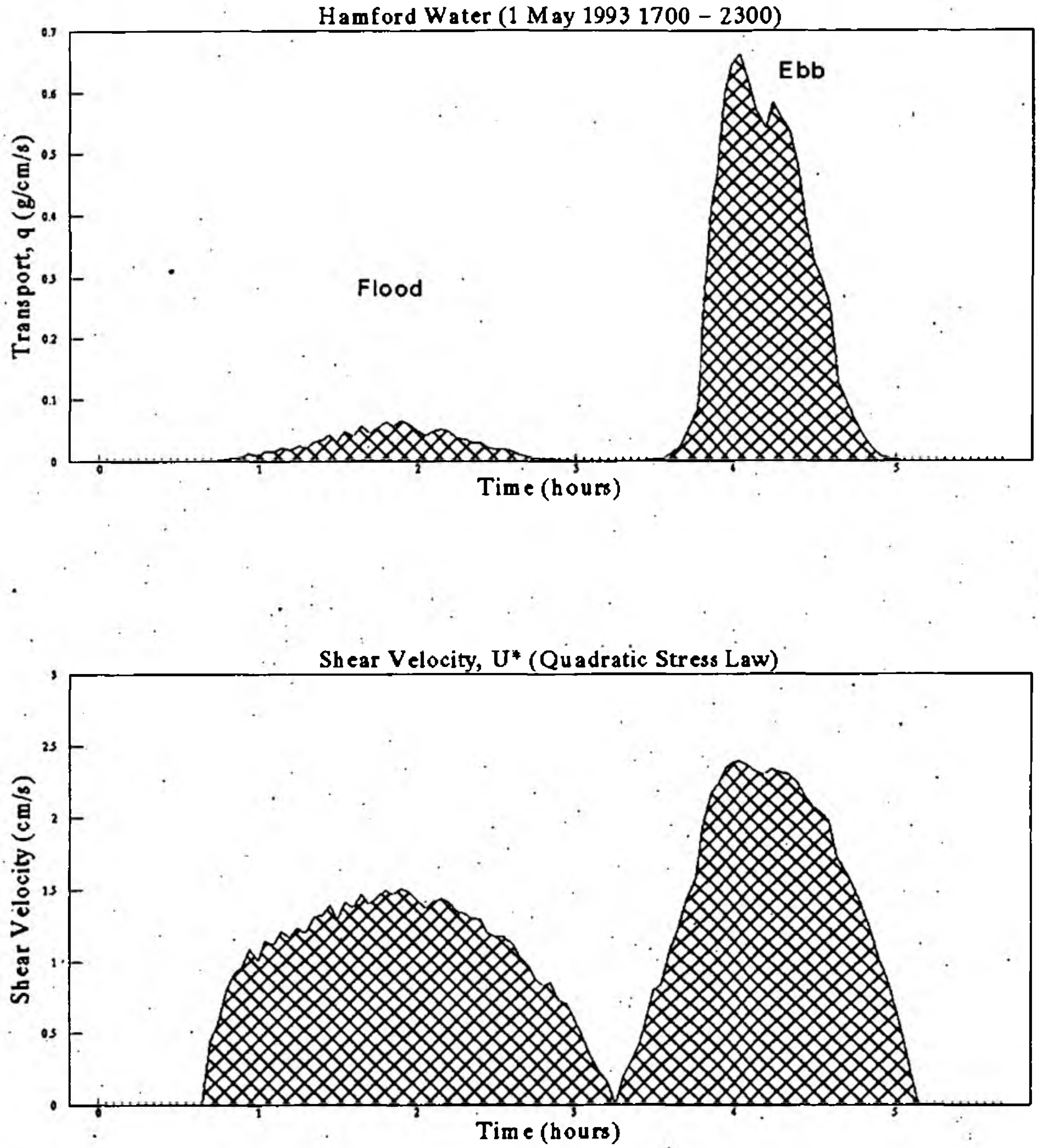


Figure 3.1.3(c) - Typical flood/ebb profile for Hamford Water
(i) Total Load Transport.
(ii) Shear velocity.

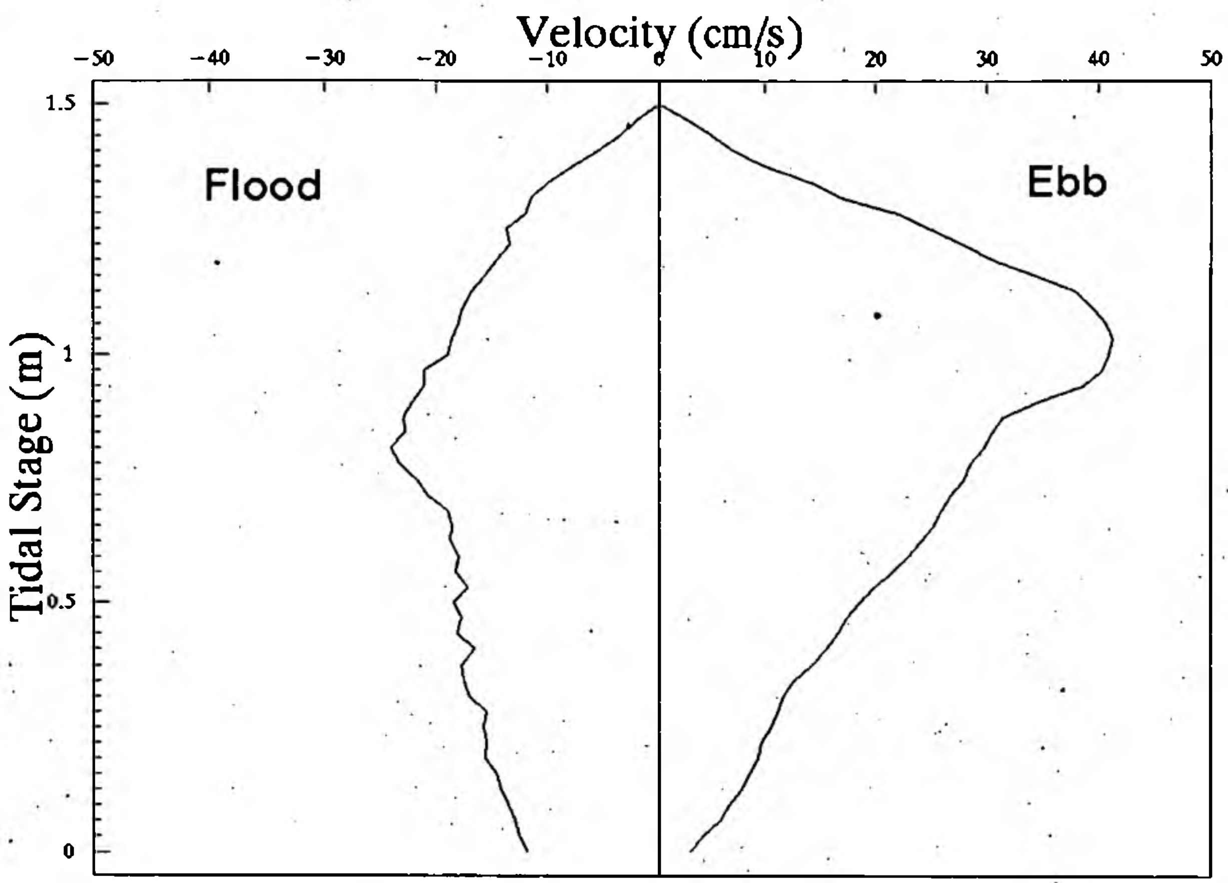


Figure 3.1.3(d) -
Typical velocity stage curve for Hamford Water.

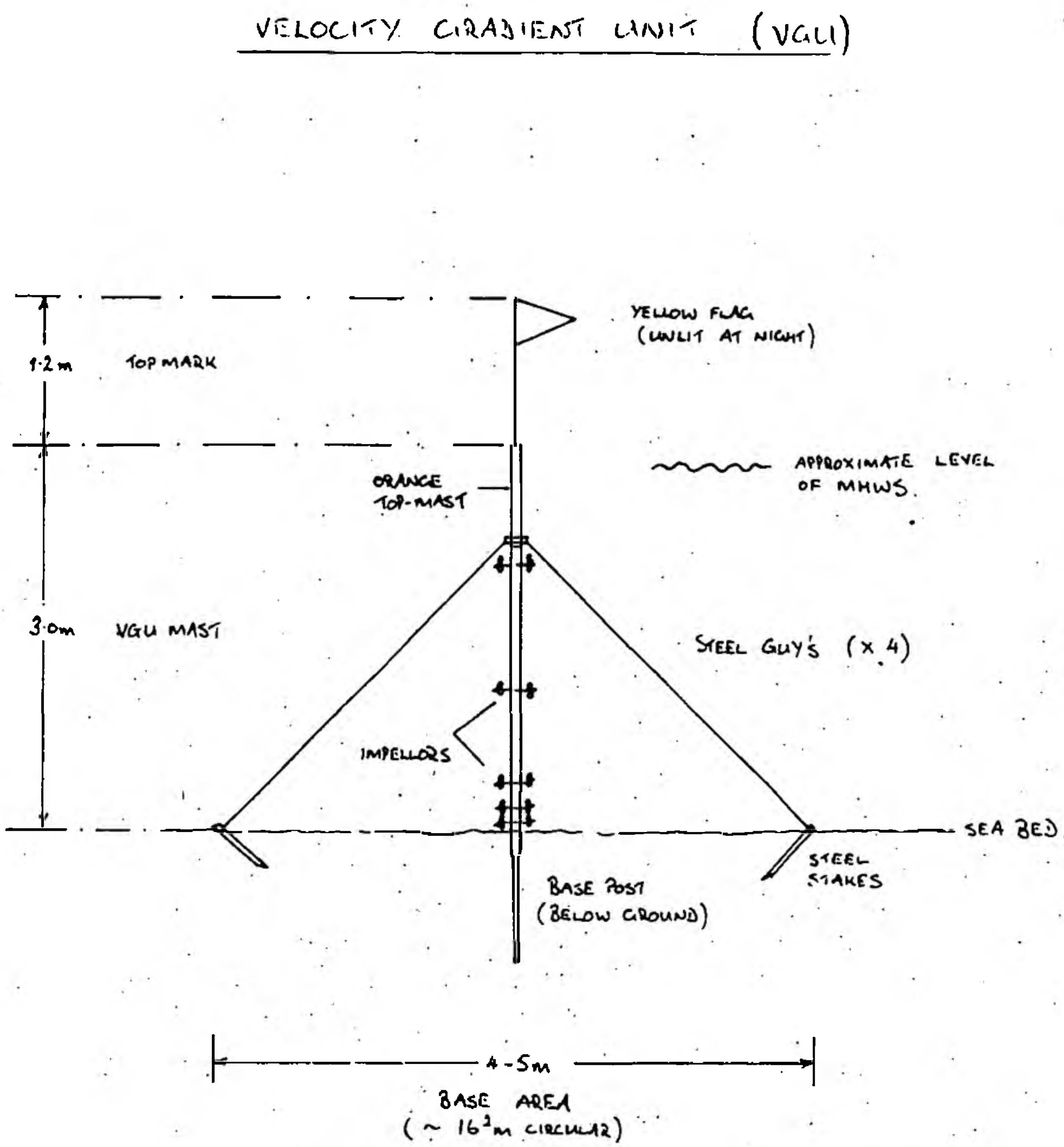


Figure 3.1.3(e) -
Velocity Gradient Unit.

3.1.4 Waves

Although the Backwaters is a relatively sheltered embayment, the effect of wave action, especially from the east, can be considerable. The effectiveness of waves depends on wind strength and directional variability, fetch, and on the frequency distribution of water stages (Allen and Pye, 1992). The wave conditions at the entrance to the Backwaters have received much attention recently, firstly by United Kingdom Atomic Energy Authority (UKEA, 1984) in conjunction with a small scale tidal energy preliminary study, and more recently concerning dredging of the entrance to Harwich Haven and options for disposal of dredged material (HR Wallingford, 1990, 1992; Posford Duvivier, 1993; WS Atkins, 1993).

UKEA (1984) calculated significant wave heights (H_s) either side of a proposed tidal barrage spanning the mouth of the Backwaters from Stone Point to the northern entrance of Bridedock Creek. On the seaward side UKEA give H_s as 3m and on the basin side, 1.5m. However, the typical event for which H_s was calculated was not stated.

More recently, and in more detail, HR Wallingford (1990) calculated typical wave conditions on the north shore of Horsey Island using a 70% wind speed for 1/1 and 1/50 year return periods. Maximum H_s were calculated at approximately 0.9m for the typical event, and about 2.3m and 3.3m for the longest north easterly and easterly fetches across the North Sea. Waves calculated were derived by hindcasting offshore conditions.
Posford Duvivier's (1993) environmental statement for Harwich Harbour discusses HR's (1992) wave modelling, which does not include the interior of the Backwaters, and argues that dredging at Harwich will not affect local waves within the Backwaters. It is assumed that the proximity of the seabed will have no significant influence on wave propagation if the depth of water is greater than half the wave length (d/1>0.5). Given that the maximum local fetch length across the Backwaters is 7.7km, an

average wind speed of 27 knots would give rise to a wave height, H_s = 0.6m and wave period of 3.1s. Such a wave would have a wavelength in deep water of 15m. Both the existing and the proposed channels have depths greater than half this value and the effects on local waves can be taken as negligible. Of more concern for the entrance to the Backwaters is the effect of longer waves originating in the North Sea (Posford Duvivier, 1993).

WS Atkins Ltd. (1993) used a near-shore spectral wave model which simulates the propagation, growth and decay of short period and short crested waves in nearshore waters. Boundary conditions were extracted from HR (1992) and output from the module is in the form of maps of significant wave height (H_s) and mean period (T). Although the modelling was completed for sediment transport work, the results illustrate a significant difference between 1/1 year events form; (a) the east and, (b) the south.

Further within the Backwaters, discussions with IOS (Draper *pers comm*), in areas such as the Wade, with short fetches (approximately 2km) and wind speeds of 30 m/s, yield a significant wave height of 0.7m, or 0.5m for winds speeds of 20 m/s. Individual wave crest to trough will reach about 1.9 times the significant height. Such waves within the Backwaters can cause considerable undercutting and collapse of saltmarsh cliffs and destroy the integrity of saltmarsh vegetation. This is clearly evident on the south side of the Wade and the north side of Horsey Island, although the latter is now partially protected by a wavebreak. The effects of wave action can be reflected in the sedimentation of saltmarshes and mudflats and down-core studies can contribute to the record of climatic variability of the Holocene (Allen and Pye, 1992).
Given the results of the work on wave climate completed to date, it is considered that no further wave modelling is required but the significance of local waves within the Backwaters should be studied with respect to their effect on the morphology of the saltmarsh and tidal creeks and flats.

3.1.5 Salt Marsh Sedimentation Rates

In considering sedimentation rates within The Walton Backwaters, the saltmarsh and fronting mudflats are taken as being an integral part of the intertidal profile. Pethick (1992) argues that low-energy coasts possess the same relationship with the forces of waves and tides as do high-energy coasts such as beaches. Beaches, as well as mudflats and marshes act as a buffer to wave energy inputs in such a manner as to resist long-term morphological change. However, the response to wave and tidal energy, of cohesionless and cohesive sediments, characteristic of beaches and marshes respectively, is fundamentally different.

Pethick (1992) considers the relationship between saltmarsh and mudflat as being similar, in some respects, to that between sand dune and beach and also between river flood plain and river channel. In the first analogy the sand dune acts as a long-term sediment store: sediment released by high-magnitude, low-frequency events is incorporated in the short-term morphological response of the beach to the imposed energy. The dunes also act as a high-energy wave buffer, dissipating energy during high-energy storm events. In the second analogy the flood plain acts as an energy buffer during flood events and also as a sediment store which may be released if major morphological response to rare events is demanded. In the same way, saltmarshes act as an energy buffer during storms and are able to release sediment during low-magnitude, high frequency events to assist in short-term morphological response of the profile to storms.

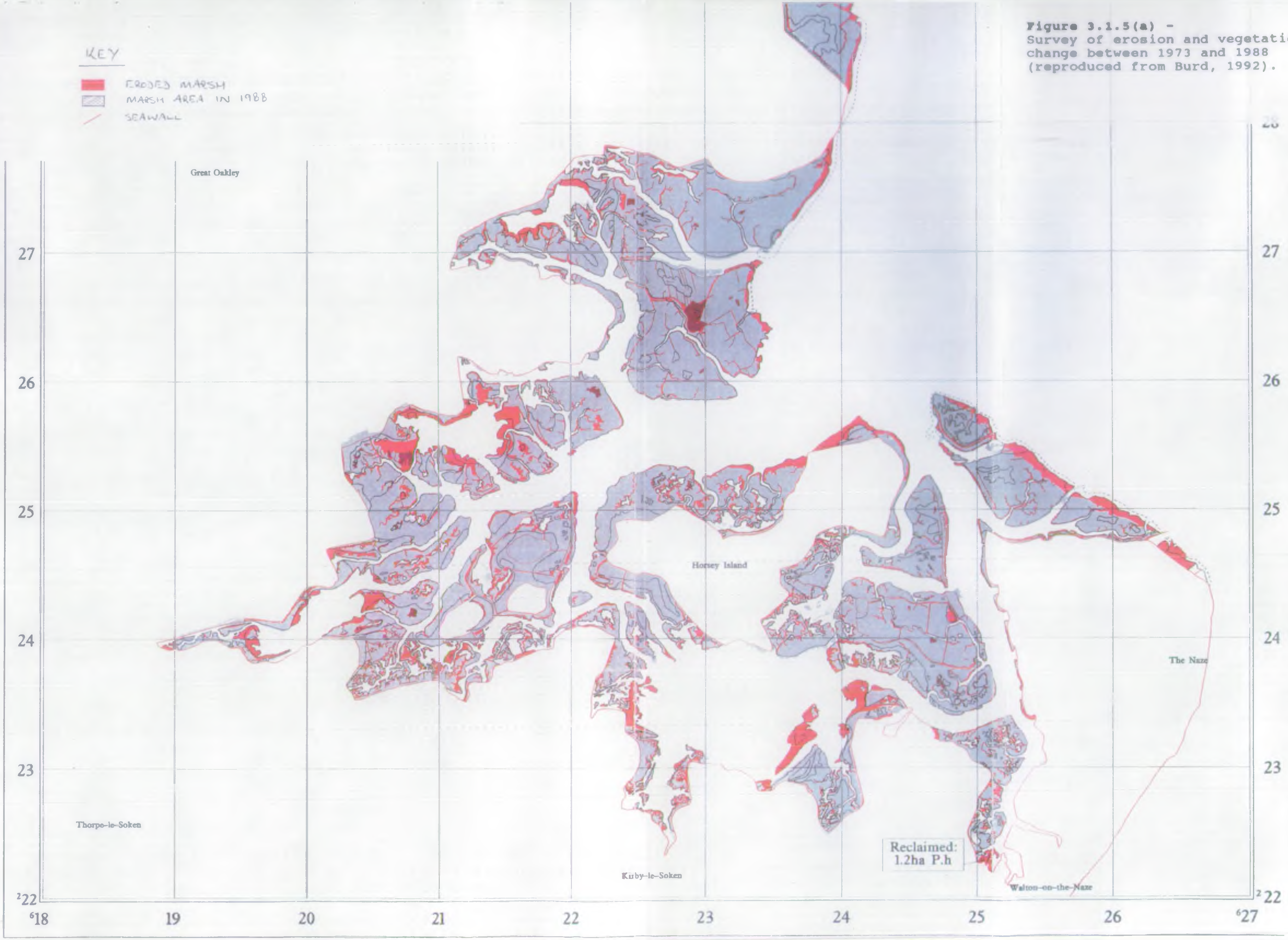
The measurement of surface morphology of saltmarshes and mudflats can provide an indication of the manner in which the intertidal profile responds to rare events as well as recording the rate of accretion or erosion. In the Walton Backwaters, evidence from bathymetric surveys (Admiralty, 1983) and vegetational surveys (Burd, 1992) indicate two distinctive, although not necessarily related, changes in the morphology of the intertidal profile:

firstly the tidal channels appear to be silting-up; and secondly, the area of saltmarsh appears to be decreasing. As discussed in section 2.3.1, a comparison of two accurate hydrographic surveys over 136 years (Admiralty, 1983) showed a general decrease in channel depths, although changes in mudflat elevation were not recorded in the first survey so no comparison of mudflat elevation could be made. Local knowledge, although not reliable but very often a good indication of long-term trends, confirms a general silting-up of the channels: for example, minor creeks with beds of gravel can no longer be walked at low tide. This factor, however, presents an initial impression, and also supports the popular classification of the Backwaters as a sediment sink. Indeed the area must be a sediment sink since the mere presence of saltmarsh vegetation on modern alluvium indicates a tendency for fine-grained sediment to accumulate.

However, Burd's (1992) survey of erosion and vegetation change between 1973 and 1988 recorded a loss of 170 ha, 19% of the original area of 876 ha (Fig. 3.1.5 (a)). Although significant areas of erosion were located on open areas exposed to the strong north-easterly winds, such as on the north side of Horsey Island, and the east side of Pewit Island and also on the open seaward edges, the main areas of loss were located within the estuary itself where dissected areas of low and pioneer marsh suffered internal disintegration. The reason for this apparent breakdown of saltmarsh is not clear although it is suggested that it is a combination of global factors (such as rising sea level) and local factors (such as marine pollution)(NRA, 1993). It does, however, help to explain the silting of the channels and decrease in charted depths: eroding saltmarsh simply releases sediment into the channels. The other significant contributing factor is most probably the asymmetry of the tidal cycle as discussed in section 3.1.4.

It is therefore, the intention of this survey to establish the rate of vertical change, if any, of the extensive areas of intertidal mudflat which is, as yet, unknown. To this end a

Figure 3.1.5(a) - Survey of erosion and vegetation change between 1973 and 1988 (reproduced from Burd, 1992).



series of monitoring points have been established in the vicinity of Kirby Creek and Kirby Quay (Fig. 3.1.5 (b)). (This area was chosen for its ease of access, a problem encountered throughout the Backwaters). A series of nine transects were established projecting from the seawall, out towards the edge of the saltmarsh. The setting-up procedure involved establishing a temporary bench mark (TBM) just below the seawall and levelled back to a known Ordnance Datum bench mark where possible. A second TBM was established at the seaward limit of the saltmarsh and using the level for sighting, a series of markers were positioned between the two TBMs. The markers consist of 10x10cm plates buried in the saltmarsh at a depth of approximately 10cm, and 5mm diameter metal stakes driven into the bottoms of creeks where they occur along the transect. After an initial settling period of a month, monitoring at monthly intervals was commenced. So far only three successive readings, including the initial reading, have been taken and no significant trends are noticeable (Figs.3.1.5 (c) 1 - 9). Leeks (1975) obtained some idea of the rate of sedimentation by measuring vertical accretion of the marshes to the north of Hamford Water. He covered 20 sample points on the saltmarsh surface with thin layers of sand about 1m² and measured accretion over 9 months (April to December 1974) and calculated a mean rate of accretion of 1.4 mm/year, a figure less than the published mean rate of sea level rise for nearby Felixstowe (1.7mm/yr). However, no attempt was made to assess any seasonal variability.

The rates of accretion and/or erosion of both tidal flats and saltmarshes has been studied by numerous authors for over a century although most work has concentrated on salt marshes. The majority of methods used to study salt marsh sedimentation look mainly at accretion and are rarely designed to measure erosion. This is simply because there has generally been no need to look at erosion on saltmarsh because they have been considered areas of deposition. Indeed this is generally the case where a salt-marsh is not affected by man-made structures such as coast defence works. Recently, increasing concern over the rate of

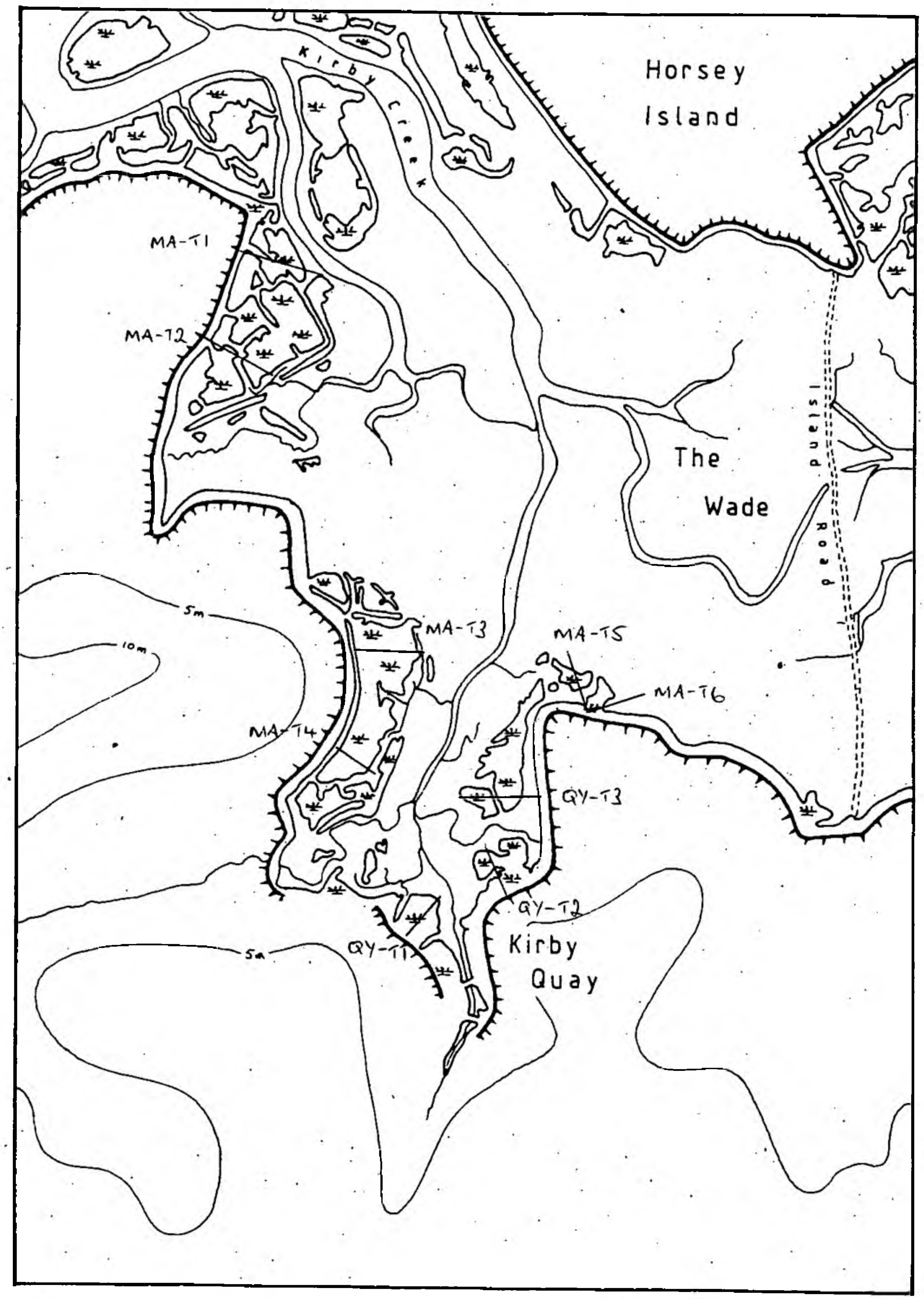


Figure 3.1.5(b) -
Location of monitoring transects
- Kirby Creek.

loss of saltmarshes has prompted a closer look at erosion rather than accretion and several studies have looked at seasonal changes in tidal flat elevation. Frostick and McCave (1979) measured the level of mud flats in the nearby Deben estuary and showed accretion rates of approximately 5 cm between April and September during algal growth, and erosion of a similar amount during the autumn and winter when algae are dead or absent. Other reports of seasonal variations include: Kestner (1961); Anderson *et al.* (1981) and Bale *et al.* (1985). More recently Kirby *et al.* (1993) studied tidal mud flat stability in Ardmillan Bay, Strangford Lough, Northern Ireland over a 22 month period. The observations point to a seasonal waxing and waning of tidal flat elevations and to the controlling influence of wind. Real sediment level changes were detected on several time-scales. Some changes were unsteady, but still following a generally unidirectional trend. On a second time scale a repeating, yearly, seasonal cycle was detected: winter/spring erosion was frequently matched by summer accretion. Gale-generated waves caused the erosion and, in summer, deposition was enhanced by algal binding. Kirby *et al.* (1993) concluded that episodic wind waves are the main cause of tidal flat instability and that large quantities of sediment are redistributed by these forces.

It is hoped that the results of monitoring the transects established in the Backwaters over the next two years will show whether seasonal variations are applicable to the apparent loss of saltmarsh. The problems of monitoring and maintaining such transects are considerable. So far only the saltmarsh and the edge of the mudflats are being monitored simply because the mudflats of the Walton Backwaters are too soft to walk on and even if markers were positioned, monitoring would destroy the surface being measured.

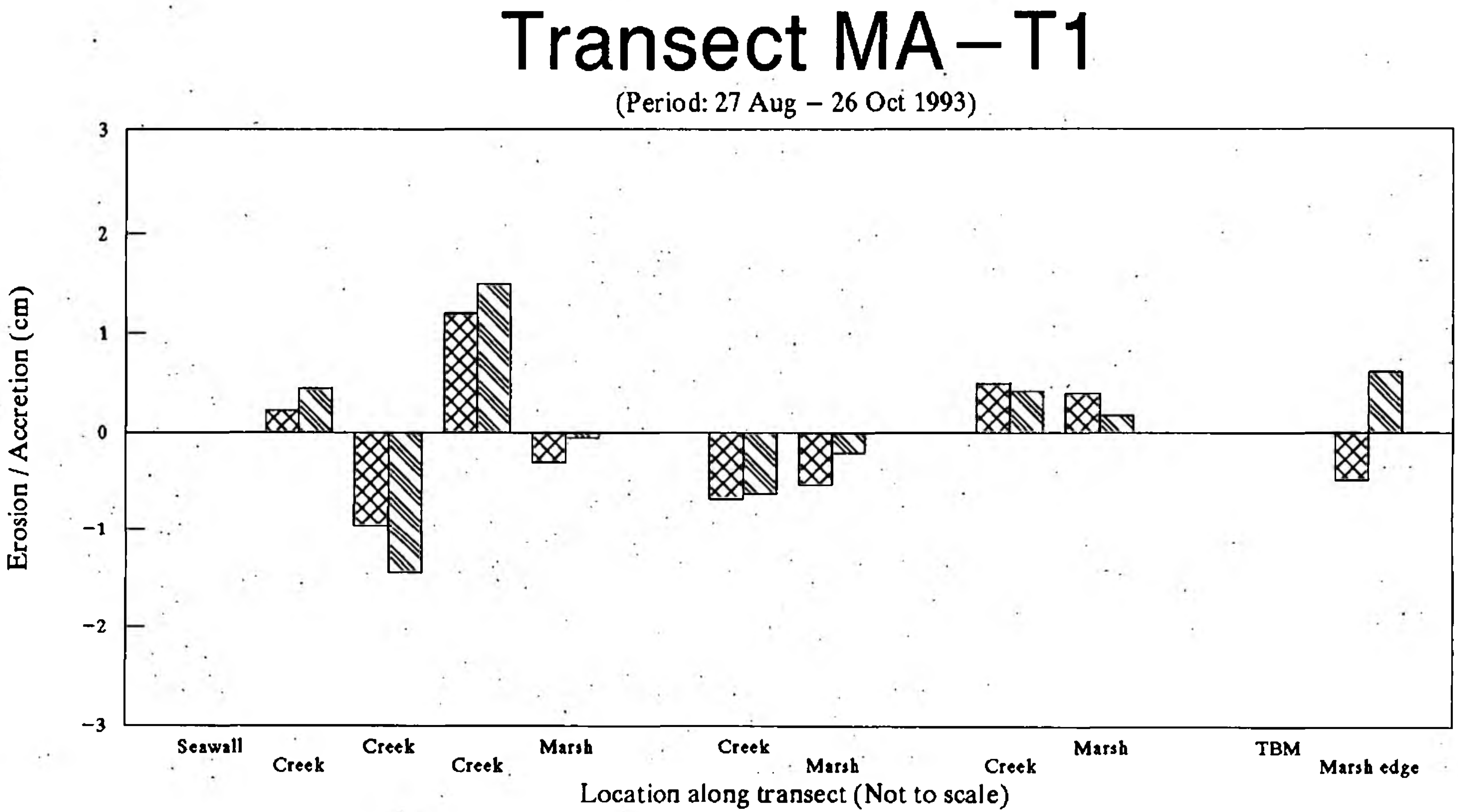


Figure 3.1.5(c)/1 – Transect MA_T1 – Accretion/erosion after 3 months.

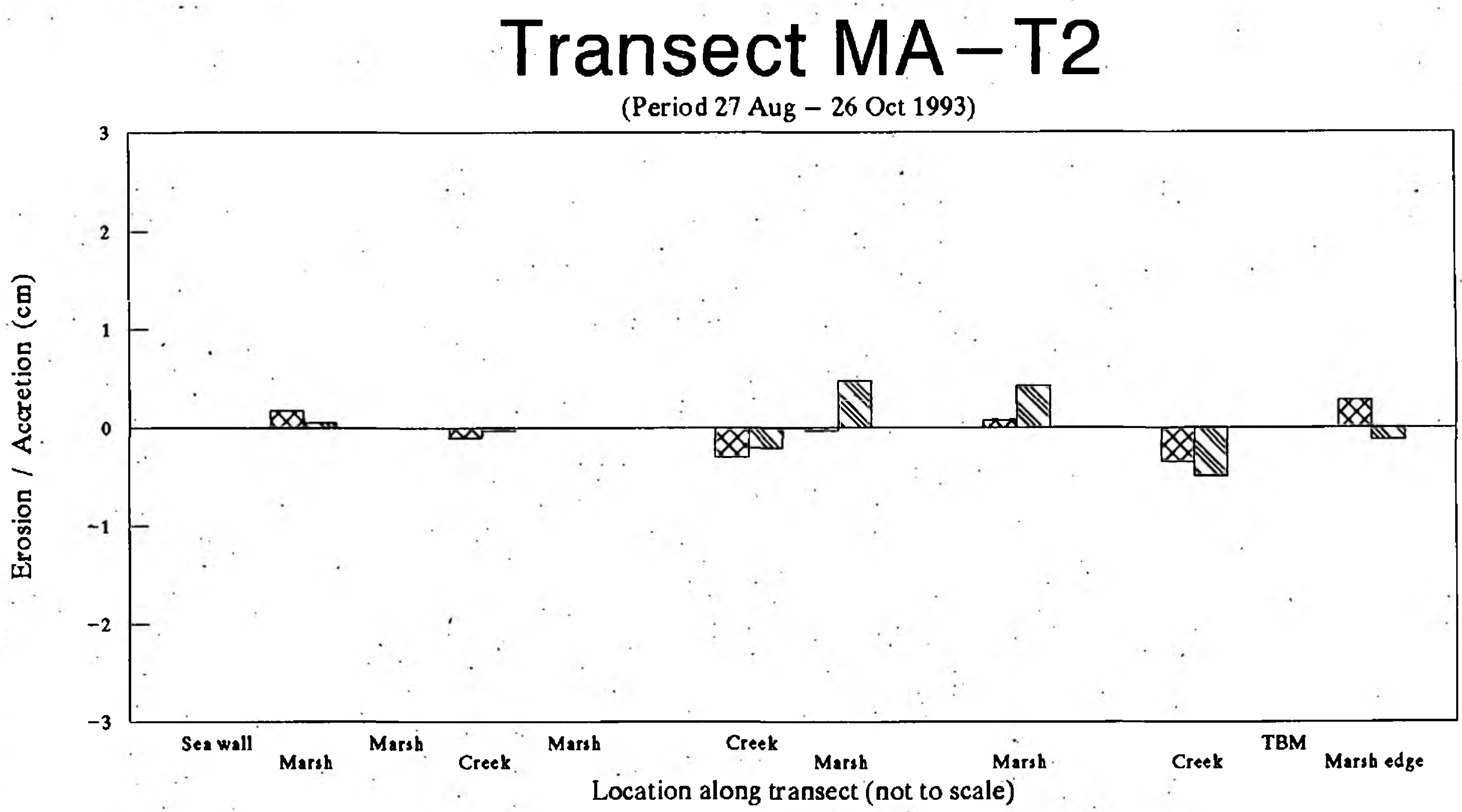


Figure 3.1.5(c)/2 – Transect MA_T2 – Accretion/erosion after 3 months.

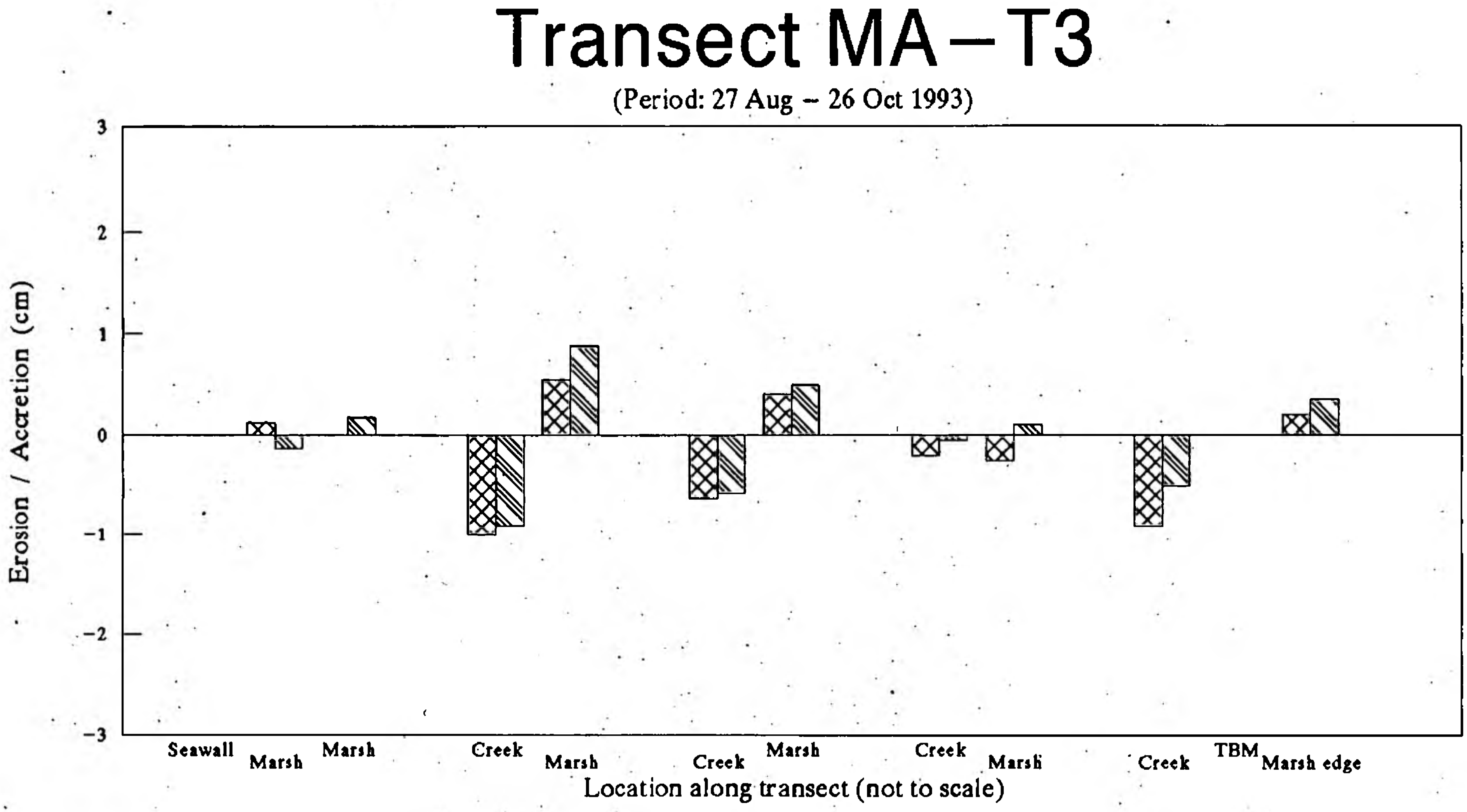


Figure 3.1.5(c)/3 – Transect MA_T3 – Accretion/erosion after 3 months.

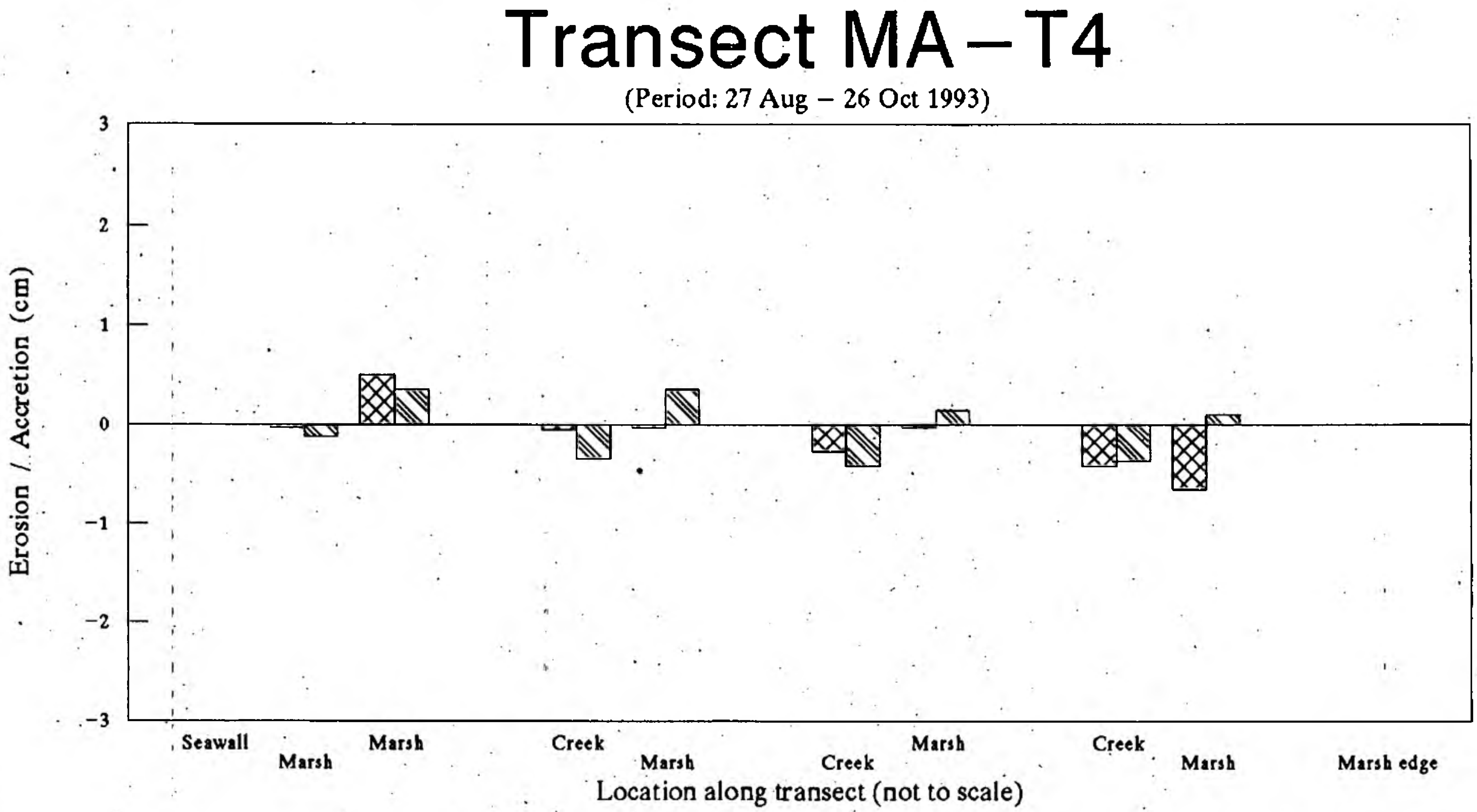


Figure 3.1.5(c)/4 – Transect MA_T4 – Accretion/erosion after 3 months.

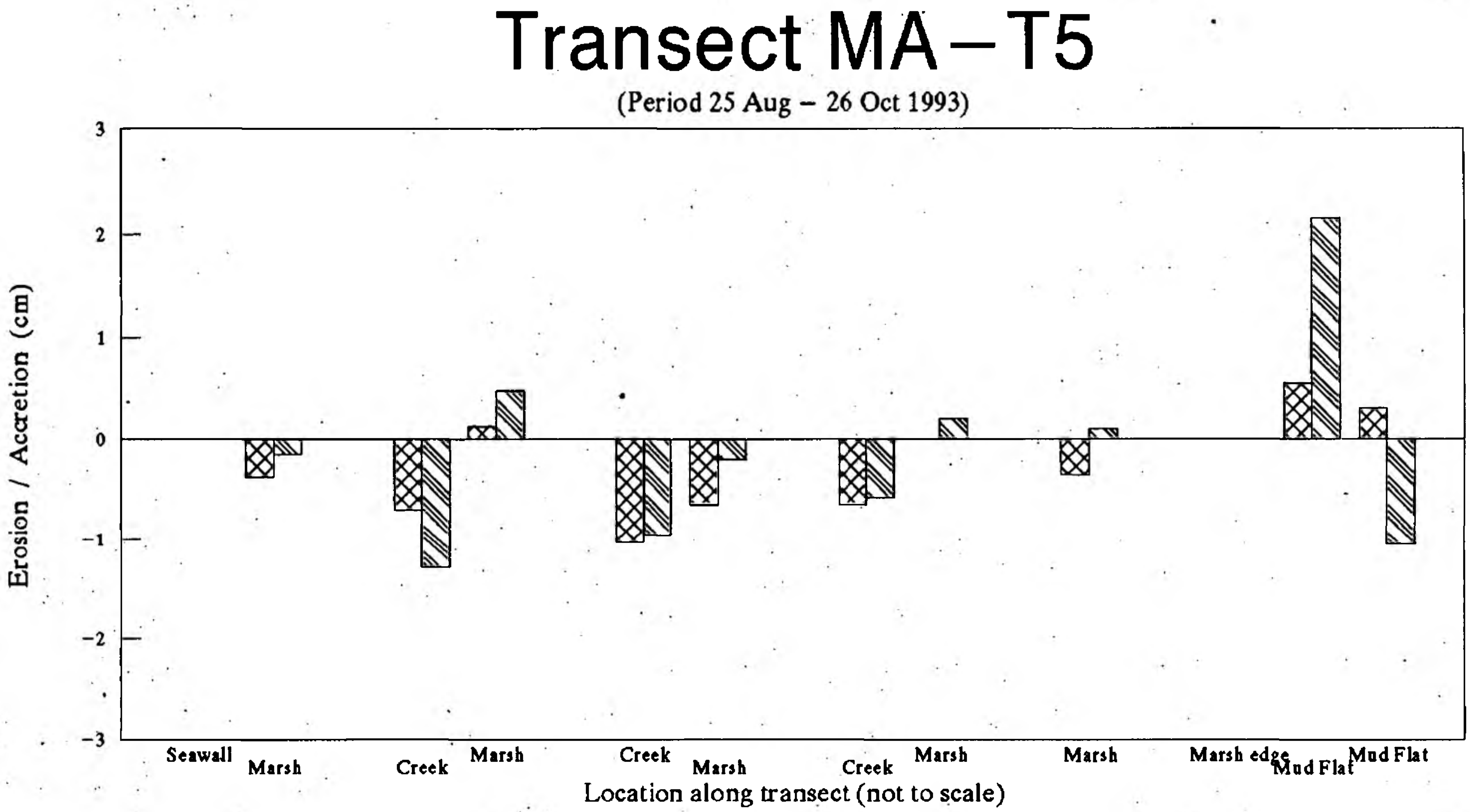


Figure 3.1.5(c)/5 – Transect MA_T5 – Accretion/erosion after 3 months.

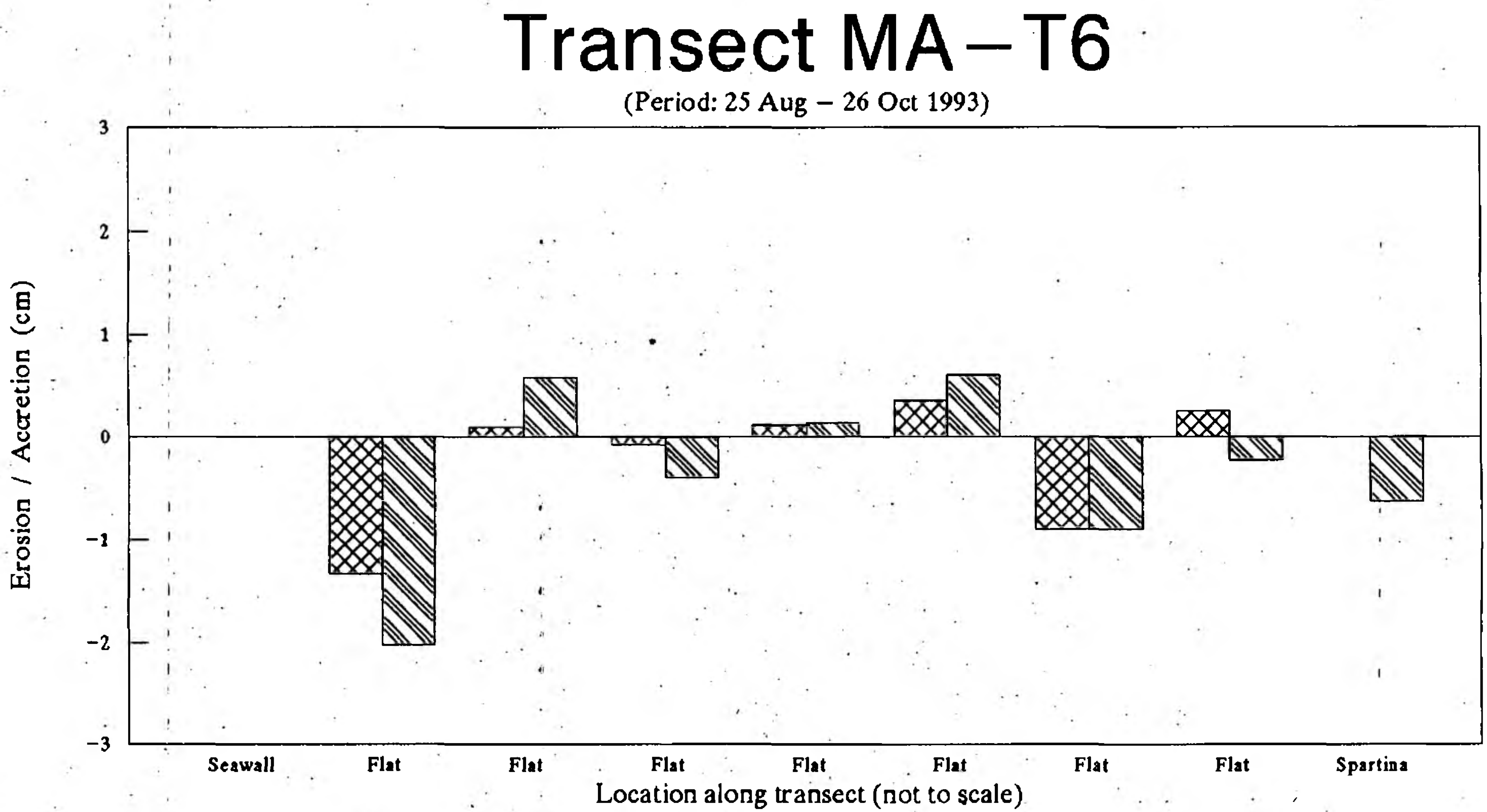


Figure 3.1.5(c)/6 – Transect MA_T6 – Accretion/erosion after 3 months.

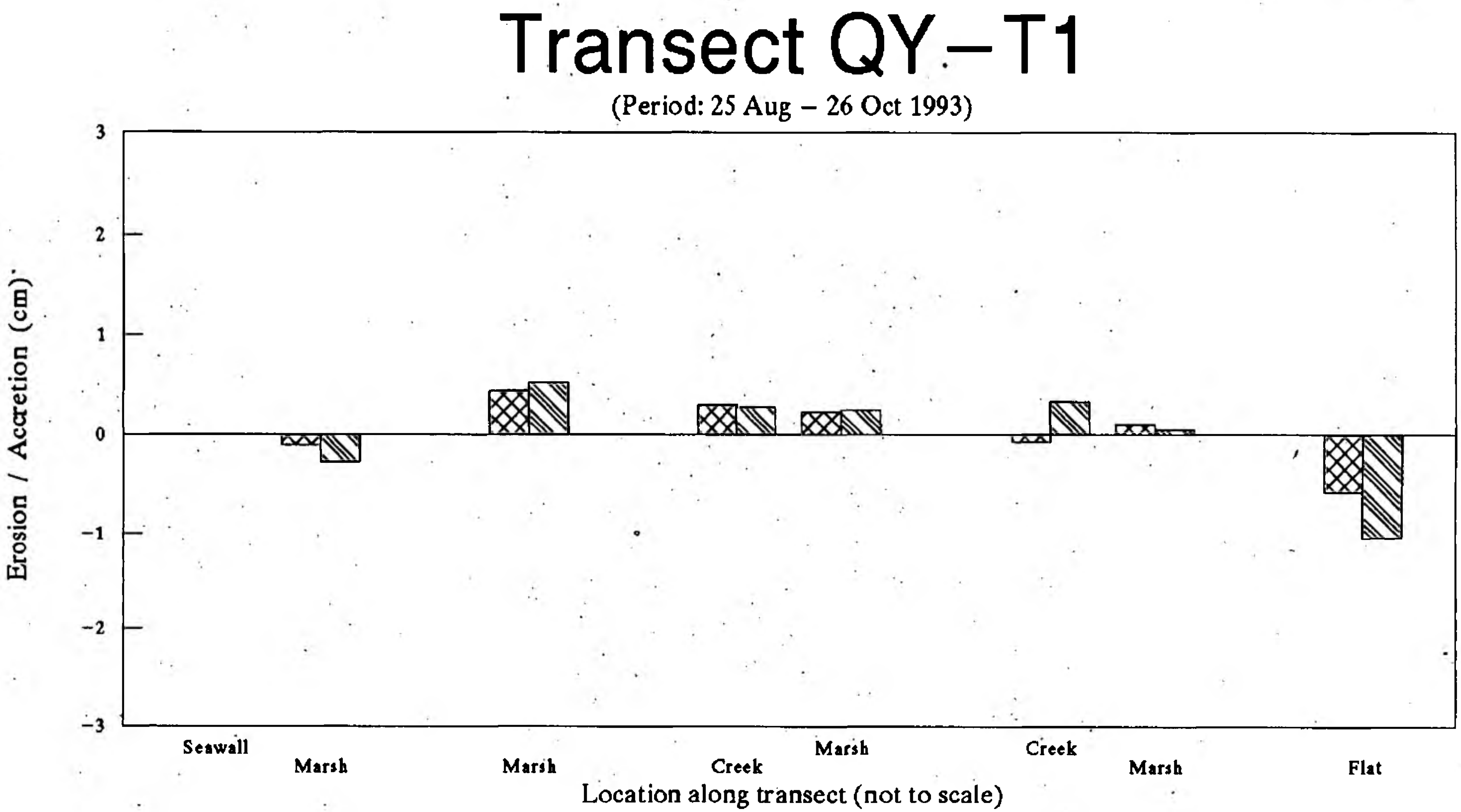


Figure 3.1.5(c)/7 – Transect QY_T1 – Accretion/erosion after 3 months.

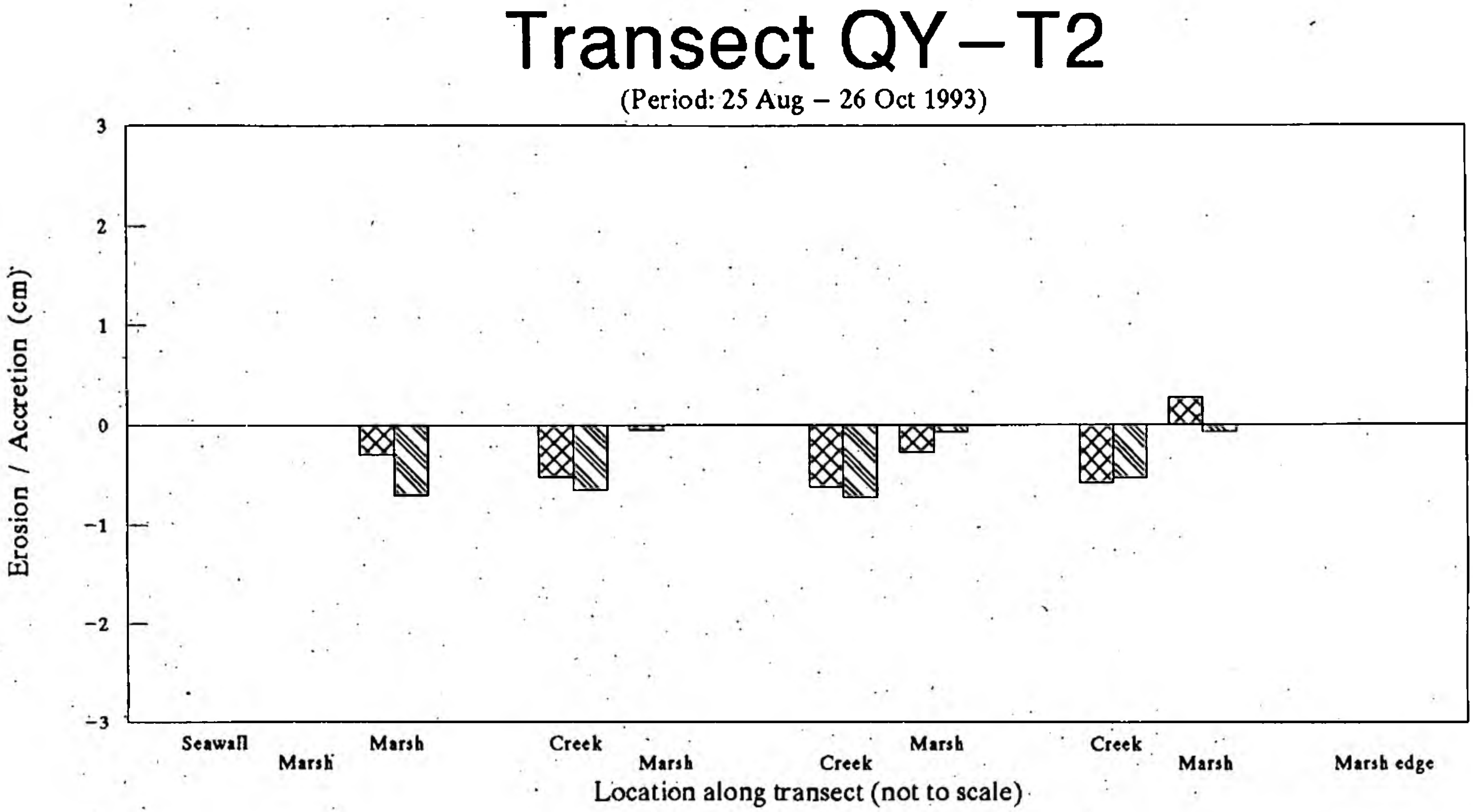


Figure 3.1.5(c)/8 – Transect QY_T2 – Accretion/erosion after 3 months.

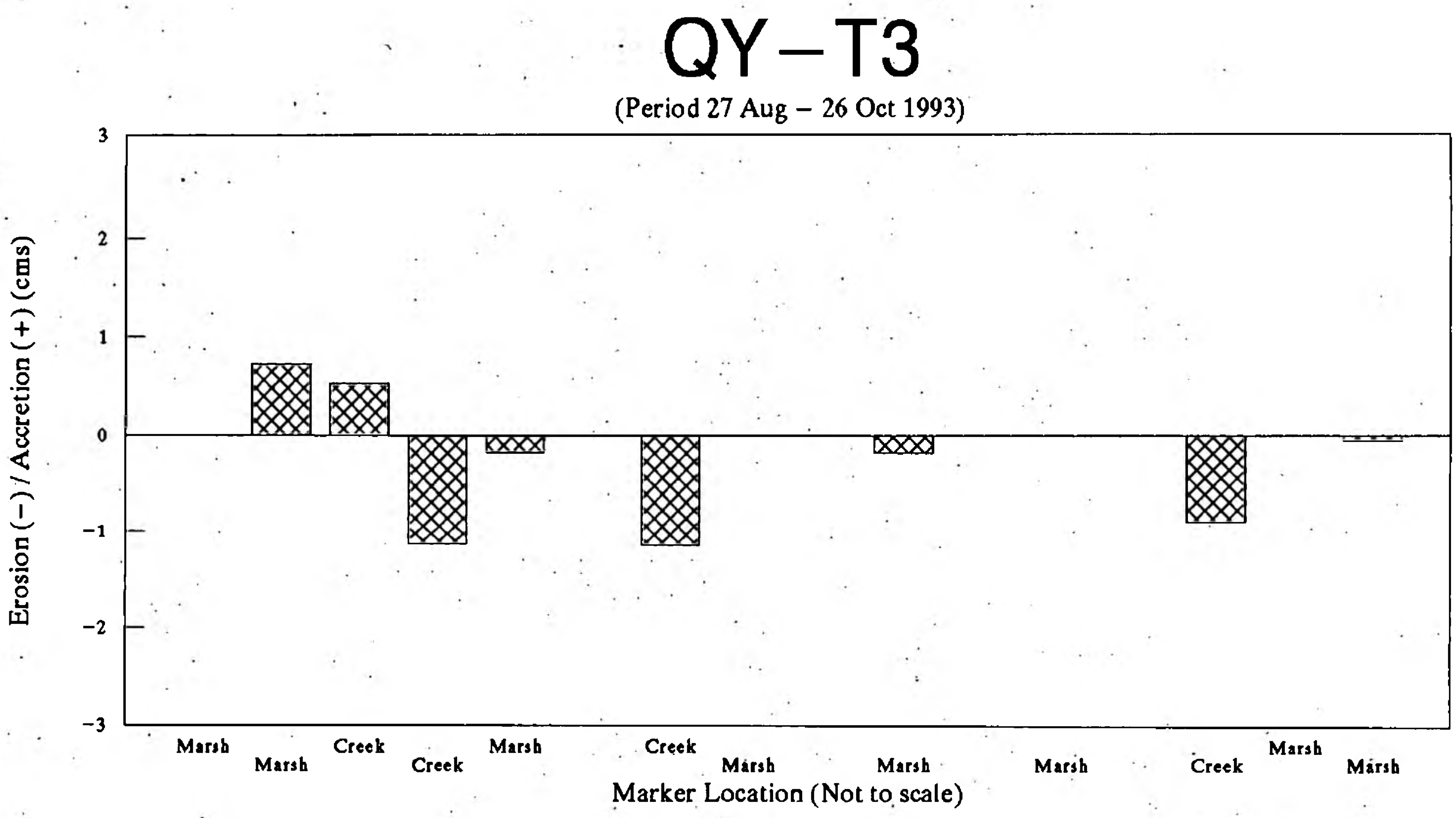


Figure 3.1.5(c)/9 – Transect QY_T3 – Accretion/erosion after 3 months.

4. Conclusion

The most significant result from work so far is the apparent distinctive tidal asymmetry. A fundamental question needs to be answered before any explanation of events can be made: is the asymmetry as observed in Walton Channel and the north shore of Hamford Water typical of the whole system? The overall direction of transport for the system needs to be confirmed. It is clear that deposition of fine grained sediment is a dominant feature of the Backwaters: initial exploratory coring shows 3 to 4 metres of Holocene alluvium on top of the predominantly London Clay basement. A very rough estimate of the rate of sediment accretion based on the amount of sediment above a 'Red Hill'[3] suggests a rate of ≈2mm $year^{-1}$. However, recent (last 150 years) historical evidence presents a contradictory picture. Historical map, chart and photographic evidence, together with local knowledge points to a widening of the mouth, a reduction of main channel depths and a general erosion and breakdown of saltmarsh throughout the area. ICES (1993) point to a periodic sediment transport system to explain short term (50 year) changes to Pye Sand but points out that this does not explain long term deterioration of the saltmarsh in the Backwaters. It is probable that such losses are a result of a combination of events: rising sea level and subsequent 'squeeze' of saltmarsh and sea defences, the effects of marine pollution, and an altered sediment transport regime. This investigation aims to determine the significance of the latter.

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[3] 'Red Hills' are mounds of reddish-brown earth left-over from salt making dating from Romano-British times. The significance of Red Hills is that it is generally understood that most pre-date the surrounding alluvium and that they were constructed on the old dry land surface before encroachment of the sea (Fawn *et al.*, 1990).

5. Future Work

The proposed course of study for the next two years includes the following:

5.1 Sediment Transport:

Extend the coverage of the Velocity Gradient Unit.
Record suspended sediment concentrations.
Complete grain-size analysis.

5.2 Saltmarsh/mudflat sedimentation:

On-going monitoring of existing transects.
Establish additional transects to encompass the whole site.
Develop a more efficient and quicker method of monitoring.

5.3 Holocene Evolution:

Commence coring programme to provide cores and core sub-samples for lithological and mineralogical/ geochemical analysis. The aim is to establish the main sediment sources in the system, and to identify any significant changes in the recent geological past.

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