Research on Sedimentation in Estuaries

SEDIMENTATION IN THE NAHOON ESTUARY

ROSIE REPORT No 10

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ABSTRACT

The Nahoon Estuary lies in the eastern Cape between East London and Beacon Bay. The Nahoon river has a catchment area of 580 km^2 in which shale-rich sedimentary rocks predominate. The estuary has a tidal reach of 4,8 km. A shallow, permanent inlet connects the estuary with the sea. Microtidal conditions prevail in the estuary.

Little fluvial sand is present in the estuary, but all clastic mud is of fluvial origin. Marine sand consisting of quartz and skeletal carbonate extends about 1 km upstream from the inlet. Bedrock crops out at various localities along the banks. Pebble lag deposits line some parts of the channel bottom. Mud often accumulates in association with aquatic vegetation, notably Zostera.

The Nahoon estuary is scenically pleasing and a popular recreation area. As a result the adjacent land has been intensively developed for residential purposes.

Although the sedimentary ecology of the Nahoon Estuary is reasonably sound, concern has been expressed about extensive influx of marine sediment into the lower estuary. This observation is probably well-founded as tidal deltas at present extend nearly 1 km up-estuary.

Five bridges traverse the estuary within a 1,5 km stretch but appear to have little adverse effect on the normal water movement pattern.

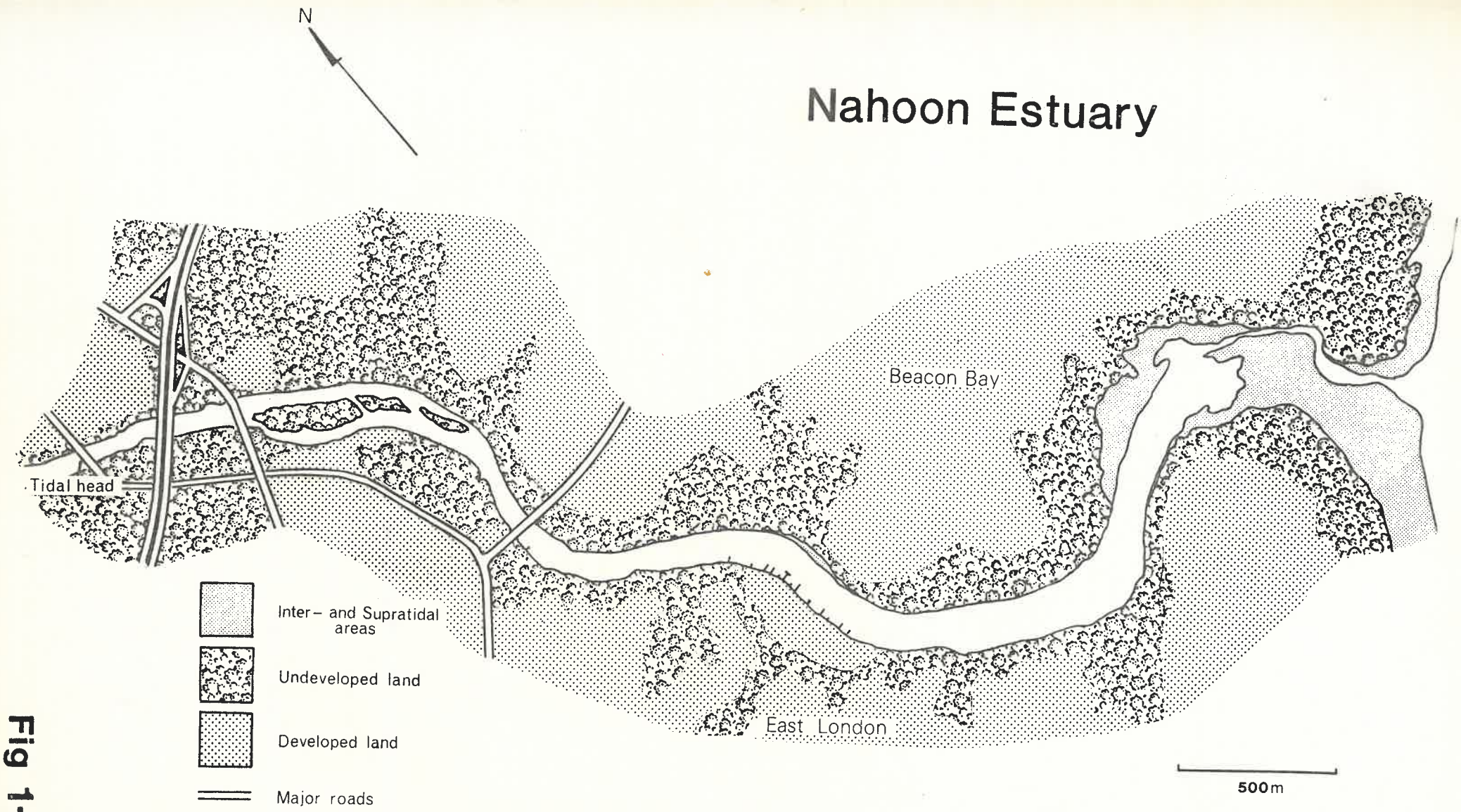

N
Nahoon Estuary
Beacon Bay
Tidal head
East London
Inter- and Supratidal areas
Undeveloped land
Developed land
Major roads
500m

Fig 1-1

SEDIMENTATION IN THE NAHOON ESTUARY

1. INTRODUCTION

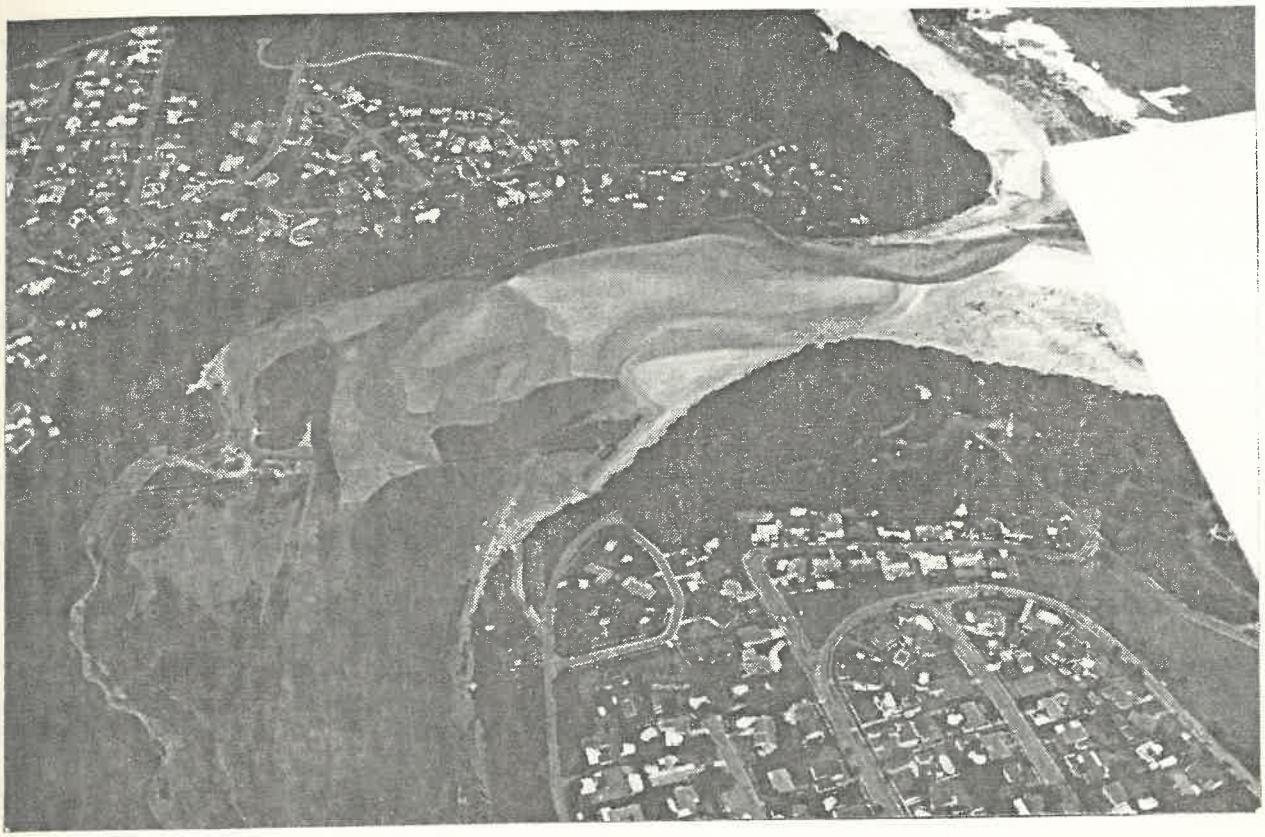
The estuary of the Nahoon River (figs 1-1 & 2-1) lies on the eastern Cape coast between East London and Beacon Bay.

The river has a drainage system (fig 2-2) which extends into the Karoo. A major reservoir on the river, the Nahoon Dam, supplies East London with water.

Residental developments occur adjacent to the estuary (fig 1-1). The estuary, a popular recreational area, is navigable by small craft for a distance of about 4,5 km from the inlet.

The aims of this study are:

1. To determine the character and source of the sediment in the estuary.
2. To establish whether net sedimentation is taking place in the estuary.
3. To establish baseline information for future studies on sedimentation rates in the estuary.
4. To comment on aspects of management for the system.



Lower Nahoon Estuary photographed during low tide (top) and high tide (left) in November 1984

(Photographs WK Illenberger)

Plate 1

2. BACKGROUND INFORMATION

2.1 CATCHMENT AREA

The 90 km long Nahoon River drains part of the eastern Cape (fig 2-1) and has its origin in the Amatole escarpment. The river has a catchment area of 580 km^2 (this study), 626 km^2 (Heydorn and Tinley, 1980) and 590 km^2 (Pitman et al., 1981). The drainage system consists of a dendritic-trellis pattern with a medium stream density (fig 2-2). A major reservoir, the Nahoon Dam, is located on the river and supplies East London with water. The dam is fed by a drainage area of 475 km^2 and has a holding capacity of 5,78 x 10^6 m^3 (Dept. of Water Affairs, 1978).

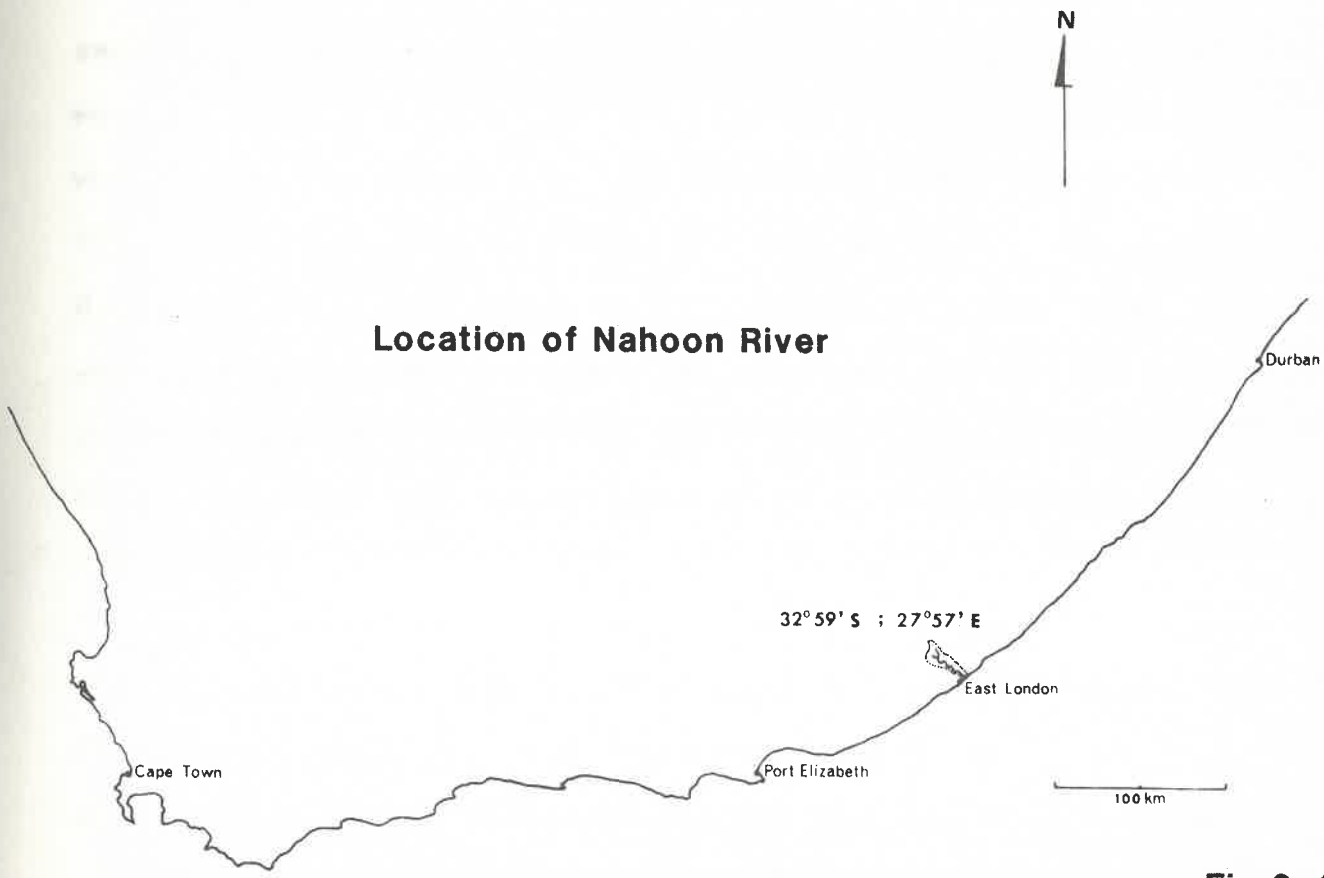


Fig 2-1

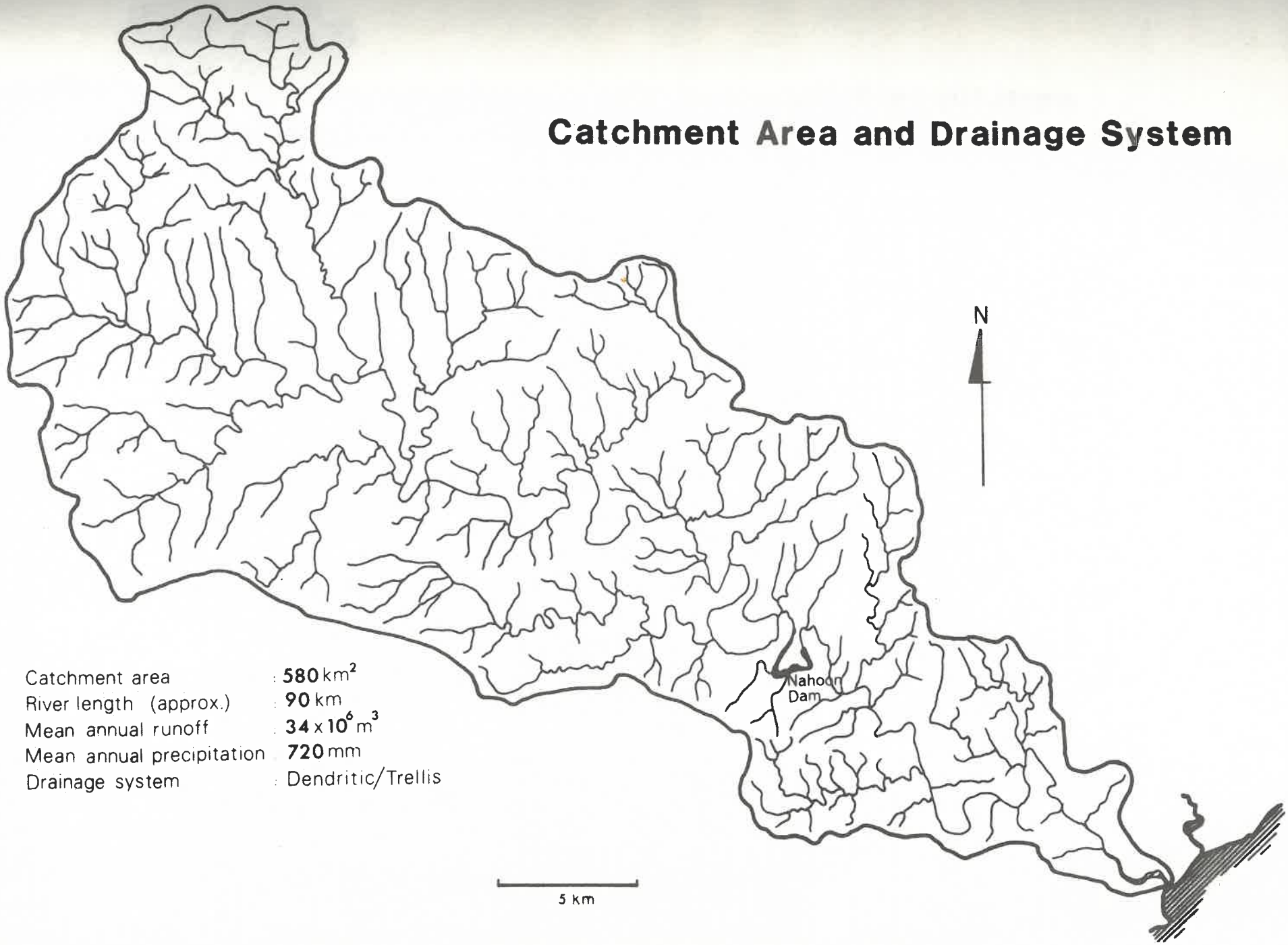
Diverse farming (sheep, cattle and various crops) is the main economic activity in the catchment area. The population density is approximately 30 persons per km^2.

The drainage basin is situated within a temperate to warm and humid region, having a summer rainy season which is at a maximum in autumn (March), and at a minimum in June. Mean annual precipitation for the drainage basin as a whole (fig 2-3), is 719 x 10^6 m^3 per year (Pitman et al.,1981) resulting in a mean annual runoff of 34 x 10^6 m^3 per year (Pitman et al., 1981). Prevailing winds blow with 18% south-west and 5% south-east frequency. Berg winds occur in autumn and winter. Average daily maximum temperatures are around 28 deg C in January and 21 deg C in July, while the average daily minimum are around 17 deg C in January and 8 deg C in July.

The rocks of the catchment area consist of mudstone and immature sandstone belonging to the Beaufort Group (fig 2-4). These rocks weather readily to produce fine-grained clastic material and sand which enter the fluvial system. Sediment yield is approximately 150 t/km^2 per annum (Noble and Hemens, 1978). Karoo dolerite dykes and sills intruded into the Beaufort Group crop out at various localities within the catchment area (fig 2-4). The dolerite weathers to produce clay and heavy minerals. These heavy minerals can constitute up to 2 to 3% of the sediment in the estuary.

Poorly developed parallel structural lineaments, spaced 5 to 10 km apart, occur in the catchment basin and lead to the development of the dendritic-trellis drainage pattern (fig 2-2).

Catchment Area and Drainage System



Catchment area	: **580** km^2
River length (approx.)	: **90** km
Mean annual runoff	: **34** x 10^6 m^3
Mean annual precipitation	: **720** mm
Drainage system	: Dendritic/Trellis

Fig 2-2

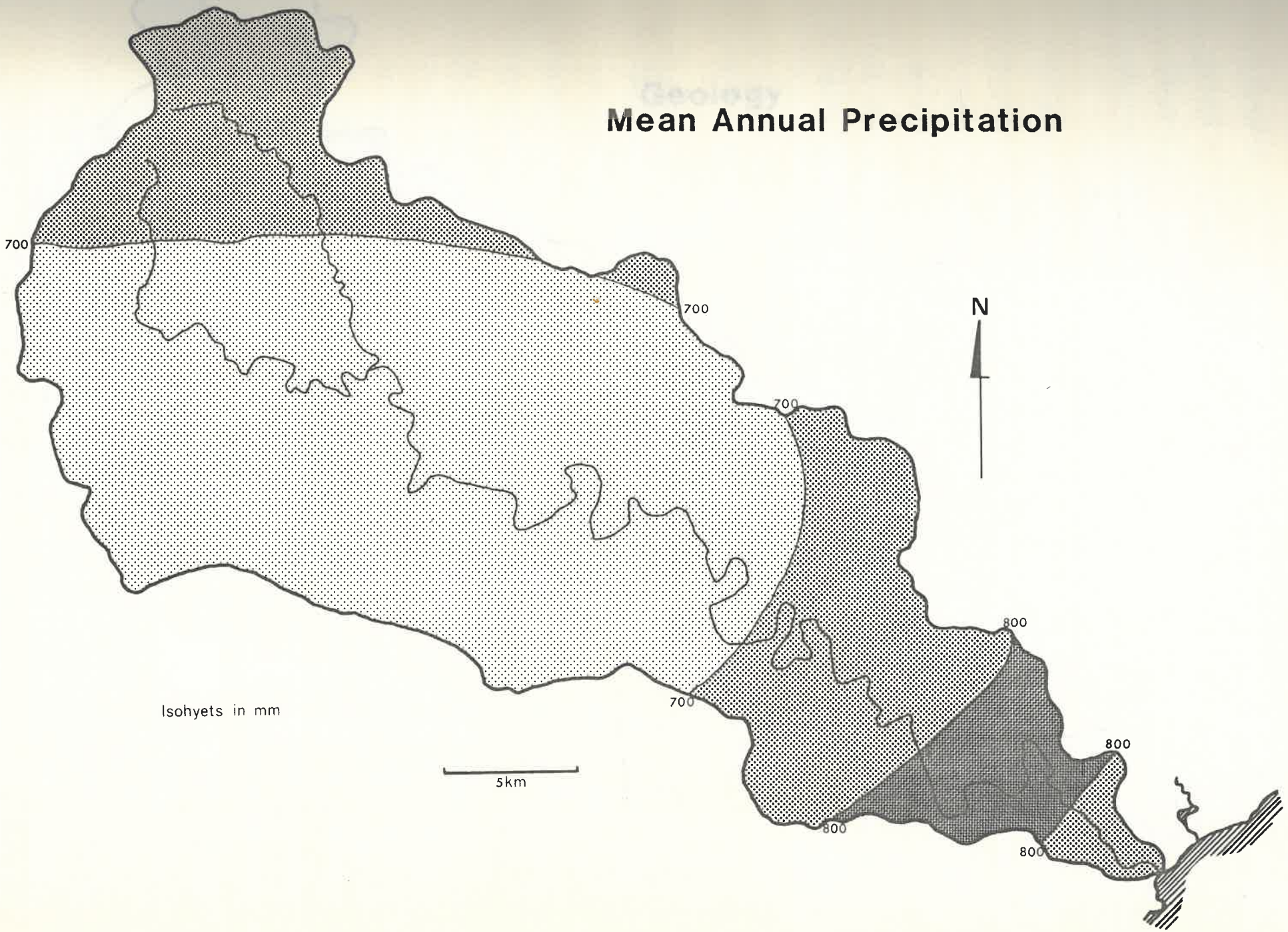

Mean Annual Precipitation
700
700
700
700
800
800
800
800
N
Isohyets in mm
5km

Fig 2-3

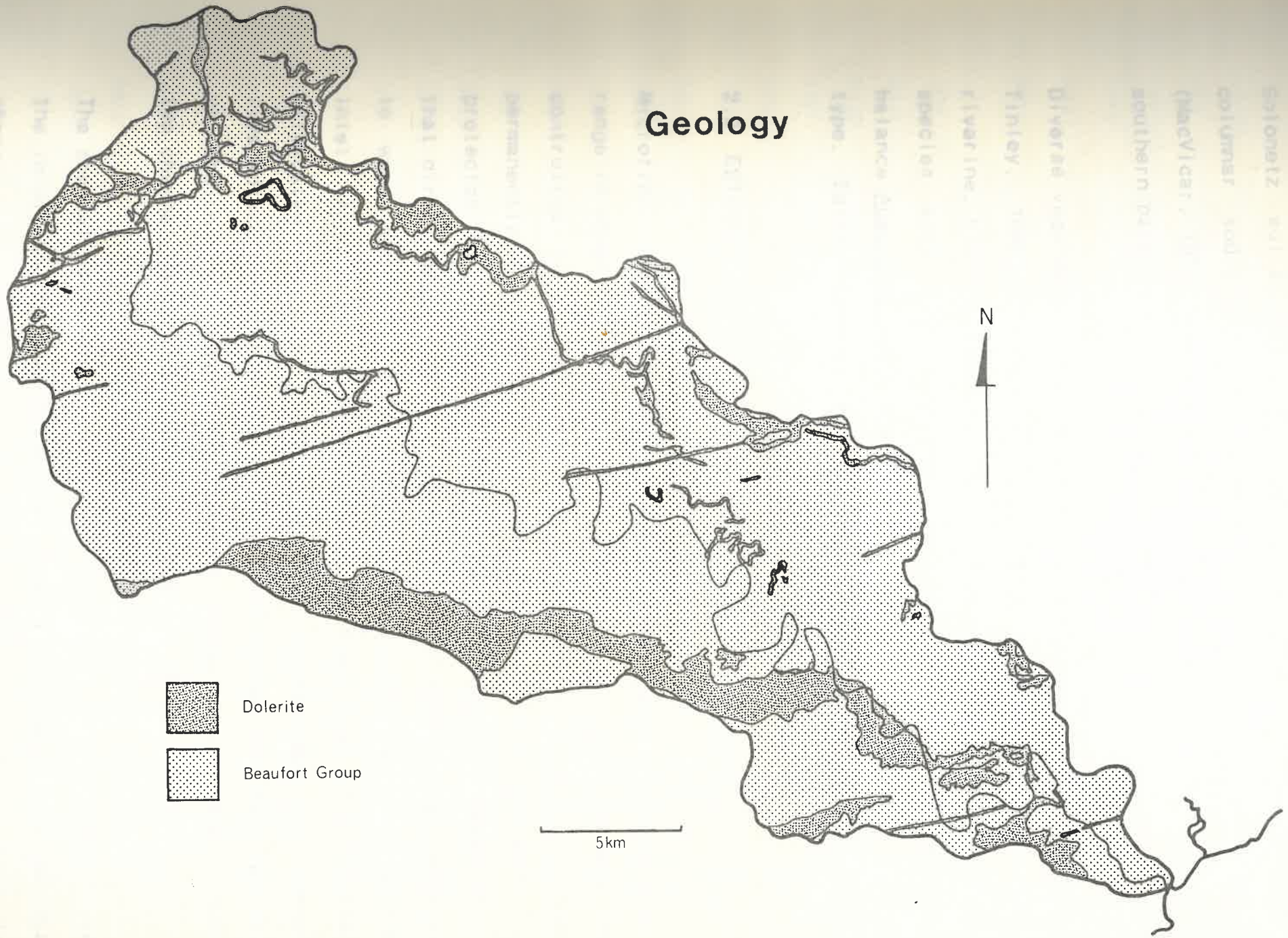


Fig 2-4

Solonetz soils consisting of thin porous topsoils underlain by a columnar sodic horizon, predominate in the catchment basin (MacVicar, 1971). Weakly developed soil occurs on rock in the southern part up to 10 km from the inlet.

Diverse vegetation patterns are found in the basin (Heydorn and Tinley, 1980). Afrotemperate forests are present in coastal, riverine, kloof and montane sites. Thickets of shade-intolerant species also occur in clumps. In areas with high soil moisture balance Acacia karroo (Soetdoring) dominates as savanna tree type. Eastern Cape varieties of grass occur throughout the area.

2.2 ESTUARY (fig 1-1)

Microtidal conditions prevail in the estuary; the spring tidal range is about 1,6 metres. The tidal limit of the estuary is controlled by a weir 4,8 km up-estuary from its shallow, permanently open inlet. The eastern bank of the inlet is protected by sandstone outcrops which restrict inlet movement in that direction (fig 2-5). A sandspit which formed as a response to wave and tidal actions, constitutes the western bank of the inlet. About 300 m up-estuary from the inlet the channel bifurcates into two tidal channels. A flood-dominant channel lies adjacent to the bedrock outcrops on the eastern bank whereas an ebb-dominent channel follows the sandy western bank. These two channels merge again 80 m up-estuary. (Plate 1, top).

The channel has a maximum width of 160 m some 800 m upstream from the inlet, and narrows to 10 m at the tidal head. A maximum channel depth of 7,5 m was measured approximately 1,1 km from the

inlet. The bottom water in this deepest section of the channel was putrid when sampled in 1984; this anoxic zone probably resulted from decaying organic matter in a stagnant saltwater lens. At neap low tide the inlet channel depth is less than 1 m. Small craft are able to navigate the estuary along the lower 4,5 km.

The lower river valley consists of an incised channel cut into bedrock in many places (fig 2-5), and steep cliffs up to 75 m high flank the waterside (fig 2-6). Pebble lag deposits occur on the channel bottom along stretches where high velocity currents operate.

Narrow estuarine mudflats and floodplains have developed as a result of sediment filling. This deposition is associated with valley drowning resulting from rising sea levels during the Flandrian transgression. Two floodplains on the eastern bank and two smaller floodplains on the western bank (fig 2-6) have a total area of about 7,2 x 10^5 m^2 between mean sea level and the 5 m contour. About one fifth of the floodplain area (1,58 x 10^5 m^2) is occupied by residential development.

Intertidal flats covered by Zostera (eel grass) are located on the eastern bank, starting 900 m from the inlet. Mud accumulates in the non-turbulent boundary layers formed as a result of the presence of these macrophytes. Although the recently deposited mud surface is level and soft, the interface with the underlying compacted mud can be irregular. This uneven and scoured surface is most likely a fluvial flood erosion surface which has been subsequently draped by mud. The age of this surface is not known

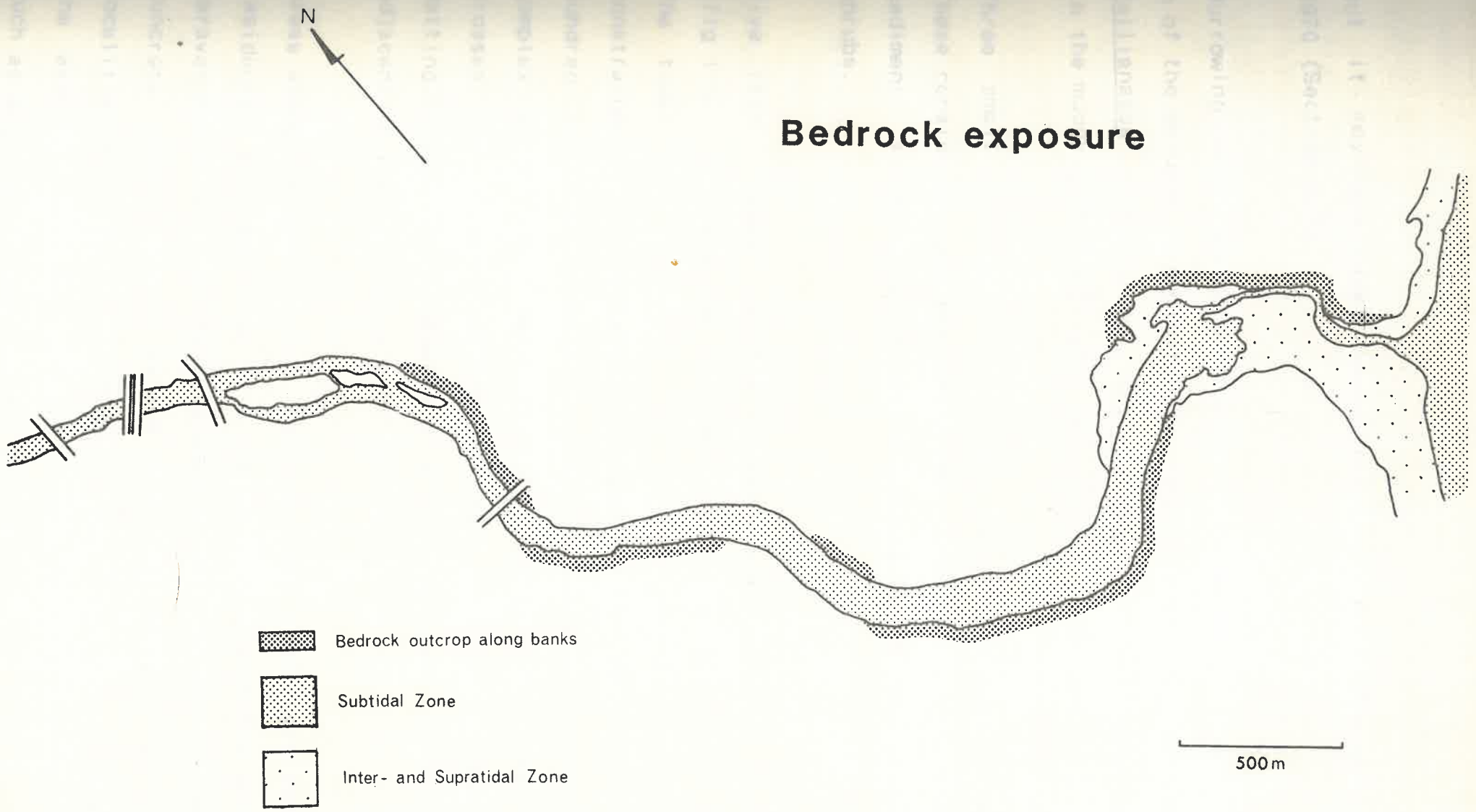

N
Bedrock exposure
Bedrock outcrop along banks
Subtidal Zone
Inter- and Supratidal Zone
500 m

Fig 2-5

but it may have formed during the major fluvial flood of August 1970 (Section 5.3).

Burrowing organisms occur throughout the estuary. The lower 800 m of the estuary is dominated by sandy sediments burrowed by Callianassa (sand prawn), whereas Upogebia (mud prawn) is found in the muddy middle and upper regions of the estuary.

Three small islands are located 3,5 km up-estuary (fig 1-1). These consist of rock and pebble debris covered by fine-grained sediment, all bound by terrestial vegetation, mostly grasses and shrubs.

Five road bridges traverse the estuary within a 1,5 km stretch (fig 1-1). Of these the upper-most De Waal Bridge is the oldest. The tidal head lies at this bridge, the tidal flow being constrained by a concrete weir underneath the bridge. Two hundred and fifty metres down-estuary a double carriage bridge complex carries the N2 national road. A municipal expressway crosses the estuary between the N2 and the lower-most Jack Batting Bridge. The abutments of a flood-ravaged bridge remain adjacent to the Jack Batting Bridge across the estuary.

Areas along the banks of the estuary have been developed for residental purposes (fig 1-1). In the vicinity of the inlet two caravan parks cater for holiday-makers. Jetties constructed from concrete and/or wood extend into the estuary at various localities along the upper estuary. Nearly the whole length of the estuary is used for water-related recreational activities such as angling, windsurfing and boating.

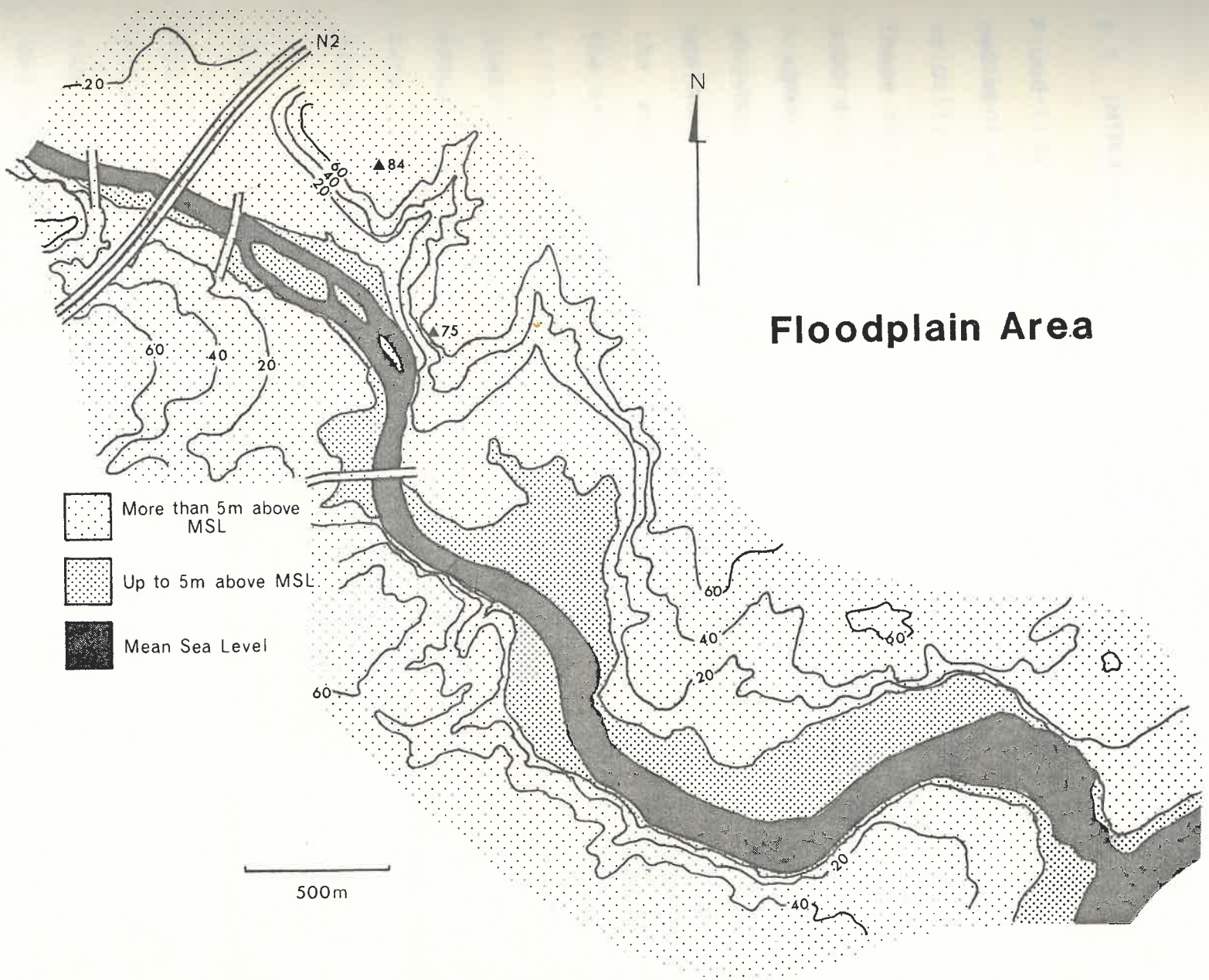

Floodplain Area
N
N2
20
60
40
20
84
75
60
40
20
60
40
20
60
60
20
40
More than 5m above MSL
Up to 5m above MSL
Mean Sea Level
500m

Fig 2-6

3. SEDIMENT DISTRIBUTION

3.1 INTRODUCTION

Flood-tidal deltas occur in the lower 1 km of the estuary; the sediment accumulates where an abrupt decrease in the current velocity occurs as the flood-tide enters deeper water (Plate 1). These sand bodies are mainly composed of quartz-rich sand with a subordinate component of marine carbonate ($CaCO_3$) shell fragments. Heavy minerals, of which ilmenite is the most abundant, constitute 2-3% of the sediment. The ilmenite is a weathering product of dolerite (fig 2-4). It is introduced into the estuarine sediments from the catchment area as well as from the adjacent beach, which also has an ilmenite content of 2-3%. Little fluvial sand is deposited in the estuary, but all the clastic suspension material is of fluvial origin. Pebble lag deposits occur near the inlet, on the channel bottom and on point bars. One kilometre from the inlet clastic mud accumulates in an area populated by Zostera.

3.2 SAND DISTRIBUTION

Grain size was determined from sediment samples taken on 13 lines across the estuary (fig 3-1). These samples were collected at the water/sediment interface, and at a depth of 0,5 m below the sediment surface. Only the intertidal and subtidal zones were sampled. Grain size distribution parameters were obtained by sieving as well as by settling tube. The samples were also analysed for their content of skeletal calcium carbonate and organic material respectively.

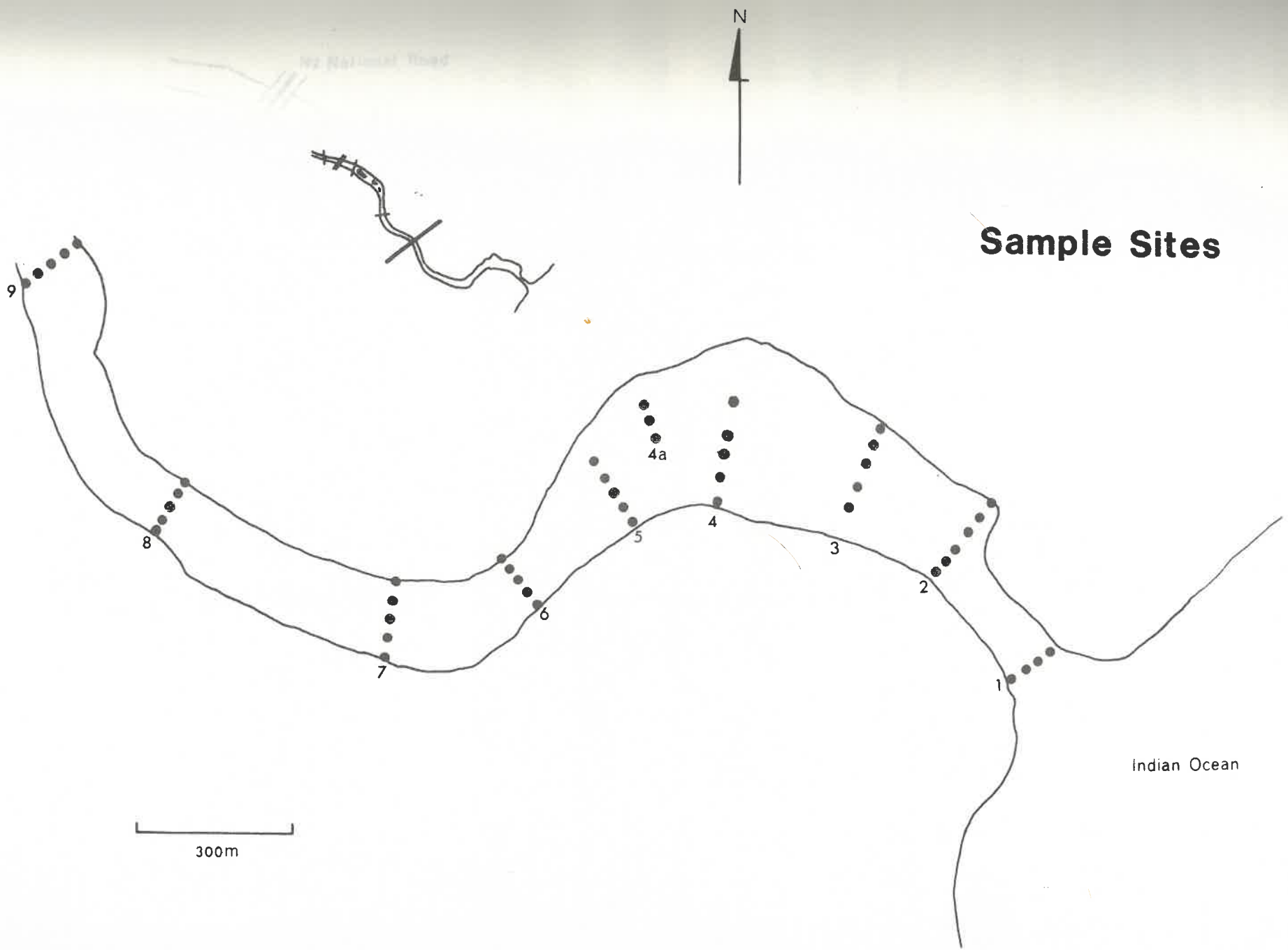
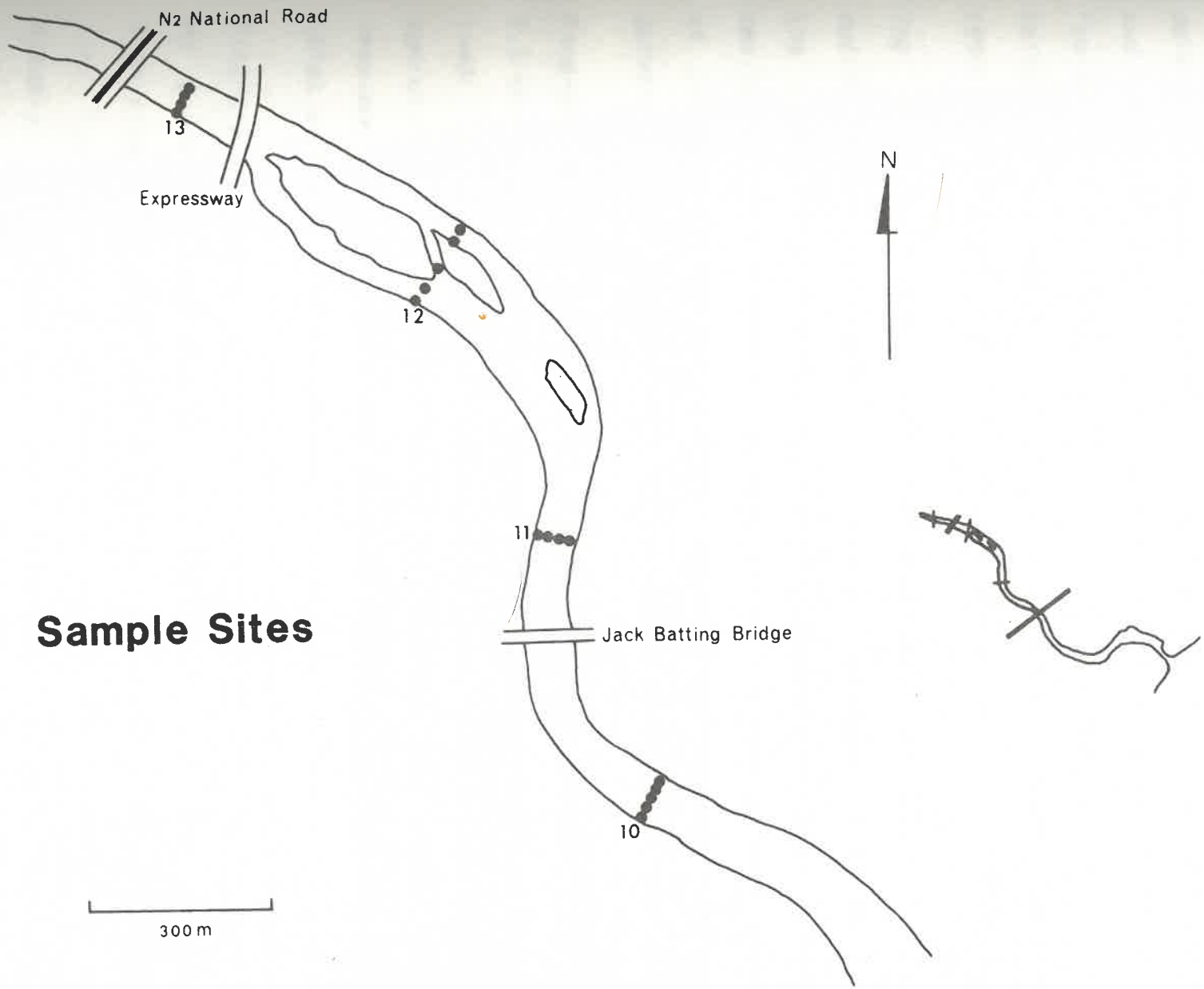


Fig 3-1



Sample Sites

Fig 3-1(cont)

Statistical parameters for the grain size distribution were determined using formulae obtained from Buller and McManus (1979) and McBride (1971). $CaCO_3$-content was determined using a "carbonate bomb" (Schink et al., 1979). Organic content was calculated by ashing (modified after McCave, 1979). Detailed results of all the sediment analyses are presented in APPENDIX 1.

The sand grain size decreases up-estuary (fig 3-2). As tidal current velocities (both ebb and flood) decrease upstream from the tidal inlet, turbulence also decreases. The ability of moving water to transport sediment grains depends on the degree of water turbulence, hence diminishing velocity upstream generally leads to the fining of sediments up-estuary.

Fine-grained marine sand with grain size ranging between 2,0 and 2,5 phi (0,25 to 0,177 mm) is distributed predominately in the lower estuary subtidal channels. These sands extend upstream approximately 1,1 km from the inlet. Pebbles and shell gravel (maximum diameter 100 mm) occur as channel lag deposits in the inlet and on the channel bottom of the lower estuary.

Fine-grained sand, (grain size smaller than 2,5 phi i.e. 0,177 mm diameter), predominates in the rest of the estuary. Significant volumes of very fine-grained sand (phi value > 3,0 i.e. less than 0,125 mm diameter) are notably absent in the estuary. This sediment distribution feature is in contrast to other estuaries studied under the ROSIE programme. Owing to the shaly nature of the catchment basin (Section 2.1), the fluvial sediment consists predominantly of mud. With little sand-sized material entering the estuary at the tidal head, the limit to which marine sand migrates up-estuary is clearly traceable.

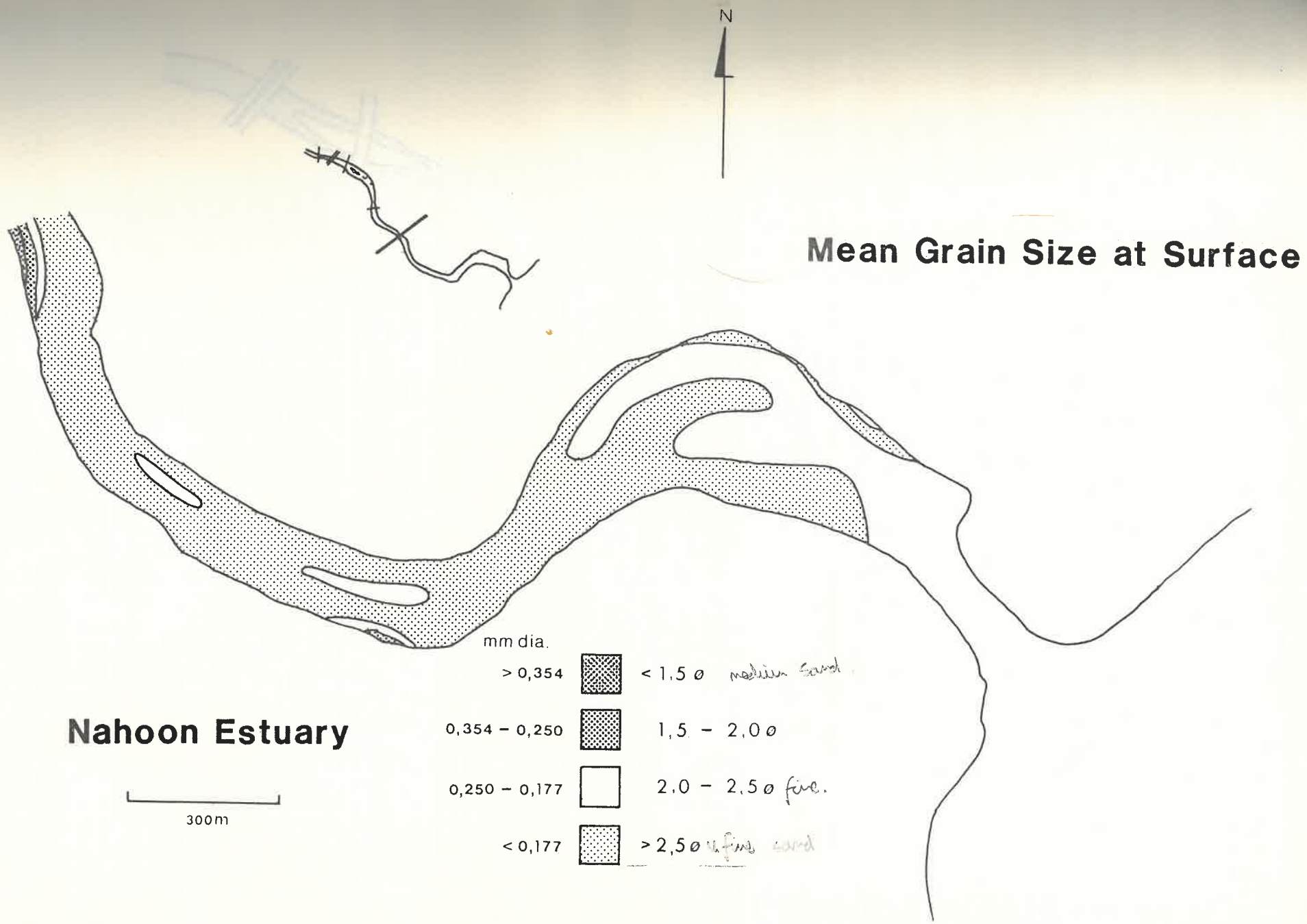

N
Mean Grain Size at Surface
Nahoon Estuary
300m
mm dia.
> 0,354
< 1,5 ø
0,354 – 0,250
1,5 – 2,0 ø
0,250 – 0,177
2,0 – 2,5 ø fine.
< 0,177
> 2,5 ø v. fine sand

Fig 3-2a

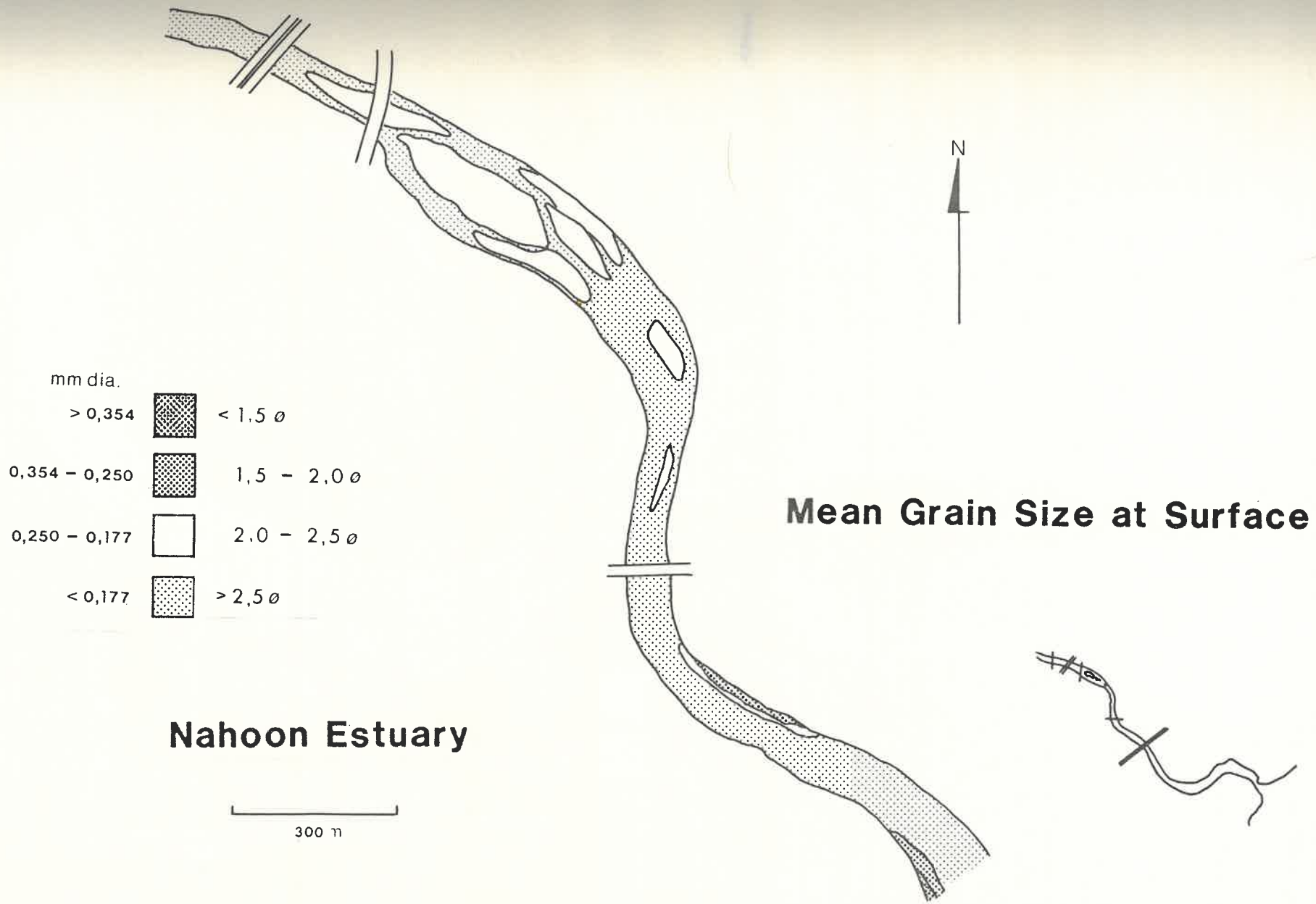

N
mm dia.
> 0,354
< 1,5 ø
0,354 – 0,250
1,5 – 2,0 ø
0,250 – 0,177
2,0 – 2,5 ø
< 0,177
> 2,5 ø
Mean Grain Size at Surface
Nahoon Estuary
300 m

Fig 3-2a(cont)

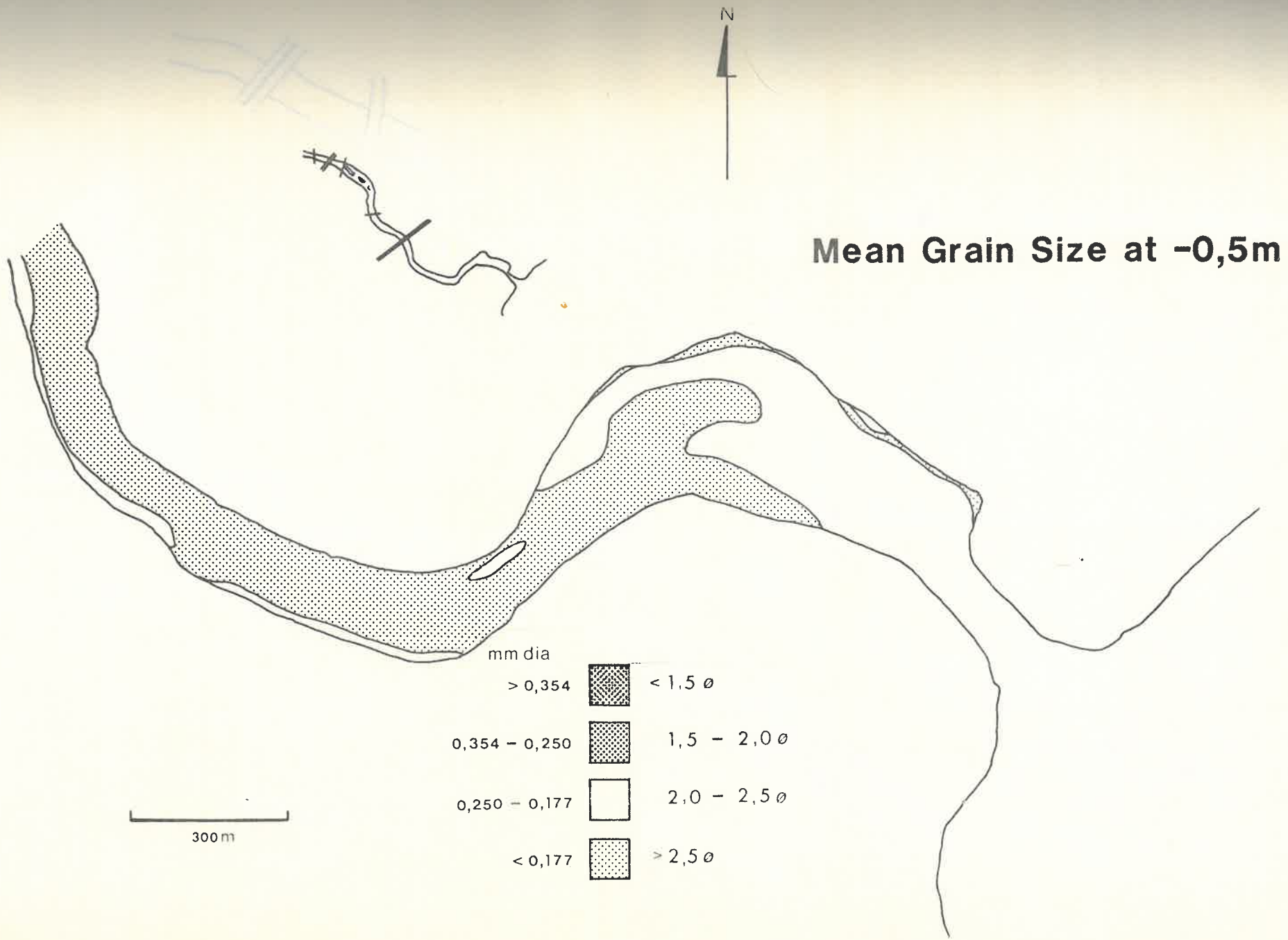

N
Mean Grain Size at -0,5m
mm dia
> 0,354
< 1,5 ø
0,354 - 0,250
1,5 - 2,0 ø
0,250 - 0,177
2,0 - 2,5 ø
< 0,177
> 2,5 ø
300 m

Fig 3-2b

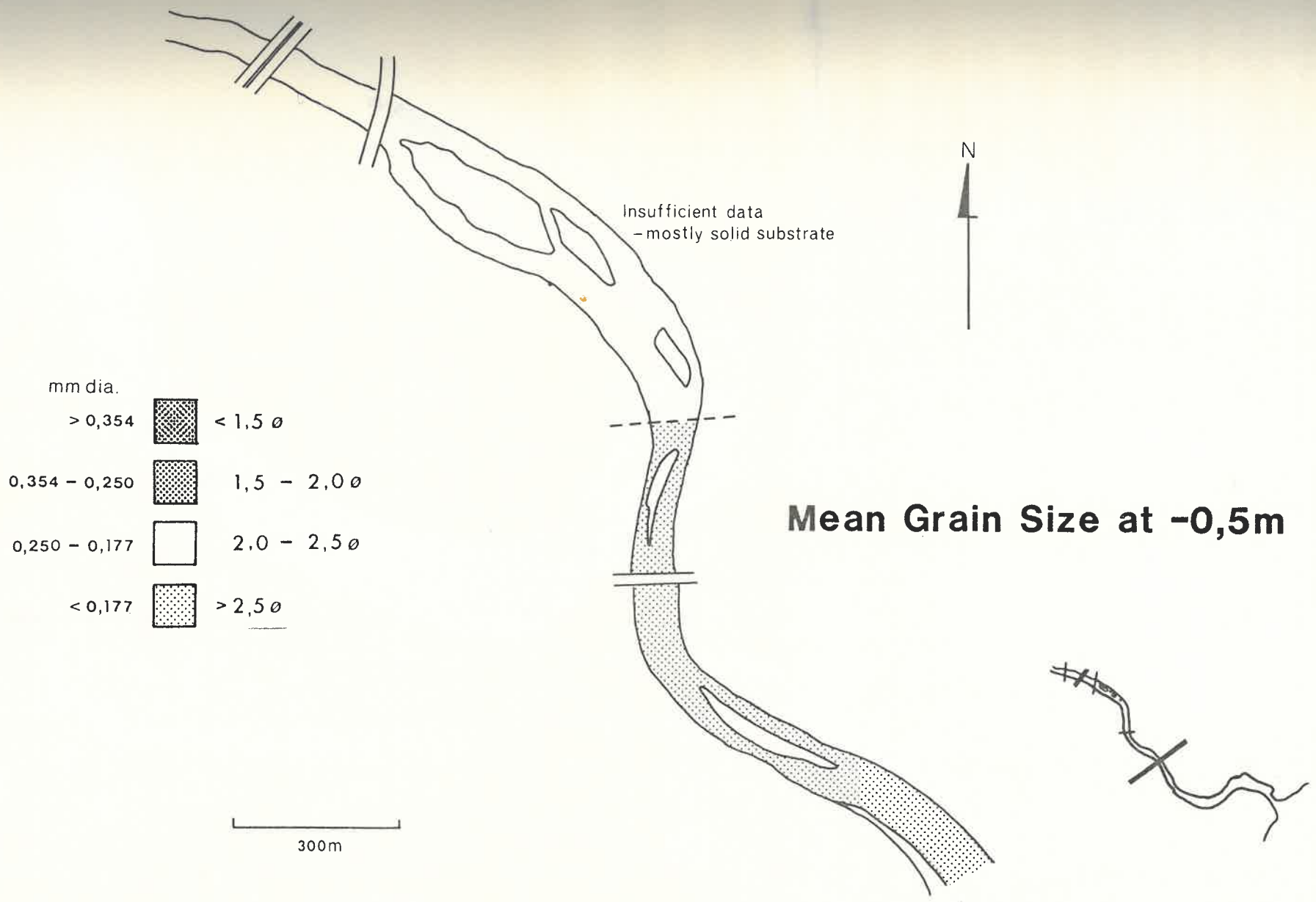

Insufficient data
– mostly solid substrate
N
mm dia.
> 0,354
< 1,5 ø
0,354 – 0,250
1,5 – 2,0 ø
0,250 – 0,177
2,0 – 2,5 ø
< 0,177
> 2,5 ø
300m
Mean Grain Size at -0,5m

Fig 3-2b(cont)

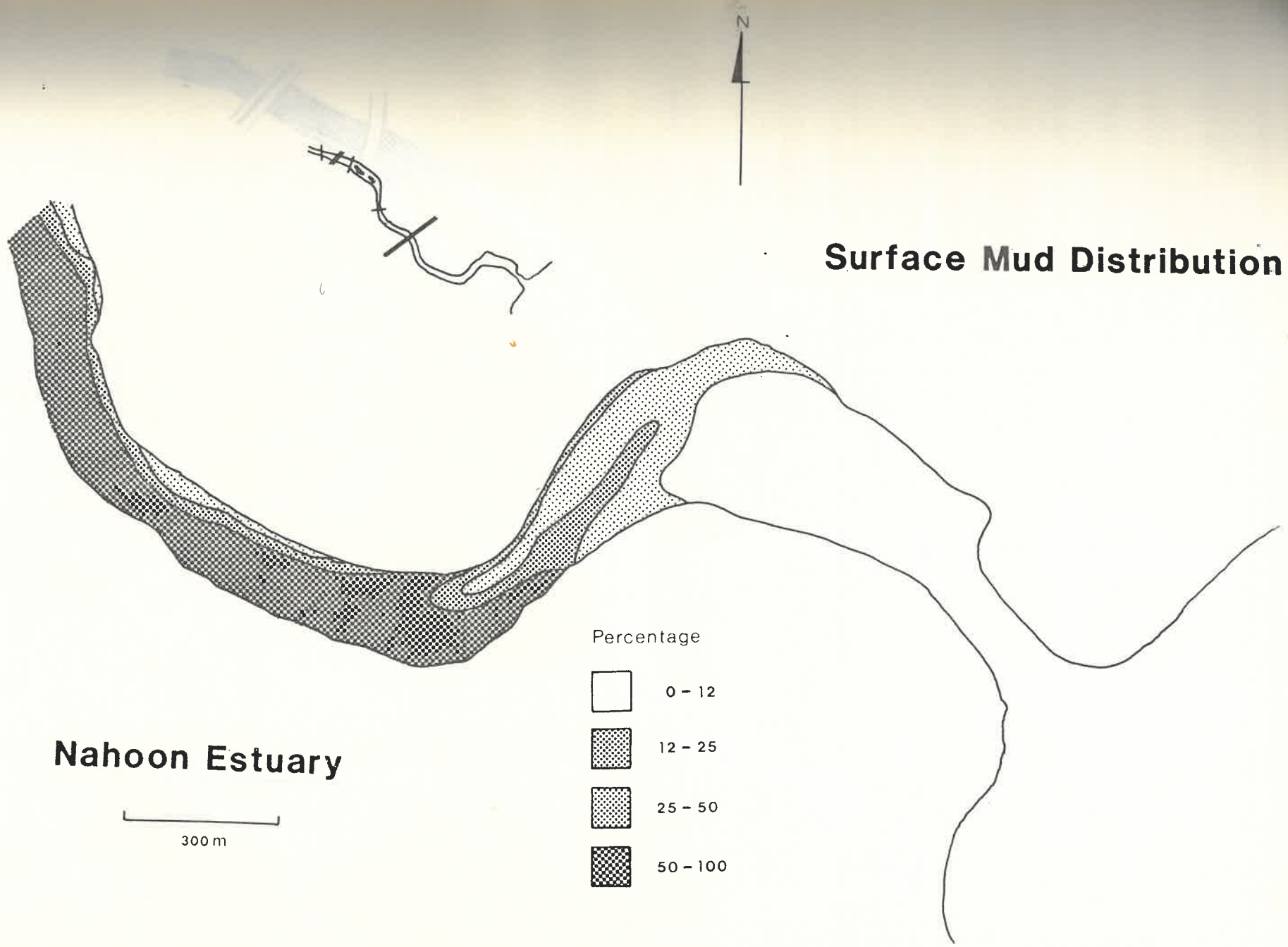

N
Surface Mud Distribution
Percentage
0 - 12
12 - 25
25 - 50
50 - 100
Nahoon Estuary
300 m

Fig 3-3a

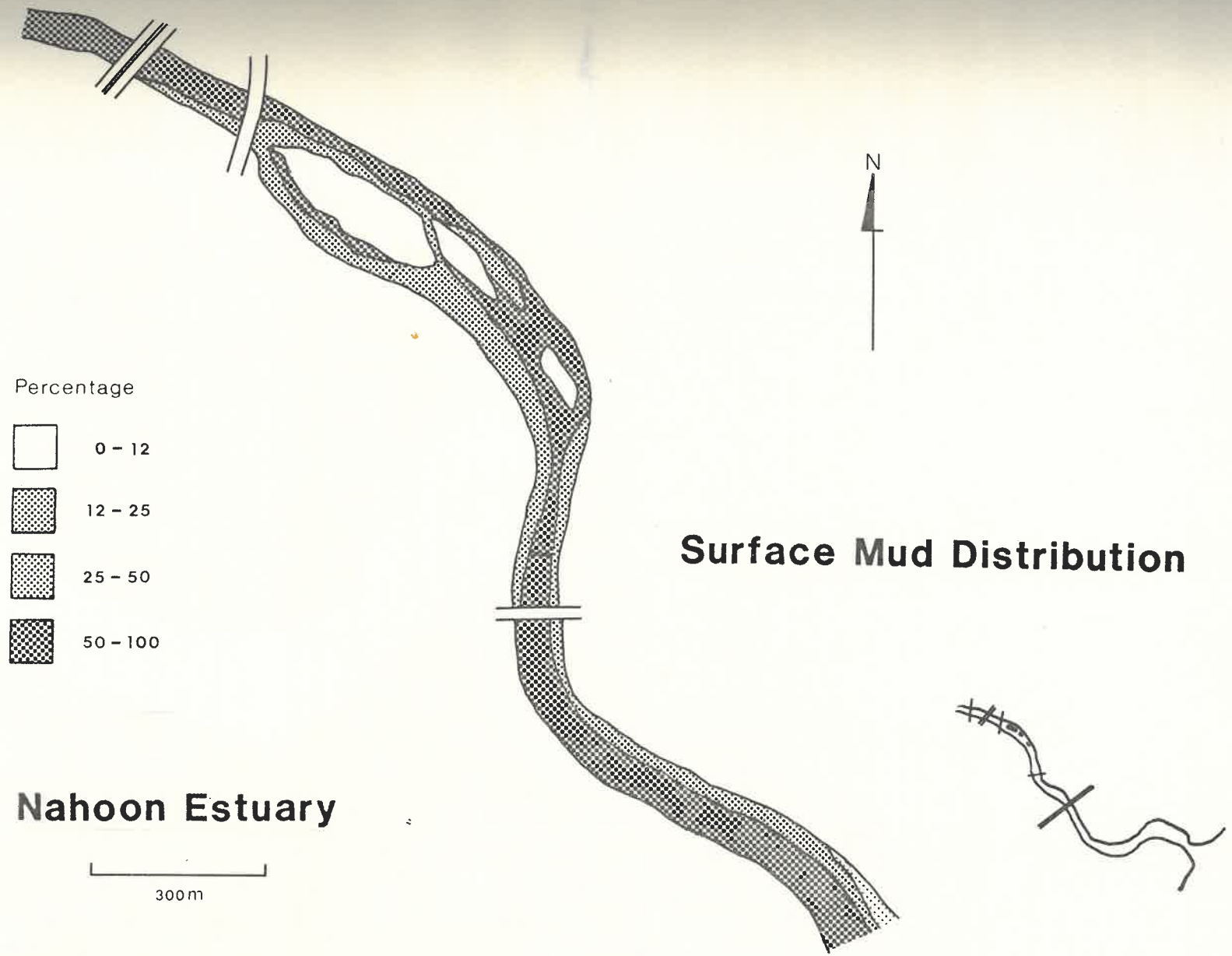

N
Percentage
0 - 12
12 - 25
25 - 50
50 - 100
Surface Mud Distribution
Nahoon Estuary
300m

Fig 3-3a(cont)

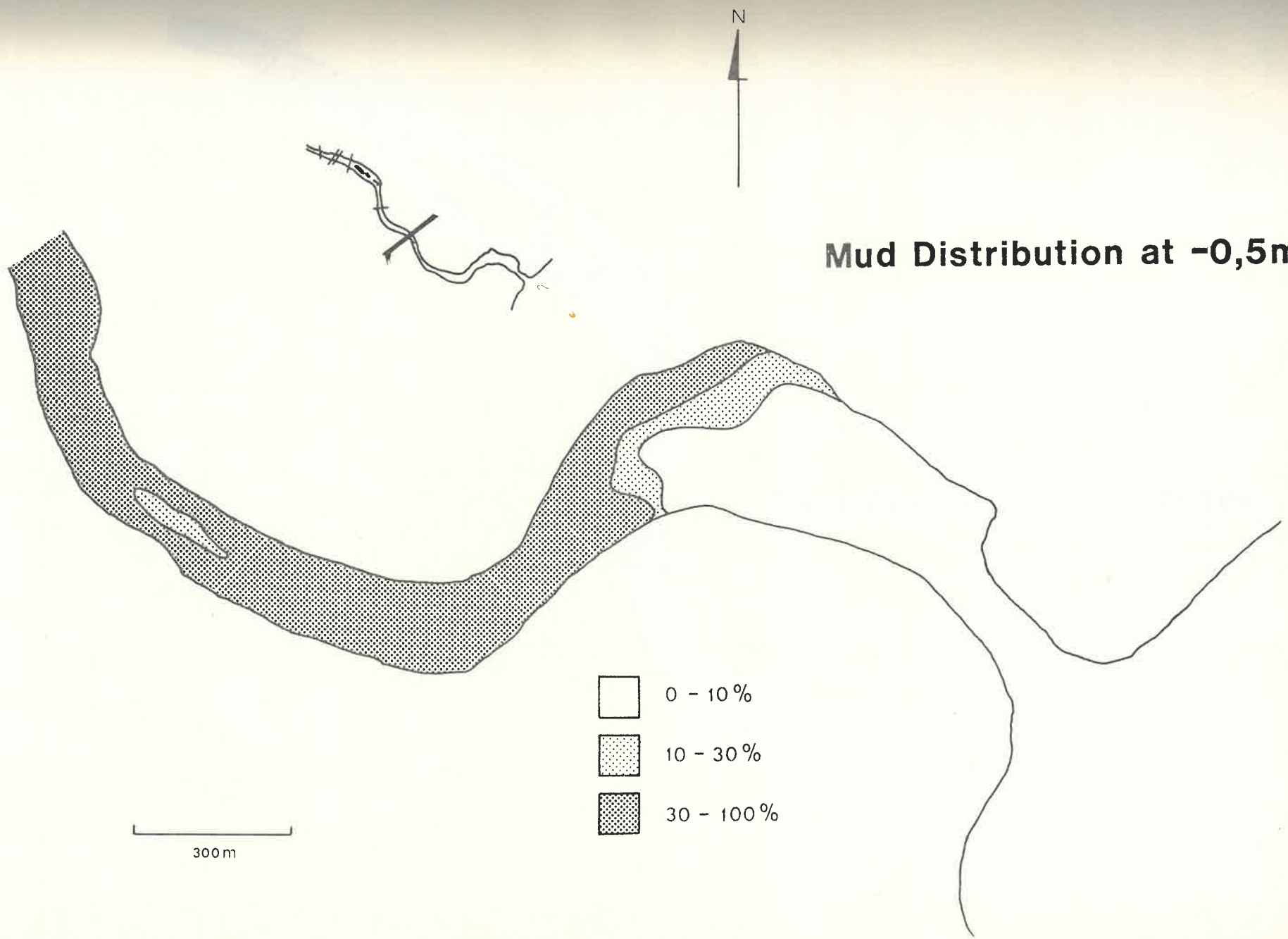


Fig 3-3b

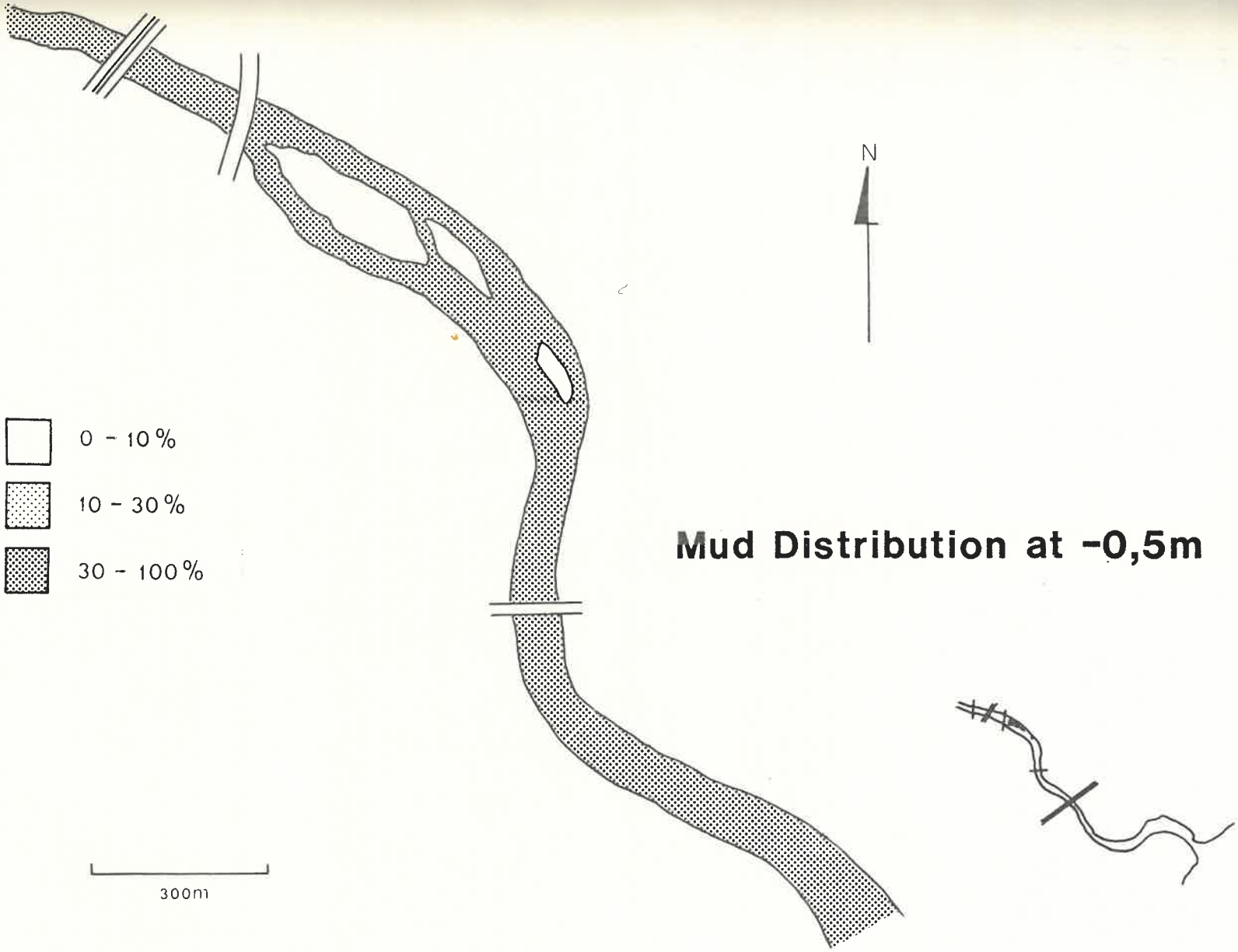


Fig 3-3b(cont)

The grain size distribution of the sediment at the water/sediment interface is similar to that of the sediment 0,5m deeper down (fig 3-2b). In the upper estuary bedrock and pebble beds were frequently encountered during the coring.

3.3 MUD DISTRIBUTION

Mud is deposited from suspension in the areas of low current velocities. Deposition from suspension is aided by flocculation. Clay floccules form when fresh water with suspended clay mixes with sea water. During mixing the clay particles become electrostatically charged so that they clump together to form floccules. With a settling velocity higher than individual clay particles, the floccules are readily deposited under non-turbulent conditions.

The mud distribution, both at the sediment surface (fig 3-3a) and at a depth of 0,5 m below the surface (fig 3-3b), follows a reciprocal pattern compared to that of sand grain size distribution (figs 3-2a and 3-2b). Little or no mud is found within the first kilometre upstream from the inlet. This presumably results from the presence of turbulent tidal currents which prevent suspended sediment from being deposited in the lower estuarine area. In the calmer water of the middle and upper estuary mud deposition takes place more readily.

Stands of aquatic vegetation, notably Zostera (eel grass), generate significant non-turbulent boundry layer zones where suspended sediment is trapped and collected (fig 5-3b).

Detailed data on grain size distribution for all the samples are listed in APPENDIX 1A.

3.4 SKELETAL CARBONATE FRACTION AND ORGANIC MATERIAL

3.4.1 Skeletal carbonate fraction

Carbonate material found in the estuarine sediment is exclusively derived from the skeletal remains of marine invertebrate organisms. This fraction gradually decreases from a maximum value of about 45% at the inlet to a trace amount at sample line 7. Samples taken 0,5 m below the sediment surface show a similar trend, but with lower carbonate content values than those of the surface sediment. The gradual decrease in carbonate from the inlet to the upsteam margin of the flood-tidal deltas supports the conclusion that the carbonate has a marine source. Skeletal carbonate is concentrated in the coarser-grained fraction of the marine sand being deposited under the turbulent flow conditions prevailing near the inlet. The finer-grained, carbonate-depleted sand is selectively moved farther up-estuary. Some of the observed reduction in carbonate content may also be the result of chemical dissolution of the carbonate fragments (Olaussen, 1980).

The carbonate percentages are presented in APPENDIX 1C.

3.4.2 Organic material

Organic material in the estuary is derived from a variety of sources, both within the estuary or from the catchment. Sources include terrestial and aquatic vegetation, faeces from burrowers, dead burrowing animals and plankton.

The content of organic material in the estuarine sediment gradually increases up-estuary from the tidal inlet. The highest concentrations of organic material occur in areas of high mud

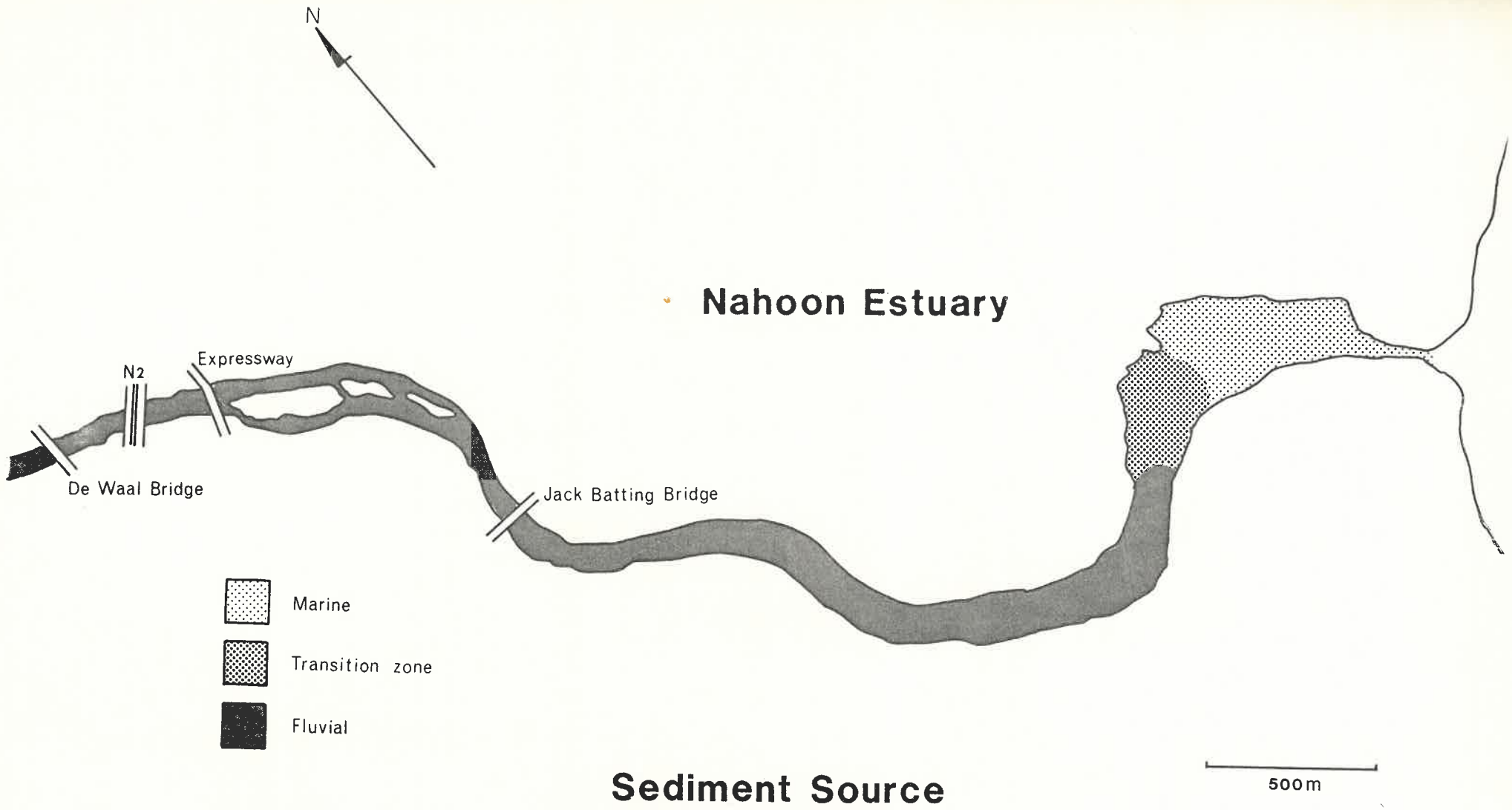
accumulation. Organic material is thus presumably deposited under similar conditions as part of the fluvially introduced suspended sediments. APPENDIX 1C details the distribution of organic carbon in the Nahoon estuarine sediment.

3.5 SEDIMENT SOURCE (fig 3-4)

Sediment in the Nahoon estuary is predominantly of fluvial origin. Marine sand that enters the estuary through the inlet only migrates about 1,1 km up-estuary; this represents less than 15% of the estuarine area. Practically no aeolian sand enters the estuary and the little that does is limited to the immediate inlet area. There is no major dune field to feed the estuary.

Sediment samples from the estuary were microscopically investigated in an attempt to identify the source. Marine sand, consisting predominantly of well-rounded mono-mineralic quartz grains and calcareous skeletal debris, extends in the form of prograding bars from the inlet to approximately 1 km up-estuary. Grains that enter at the tidal head of the estuary are less well-rounded. Fluvial grains are angular and have a high proportion of rock fragments.

The fluvial sediment consists largely of very fine-grained material. These sediments are weathering products of the shale-rich Beaufort Group (Section 2.1). The Nahoon drainage basin has a high sediment yield of approximately 150 t/km^2 per annum (Noble and Hemens, 1978). Due to the very fine-grained nature of this material it is transported almost entirely as suspension load. A comparison with other data (Sections 3.2 and 3.3) shows that fluvial mud makes up a considerable part of the sediment, but is less abundant in the lower 1,1 km of the



Sediment Source

Fig 3-4

estuary.

Two to three percent of the fluvial sediment consists of heavy minerals which originate from the weathered dolerite in the catchment area.

Marine-derived sediment enters the estuary from the sea via the inlet. This marine sand enters the estuary during the tidal flood. These marine sediments are re-worked by the tidal currents and are gradually transported up-estuary. At the time of investigation (March and November 1984), marine sand was encountered approximately up to sample line 6 (fig 3-1 & plate 1), that is 1200 m from the inlet.

Local erosion base was encountered at various localities along the upper estuary during sampling. It consisted of either solid bedrock or channel lag pebbles. This is an indication that sediment accumulation is mostly confined to the lower estuary.

4. SECTIONS ACROSS THE ESTUARINE CHANNEL

4.1 GENERAL

Eight cross-sections were surveyed at selected intervals across the channels of the Nahoon estuary between the inlet and the tidal head with mid-tide level as the datum level (fig 4-1).

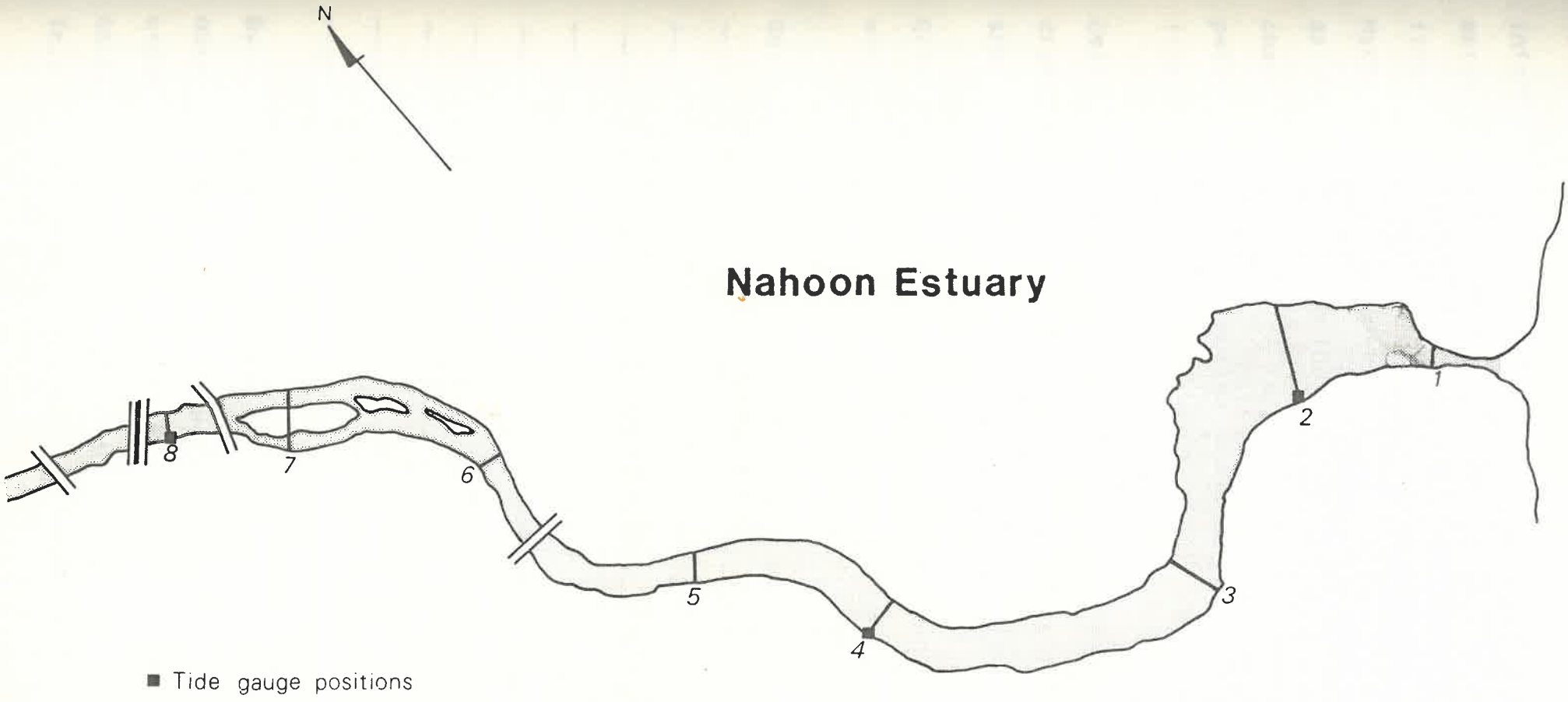
The position of the mid-tide level in the Nahoon estuary was determined using a set of 3 tide guages placed at the inlet, near the mid-estuary and at the tidal head (fig 4-1). The cross-section surveys were tied to the mid-tide level thus determined during November 1984.

Measurements were taken by engineer's level. The stadia rod was placed at topographic inflections on the subaerial part of the section line; for the underwater parts of the channel surveys the stadia rod was placed in position by a diver at stations about 5 m apart along the survey lines. In those areas where the water depths exceeded 4 m (the length of the stadia rod used) a suitable extension piece was fixed to the rod in order to extend the rod above the water level.

4.2 INTERPRETATION OF RESULTS

Cross-sectional data can be used to establish a reliable baseline for comparison with future measured profiles. Such a comparison will assist in determing whether long term sedimentation or erosion has taken place.

The survey data can also be used in hydraulic studies. This



Cross Sections Surveyed

Fig 4-1

information aids in predicting the hydraulic reaction of the estuary under changed environmental conditions resulting from floods, reduced discharge, bridges, dams, and other factors. Hydraulic radius and wetted perimeter have hydraulic significance as measures of both the extent of solid-fluid contact and of the channel efficiency. A large cross-sectional area relative to perimeter length implies reduced frictional retardation of the flow.

Detailed information on the cross-section co-ordinates, cross-sectional areas, hydraulic radii, effective channel widths and cross-section diagrams are presented in APPENDIX 2.

Cross-sectional areas, hydraulic radii and the effective channel width at mid-tide level are tabulated below:

Section no	Cross-sectional area m^2	Hydraulic radius m	Width m
1	64.0	0.60	108.7
2	224.9	0.75	300.3
3	383.1	2.41	158.2
4	309.6	2.43	127.1
5	200.2	2.45	81.0
6	217.3	3.21	63.1
7	99.5	1.19	82.0
8	126.1	2.20	56.4

By plotting the above data (figs 4-2, 4-3, 4-4) a number of observations can be made. The sudden increase in the cross-sectional area and hydraulic radius between lines 2 and 3 corresponds to the limit of the prograding marine sediment bars. This indicates that the growth of these bars is leading to

NAHOON ESTUARY

Effective channel widths below MTL

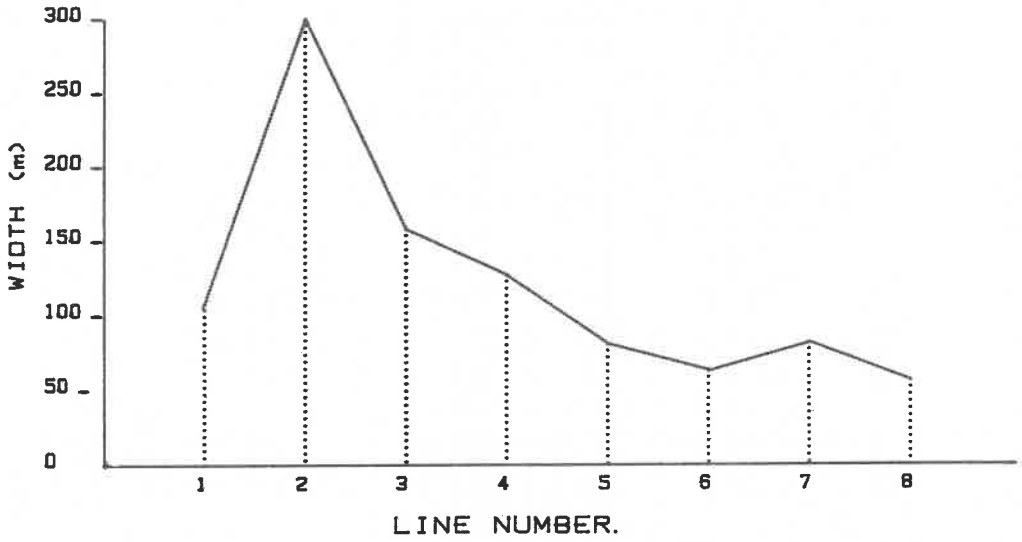


Fig 4-2

NAHOON ESTUARY

Hydraulic radii below MTL

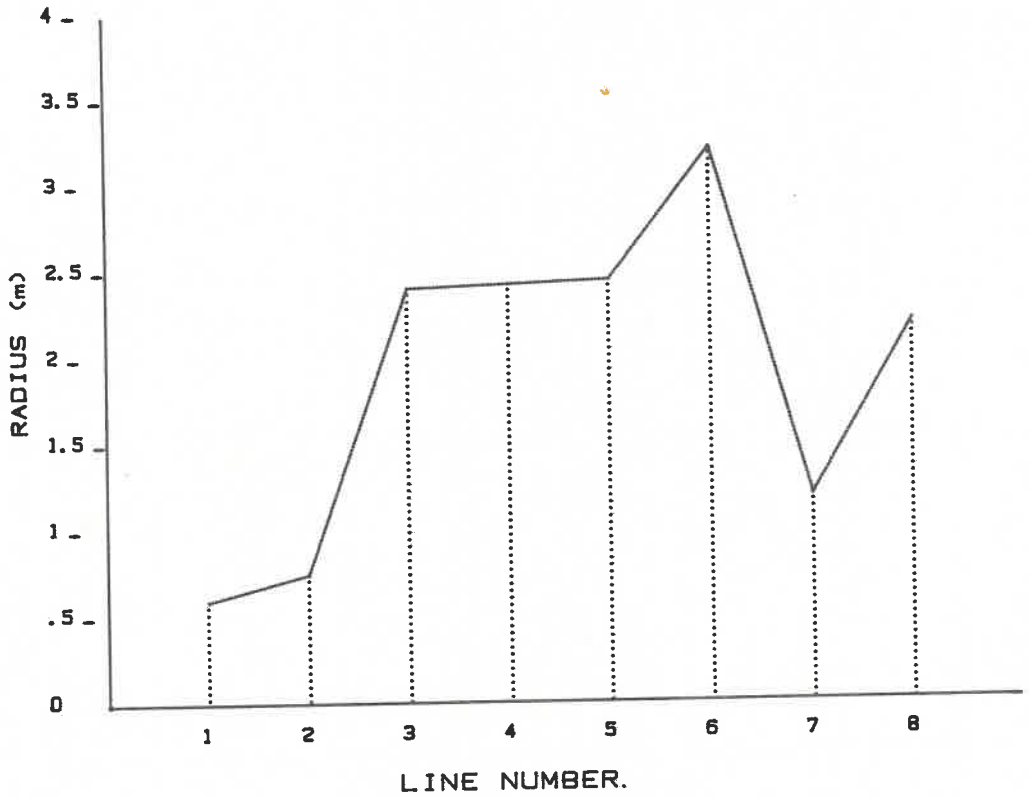


Fig 4-3

NAHOON ESTUARY

Cross-sectional areas below MTL

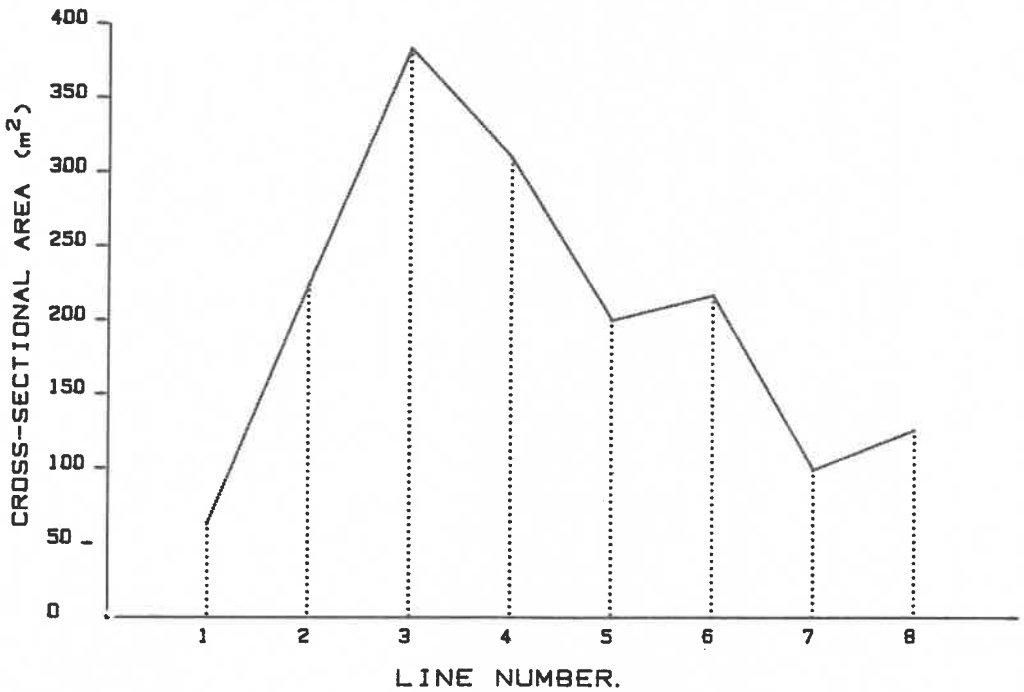


Fig 4-4

shoaling of existing channels.

Reduced hydraulic radius does not necessarily indicate shoaling as different channel types have different hydraulic properties. Channel width is influenced by an interaction of discharge and bank material properties. A channel cut in cohesive sediment is generally narrower and deeper than a comparable channel excavated in sand, given that the two channels have equal discharges. Thus sand-bedded channels tend to be wider and shallower, giving a relatively low hydraulic radius compared to that of a deeper and clayey channel. However, from line 3 through to lines 2 and 1, the cross-sectional area decreases simultaneously with hydraulic radius, indicating net sedimentation.

Comparison of the effective channel widths at the mid-tide level indicates a general down-estuary widening of the channel (fig 4-4). This results mostly from valley morphology and the gradual down-estuary decrease in mud content. The lower estuary is predominantly sandy and therefore the channel is able to establish itself relatively freely within the sand bodies.

5. AERIAL PHOTOGRAPHY

5.1 INTRODUCTION

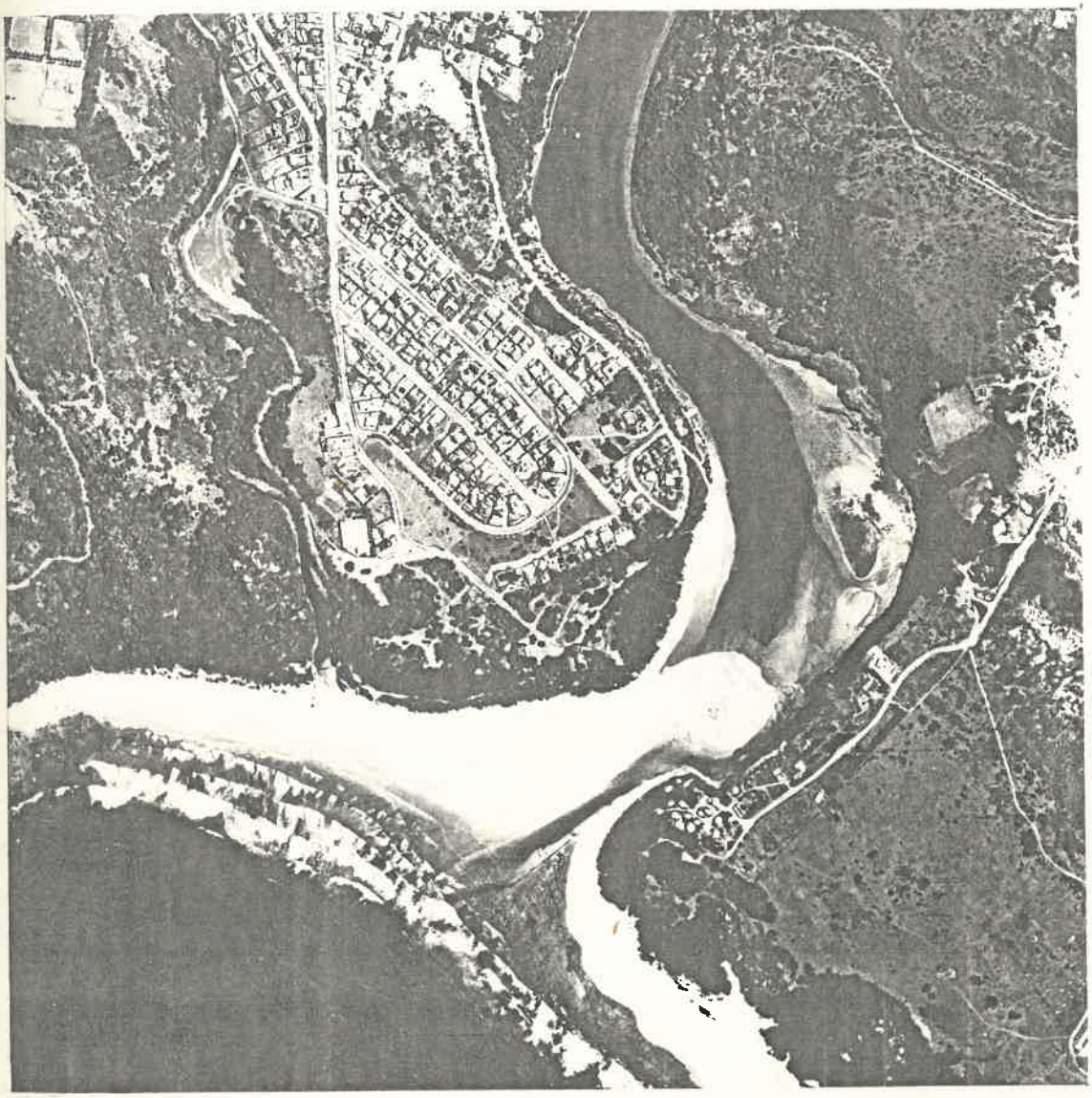
Historical aerial photographs (1964, fig 5-1; 1972, fig 5-2; 1983, fig 5-3) indicate that only the inlet area shows any significant recent changes, and interpretations are confined to this region.

5.2 INLET BEHAVIOUR

The photographs show that the present configuration of the sand bodies in and around the inlet have undergone various changes over the last 20 years. The sand bars of the lower estuary constitute a flood-tidal delta deposited during the abrupt deceleration of the flood-tidal currents as the ocean water enters the wide estuary after jetting through the constricted tidal inlet. Flood-tidal deltas are commonly associated with inlets on wave-dominated microtidal coasts (Hubbard et al., 1979).

On each of the 3 historical aerial photographs a 30 to 40 metre wide inlet channel can be recognised. The position and morphology of the inlet channel are determined by various factors. Of these the prevailing longshore current and estuarine tidal prism are the most important. The dominant longshore current flows eastward and as expected the inlet tends to move in that direction. This is indicated on each photograph. The channel preferentially occupies the easternmost position of the stunted barrier system. Continued eastward movement of the inlet is prevented by bedrock exposed on the eastern bank.

11 SEPT 1964



EL MUNICIPALITY

200m

N

Fig 5-1a

Line diagram of 1964 aerial photograph

Lower estuary

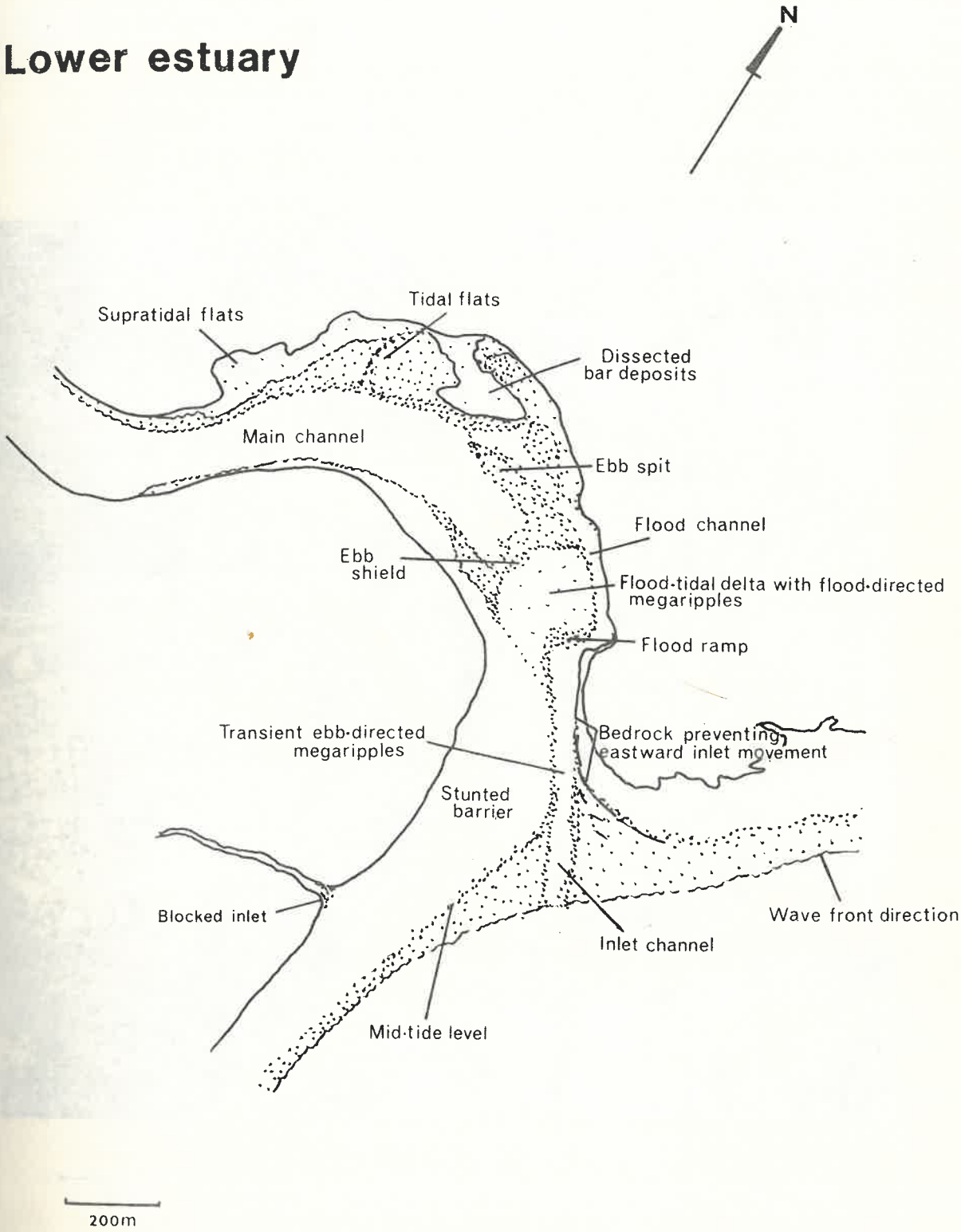


Fig 5-1b

8 JUNE 1972

200m

N

Fig 5-2a

Line diagram of 1972 aerial photograph

Lower estuary

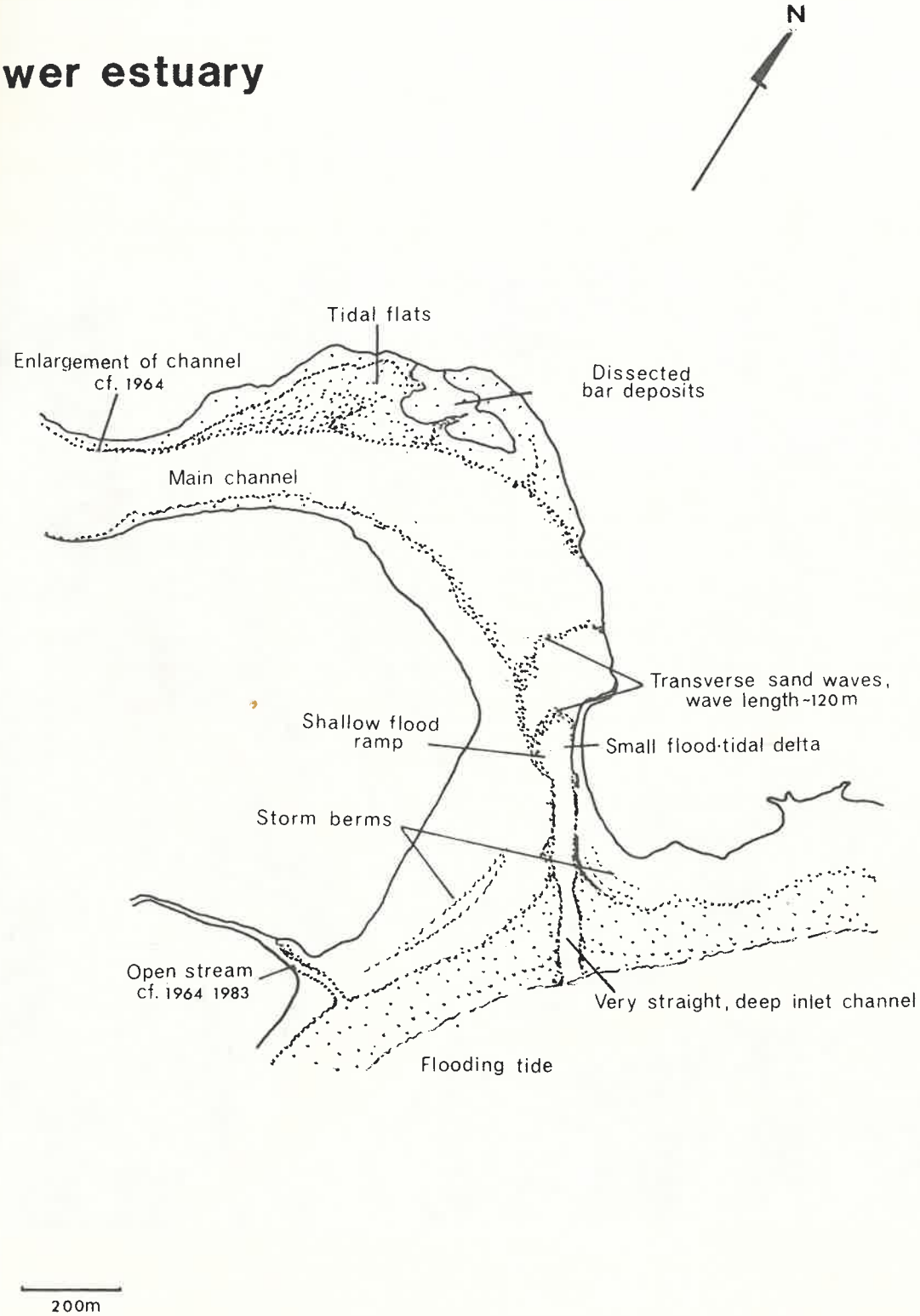
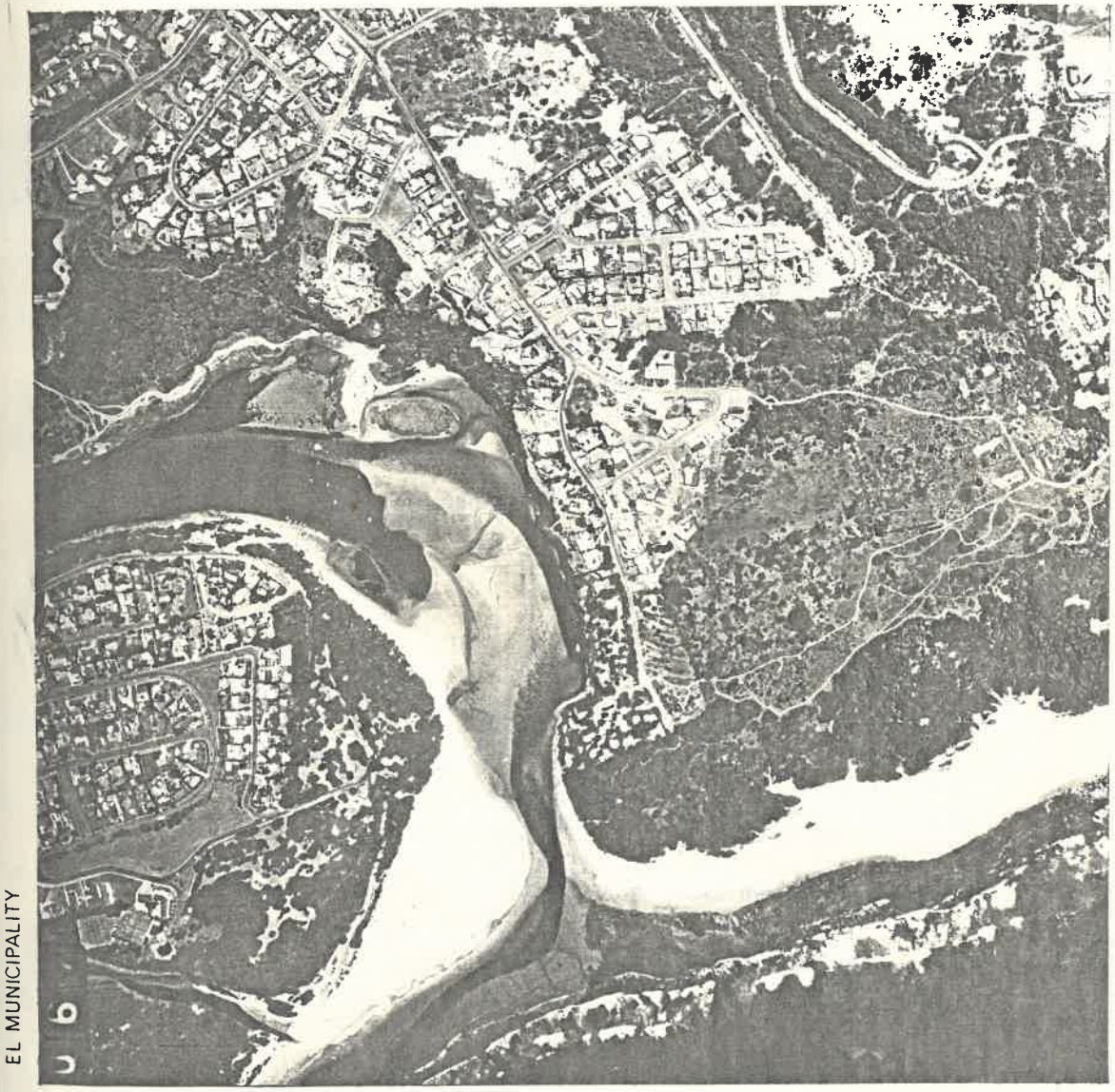


Fig 5-2b

21 MARCH 1983



200m

N

Fig 5-3a

Line diagram of 1983 aerial photograph

Lower estuary

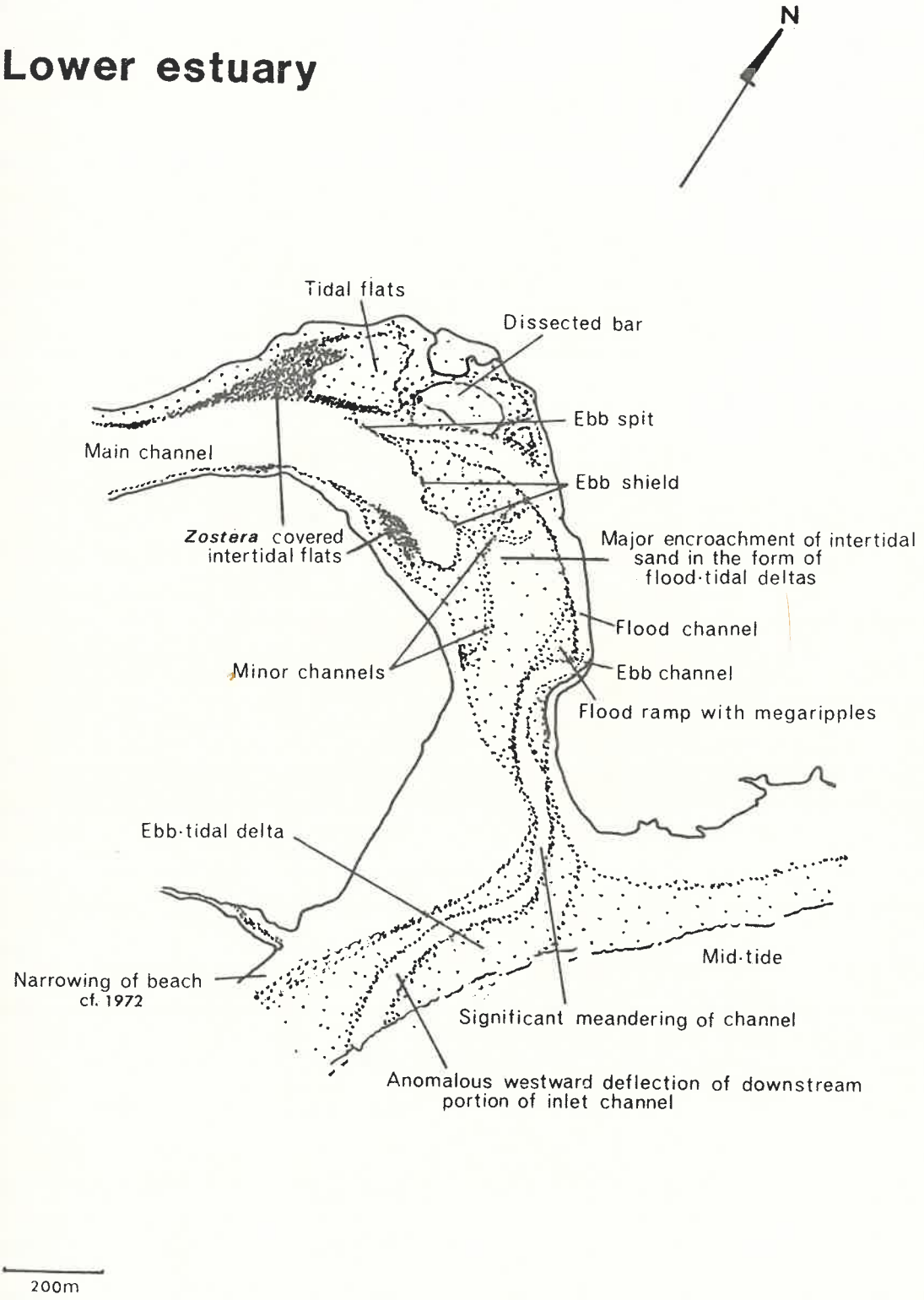


Fig 5-3b

In 1983 the submarine extension of the inlet channel into the surf zone trended westward (fig 5-3). This is in marked contrast with the other two photographs (fig 5-1, 5-2) where the inlet channel is shown to run straight out into the surf. This apparently anomalous channel drift tendency is probably a meander phenomenon. Meander sinuosity is a result of the interplay between bank material properties, wavelength and channel width (Zeller, 1967; Richards, 1982).

In order to investigate the possibility of meandering, the sinuosity value of each meander was calculated (fig 5-4). To obtain sinuosity values, the axial wavelength and arc wavelength of each meander must be known. Measurements of observed meander radii and channel parameters were used to calculate both the axial and arc wavelengths for each meander. Calculations are shown on figure 5-4.

The calculated sinuosity value for each meander, including that portion which extended into the surf zone, corresponds closely to each other. These similarities support the proposition that this part of the channel is a conventional meandering channel.

The average wave action, and the resultant longshore currents, were possibily of a relatively low magnitude during the period immediately preceding the date of photography. The submarine meander extention was subsequently not obliterated.

The 1983 meander is probably also related to the extensive development of the flood-tidal delta present at that time. The 1983 photograph (fig 5-3) shows that the volume of sediment in the lower estuary is considerably more than indicated by the 1964 and 1972 photographs (figs 5-1 and 5-2). In 1964 and 1972 the

Meander Sinuosity
1983 Aerial photograph

Axial wavelength Equation used: $L = 4.59 r_c^{0.98}$ r_c = radius of curvature	Arc wavelength λ Physically measured to scale from the aerial photography	Sinuosity $p = \frac{\lambda}{L}$
Curve 1 r_c = 263 m Substitute in eq. L = 1079 m	505 m	0.47
Curve 2 r_c = 126 m Substitute in eq. L = 525 m	263 m	0.50
Curve 3 r_c = 126 m Substitute in eq. L = 525 m	253 m	0.48
Curve 4 r_c = 232 m Substitute in eq. L = 955 m	421 m (superimposing)	0.44

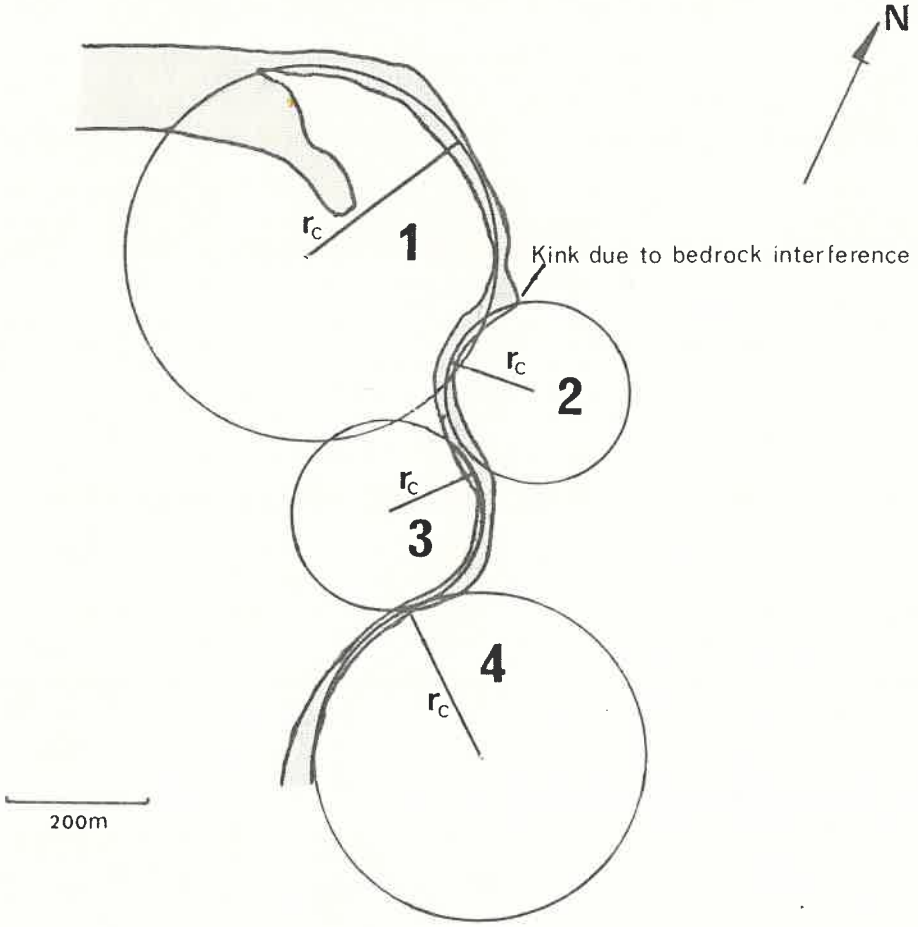


Fig 5-4

lower estuary was much deeper and no meandering channel developed.

5.3 THE INFLUENCE OF FRESHWATER FLOODS

A severe freshwater flood, of which the discharge is unknown, occurred during August 1970 (Dept. of Water Affairs, 1978). An indication of its probable discharge is given in Section 6.3. Its effects are clearly discernable on the 1972 photograph (fig 5-2). This flood scoured practically all unconsolidated sediment from the lower estuary out to sea. In 1972 sand shoals were almost entirely absent in the lower estuary and only a small flood-tidal delta was present.

The overall estuarine sediment budget is controlled by interaction of tidal deposition and freshwater flood erosion. The effect of fluvial floods in scouring marine-derived sediment from the estuary is illustrated by comparing the figs 5-2 and 5-3.

Discharge data of the Nahoon River (Dept. of Water Affairs, 1978) indicate that since 1970 no flood occurred that could have produced any significant sediment scouring.

5.4 SEDIMENT ACCUMULATION

Development of the estuary (figs 5-1, 5-2, 5-3) indicates the extent to which sediment has accumulated since 1964.

In 1972 an estimated area of 5,96 x 10^4 m^2 in the lower estuary was occupied by intertidal sand bars. By 1983 this area had increased to 12,71 x 10^4 m^2. It is estimated that the marine sediment influx since 1972 resulted in the intertidal sand bodies

growing by 0,6 x 10^4 m^2 per year. A reliable estimate of sediment volumes cannot be calculated using data based on historical aerial photographs.

However, the sediment volume can be estimated if the pre-depositional water depth is assumed to have been between 1 and 2 metres. Conservatively estimated, 6 x 10^4 m^3 to 1.4 x 10^5 m^3 of marine-derived sand has entered the lower Nahoon estuary since 1972. This is a measure of the amount of sediment which can be flushed out of the estuary during a major fluvial flood.

5.5 RESIDENTIAL DEVELOPMENT

Intensive residential development of the area surrounding the estuary banks has occurred over the last 20 years. The 1964 aerial photograph shows that the western East London areas adjoining the Nahoon estuary were already developed. This area has since remained more or less unaltered.

Land on the eastern, Beacon Bay bank of the estuary was virtually undeveloped in 1964. The only exception was the Blue Bend holiday resort (fig 5-1) near the inlet, and one or two farm buildings. By 1972 urban development of the western bank had started in earnest. By 1983 nearly all the available land on the western bank had been developed. The three aerial photographs indicate increased utilization of the surrounding areas.

6. MANAGEMENT OF THE ESTUARINE AREA

6.1 INTRODUCTION

Ever increasing utilization of the areas surrounding the Nahoon estuary can be expected in the future. A result of this influx of people and the related infrastructure is that increased demand for recreational facilities will be placed on the estuarine environment.

6.2 EFFECT OF BRIDGES AND EMBANKMENTS

Five road bridges traverse the estuary within a 1,5 km stretch (fig 1-1). These constructions have little effect on tidal circulation and dynamics of the estuary. The uppermost bridge has a weir underneath it which acts as a physical barrier to all tidal movement farther upstream. However, this artificial tidal head lies close to where the natural head was and has a negligible effect on overall tidal dynamics.

Bridges across estuaries must be designed to allow for freshwater floods. Poorly planned bridges and/or embankments act as damming obstructions during severe fluvial floods. The bridges across the Nahoon estuary are unlikely to significantly influence the backwater curve. Channel and floodplain infill was kept to a minimum during construction. Furthermore, the roadway surfaces are well above natural flood levels.

6.3 EFFECT OF FLUVIAL INUNDATION

The tidal hydraulic dimensions of an estuary are often inadequate to handle the increased discharge of a severe fresh water flood. This situation is aggravated whenever a fluvial flood coincides with a marine storm or spring high tide flood. As a result the estuary bursts its banks during a flood so that the usually dry supratidal zones and floodplains are inundated. Should the floodplains be altered artifically, be it by infilling, permanent construction or destruction of natural vegetation, the ability of floodplains to cope with severe floods could be greatly impaired. If the natural function of the floodplain to act as an "emergency" channel is reduced, the backwater curve of the river will be modified, leading to potential increased damage to properties located upstream of the obstruction.

Severe flood damage was caused to properties in low-lying areas along the banks of the Nahoon estuary during the floods of late August 1970. The lower-most Jack Batting Bridge, which was more than 5 m above the mean sea level, was completely destroyed and swept away, illustrating the severity of the flood. Although no river runoff data are available at the head of the estuary the monthly inflow figures of the Nahoon Dam (fig 2-2) indicate the extent of the flood (Dept. of Water Affairs, 1978). The average monthly inflow for August of the four years preceding 1970 was $2,9 \times 10^4 m^3$, whereas the monthly inflow of August 1970 was no less than $1,71 \times 10^8 m^3$, an increase by a factor of some 6000.

It is advisable that the remaining floodplains of the estuary are preserved in their present condition as much as possible. Floodplains enable an estuarine system to cope with severe fluvial inundation by providing buffer areas which absorb the

increased water volume.

6.4 SEDIMENT REMOVAL

Excessive volumes of marine-derived sand are reported to be accumulating in the lower estuary. In November 1984 sand bars were observed to extend approximately 800 metres up-estuary from the inlet (Plate 1). Aerial photograph interpretation (Section 6) also indicated a net sediment influx for the period 1972 to 1983.

The present Nahoon estuary was established when the rapidly rising water of the latest rise of the sealevel (Flandrian transgression) drowned the river valley. This established a low energy hydraulic regime and enabled sediment to be readily deposited within the estuary. Estuaries are, however, dynamic systems. A balance is maintained by fresh water floods that periodically scour tide-deposited sediment out to sea. During periods of drought, or during normal low water stages, when the fluvial system does not operate fully, sediment accumulates, particularly in the lower estuary.

Recent sediment accumulation in the Nahoon estuary results from an absence, since August 1970, of a flood with a discharge volume high enough to scour a significant volume of sediment from the estuary. Under the prevailing drought conditions fresh water retention by dams in the catchment area has probably increased so that the potential scouring effect of more recent floods was diminished. The situation within the lower estuary could improve after the next major fluvial flood. The chance of a high discharge flood occurring depends on unpredictable climatic

factors.

Dredging may have to be considered in the long term if natural flooding does not remove the accumulated sediment in the estuary. At present this is not considered necessary as the marine sediment is unconsolidated and a substantial fluvial flood should manage to remove a major portion of the sediment.

Should recreational considerations justify dredging, it must be noted that such an operation will have to be repeated every 15 to 20 years. Also, if dredging is considered viable, spoil disposal requires careful attention. For instance, considering that the major source of sediment deposited in the lower estuary is derived from the adjacent beach area, especially the upstream part with respect to the prevailing longshore currents, the location of dredge spoil disposal should be such as to ensure that the disposed sediment is transported away from the inlet area, and not towards it. Other considerations include the cost of the operation and a general protection of the existing environment.

7. CONCLUSION

The estuarine environment depends on the interaction of numerous factors: the volume and frequency of freshwater discharge; inlet configuration; wave regime; interaction between sea and fresh water; tidal action and the amount and type of sediment present.

As the state of the sedimentary ecology in the Nahoon estuary is still reasonably sound, it is essential that the status quo of the environmental factors is maintained.

Sedimentation taking place in the lower estuary is related to the natural occurrence of random fluvial floods that scour accumulated sediments from the estuary. The sediments that cause shoaling are primarily of marine origin; influx of such sediment cannot be reduced by artificial means. The extent of sediment accumulation in the estuary will generally become more serious if fresh water retention increases in the catchment area, be it by increased water demand in the catchment or through drought conditions. Artificial removal of accumulated shoals, such as by dredging, will require careful planning and budgeting.

ACKNOWLEDGEMENTS

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APPENDIX 1

This section details the sediment data calculated for the Nahoon Estuary. The sample lines are marked on figure 4-1. The position of the sample stations can be found from the coded station numbers. For example N1-1T originates from the Nahoon ("N" in the code) and was collected on line number 1 ("1", see fig 4-1). It was taken at the bed surface ("T" denotes TOP) at position 1 on that line. This sampling spot (indicated as a dot, fig 4-1) is the first from the LEFT, looking up-estuary. Samples were also collected 0,5 m below the sediment surface by coring. These samples are indicated by a "B" (for BOTTOM) in the code.

All grain sizes listed below are in PHI-units and NOT in mm. (PHI = $-\log_2$ [grain size in mm/1mm]).

Sediment samples were analysed both by sieve and settling tube methods.

Section A lists the grain size class distribution of the samples. Section B gives the statistical parameters. Sections A1 and B1 represent the sieve results, whereas Sections A2, B2 and B3 give the settling tube results calculated by both graphical and moment statistical methods. Section C lists the respective contents of bioclastic carbonate and of organic material.

APPENDIX 1A

This section lists the grain size class distributions.

The parameters listed below are as follows:

VCS - Very coarse sand (grain dia. 1 mm to 2 mm; 0 to -1 PHI)

CS - Coarse sand (grain dia. 0,5 mm to 1 mm; 1 to 0 PHI)

MS - Medium sand (grain dia. 0,25 mm to 0,5 mm; 2 to 1 PHI)

FS - Fine sand (grain dia. 0,125 mm to 0,25 mm; 3 to 2 PHI)

VFS - Very fine sand (grain dia. 0,063 mm to 0,125 mm; 4 to 3 PHI)

Mud - Silt and clay (grain dia. less than 0,063 mm; > to 4 PHI)

SECTION A1 - Sieve results

Sample no	Percentage						
	>VCS	VCS	CS	MS	FS	VFS	Mud
N1-1T	0.0	0.0	0.0	22.1	75.6	1.7	0.6
N1-1B	0.0	0.0	0.0	27.1	70.1	1.6	1.2
N1-2T	0.0	0.0	0.2	12.3	81.0	4.9	1.6
N1-2B	0.0	0.4	1.1	44.5	50.6	2.2	1.1
N1-3T	Rocky bottom						
N1-3B	Rocky bottom						
N1-4T	0.0	0.0	0.0	14.1	80.8	3.8	1.3
N1-4B	1.2	1.4	3.5	41.7	48.8	1.8	1.6
N2-1T	0.0	0.0	0.0	13.4	81.7	3.1	1.8
N2-1B	0.0	0.0	0.0	1.2	92.8	4.8	1.2
N2-2T	0.3	0.0	0.5	29.9	66.8	1.3	1.3
N2-2B	0.0	0.0	0.3	18.3	79.6	0.8	1.0
N2-3T	0.0	0.0	0.2	9.6	85.7	2.9	1.5
N2-3B	0.0	0.0	0.0	8.6	88.1	1.9	1.4
N2-4T	0.0	0.0	1.4	22.0	73.1	1.7	1.7
N2-4B	0.0	0.0	0.5	47.0	50.9	0.2	1.4
N2-5T	0.0	0.0	1.2	49.6	47.1	0.5	1.5
N2-5B	0.0	0.0	0.7	26.3	70.5	1.0	1.5
N2-6T	0.0	0.0	0.3	8.8	81.8	6.6	2.5
N2-6B	0.2	0.5	1.5	36.9	57.2	2.0	1.7
N3-1T	0.0	0.0	0.0	5.5	89.2	3.5	1.8
N3-1B	Rocky bottom						
N3-2T	0.0	0.0	0.3	8.8	85.0	4.3	1.8
N3-2B	0.3	0.0	0.3	12.5	82.9	2.6	1.5
N3-3T	0.0	0.0	0.5	10.6	82.2	4.3	2.4
N3-3B	0.0	0.0	0.4	16.7	78.6	2.7	1.6
N3-4T	0.0	0.0	0.8	20.6	75.2	1.8	1.8
N3-4B	0.0	0.0	0.7	17.4	77.2	2.7	1.9
N3-5T	0.5	0.5	2.1	73.8	21.9	0.0	1.4
N3-5B	1.8	1.8	6.8	70.6	17.3	0.0	1.6
N4-1T	0.5	0.7	1.2	9.1	78.7	6.7	3.1
N4-1B	Rocky bottom						
N4-2T	0.5	0.0	0.5	3.2	83.9	7.5	4.3
N4-2B	0.0	0.0	0.0	3.5	86.7	6.5	3.3
N4-3T	0.0	0.2	2.0	32.3	59.4	4.4	1.7
N4-3B	0.0	0.0	0.9	39.5	56.5	1.6	1.4
N4-4T	0.0	0.0	0.8	14.8	80.8	1.8	1.8
N4-4B	0.0	0.0	0.7	33.3	62.9	1.4	1.7
N4-5T	0.0	0.0	0.0	6.2	77.7	12.2	3.9
N4-5B	0.2	0.2	0.7	7.7	56.9	15.8	18.6
N4a-1T	2.1	1.7	2.1	4.6	17.8	14.5	57.3
N4a-1B	0.0	0.0	1.7	9.6	65.0	16.8	6.9
N4a-2T	0.6	1.1	1.7	4.5	31.3	16.2	44.7
N4a-2B	0.0	0.2	0.5	2.2	24.9	14.4	57.9
N4a-3T	0.9	0.9	1.1	11.1	57.6	7.5	21.1
N4a-3B	0.0	0.2	0.6	7.8	48.7	5.6	37.1

Sample no	Percentage						
	>VCS	VCS	CS	MS	FS	VFS	Mud
N5-1T	Rocky bottom						
N5-1B	Rocky bottom						
N5-2T	0.0	0.0	0.5	2.8	62.7	13.5	20.6
N5-2B	0.3	0.3	0.0	0.3	3.0	3.0	93.1
N5-3T	0.2	0.2	0.7	2.8	68.1	13.4	14.6
N5-3B	0.9	0.0	0.0	0.9	4.3	4.3	89.7
N5-4T	3.9	1.6	1.3	3.2	31.5	19.5	39.0
N5-4B	0.2	0.0	1.3	10.1	63.8	12.1	12.5
N5-5T	0.7	0.7	1.1	9.9	53.3	9.4	24.8
N5-5B	1.1	0.3	0.8	6.7	39.4	5.4	46.4
N6-1T	Rocky bottom						
N6-1B	Rocky bottom						
N6-2T	1.1	0.0	0.7	1.1	11.2	8.7	77.3
N6-2B	0.0	0.0	0.0	0.0	0.8	0.8	98.4
N6-3T	0.9	0.0	0.3	1.9	12.8	9.3	74.8
N6-3B	0.4	0.4	0.0	0.4	1.2	1.2	96.4
N6-4T	2.2	0.9	0.9	5.4	55.6	17.5	17.7
N6-4B	8.8	10.2	6.8	4.1	14.3	17.7	38.1
N6-5T	0.8	0.5	1.4	2.7	13.3	15.2	66.1
N6-5B	1.9	1.6	2.7	6.1	29.7	16.7	41.4
N7-1T	Rocky bottom						
N7-1B	Rocky bottom						
N7-2T	0.7	0.0	0.0	0.4	1.1	1.4	96.5
N7-2B	0.0	0.0	0.0	0.0	0.4	0.0	99.6
N7-3T	16.0	0.7	1.0	1.7	3.8	2.8	74.0
N7-3B	Rocky bottom						
N7-4T	13.9	1.5	1.2	1.8	10.6	11.8	59.1
N7-4B	Rocky bottom						
N7-5T	1.9	0.3	1.3	3.0	12.1	14.3	67.1
N7-5B	0.2	0.5	1.6	5.0	29.7	13.8	49.2
N8-1T	Rocky bottom						
N8-1B	Rocky bottom						
N8-2T	0.0	0.0	0.0	0.0	1.0	2.1	96.9
N8-2B	0.0	0.0	0.3	0.0	0.7	1.0	97.9
N8-3T	0.0	0.3	2.0	2.0	1.0	0.3	94.4
N8-3B	2.2	11.1	28.1	24.9	6.9	1.2	25.4
N8-4T	0.2	0.2	0.7	10.4	52.3	16.3	19.9
N8-4B	0.0	0.3	0.5	1.3	22.8	20.1	55.0
N8-5T	1.6	0.8	2.3	7.8	27.5	13.2	46.8
N8-5B	0.5	0.3	0.8	4.6	39.0	16.2	38.7
N9-1T	42.9	7.3	2.5	2.3	7.3	3.6	34.1
N9-1B	Rocky bottom						
N9-2T	13.5	2.2	0.6	0.9	2.5	2.5	77.7
N9-2B	Rocky bottom						
N9-3T	0.0	0.0	0.0	0.0	0.9	0.9	98.2
N9-3B	0.0	0.0	0.0	0.0	0.8	0.4	98.9
N9-4T	0.0	0.0	0.2	0.5	14.2	31.8	53.3
N9-4B	0.3	0.0	0.0	0.3	5.4	9.0	85.1
N9-5T	0.0	0.0	0.9	4.0	51.2	20.9	22.9
N9-5B	0.0	0.0	0.6	2.9	28.0	20.3	48.3

Sample no	Percentage						
	>VCS	VCS	CS	MS	FS	VFS	Mud
N10-1T	Rocky bottom						
N10-1B	Rocky bottom						
N10-2T	0.0	0.0	0.0	0.0	0.9	1.3	97.8
N10-2B	0.0	0.0	0.0	0.0	0.4	0.0	99.6
N10-3T	0.4	0.4	0.8	3.8	5.4	4.6	84.7
N10-3B	0.0	0.0	1.0	34.9	34.4	2.6	27.1
N10-4T	7.1	1.6	1.1	7.6	39.2	12.1	31.3
N10-4B	Rocky bottom						
N10-5T	9.0	9.8	5.3	4.9	21.5	9.6	39.8
N10-5B	8.1	5.0	3.1	4.3	19.3	11.2	49.0
N11-1T	0.0	0.0	0.5	1.0	29.9	21.3	47.3
N11-1B	Rocky bottom						
N11-2T	0.4	1.2	2.0	3.5	40.2	8.6	44.1
N11-2B	0.8	0.6	2.3	9.9	35.5	12.7	38.3
N11-3T	0.8	1.6	1.6	1.6	1.6	1.6	91.0
N11-3B	0.4	0.7	0.7	0.4	0.7	1.1	96.0
N11-4T	0.6	0.3	1.2	3.3	28.8	27.6	38.3
N11-4B	Rocky bottom						
N12-1T	2.6	2.9	2.6	7.3	28.1	12.4	44.2
N12-1B	Rocky bottom						
N12-2T	0.9	1.5	7.8	18.0	25.8	8.7	37.2
N12-2B	Rocky bottom						
N12-3T	2.4	1.8	4.4	8.0	33.0	18.9	31.6
N12-3B	Rocky bottom						
N12-4T	40.4	9.9	13.2	8.6	11.2	3.2	13.5
N12-4B	8.3	16.7	16.7	16.7	16.7	16.7	8.3
N12-5T	2.9	4.7	3.9	6.1	36.9	16.7	28.7
N12-5B	Rocky bottom						
N13-1T	0.2	0.5	0.5	0.9	13.3	12.8	71.8
N13-1B	Rocky bottom						
N13-2T	1.5	1.0	2.4	2.4	9.7	4.9	78.2
N13-2B	Rocky bottom						
N13-3T	0.0	0.0	0.0	0.0	3.2	0.8	96.0
N13-3B	0.8	1.6	1.6	1.6	1.6	1.6	91.1
N13-4T	2.9	0.8	1.9	10.3	48.0	13.8	22.3
N13-4B	Rocky bottom						

SECTION A2 - Settling tube results

Sample no	Percentage						
	>VCS	VCS	CS	MS	FS	VCS	Mud
N1-1T	0.0	0.0	0.0	20.9	74.1	4.4	0.6
N1-1B	0.0	0.1	0.6	18.7	74.7	4.7	1.2
N1-2T	0.0	0.2	0.7	7.2	69.6	20.7	1.6
N1-2B	0.0	0.0	0.4	40.7	54.3	3.6	1.1
N1-3T	Rocky bottom						
N1-3B	Rocky bottom						
N1-4T	0.0	0.3	0.8	12.2	74.6	10.7	1.3
N1-4B	1.2	0.1	0.7	38.6	54.8	3.0	1.6
N2-1T	0.0	0.5	0.0	14.7	80.5	2.4	1.8
N2-1B	0.0	0.0	0.2	0.0	83.3	15.3	1.2
N2-2T	0.3	0.0	0.1	23.7	72.3	2.3	1.3
N2-2B	0.0	0.0	0.2	11.0	84.8	3.0	1.0
N2-3T	0.0	0.5	0.0	9.5	82.3	6.2	1.5
N2-3B	0.0	0.0	0.2	5.6	83.3	9.5	1.4
N2-4T	0.0	0.0	0.8	11.7	78.4	7.4	1.7
N2-4B	0.0	0.6	0.0	35.0	61.7	1.3	1.4
N2-5T	0.0	0.2	0.0	26.0	70.1	2.1	1.5
N2-5B	0.0	0.4	0.2	13.4	81.5	3.0	1.5
N2-6T	0.0	0.0	0.7	3.5	78.8	14.5	2.5
N2-6B	0.2	0.0	0.9	20.2	73.2	3.8	1.7
N3-1T	0.0	0.8	0.0	2.4	79.0	16.0	1.8
N3-1B	Rocky bottom						
N3-2T	0.0	0.0	0.0	6.5	76.2	15.5	1.8
N3-2B	0.3	0.0	0.2	9.0	79.7	9.3	1.5
N3-3T	0.0	0.0	1.0	8.3	71.4	16.9	2.4
N3-3B	0.0	1.0	0.6	12.1	74.6	10.2	1.6
N3-4T	0.0	0.0	0.1	12.3	78.0	7.9	1.8
N3-4B	0.0	0.6	0.5	9.6	74.0	13.4	1.9
N3-5T	0.5	0.0	1.1	64.2	31.8	1.0	1.4
N3-5B	1.8	0.5	3.3	67.6	25.3	0.0	1.6
N4-1T	0.5	0.5	1.6	7.7	71.9	14.8	3.1
N4-1B	Rocky bottom						
N4-2T	0.5	0.9	1.1	2.1	73.0	18.1	4.3
N4-2B	0.0	1.5	0.0	1.9	74.3	18.9	3.3
N4-3T	0.0	0.4	0.7	28.4	65.1	3.7	1.7
N4-3B	0.0	0.2	0.0	29.6	62.6	6.3	1.4
N4-4T	0.0	0.1	0.0	13.0	79.5	5.6	1.8
N4-4B	0.0	0.0	0.9	31.4	64.0	2.0	1.7
N4-5T	0.0	0.0	0.6	6.4	68.8	20.2	3.9
N4-5B	0.2	0.0	0.6	5.9	53.2	21.5	18.6
N4a-1T	2.1	0.0	0.7	3.7	16.6	19.5	57.3
N4a-1B	0.0	0.1	0.7	7.1	52.8	32.5	6.9
N4a-2T	No result						
N4a-2B	No result						
N4a-3T	No result						
N4a-3B	0.0	0.4	0.2	7.6	46.5	8.1	37.1

Sample no	Percentage						
	>VCS	VCS	CS	MS	FS	VFS	Mud
N5-1T	Rocky bottom						
N5-1B	Rocky bottom						
N5-2T	0.0	0.0	1.7	0.6	39.9	37.2	20.6
N5-2B	0.3	0.0	0.4	0.1	2.1	4.0	93.1
N5-3T	0.2	0.0	0.9	1.3	41.6	41.4	14.6
N5-3B	0.9	0.0	0.1	0.8	2.6	5.9	89.7
N5-4T	3.9	0.0	0.5	3.3	24.9	28.4	39.0
N5-4B	0.2	0.0	1.0	8.6	55.8	21.9	12.5
N5-5T	0.7	0.0	1.0	8.6	49.9	15.0	24.8
N5-5B	1.1	0.0	0.5	5.2	36.4	10.3	46.4
N6-1T	Rocky bottom						
N6-1B	Rocky bottom						
N6-2T	1.1	0.5	0.0	0.6	7.4	13.1	77.3
N6-2B	0.0	0.0	0.0	0.1	0.6	0.9	98.4
N6-3T	0.9	0.0	0.2	2.2	9.8	12.1	74.8
N6-3B	0.4	0.1	0.1	0.5	0.8	1.7	96.4
N6-4T	2.2	0.0	0.6	3.4	52.7	23.5	17.7
N6-4B	8.8	0.4	1.3	4.1	16.7	30.6	38.1
N6-5T	0.8	0.1	0.4	1.8	9.8	21.0	66.1
N6-5B	1.9	0.1	3.1	6.0	26.0	21.6	41.4
N7-1T	Rocky bottom						
N7-1B	Rocky bottom						
N7-2T	0.7	0.0	0.0	0.2	1.0	1.6	96.5
N7-2B	0.0	0.0	0.0	0.0	0.1	0.2	99.6
N7-3T	16.0	0.2	1.1	1.5	5.3	1.9	74.0
N7-3B	Rocky bottom						
N7-4T	13.9	0.4	0.5	1.1	7.8	17.2	59.1
N7-4B	Rocky bottom						
N7-5T	1.9	0.2	0.9	3.7	11.0	15.2	67.1
N7-5B	0.2	0.3	2.1	5.2	22.9	20.1	49.2
N8-1T	Rocky bottom						
N8-1B	Rocky bottom						
N8-2T	0.0	0.1	0.0	0.3	1.0	1.8	96.9
N8-2B	0.0	0.0	0.1	0.0	0.7	1.3	97.9
N8-3T	0.0	0.0	1.9	2.7	0.6	0.4	94.4
N8-3B	2.2	5.2	24.7	35.4	5.5	1.5	25.4
N8-4T	0.2	0.1	0.0	7.4	50.1	22.3	19.9
N8-4B	0.0	0.0	0.5	0.3	15.5	28.7	55.0
N8-5T	1.6	0.0	1.8	6.9	25.5	17.5	46.8
N8-5B	0.5	0.2	0.2	3.6	28.0	28.7	38.7
N9-1T	42.9	9.0	2.3	2.0	7.1	2.6	34.1
N9-1B	Rocky bottom						
N9-2T	13.5	4.0	1.0	0.5	1.1	2.2	77.7
N9-2B	Rocky bottom						
N9-3T	0.0	0.1	0.0	0.2	0.6	0.9	98.2
N9-3B	0.0	0.0	0.0	0.1	0.4	0.6	98.9
N9-4T	0.0	0.0	0.3	0.1	6.5	39.8	53.3
N9-4B	0.3	0.0	0.6	0.4	4.5	9.1	85.1
N9-5T	0.0	0.0	0.4	3.5	34.1	39.1	22.9
N9-5B	0.0	0.0	0.5	1.8	19.5	29.9	48.3

Sample no	Percentage						
	>VCS	VCS	CS	MS	FS	VFS	Mud
N10-1T	Rocky bottom						
N10-1B	Rocky bottom						
N10-2T	0.0	0.1	0.0	0.2	0.7	1.3	97.8
N10-2B	0.0	0.0	0.0	0.1	0.1	0.2	99.6
N10-3T	0.4	0.0	0.8	1.6	4.7	7.9	84.7
N10-3B	0.0	0.0	0.7	33.2	35.1	3.8	27.1
N10-4T	7.1	0.3	1.0	6.1	38.5	15.7	31.3
N10-4B	Rocky bottom						
N10-5T	9.0	6.6	7.0	5.6	24.4	7.5	39.8
N10-5B	8.1	2.1	3.9	4.2	16.4	16.3	49.0
N11-1T	0.0	0.1	0.3	0.4	20.6	31.3	47.3
N11-1B	Rocky bottom						
N11-2T	0.4	0.6	0.5	2.9	32.7	18.8	44.1
N11-2B	0.8	0.1	1.9	9.5	31.4	18.1	38.3
N11-3T	0.8	0.0	0.6	0.8	2.1	4.8	91.0
N11-3B	0.4	0.0	0.1	0.3	1.6	1.6	96.0
N11-4T	0.6	1.0	0.5	2.4	16.0	41.1	38.3
N11-4B	Rocky bottom						
N12-1T	2.6	0.4	4.0	9.3	28.8	10.8	44.2
N12-1B	Rocky bottom						
N12-2T	0.9	0.3	6.5	18.5	27.5	9.0	37.2
N12-2B	Rocky bottom						
N12-3T	2.4	0.2	5.0	9.3	29.1	22.4	31.6
N12-3B	Rocky bottom						
N12-4T	40.4	4.6	16.5	10.5	12.3	2.1	13.5
N12-4B	No result						
N12-5T	2.9	5.2	6.4	6.1	33.5	17.2	28.7
N12-5B	Rocky bottom						
N13-1T	0.2	0.0	0.8	0.8	9.5	17.0	71.8
N13-1B	Rocky bottom						
N13-2T	1.5	1.5	2.1	1.5	9.2	6.0	78.2
N13-2B	Rocky bottom						
N13-3T	0.0	0.0	0.3	0.1	2.0	1.6	96.0
N13-3B	0.8	0.0	0.2	2.5	2.1	3.3	91.1
N13-4T	2.9	0.4	0.9	9.2	38.7	25.6	22.3
N13-4B	Rocky bottom						

APPENDIX 1 B

This section lists the statistical parameters of the Nahoon estuary sediments. NOTE that the statistical parameters only apply to the sand size classes. Silt and clay are EXCLUDED from these parameters.

The parameters listed below are as follows:

Med. - The distribution median in PHI-units (Md = P50) *

Mean - The mean grain size in PHI-units (M = (P16 + P84)/2)

Sort - Grain sorting in PHI-units (S = (P84 - P16)/2)

Ske. - Distribution skewness in PHI-units (Sk = (M - Md)/S)

Kurt - Distribution kurtosis in PHI-units

(Ku = (((P95 - P5)/2) - S)/S)

* Px is the xth percentile of the relevant distribution.

PHI = $-\log_2$ (grain size in mm/1 mm)

SECTION B1 - Sieve results

Sample no	MEDN	MEAN	SORT	SKEWN	KURT
N1-1T	2.35	2.33	0.48	-0.05	0.44
N1-1B	2.28	2.27	0.50	-0.03	0.40
N1-2T	2.60	2.48	0.42	-0.28	0.64
N1-2B	2.07	2.13	0.62	0.09	0.47
N1-3T	Rocky bottom				
N1-3B	Rocky bottom				
N1-4T	2.56	2.46	0.43	-0.24	0.58
N1-4B	2.04	2.07	0.63	0.05	0.52
N2-1T	2.53	2.45	0.42	-0.19	0.61
N2-1B	2.70	2.67	0.26	-0.13	0.74
N2-2T	2.25	2.23	0.52	-0.04	0.40
N2-2B	2.36	2.35	0.44	-0.00	0.55
N2-3T	2.53	2.48	0.39	-0.14	0.59
N2-3B	2.56	2.49	0.38	-0.19	0.58
N2-4T	2.38	2.30	0.52	-0.15	0.51
N2-4B	2.02	2.03	0.43	0.02	0.75
N2-5T	1.98	2.01	0.44	0.07	0.82
N2-5B	2.26	2.25	0.49	-0.03	0.44
N2-6T	2.60	2.51	0.40	-0.22	0.76
N2-6B	2.15	2.16	0.54	0.02	0.59
N3-1T	2.63	2.54	0.36	-0.24	0.47
N3-1B	Rocky bottom				
N3-2T	2.61	2.51	0.39	-0.25	0.63
N3-2B	2.54	2.46	0.41	-0.20	0.64
N3-3T	2.60	2.49	0.41	-0.27	0.66
N3-3B	2.49	2.40	0.45	-0.19	0.56
N3-4T	2.37	2.33	0.49	-0.08	0.47
N3-4B	2.45	2.38	0.47	-0.15	0.54
N3-5T	1.77	1.79	0.36	0.08	0.87
N3-5B	1.66	1.60	0.46	-0.14	0.93
N4-1T	2.61	2.50	0.42	-0.26	0.90
N4-1B	Rocky bottom				
N4-2T	2.70	2.65	0.30	-0.19	0.97
N4-2B	2.69	2.62	0.31	-0.22	0.75
N4-3T	2.38	2.24	0.62	-0.22	0.47
N4-3B	2.14	2.17	0.56	0.04	0.51
N4-4T	2.56	2.44	0.43	-0.28	0.66
N4-4B	2.24	2.22	0.56	-0.05	0.46
N4-5T	2.65	2.57	0.40	-0.19	0.94
N4-5B	2.67	2.63	0.51	-0.08	0.97
N4a-1T	2.72	2.62	0.92	-0.11	1.01
N4a-1B	2.65	2.58	0.50	-0.14	1.03
N4a-2T	2.74	2.76	0.68	0.03	1.09
N4a-2B	2.81	2.91	0.65	0.16	0.62
N4a-3T	2.53	2.45	0.48	-0.18	1.05
N4a-3B	2.57	2.48	0.44	-0.19	1.00
N5-1T	Rocky bottom				
N5-1B	Rocky bottom				

Sample no	MEDN	MEAN	SORT	SKEWN	KURT
N5-2T	2.75	2.75	0.29	-0.00	1.49
N5-2B	2.93	2.95	0.65	0.03	2.37
N5-3T	2.74	2.72	0.28	-0.09	1.49
N5-3B	2.94	3.01	0.63	0.12	0.85
N5-4T	2.80	2.82	0.65	0.03	1.21
N5-4B	2.59	2.51	0.46	-0.17	1.06
N5-5T	2.56	2.48	0.48	-0.17	1.19
N5-5B	2.56	2.48	0.46	-0.19	1.08
N6-1T	Rocky bottom				
N6-1B	Rocky bottom				
N6-2T	2.88	2.99	0.53	0.20	1.22
N6-2B	3.00	3.17	0.51	0.33	0.32
N6-3T	2.86	2.88	0.58	0.04	0.91
N6-3B	2.75	2.54	0.89	-0.24	1.57
N6-4T	2.71	2.68	0.52	-0.04	0.95
N6-4B	2.62	1.58	1.79	-0.58	0.27
N6-5T	2.92	2.89	0.81	-0.05	0.89
N6-5B	2.69	2.65	0.81	-0.05	1.02
N7-1T	Rocky bottom				
N7-1B	Rocky bottom				
N7-2T	3.00	2.91	0.77	-0.12	0.43
N7-2B	2.75	2.75	0.17	0.00	0.32
N7-3T	2.45	2.22	1.31	-0.17	0.57
N7-3B	Rocky bottom				
N7-4T	2.88	2.78	0.88	-0.11	1.30
N7-4B	Rocky bottom				
N7-5T	2.93	2.86	0.82	-0.07	0.80
N7-5B	2.73	2.71	0.65	-0.03	1.04
N8-1T	Rocky bottom				
N8-1B	Rocky bottom				
N8-2T	3.38	3.22	0.60	-0.26	0.42
N8-2B	3.00	2.12	1.64	-0.54	0.15
N8-3T	1.19	1.38	0.95	0.20	0.67
N8-3B	0.90	0.92	0.90	0.02	0.74
N8-4T	2.61	2.60	0.57	-0.02	0.85
N8-4B	2.93	3.02	0.59	0.15	0.59
N8-5T	2.61	2.55	0.80	-0.07	0.84
N8-5B	2.73	2.75	0.58	0.03	0.84
N9-1T	1.81	1.19	1.81	-0.34	0.26
N9-1B	Rocky bottom				
N9-2T	2.25	1.47	1.89	-0.42	0.22
N9-2B	Rocky bottom				
N9-3T	3.00	3.00	0.68	0.00	0.32
N9-3B	2.75	2.75	0.51	0.00	0.32
N9-4T	3.31	3.24	0.55	-0.12	0.41
N9-4B	3.20	3.18	0.58	-0.03	0.51
N9-5T	2.76	2.79	0.52	0.04	0.83
N9-5B	2.86	2.90	0.59	0.07	0.74
N10-1T	Rocky bottom				
N10-1B	Rocky bottom				
N10-2T	3.25	3.25	0.55	0.00	0.25
N10-2B	2.75	2.75	0.17	0.00	0.32

Sample no	MEDN	MEAN	SORT	SKEWN	KURT
N10-3T	2.41	2.50	0.98	0.09	0.71
N10-3B	2.01	2.06	0.56	0.09	0.64
N10-4T	2.56	2.56	0.59	-0.01	1.11
N10-4B	Rocky bottom				
N10-5T	2.31	1.47	1.66	-0.51	0.34
N10-5B	2.59	1.99	1.36	-0.44	0.63
N11-1T	2.89	3.02	0.51	0.24	0.74
N11-1B	Rocky bottom				
N11-2T	2.60	2.53	0.46	-0.15	1.92
N11-2B	2.57	2.47	0.71	-0.14	0.86
N11-3T	1.50	1.50	1.70	0.00	0.32
N11-3B	2.00	1.58	1.78	-0.24	0.27
N11-4T	2.93	2.97	0.67	0.06	0.72
N11-4B	Rocky bottom				
N12-1T	2.57	2.43	0.84	-0.17	1.29
N12-1B	Rocky bottom				
N12-2T	2.15	2.00	0.96	-0.16	0.67
N12-2B	Rocky bottom				
N12-3T	2.67	2.50	0.88	-0.19	0.91
N12-3B	Rocky bottom				
N12-4T	1.00	1.21	1.43	0.15	0.38
N12-4B	1.50	1.50	1.70	-0.00	0.32
N12-5T	2.63	2.42	0.87	-0.25	1.33
N12-5B	Rocky bottom				
N13-1T	2.94	3.01	0.61	0.11	0.82
N13-1B	Rocky bottom				
N13-2T	2.54	2.13	1.20	-0.34	0.57
N13-2B	Rocky bottom				
N13-3T	2.75	2.75	0.35	0.00	0.79
N13-3B	1.50	1.50	1.70	0.00	0.32
N13-4T	2.56	2.52	0.59	-0.07	1.07
N13-4B	Rocky bottom				

SECTION B2 - Settling tube results - graphical method

Sample no	Medn	Mean	Sort	Skewn	Kurt
N1-1T	2.37	2.35	0.45	-0.02	0.45
N1-1B	2.39	2.37	0.45	-0.04	0.45
N1-2T	2.76	2.67	0.42	-0.22	0.72
N1-2B	2.15	2.15	0.55	-0.00	0.45
N1-3A	Rocky bottom				
N1-3B	Rocky bottom				
N1-4T	2.58	2.50	0.45	-0.18	0.64
N1-4B	2.12	2.11	0.49	-0.02	0.64
N2-1T	2.48	2.42	0.40	-0.13	0.56
N2-1B	2.80	2.75	0.25	-0.21	0.82
N2-2T	2.30	2.26	0.41	-0.11	0.65
N2-2B	2.46	2.44	0.38	-0.06	0.58
N2-3T	2.52	2.50	0.39	-0.07	0.60
N2-3B	2.64	2.59	0.35	-0.14	0.72
N2-4T	2.51	2.48	0.42	-0.08	0.66
N2-4B	2.13	2.13	0.38	0.01	0.65
N2-5T	2.20	2.21	0.37	0.04	0.63
N2-5B	2.41	2.39	0.37	-0.04	0.68
N2-6T	2.71	2.65	0.34	-0.15	0.83
N2-6B	2.32	2.33	0.44	0.02	0.50
N3-1T	2.74	2.68	0.32	-0.19	0.87
N3-1B	Rocky bottom				
N3-2T	2.73	2.63	0.37	-0.26	0.82
N3-2B	2.59	2.54	0.40	-0.14	0.72
N3-3T	2.72	2.61	0.42	-0.25	0.72
N3-3B	2.61	2.50	0.45	-0.24	0.79
N3-4T	2.55	2.49	0.42	-0.14	0.68
N3-4B	2.62	2.54	0.44	-0.19	0.75
N3-5T	1.88	1.91	0.31	0.09	0.76
N3-5B	1.81	1.79	0.37	-0.07	0.73
N4-1T	2.69	2.58	0.41	-0.26	0.87
N4-1B	Rocky bottom				
N4-2T	2.81	2.78	0.29	-0.12	1.14
N4-2B	2.80	2.74	0.33	-0.17	0.87
N4-3T	2.30	2.28	0.52	-0.03	0.47
N4-3B	2.28	2.30	0.53	0.05	0.51
N4-4T	2.60	2.49	0.42	-0.25	0.62
N4-4B	2.24	2.20	0.46	-0.09	0.60
N4-5T	2.71	2.69	0.43	-0.05	0.81
N4-5B	2.78	2.73	0.49	-0.10	0.77
N4a-1T	2.97	2.87	0.66	-0.14	0.81
N4a-1B	2.84	2.79	0.48	-0.11	0.91
N4a-2T	2.93	2.94	0.54	0.01	0.89
N4a-2B	3.04	3.03	0.59	-0.02	0.62
N4a-3T	2.60	2.51	0.47	-0.19	0.99
N4a-3B	2.59	2.51	0.45	-0.16	0.75
N5-1T	Rocky bottom				
N5-1B	Rocky bottom				

Sample no	Medn	Mean	Sort	Skewn	Kurt
N5-2T	2.97	2.98	0.31	0.03	1.04
N5-2B	3.11	2.99	0.51	-0.23	1.10
N5-3T	2.99	2.98	0.30	-0.03	0.93
N5-3B	3.14	3.04	0.58	-0.17	1.01
N5-4T	3.00	2.96	0.54	-0.08	0.83
N5-4B	2.67	2.65	0.54	-0.04	0.76
N5-5T	2.65	2.60	0.51	-0.11	0.83
N5-5B	2.65	2.61	0.49	-0.09	0.85
N6-1T	Rocky bottom				
N6-1B	Rocky bottom				
N6-2T	3.12	3.05	0.54	-0.13	0.72
N6-2B	3.10	3.13	0.58	0.04	0.48
N6-3T	3.00	2.83	0.61	-0.27	0.68
N6-3B	3.07	2.71	0.89	-0.40	0.61
N6-4T	2.82	2.82	0.41	0.00	0.88
N6-4B	3.11	2.96	0.68	-0.22	0.99
N6-5T	3.17	3.05	0.59	-0.20	0.80
N6-5B	2.78	2.72	0.73	-0.07	0.93
N7-1T	Rocky bottom				
N7-1B	Rocky bottom				
N7-2T	3.16	2.99	0.60	-0.28	0.46
N7-2B	3.17	2.85	0.79	-0.41	1.87
N7-3T	2.45	2.21	0.92	-0.26	0.90
N7-3B	Rocky bottom				
N7-4T	3.21	3.04	0.58	-0.29	0.87
N7-4B	Rocky bottom				
N7-5T	2.98	2.82	0.81	-0.19	0.69
N7-5B	2.85	2.72	0.68	-0.18	0.97
N8-1T	Rocky bottom				
N8-1B	Rocky bottom				
N8-2T	3.23	3.02	0.82	-0.26	1.02
N8-2B	3.26	3.15	0.67	-0.16	0.31
N8-3T	1.26	1.40	0.66	0.21	0.66
N8-3B	1.13	1.10	0.73	-0.04	0.74
N8-4T	2.72	2.70	0.55	-0.04	0.70
N8-4B	3.17	3.13	0.48	-0.09	0.58
N8-5T	2.74	2.69	0.71	-0.08	0.77
N8-5B	2.96	2.97	0.57	0.01	0.78
N9-1T	1.12	1.13	1.72	0.00	0.20
N9-1B	Rocky bottom				
N9-2T	0.77	1.44	1.91	0.35	0.16
N9-2B	Rocky bottom				
N9-3T	2.95	2.77	0.95	-0.19	0.60
N9-3B	3.14	3.03	0.73	-0.15	0.25
N9-4T	3.48	3.42	0.40	-0.14	0.60
N9-4B	3.25	3.12	0.64	-0.19	0.86
N9-5T	3.01	2.95	0.49	-0.12	0.79
N9-5B	3.11	3.05	0.55	-0.11	0.64
N10-1T	Rocky bottom				
N10-1B	Rocky bottom				
N10-2T	3.17	3.03	0.74	-0.19	0.49
N10-2B	2.85	1.47	2.14	-0.65	0.06

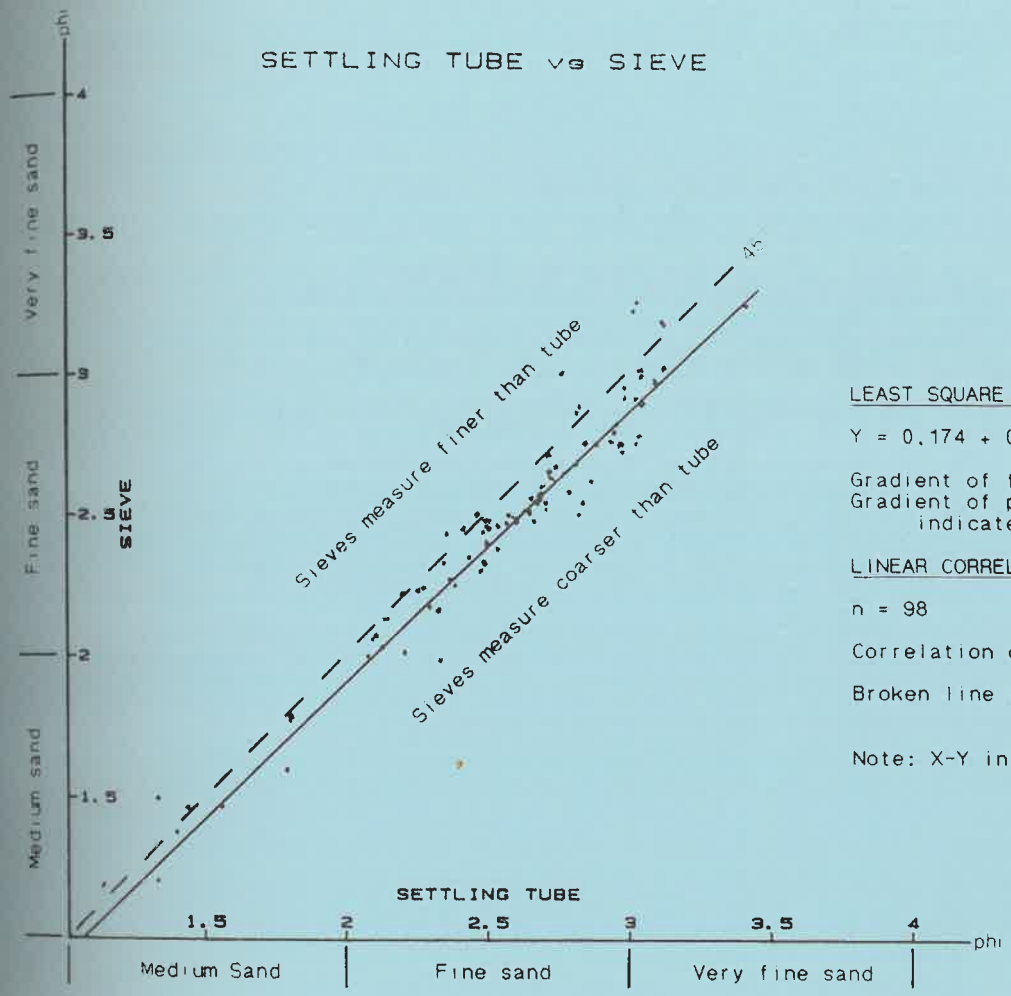
Sample no	Medn	Mean	Sort	Skewn	Kurt
N10-3T	3.08	2.83	0.82	-0.30	0.75
N10-3B	2.05	2.10	0.49	0.11	0.70
N10-4T	2.63	2.66	0.58	0.05	0.83
N10-4B	Rocky bottom				
N10-5T	2.38	1.56	1.42	-0.58	0.42
N10-5B	2.77	2.34	1.09	-0.39	0.73
N11-1T	3.11	3.13	0.47	0.04	0.62
N11-1B	Rocky bottom				
N11-2T	2.82	2.84	0.49	0.03	1.13
N11-2B	2.66	2.57	0.70	-0.14	0.76
N11-3T	3.11	2.88	0.86	-0.27	0.71
N11-3B	2.86	2.87	0.73	0.02	0.43
N11-4T	3.23	3.10	0.56	-0.22	0.97
N11-4B	Rocky bottom				
N12-1T	2.49	2.36	0.76	-0.18	0.97
N12-1B	Rocky bottom				
N12-2T	2.22	2.08	0.89	-0.16	0.64
N12-2B	Rocky bottom				
N12-3T	2.73	2.47	0.86	-0.31	0.81
N12-3B	Rocky bottom				
N12-4T	1.13	1.33	1.19	0.17	0.40
N12-4B	Rocky bottom				
N12-5T	2.61	2.06	1.15	-0.48	0.65
N12-5B	Rocky bottom				
N13-1T	3.16	3.05	0.61	-0.18	0.62
N13-1B	Rocky bottom				
N13-2T	2.62	2.14	1.23	-0.40	0.58
N13-2B	Rocky bottom				
N13-3T	2.90	2.89	0.60	-0.02	1.42
N13-3B	2.55	2.85	1.02	0.30	0.10
N13-4T	2.75	2.71	0.66	-0.05	0.76
N13-4B	Rocky bottom				

SECTION B3 - Settling tube results - moment statistical method

Sample no	Medn	Mean	Sort	Skewn	Kurt
N1-1T	2.37	2.36	0.41	-0.27	6.43
N1-1B	2.39	2.37	0.46	-1.53	12.96
N1-2T	2.76	2.68	0.49	-1.66	10.87
N1-2B	2.15	2.17	0.48	1.08	-2.84
N1-3T	Rocky bottom				
N1-3B	Rocky bottom				
N1-4T	2.58	2.50	0.52	-2.07	13.52
N1-4B	2.12	2.12	0.51	-0.07	4.01
N2-1T	2.48	2.42	0.42	-2.29	16.98
N2-1B	No results				
N2-2T	2.30	2.29	0.35	2.41	-20.20
N2-2B	2.46	2.44	0.34	0.15	-3.98
N2-3T	2.52	2.49	0.37	-2.24	17.74
N2-3B	2.64	2.61	0.32	2.29	-29.15
N2-4T	2.51	2.49	0.39	0.59	-5.04
N2-4B	2.13	2.12	0.42	-1.40	15.05
N2-5T	2.20	2.22	0.35	1.28	-5.83
N2-5B	2.41	2.37	0.42	-2.87	23.70
N2-6T	2.71	2.68	0.33	1.85	-9.26
N2-6B	2.32	2.33	0.40	1.81	-10.41
N3-1T	2.74	2.70	0.35	-0.22	-5.37
N3-1B	Rocky bottom				
N3-2T	2.73	2.67	0.35	1.19	-17.13
N3-2B	2.59	2.55	0.39	-0.47	-0.86
N3-3T	2.72	2.65	0.34	4.19	-52.74
N3-3B	2.61	2.50	0.53	-1.94	9.88
N3-4T	2.55	2.51	0.42	-0.89	8.88
N3-4B	2.62	2.55	0.50	-1.53	10.27
N3-5T	1.88	1.91	0.30	5.50	-30.85
N3-5B	1.81	1.78	0.45	-1.43	13.04
N4-1T	2.69	2.58	0.55	-2.31	13.32
N4-1B	Rocky bottom				
N4-2T	2.81	2.75	0.51	-3.41	22.39
N4-2B	2.80	2.72	0.54	-3.82	24.88
N4-3T	2.30	2.28	0.51	-0.45	4.66
N4-3B	2.28	2.29	0.49	-0.13	4.79
N4-4T	2.60	2.52	0.40	-0.48	2.47
N4-4B	2.24	2.22	0.43	0.46	-1.70
N4-5T	2.71	2.69	0.43	1.06	-9.49
N4-5B	2.78	2.76	0.42	2.71	-21.58
N4a-1T	2.97	2.84	0.76	-1.57	7.57
N4a-1B	2.84	2.78	0.55	-0.91	4.21
N4a-2T	2.93	2.89	0.64	-1.63	9.69
N4a-2B	3.04	2.99	0.64	-1.39	7.37
N4a-3T	2.60	2.54	0.55	-0.64	3.67
N4a-3B	2.59	2.54	0.53	-1.29	8.72
N5-1T	Rocky bottom				
N5-1B	Rocky bottom				

Sample no	Medn	Mean	Sort	Skewn	Kurt
N5-2T	2.97	2.92	0.55	-3.39	21.80
N5-2B	3.11	2.97	0.62	-1.06	0.87
N5-3T	2.99	2.94	0.44	-3.34	27.28
N5-3B	3.14	3.02	0.63	-0.84	1.73
N5-4T	3.00	2.94	0.53	0.24	-4.30
N5-4B	2.67	2.64	0.56	-0.38	2.65
N5-5T	2.65	2.62	0.50	0.97	-6.68
N5-5B	2.65	2.61	0.55	-0.65	5.33
N6-1T	Rocky bottom				
N6-1B	Rocky bottom				
N6-2T	3.12	3.01	0.68	-2.40	13.35
N6-2B	3.10	3.09	0.51	0.25	-3.72
N6-3T	3.00	2.87	0.60	-0.60	1.91
N6-3B	3.07	2.85	0.84	-1.10	3.29
N6-4T	2.82	2.82	0.39	2.60	-22.52
N6-4B	3.11	2.93	0.81	-1.64	6.67
N6-5T	3.17	3.05	0.63	-1.01	3.18
N6-5B	2.78	2.67	0.79	-0.81	3.03
N7-1T	Rocky bottom				
N7-1B	Rocky bottom				
N7-2B	3.17	2.78	1.20	-2.03	6.80
N7-3T	2.45	2.27	0.98	-0.85	3.38
N7-3B	Rocky bottom				
N7-4T	3.21	3.03	0.72	-1.79	7.19
N7-4B	Rocky bottom				
N7-5T	2.98	2.81	0.86	-1.17	4.60
N7-5B	2.85	2.70	0.79	-1.32	5.42
N8-1T	Rocky bottom				
N8-1B	Rocky bottom				
N8-2T	3.23	2.98	0.94	-1.50	5.67
N8-2B	3.26	3.20	0.46	4.33	-43.07
N8-3T	1.26	1.40	0.75	1.38	4.82
N8-3B	1.13	1.14	0.76	0.53	3.95
N8-4T	2.72	2.71	0.52	0.73	-4.08
N8-4B	3.17	3.12	0.55	-2.46	17.62
N8-5T	2.74	2.66	0.73	-0.64	3.21
N8-5B	2.96	2.92	0.63	-1.31	7.00
N9-1T	1.12	1.14	1.56	0.11	1.42
N9-1B	Rocky bottom				
N9-2T	0.77	1.22	1.67	0.32	1.46
N9-2B	Rocky bottom				
N9-3T	2.95	2.79	0.96	-1.24	4.70
N9-3B	Rocky bottom				
N9-4T	3.48	3.42	0.30	9.12	-160.76
N9-4B	3.25	3.11	0.62	0.47	-11.25
N9-5T	3.01	2.93	0.57	-1.52	8.68
N9-5B	3.11	3.04	0.56	-0.96	4.80
N10-1T	Rocky bottom				
N10-1B	Rocky bottom				
N10-2T	3.17	3.05	0.68	-0.67	3.10
N10-2B	2.85	2.45	1.32	-1.39	4.33
N10-3T	3.08	2.82	0.88	-0.92	3.36

Sample no	Medn	Mean	Sort	Skewn	Kurt
N10-3B	2.05	2.10	0.54	0.68	4.23
N10-4T	2.63	2.61	0.69	-1.24	7.30
N10-4B	Rocky bottom				
N10-5T	2.38	1.89	1.29	-0.71	2.25
N10-5B	2.77	2.46	1.09	-1.03	3.11
N11-1T	3.11	3.09	0.54	-2.05	14.31
N11-1B	Rocky bottom				
N11-2T	2.82	2.77	0.65	-1.60	8.48
N11-2B	2.66	2.57	0.71	-0.56	2.51
N11-3T	3.11	2.88	0.79	-0.91	5.70
N11-3B	2.86	2.83	0.81	-1.66	8.67
N11-4T	3.23	3.07	0.75	-2.23	9.97
N11-4B	Rocky bottom				
N12-1T	2.49	2.36	0.85	-0.94	4.08
N12-1B	Rocky bottom				
N12-2T	2.22	2.12	0.88	-0.41	2.76
N12-2B	Rocky bottom				
N12-3T	2.73	2.54	0.91	-1.07	3.92
N12-3B	Rocky bottom				
N12-4T	1.13	1.28	1.08	0.24	2.14
N12-4B	Rocky bottom				
N12-5T	2.61	2.28	1.12	-1.12	3.39
N12-5B	Rocky bottom				
N13-1T	3.16	3.05	0.65	-1.12	3.93
N13-1B	Rocky bottom				
N13-2T	2.62	2.35	1.12	-0.97	3.05
N13-2B	Rocky bottom				
N13-3T	2.90	2.85	0.66	-1.45	9.03
N13-3B	Rocky bottom				
N13-4T	2.75	2.69	0.71	-1.02	5.68
N13-4B	Rocky bottom				



LEAST SQUARE DATA POINT FIT

Y = 0.174 + 0.988X n = 98

Gradient of fit indicated by solid line
Gradient of perfect fit (45 degrees) indicated by broken line

LINEAR CORRELATION

n = 98

Correlation coefficient, r = 0.968

Broken line indicates r = 1

Note: X-Y intercept on graph is 1.1

APPENDIX 1 C

This section lists the respective contents of $CaCO_3$ and of ashed organic material.

The parameters listed below are as follows:

% Carb. - The percentage (m/m) of carbonate in the sediment samples expressed as $CaCO_3$.

% Org C - The percentage organic material in the samples.

The "tr" occurring in some columns denotes trace amounts of carbonate. The sample effervesced when the acid was added but the carbonate content was too low to register a reading.

Only those samples that could be analysed are given, e.g. gravel or bedrock sample sites are excluded.

Sample number	% Carb.	% Org C
N1-1T	29.5	1.11
N1-1B	48.0	0.95
N1-2T	31.5	1.06
N1-2B	59.2	1.20
N1-4T	34.0	0.97
N1-4B	51.8	1.25
N2-1T	32.4	0.92
N2-1B	27.1	0.94
N2-2T	38.4	0.89
N2-2B	39.9	0.90
N2-3T	38.1	0.99
N2-3B	41.2	1.15
N2-4T	65.9	1.84
N2-4B	31.1	0.93
N2-5T	48.4	1.21
N2-5B	43.3	1.29
N2-6T	57.6	1.57
N2-6B	47.2	1.09
N3-1T	37.5	0.76
N3-2T	35.9	1.15
N3-2B	40.6	1.23
N3-3T	45.7	1.29
N3-3B	26.2	1.15
N3-4T	39.1	1.16
N3-4B	27.9	1.22
N3-5T	44.9	0.96
N3-5B	44.9	1.53
N4-1T	21.5	0.90
N4-2T	26.1	1.65
N4-2B	39.9	1.40
N4-3T	45.3	1.28
N4-3B	43.4	0.97
N4-4T	48.5	1.18
N4-4B	35.6	1.07
N4-5T	12.7	0.98
N4-5B	16.4	2.18
N4a-1T	2.7	5.10
N4a-1B	1.6	0.76
N4a-2T	3.4	3.74
N4a-2B	6.0	2.59
N4a-3T	21.9	2.21
N4a-3B	12.6	3.06
N5-2T	29.9	1.96
N5-2B	1.9	6.12
N5-3T	30.4	2.88
N5-3B	2.4	5.23
N5-4T	1.9	3.40
N5-4B	3.8	0.94
N5-5T	17.1	1.66
N5-5B	12.2	3.13

Sample number	%Carb.	%Org C
N6-2T	1.6	4.59
N6-2B	2.5	5.69
N6-3T	2.5	5.19
N6-3B	2.6	6.39
N6-4T	3.6	2.20
N6-4B	1.6	14.45
N6-5T	5.1	2.10
N6-5B	3.8	2.36
N7-2T	tr	5.23
N7-2B		6.86
N7-3T	tr	4.06
N7-4T	tr	3.55
N7-5T		3.64
N7-5B		2.38
N8-2T	No $CaCO_3$% was observed	5.85
N8-2B	for the remainder of the	5.38
N8-3T	samples	7.43
N8-3B		2.26
N8-4T		1.19
N8-4B		3.44
N8-5T		2.56
N8-5B		2.89
N9-1T		2.03
N9-2T		5.24
N9-3T		6.73
N9-3B		6.95
N9-4T		2.85
N9-4B		5.81
N9-5T		2.31
N9-5B		2.78
N10-2T		8.23
N10-2B		7.74
N10-3T		6.82
N10-3B		2.42
N10-4T		2.52
N10-5T		2.45
N10-5B		2.80
N11-1T		3.27
N11-2T		6.05
N11-2B		2.78
N11-3T		10.60
N11-3B		7.57
N11-4T		9.77
N12-1T		3.16
N12-2T		3.18
N12-3T		3.45
N12-4T		2.21
N12-5T		2.28
N13-1T		3.31

Sample number	%Carb.	%Org C
N13-2T		8.09
N13-3T		9.67
N13-3B		9.31
N13-4T		2.49

APPENDIX 2

This section lists the cross section information of the Nahoon estuary. The section positions are given on figure 4-1. Part A lists the vertical section co-ordinates with respect to mid-tide level. Part B gives the cross section diagrams and Part C shows the respective cross-sectional areas, channel widths and hydraulic radii of the channel sections using mid-tide level as datum.

APPENDIX 2 A

This section gives the section co-ordinates for channel profiles measured in the Nahoon estuary. The positions of the sections are indicated on figure 4-1. The datum, mid-tide level, was calculated from the water level at each station and interpolated between tide gauges (fig 4-1). the water level at a given time with the tide level at that time.

CROSS-SECTION CO-ORDINATES FOR THE NAHOON ESTUARY"

Co-ordinates for Section 1

Distance	Height (MTL)
-18.0	1.00
-1.0	0.70
0.0	0.15
13.6	-0.06
51.0	-0.16
52.6	-0.54
56.2	-1.14
63.8	-1.34
76.2	-0.90
89.4	-0.88
105.7	-0.99
112.5	-0.50
117.0	-0.17
124.2	0.68
125.0	1.00

This line has 15 stations

Co-ordinates for Section 2

Distance	Height (MTL)
0.0	0.79
9.5	0.44
11.8	0.37
34.2	0.00
42.7	-0.1
61.2	-0.29
72.6	-0.45
81.8	-1.12
86.7	-1.61
97.6	-2.07
104.2	-2.18
119.7	-2.00
126.3	-1.56
131.1	-0.49
156.2	-0.16
174.7	-0.18
178.2	0.04
213.7	0.02
229.2	-0.50
244.2	-0.93
259.2	-0.99
284.7	-1.45
293.7	-1.01
300.7	-0.50
336.7	-0.53
370.7	-0.24
372.7	0.70

This line has 27 stations

Co-ordinates for section 3

Distance	Height (MTL)
0.0	1.06
2.4	0.23
3.9	-0.40
5.9	-1.05
10.4	-2.58
16.4	-3.37
24.4	-3.98
29.4	-4.23
34.4	-4.26
44.4	-4.16
50.4	-3.76
58.4	-3.47
66.4	-3.25
72.9	-3.03
79.4	-2.74
87.4	-2.50
97.4	-2.28
102.4	-2.02
111.8	-1.84
120.4	-1.36
128.4	-1.20
139.6	-1.14
144.4	-0.58
152.7	-0.71
155.5	-0.46
160.7	-0.11
162.4	0.34
171.7	0.55
174.1	1.21

This line has 29 stations

Co-Ordinates for Section 4

Distance	Height (MTL)
0.0	0.58
2.5	0.36
3.5	0.32
4.0	0.23
4.0	-0.03
6.7	-0.24
13.8	-0.61
19.8	-1.41
26.5	-1.96
31.5	-2.16
42.0	-2.85
49.5	-3.62
59.5	-4.79
68.5	-4.92
79.5	-3.61
89.5	-2.91
99.5	-2.26
108.5	-1.87

126.0	-0.17
145.5	0.48

This line has 20 stations

Co-ordinates for Section 5

Distance	Height (MTL)
0.0	-0.13
1.2	-0.81
6.1	-2.14
14.1	-2.72
22.2	-3.26
30.6	-3.14
40.2	-3.38
47.6	-3.54
53.1	-2.87
60.6	-2.40
68.9	-1.47
75.1	-0.97
75.7	-0.94
80.4	-0.46
80.9	-0.02
84.6	0.66
86.6	0.48
89.1	0.66

This line has 18 stations

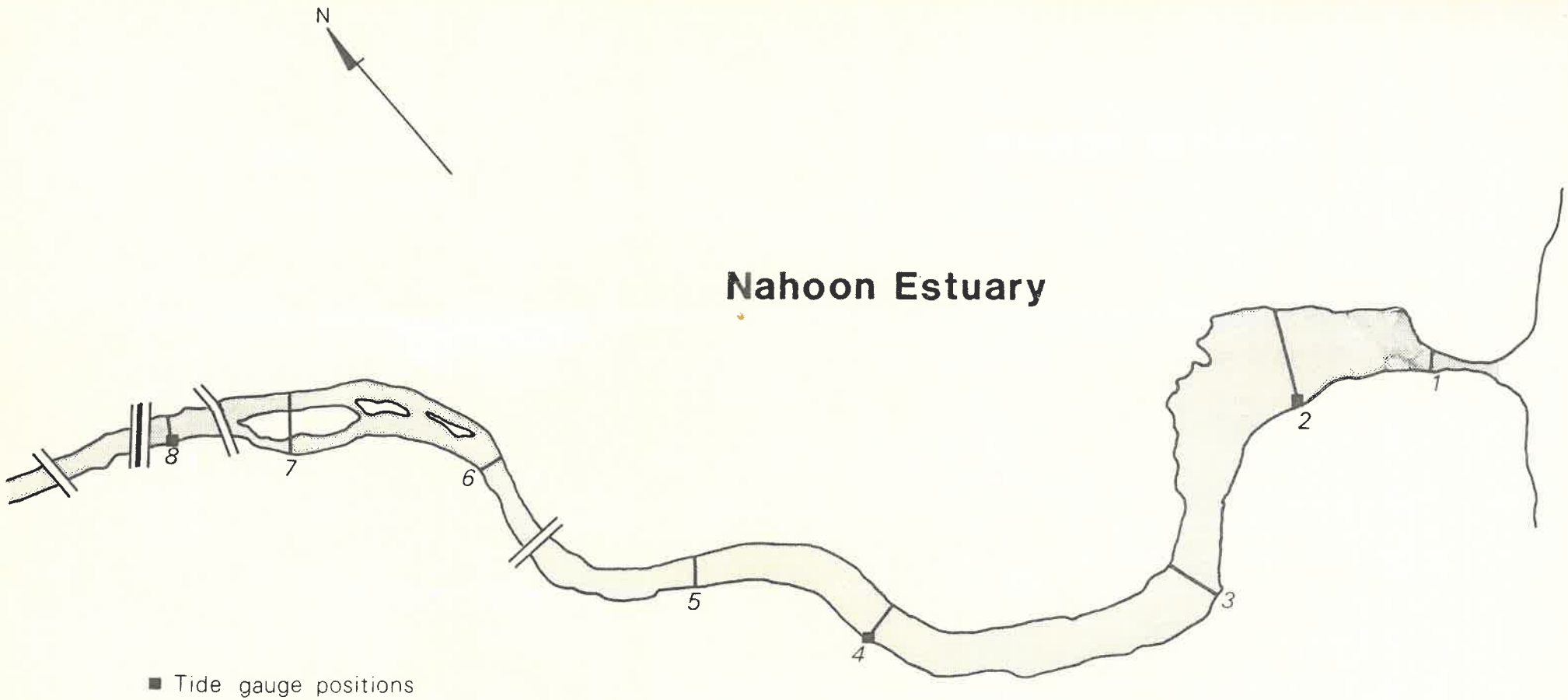
Co-ordinates for Section 6

Distance	Height (MTL)
0.0	1.10
2.0	1.10
2.3	0.10
6.7	-0.68
12.0	-1.46
21.5	-2.40
31.5	-4.56
42.0	-4.46
51.5	-3.96
60.0	-5.66
65.0	-4.76
66.0	-0.98
66.0	0.04

This line has 13 stations

APPENDIX 2 B

The following diagrams illustrate the sections (fig 4-1) across the Nahoon estuary channel. All sections are viewed up-estuary and are shaded below the mid-tide level.

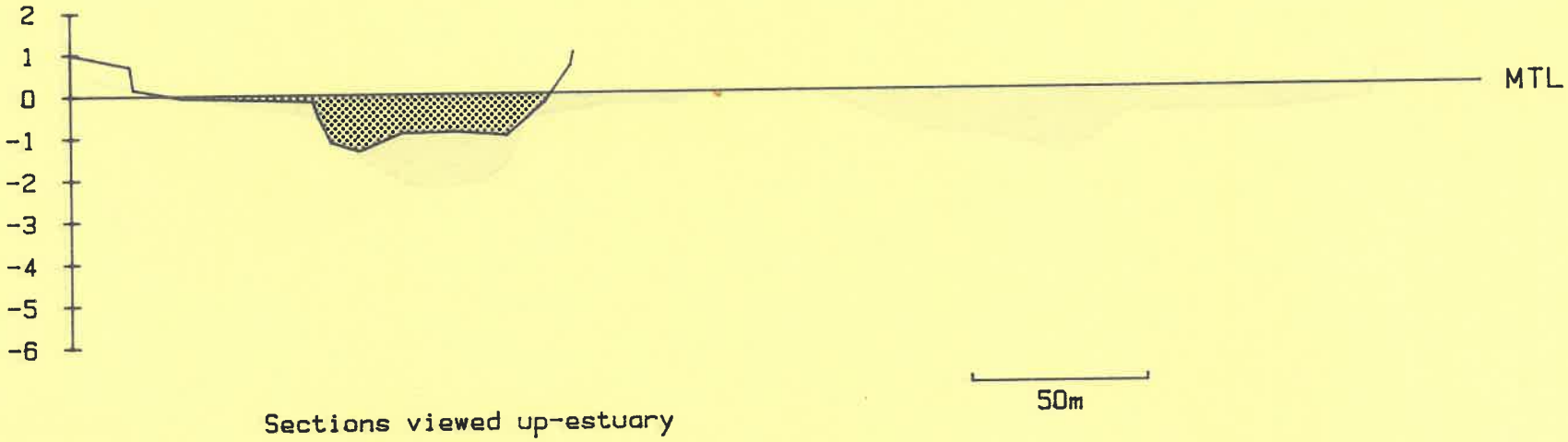


Cross Sections Surveyed

Fig 4-1

Section 1.

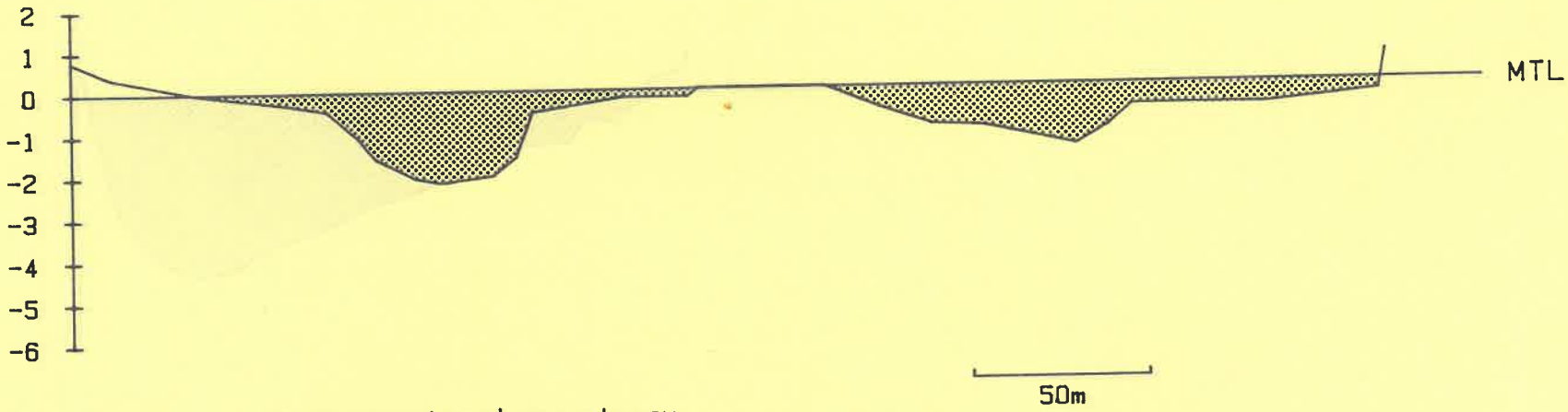
NAHOON ESTUARY



Sections viewed up-estuary

Section 2.

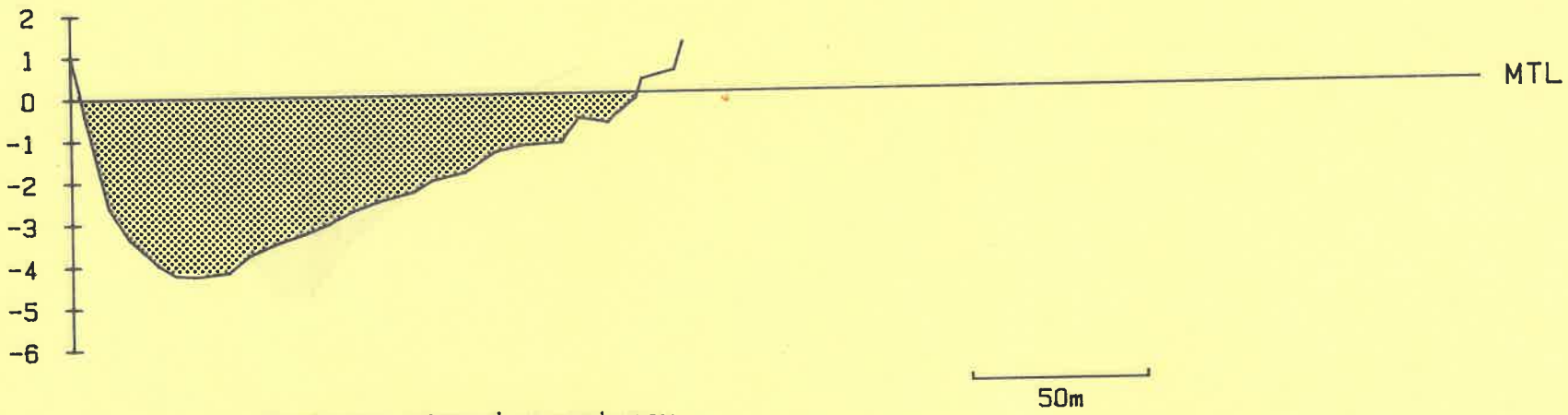
NAHOON ESTUARY



Sections viewed up-estuary

Section 3.

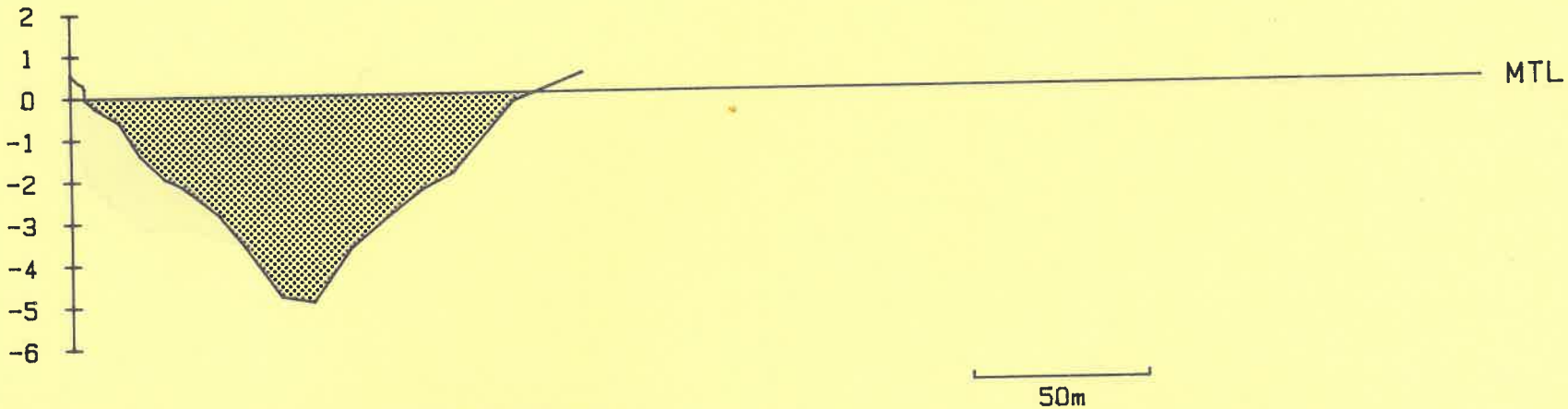
NAHOON ESTUARY



Sections viewed up-estuary

Section 4.

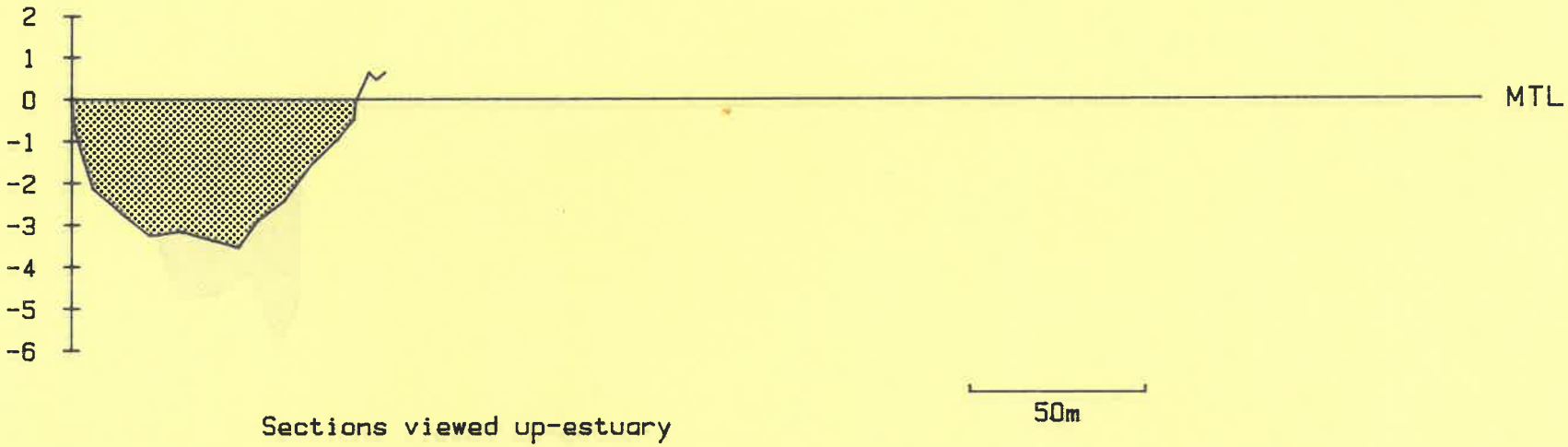
NAHOON ESTUARY



Sections viewed up-estuary

Section 5.

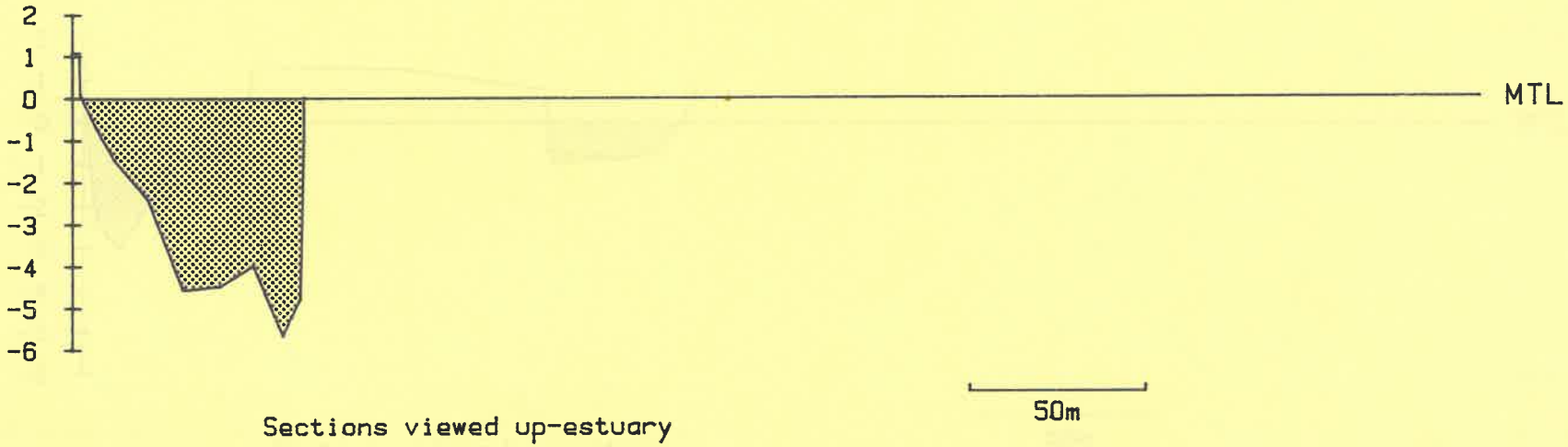
NAHOON ESTUARY



Sections viewed up-estuary

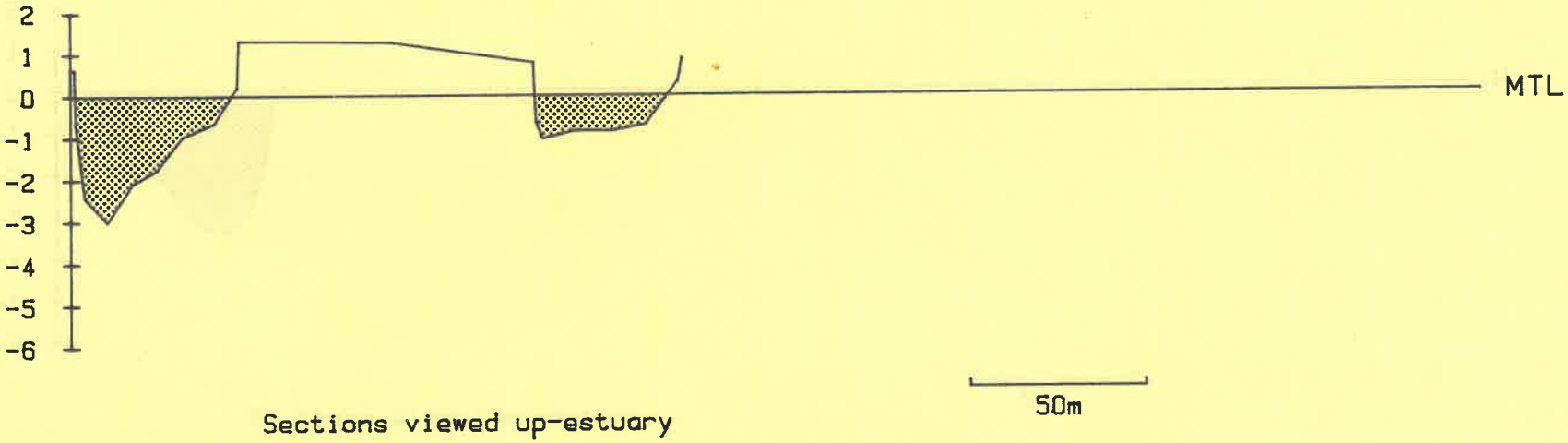
Section 6.

NAHOON ESTUARY



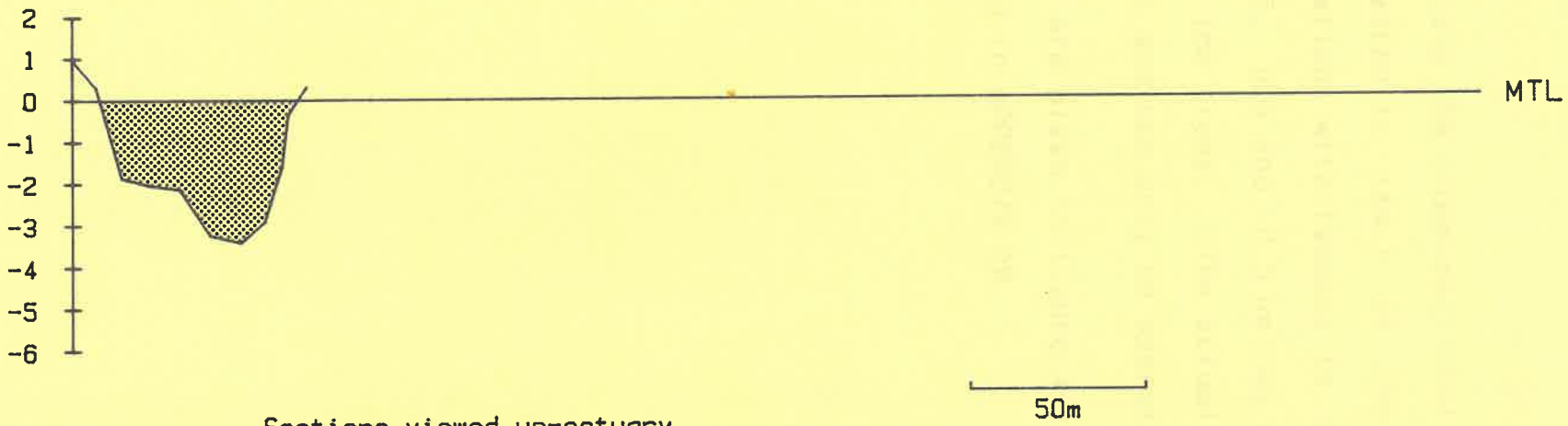
Section 7.

NAHOON ESTUARY



Section 8.

NAHOON ESTUARY



Sections viewed up-estuary

APPENDIX 2 C

This section lists the cross-sectional areas, effective channel widths and hydraulic radii of the Nahoon estuary channels at different elevations with respect to the mid-tide level. The levels at 0.5, 0.0 and -0.5 metres correspond approximately to high, mid- and low tides. (The actual levels change along the estuary channel and can only be approximated.)

Line positions are given in figure 4-1. The different sections are illustrated in APPENDIX 2B.

CROSS SECTION INFORMATION FOR THE NAHOON ESTUARY

Elevations in the left hand column (ELEV.) are wrt MSL

Cross section data for line 1

ELEV (m)	X-AREA (m)	HYDR R (m)	WIDTH (m)
1.00	189.6	1.32	143.0
0.50	124.5	1.01	123.3
0.00	64.8	0.60	108.7
-0.50	28.4	0.47	60.1
-1.00	3.5	0.19	18.0

Cross section data for line 2

ELEV (m)	X-AREA (m)	HYDR R (m)	WIDTH (m)
1.00	585.0	1.57	372.7
0.50	399.9	1.10	364.4
0.00	224.9	0.75	300.3
-0.50	105.3	0.62	168.8
-1.00	48.9	0.59	82.7

Cross section data for line 3

ELEV (m)	X-AREA (m)	HYDR R (m)	WIDTH (m)
1.00	549.2	3.15	173.2
0.50	463.5	2.75	167.9
0.00	383.1	2.41	158.2
-0.50	305.6	2.02	150.8
-1.00	235.2	1.74	135.1

Cross section data for line 4

ELEV (m)	X-AREA (m)	HYDR R (m)	WIDTH (m)
1.00	450.0	3.08	145.5
0.50	377.3	2.60	144.6
0.00	309.6	2.43	127.1
-0.50	250.3	2.25	110.9
-1.00	197.7	1.96	100.7

Cross section data for line 5

ELEV (m)	X-AREA (m)	HYDR R (m)	WIDTH (m)
1.00	285.6	3.18	89.1
0.50	241.4	2.84	84.2
0.00	200.2	2.45	81.0
-0.50	160.0	2.01	79.4
-1.00	121.9	1.67	72.8

Cross section data for line 6

ELEV (m)	X-AREA (m)	HYDR R (m)	WIDTH (m)
1.00	281.1	4.06	64.0
0.50	249.1	3.63	63.8
0.00	217.3	3.21	63.1
-0.50	186.4	2.90	60.3
-1.00	157.0	2.59	57.1

Cross section data for line 7

ELEV (m)	X-AREA (m)	HYDR R (m)	WIDTH (m)
1.00	188.7	1.70	107.7
0.50	142.3	1.58	87.5
0.00	99.5	1.19	82.0
-0.50	60.7	0.82	73.2
-1.00	32.4	1.04	30.6

Cross section data for line 8

ELEV (m)	X-AREA (m)	HYDR R (m)	WIDTH (m)
1.00	188.0	2.77	66.8
0.50	155.8	2.48	61.9
0.00	126.1	2.20	56.4
-0.50	99.3	1.89	51.8
-1.00	74.0	1.48	49.4