

Research on Sedimentation in Estuaries

SEDIMENTATION
IN THE KABELJOUS ESTUARY

ROSIE REPORT No 8

By: JSV Reddering
K Esterhuysen

Project leader: IC Rust



Department of Geology
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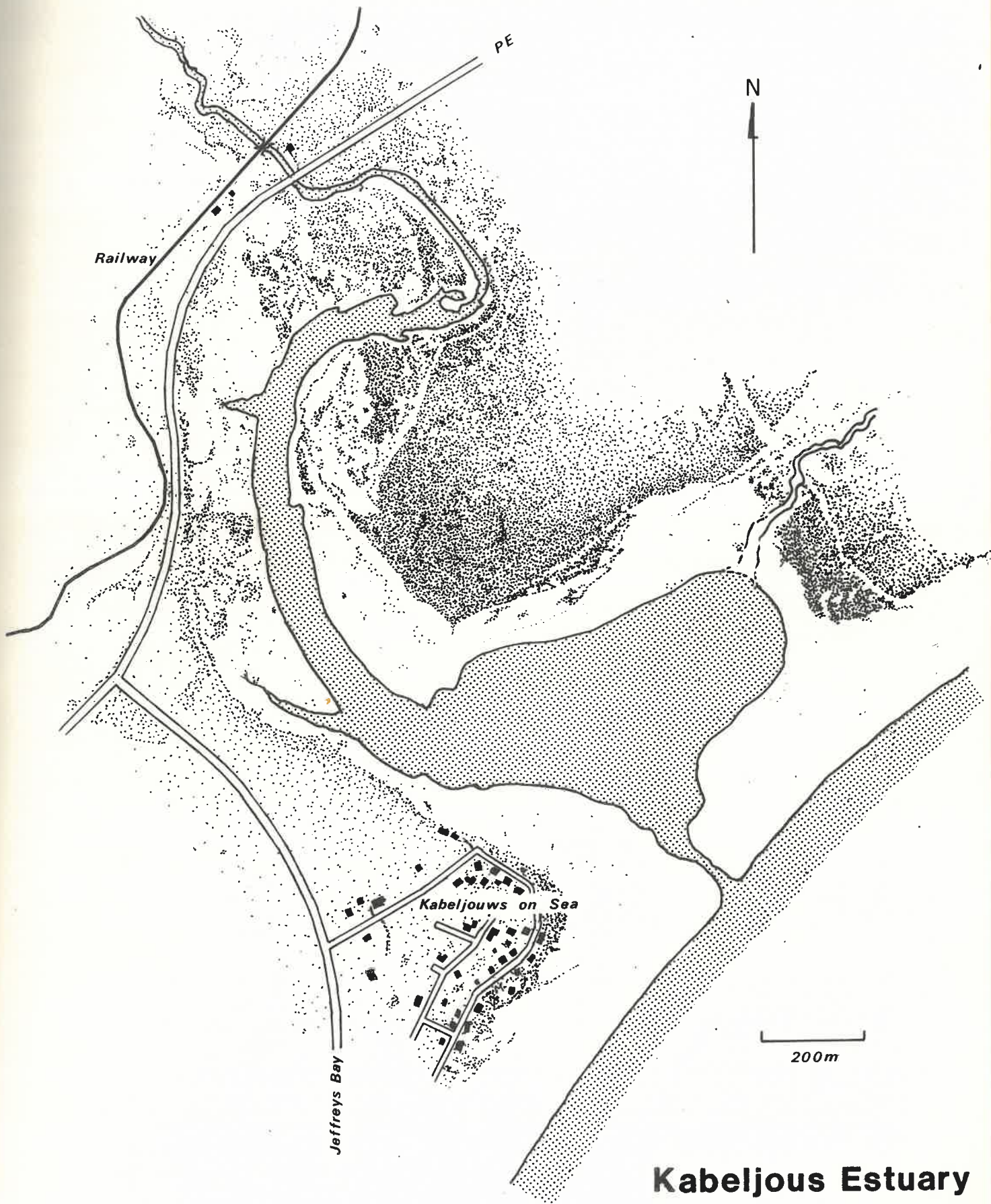
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ABSTRACT

The Kabeljous estuary is small, predominantly sandy and has a periodically blocked inlet. It lies in the eastern Cape just north of Jeffreys Bay.

The sediment in the Kabeljous estuary becomes progressively coarser-grained up-estuary from the inlet. Sand consisting predominantly of quartz and skeletal calcium carbonate enters the estuary from the sea by the action of tide, wind and barrier overwash. Sediment in the upper estuary is land-derived and consists of quartzite pebbles, sand and mud. Organic material in the estuary is largely derived from filamentous algae that grow while the inlet is blocked and all tidal action ceases.

The estuary is practically in its natural state. A large part of it is privately owned and little development has taken place adjacent to it. The sedimentary state of the Kabeljous estuary is superior to that of the nearby Seekoei estuary, which is also locally administered but with injudicious consideration for natural processes.



Kabeljous Estuary

FIG 1.1

SEDIMENTATION IN THE KABELJOUS ESTUARY

1. INTRODUCTION

The Kabeljous estuary is a small system situated on St Francis Bay in the eastern Cape. It lies about 3 km north of Jeffreys Bay, and a small holiday resort, Kabeljouws-on-Sea, lies on the seaward end of its western bank (fig. 1.1).

Land ownership is unusual because sections of the estuary are privately owned. The public do not have free access to these areas.

The catchment area has no major dams and the estuary is largely in its natural state.

The purpose of this study is to:

1. Describe the sediment distribution in the estuary;
2. Compare the state of the Kabeljous estuary with that of the Seekoei estuary, 10 km farther south.

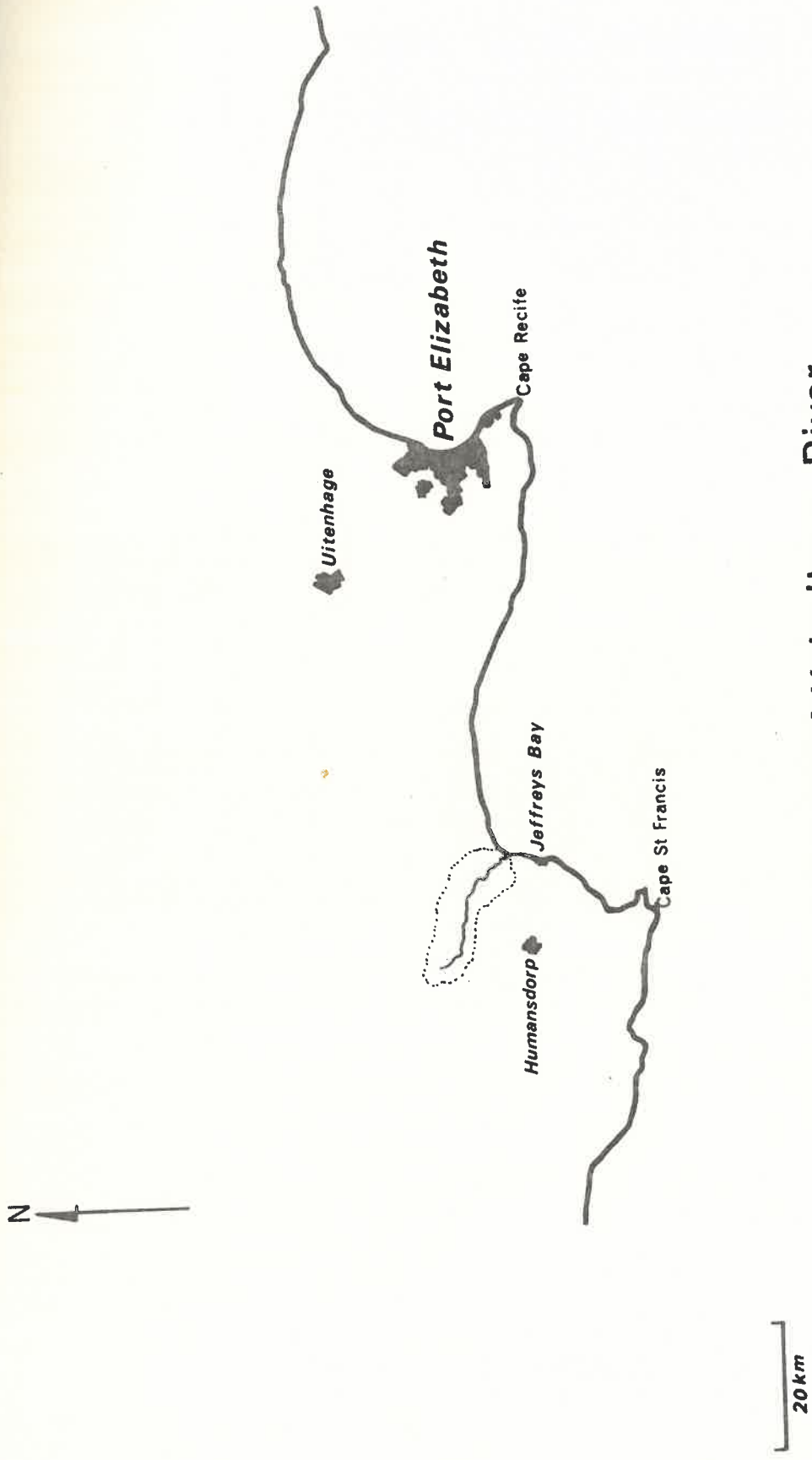
2. BACKGROUND INFORMATION

2.1 Catchment area

This small catchment area (238 km²; 312 km² - Heydorn and Tinley, 1980) lies adjacent to St Francis Bay (fig. 2.1). It is situated between the respective catchment basins of the Seekoei River to the south and the Gamtoos River to the north. The drainage basin lies mostly on a raised coastal marine platform. In the western section steep-sided hills are weathered from Table Mountain quartzite.

The geological structure consists of an anticline with Table Mountain quartzite at the core, and Bokkeveld slate in the flanks (fig. 2.3). To the south-east this succession is unconformably overlain by conglomerate and sandstone of the Mesozoic Gamtoos basin.

Rain falls throughout the year with slight spring and autumn peaks. Precipitation is cyclonic and orographic so that hail and thunder activity are uncommon. Mean annual precipitation is about 450 mm and mean annual runoff is about of $27 \times 10^6 \text{ m}^3$ (Heydorn and Tinley, 1980). South-westerly winds prevail over the area, whereas south-easterlies occur mostly in summer. Hot dry berg winds from the north or north-west blow in late autumn



Location of Kabeljous River
34° 00' S ; 24° 56' E

FIG 2.1

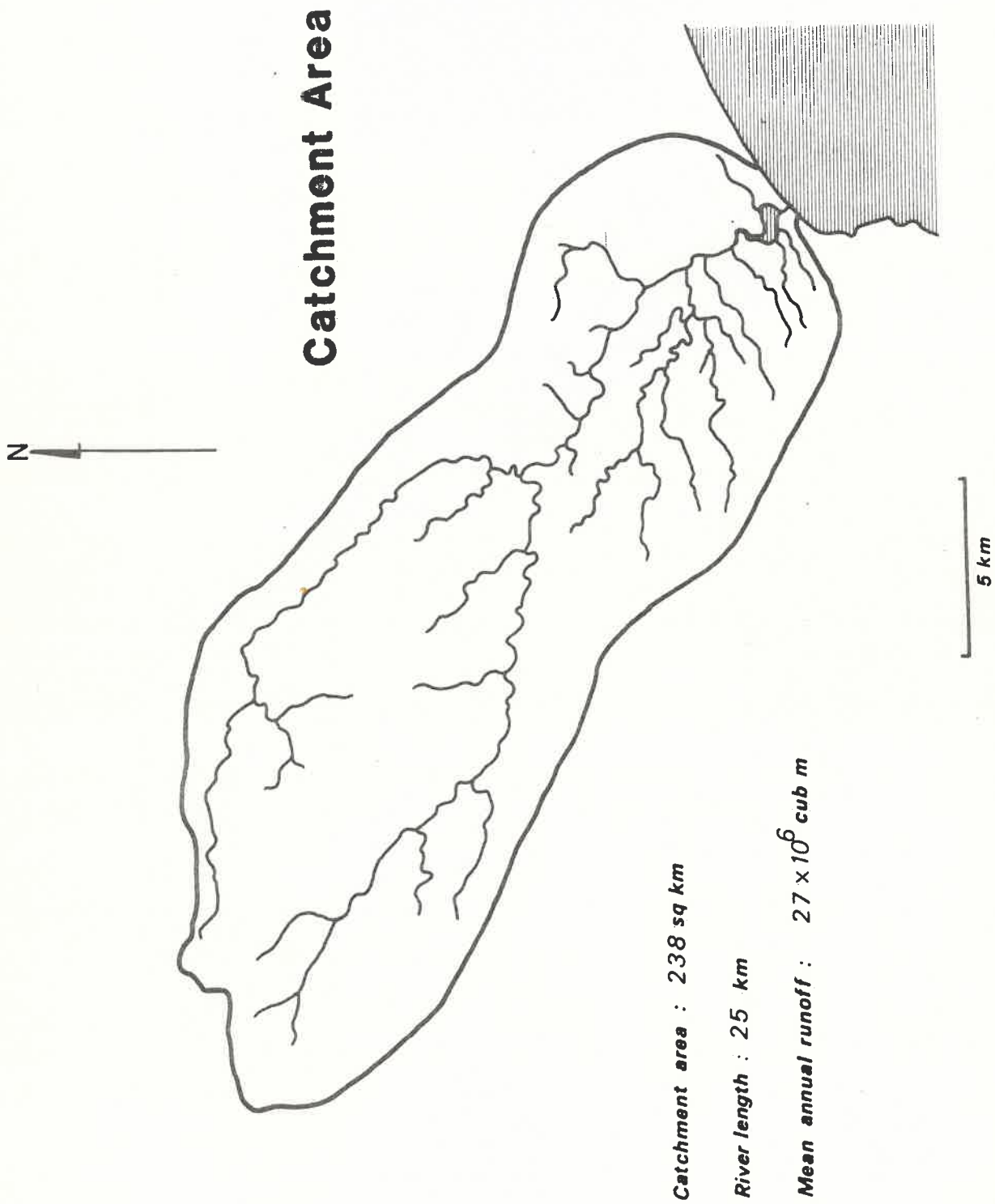


FIG 2.2

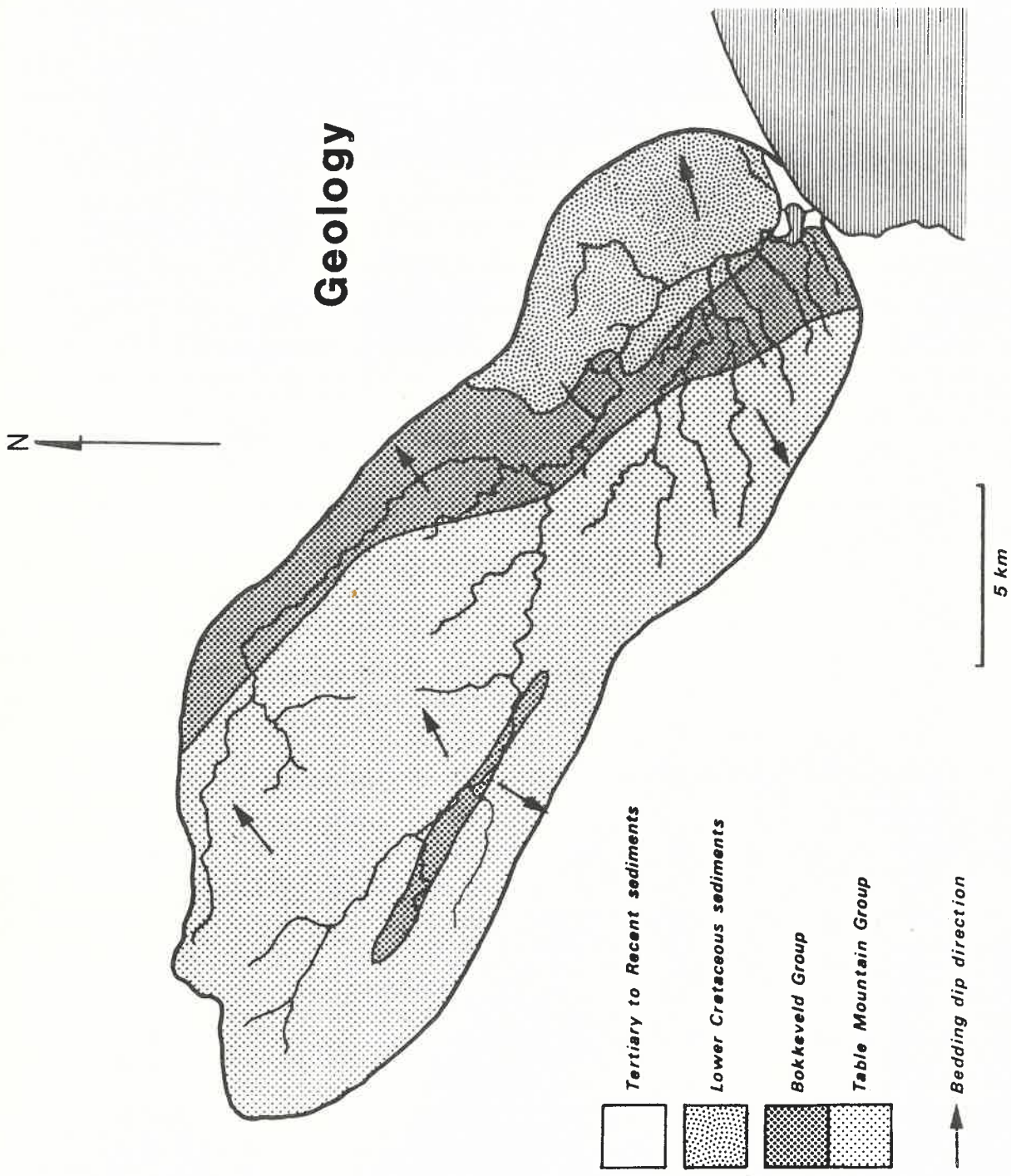


FIG 2.3

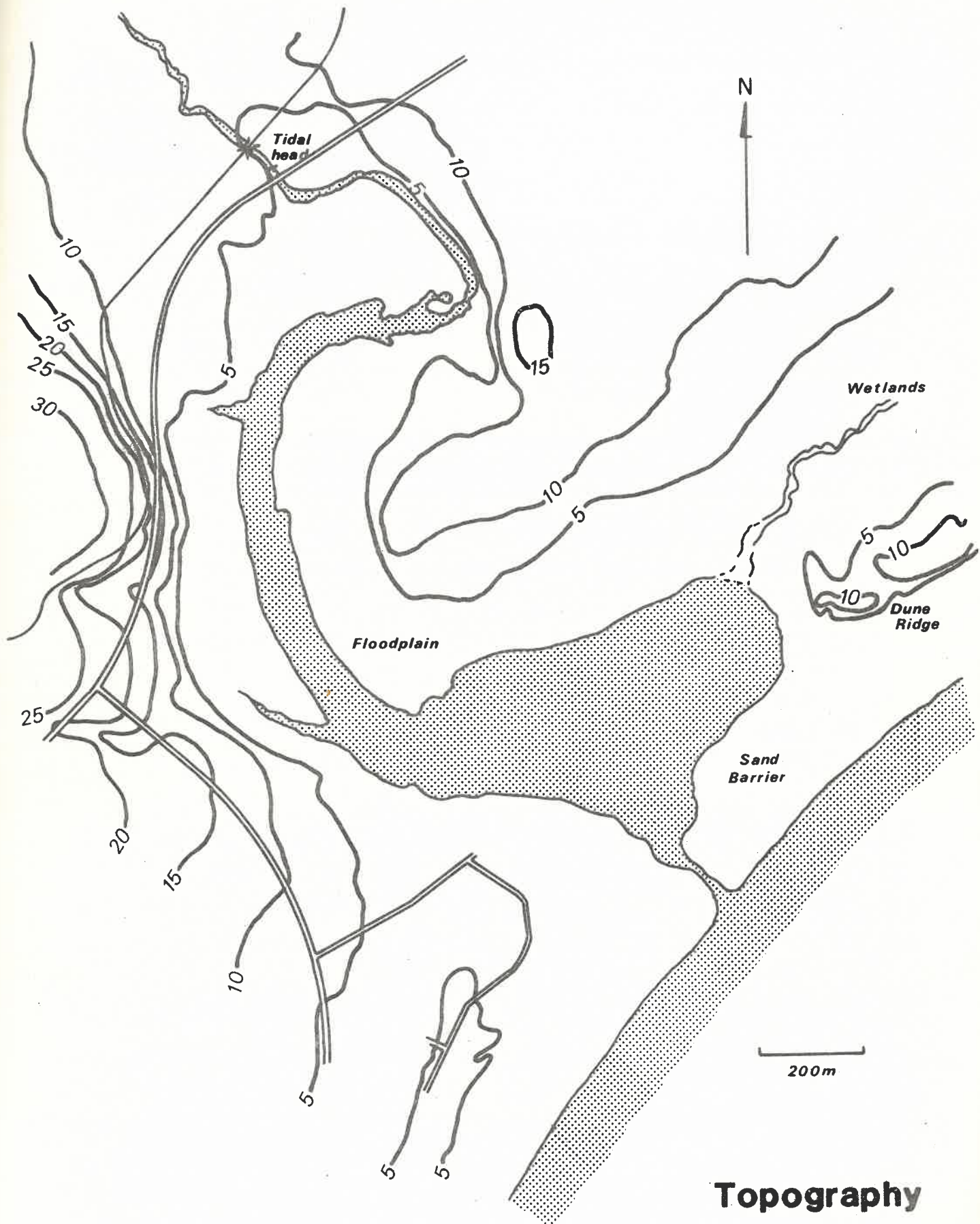
and early spring.

Soil and vegetation trends depend on the bedrock material and climate. Soils consist mostly of thin lithosols. Exposed bedrock occurs over large areas (MacVicar, 1971). Lime is present in areas where Mesozoic deposits underlie the soil. Vegetation consists largely of fynbos (Acocks, 1975) which is usually associated with the acid soils derived from the Table Mountain quartzite. Exotic vegetation (Rooikrans and Port Jackson willows, Acacia spp) have in recent years invaded large areas of the catchment.

Land use is mainly agricultural with emphasis on livestock farming. Crop farming is practised on a limited scale, mostly in the areas underlain by Bokkeveld slate.

2.2 Estuary

The tidal head of the estuary is at a low causeway just upstream of the old national road bridge. In its upper reaches the estuary has 2,5 m high banks consisting of gravel and partly consolidated sand deposits. The relief flattens down-estuary and the pebble-lined channel becomes sandy, grading into an intertidal flat at its seaward end. The supratidal area is narrow. At its seaward end the estuary is separated from the sea by a sand barrier (fig. 2.4). This is periodically breached to form a tidal inlet.



Contours (m) wrt MSL

Topography

FIG 2.4

The inlet of the estuary is normally blocked because of the inability of the feeble tidal currents to scour wave deposited sand from the inlet channel.

The deposits of the estuary overlie Mesozoic conglomerate and sandstone. The estuary lies close to the unconformable contact between these Mesozoic deposits and the underlying Bokkeveld slate. The hills to the south-west of the estuary consist of Bokkeveld slate.

Kabeljous-on-Sea is a holiday resort on the western bank of the estuary. A coastal dune ridge starts on the eastern bank and extends eastward, eventually to merge with the large dune field to the west of the Gamtoos estuary. The freshwater creek which drains the wetland between the dune ridge and the hinterland, and which joins the eastern edge of the estuary (fig. 2.4), becomes tidal at high spring tide when the inlet is open.

The term "estuary" can strictly not be applied to this coastal body of water as it does not have a permanently open tidal inlet, which is per definition a prerequisite. This type of system is often referred to as a "blind estuary" but the term "ephemeral estuary" is preferred here (see Reddering and Esterhuysen, 1982).

When the inlet is blocked, the water in the estuary stagnates. During the field work excursion in November, 1982, the tidal flats were covered knee-deep by water and abundant algae were present.

3. SEDIMENT DISTRIBUTION

3.1 Introduction

Sediment samples were collected on a pre-determined grid (fig. 3.1), both at the bed and 50 cm below the sediment surface. The sample lines are spaced 250 m apart. As the inlet was blocked at the time of sampling, line 1 was not sampled. Up-estuary from line 8 the sediment consists of conglomerate with well-rounded clasts. This part of the channel was also not sampled.

3.2 Sand distribution

A curious reversal of the "normal" up-estuary fining of sediment occurs (fig 3.2). The sand in the estuary becomes finer-grained seaward because the fluvial sand is coarser-grained than the beach-derived material of the lower estuary. Near the head of the estuary the sediment consists mostly of pebbles derived from the Mesozoic conglomerate which outcrops in the nearby riverbank.

The sand 50 cm below the bed surface (fig. 3.2 b) has about the same mean grain size as at the surface but on the western bend of the estuary the sediment becomes finer-grained downward.

Sediment Sample Sites

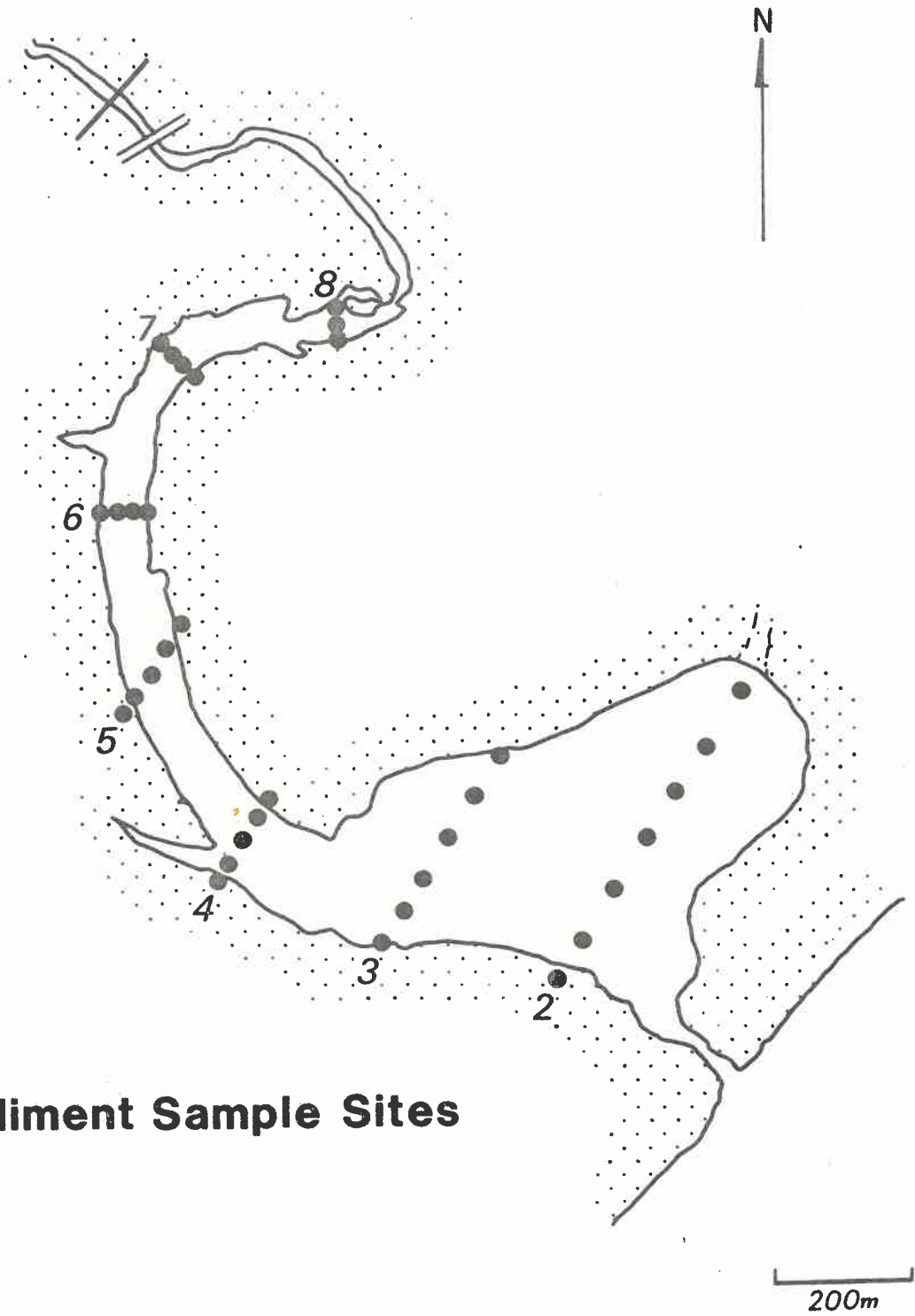
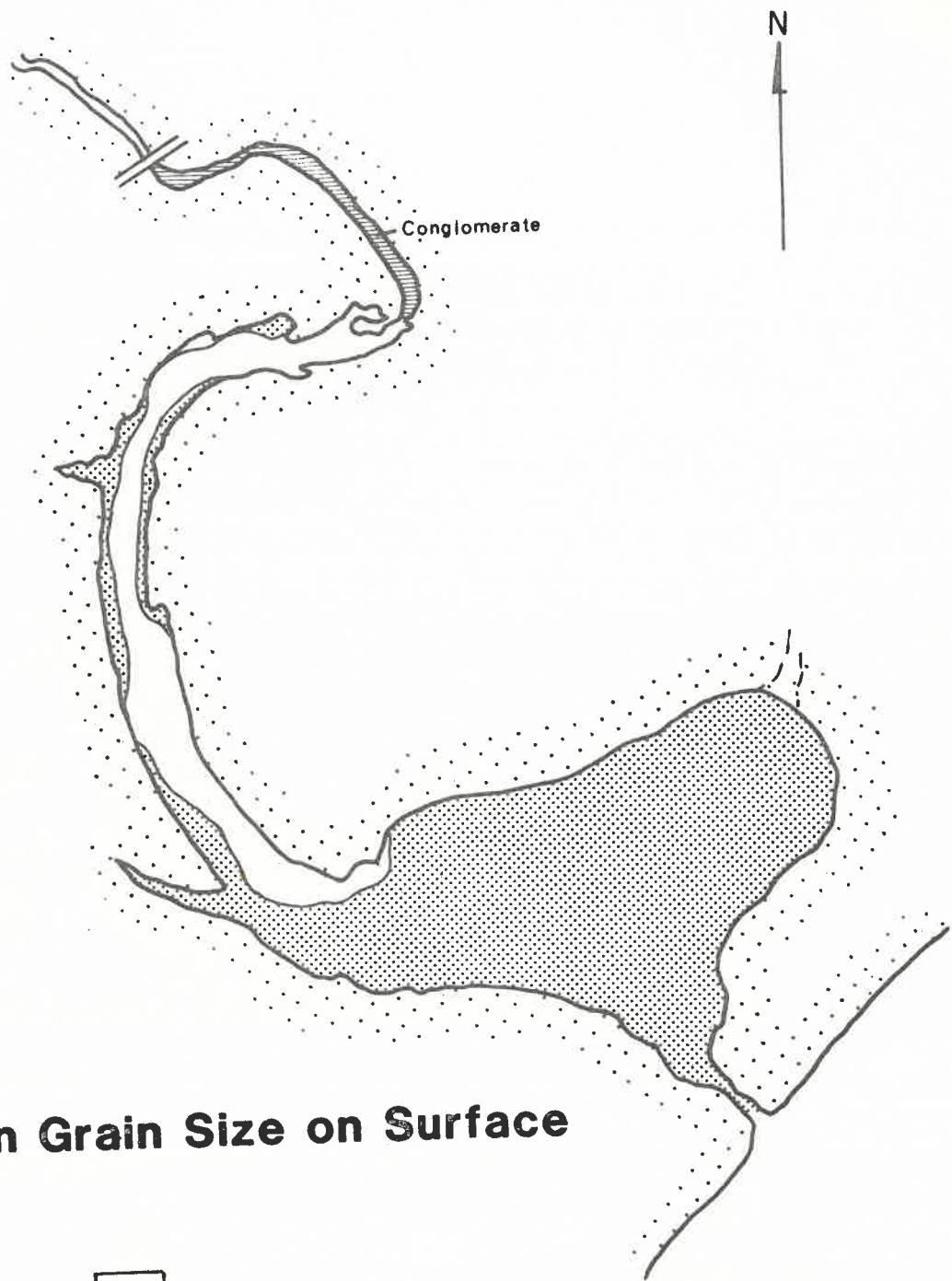


FIG 3.1



Mean Grain Size on Surface

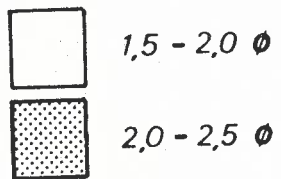
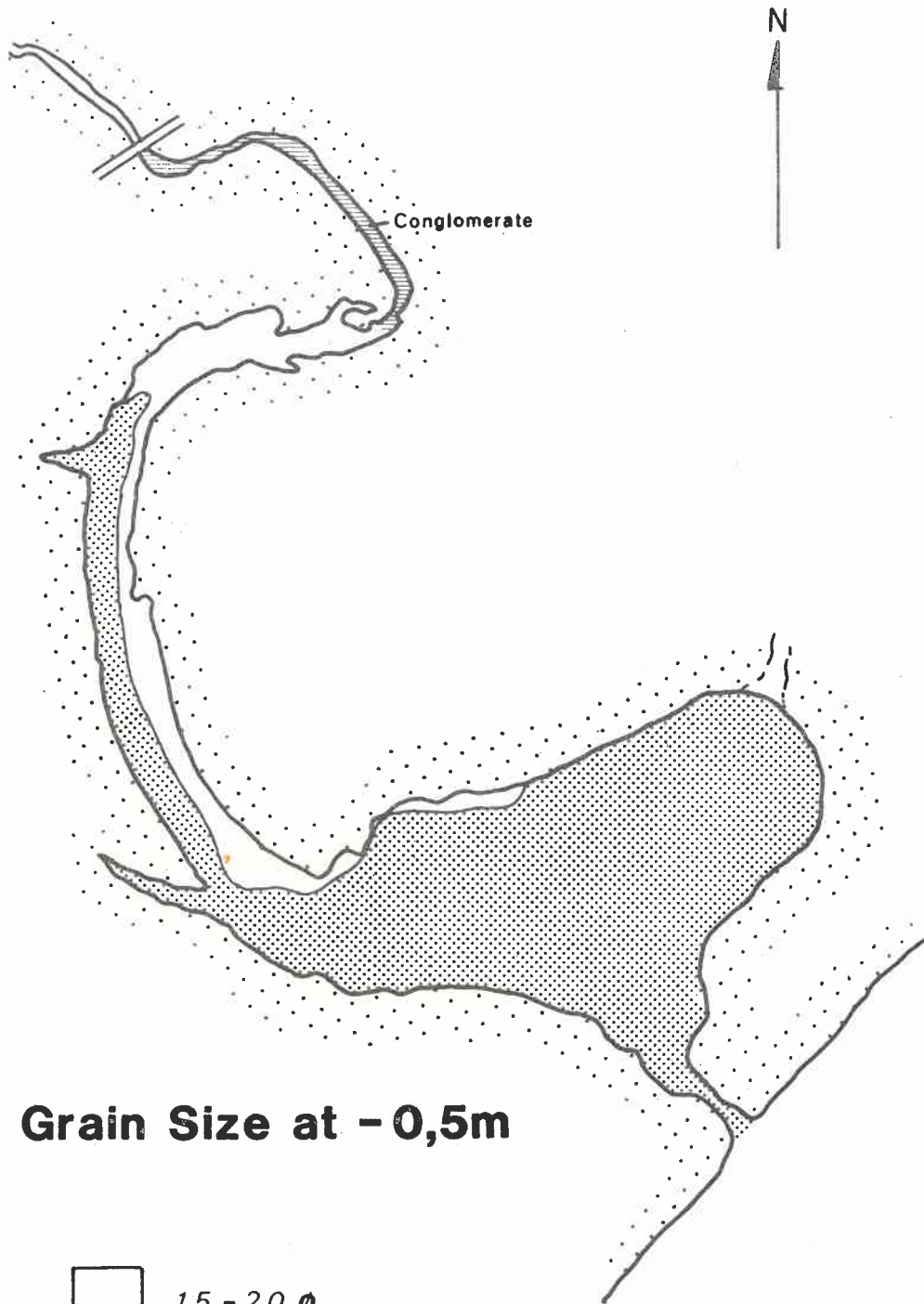


FIG 3.2A



Mean Grain Size at -0,5m

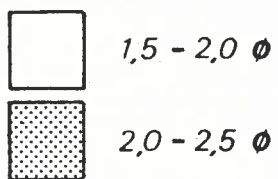


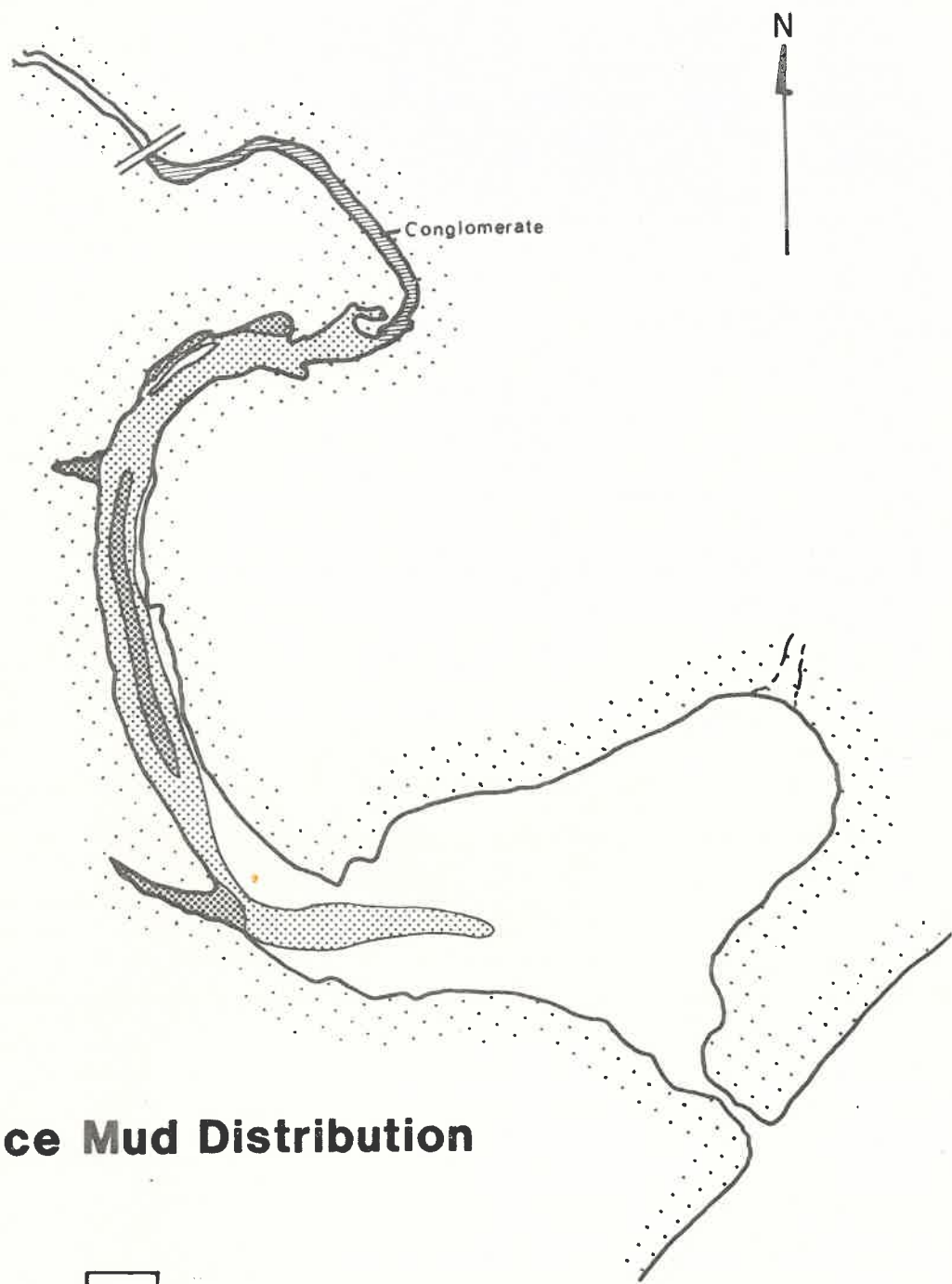
FIG 3.2B

3.3 Mud distribution

The provenance provides little mud to the estuary, thus the mud content in the sediments is generally low (average value 10,7 percent - standard deviation 11,8). The mud content increases gradually up-estuary from the inlet (APPENDIX I; fig. 3.3). The surface mud content is more than 30 percent in the deep channel section of the middle estuary (fig. 3.3a). Samples 0,5 m below the bed surface generally contain less mud than those taken at the sediment surface (fig. 3.3b). During fairweather conditions mud is accumulated on the existing sand bed which was previously deposited under turbulent conditions of a river flood. The samples were collected in November, 1982 during a period of fair weather and as a result the mud content of the surface sediment is comparatively high.

3.4 Carbonate and organic content

The carbonate component of the sediment in the estuary is of marine derivation and consists of skeletal shell fragments, mainly derived from molluscs. Carbonate is limited to the lower 750 m of the estuary reach. Carbonate-cemented sediment was encountered at two sampling stations: KB 3;6B and KB 4;1B (fig. 3.1). Core pipe penetration was reduced by the semi-calcified sediment. Carbonate cementation of comparatively young sediments is consistent with findings of Blatt et al. (1972, p.424).



Surface Mud Distribution

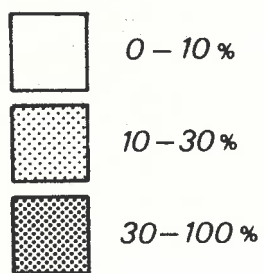
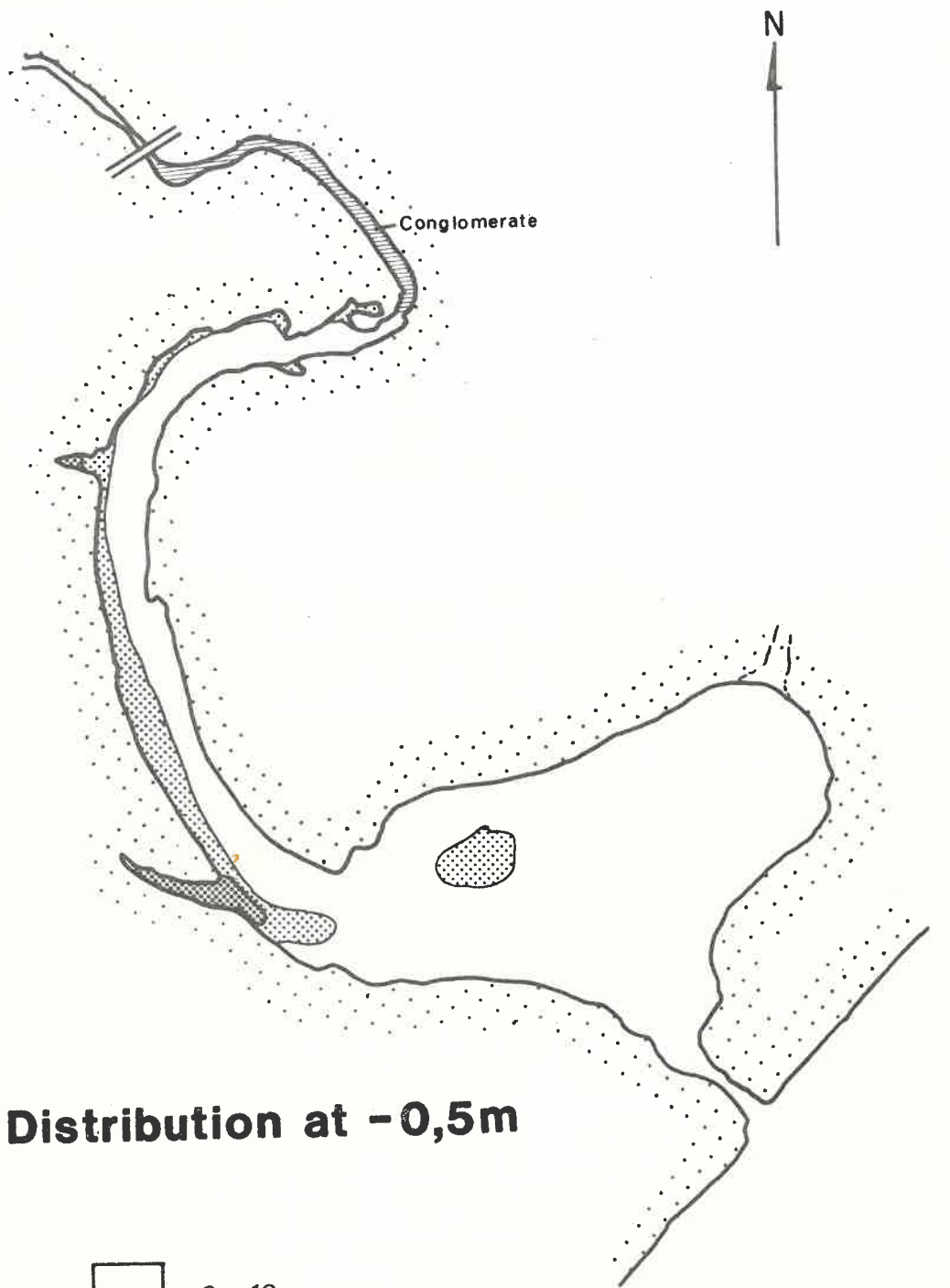
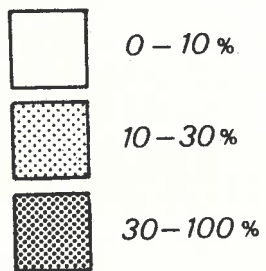


FIG 3.3A



Mud Distribution at -0,5m



200 m

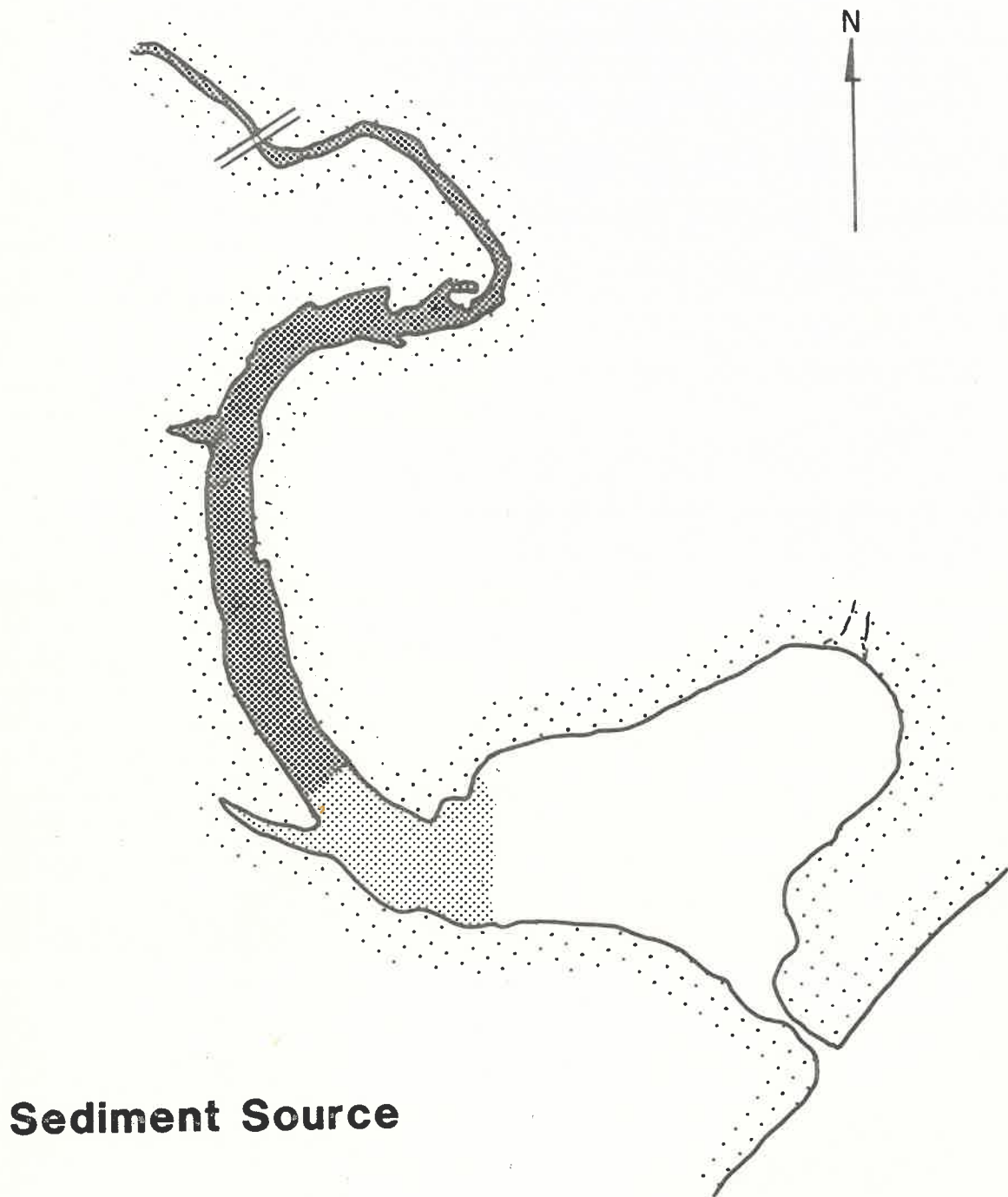
FIG 3.3B

The organic content of the sediment in the estuary fluctuates between 0,65 and 5,85 percent. This results from the unavoidable inclusion of filamentous green algae (section 2.2) into the samples. The high values are consequently not representative because the algae were not part of the sediment but formed a mat on its surface.

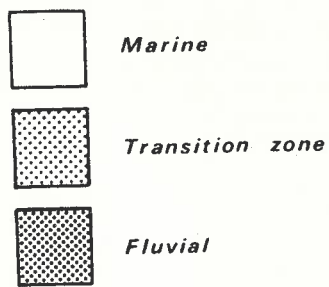
3.5 Sediment source (fig. 3.4)

Two sources contribute sediment to the estuary. Fluvially derived pebbles, sand and mud enter at the tidal head of the estuary. From there it is distributed into the estuary mainly by freshwater floods. Mud may be re-distributed by tidal currents. Locally derived storm water containing suspended clay floats on the saline estuary water and is dispersed over the whole estuary by wind. The pebbles which presently occur in the upper estuary were probably deposited a long time ago because there is no apparent accumulation of pebbles upstream of the causeway. If the transport of pebble-sized clasts were still taking place, the upstream area of the causeway would have acted as a local depositional trap, but because no such accumulation has developed the pebble deposit in the upper estuary predates the causeway, and no present sedimentation of pebbles is taking place.

Beach sand enters the seaward end of the estuary by three mechanisms. When the inlet is open flood tides deposit beach



Sediment Source



200m

FIG 3.4

sand in the estuary. Wind-blown sand also enters across the barrier, and during storms waves can wash over the barrier and deposit entrained beach sand in the estuary. Tidal action reworks this sand in the estuary and gradually moves it up-estuary. Marine and fluvial sand mixes in the first channel bend (fig. 3.4). At present marine sand lines the bottom of the mid-channel in this bend but it is evident that a significant flood could substantially modify the present situation.

4. THE KABELJOUS and SEEKOEI ESTUARIES: A CONTRAST IN MANAGEMENT APPROACH

4.1 Introduction

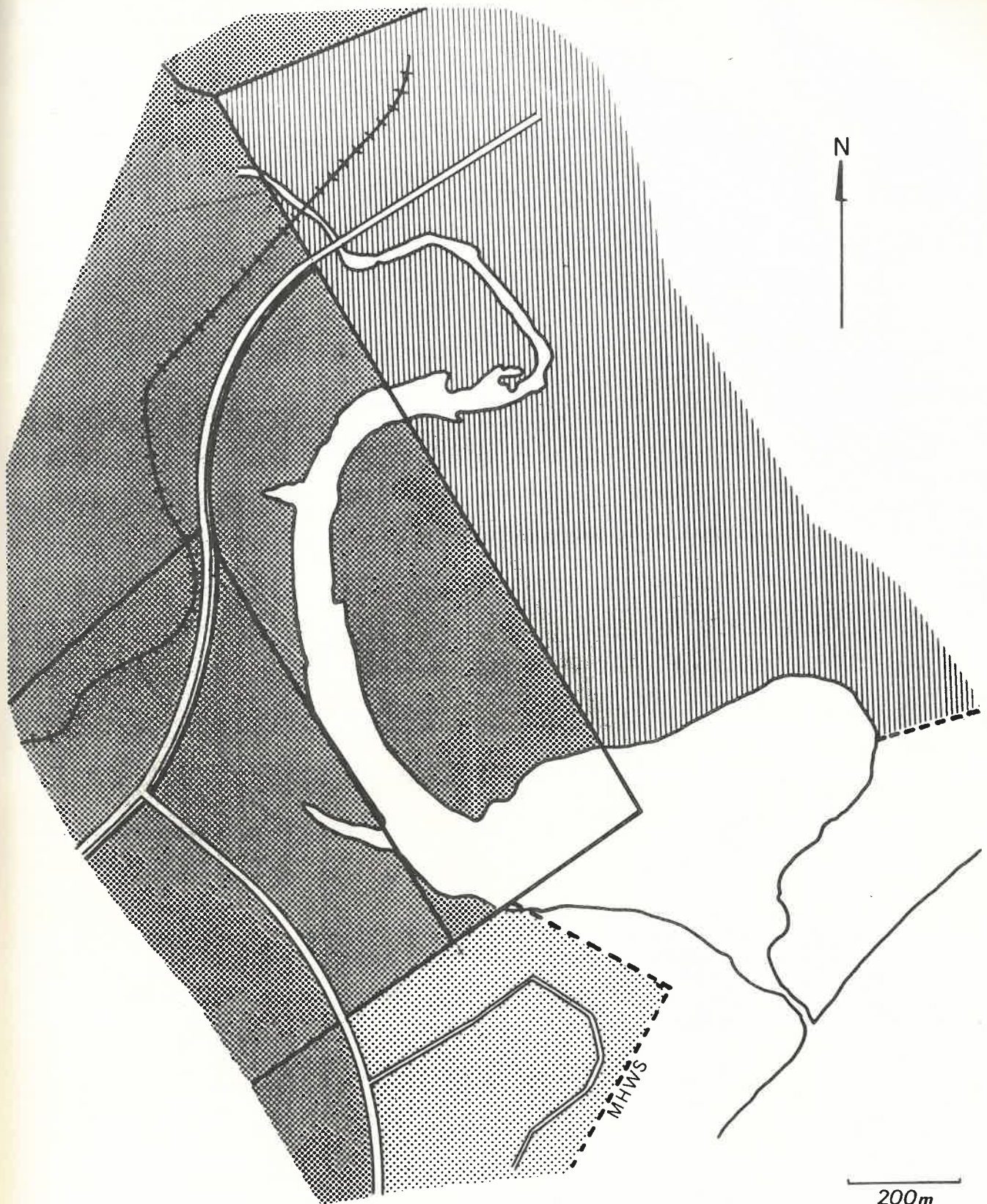
This section highlights the differences in management approach at the Kabeljous and Seekoei estuaries to indicate the resultant effect on the respective systems. The estuaries are similar in many respects: they are of comparable size; both have periodically blocked inlets and are thus sensitive to hydraulic change; they have comparable catchment areas, and, as these lie adjacent to each other, the influences of climate, vegetation, geology, soil types and geomorphology are all similar; both estuaries are privately owned or administered by local authorities (as opposed to provincial or central government), and townships are developed adjacent to both estuaries. These conditions present an opportunity to investigate management procedure and its effect on the estuarine environment.




Detailed background information on the Seekoei estuary is given by Esterhuysen (1983a, 1983b). Similar data on the Kabeljous estuary are given in section 2 of this report.

4.2 Development history of the Kabeljous estuary

This estuary is partly private ground and partly public outspan. The public area is at present administrated by the Humansdorp Divisional Council (fig 4.1). The old national road bridge and a narrow gauge train bridge cross the upper estuary. The tidal head is at a causeway of unknown age. This was probably constructed to prevent the river upstream from becoming salty as it would then be worthless for livestock watering.

Cattle farming is at present the main activity on the banks of the estuary. All building development on or near the banks of the estuary is on the western bank where private houses have been built over the last decade. The only active management aspect concerns the decision whether or not to open the inlet when it is blocked. Different priorities influence opinions on the matter. Those in favour of allowing the natural course of events to persist are concerned that fish in the estuary may be driven away as a result of mechanical inlet opening. Others argue that higher groundwater levels associated with a closed inlet constitute a threat to their property. Neither argument is strictly valid. An artificially opened inlet is unlikely to adversely affect fish movements. On the other hand, properties should not have been built where they can be influenced by rising groundwater levels in nearby body of water.



-  *Private*
-  *Township (Jeffreys Bay Municipality)*
-  *Humansdorp Divisional Council*

Land Ownership

FIG 4.1

4.3 Development history of the Seekoei estuary

Of the two estuaries the Seekoei is aesthetically probably the more pleasing. It was entirely privately owned until the southern bank was proclaimed as the township of Paradise Beach (1966), which is now administrated by the Humansdorp Divisional Council. By 1971 another township, Aston Bay, was proclaimed on the northern bank of the estuary. It is now managed by the Jeffreys Bay Town Council. The Seekoei estuary is likely to have been the main attraction when the towns were first developed on its banks.

Before township development took place the estuary had a prolific bird life. The Seekoei Nature Reserve was established by the Cape Nature Conservation Department with the aim of protecting this fauna.

The diverted inlet and a causeway across the Seekoei estuary have had adverse environmental effects on the estuary. During development of the Aston Bay beach amenities in 1971, the existing natural inlet was filled in because it was in the way of the proposed swimming bath complex. A new inlet was dug to the south of its old position. The new inlet represented a more direct route to the sea, and owing to the increased water slope, the estuary was almost completely drained at low tide. Had the situation been left to stabilize a new equilibrium would probably

have been established with no long term detrimental effect on the estuary. However, because bird numbers dwindled dramatically as a result of the low water level, a low weir was constructed across the estuary to retain some water in its upper reaches at low tide. This had the desired effect and the estuary was restored to resemble its former state.

At very low tide the estuary could be crossed along the weir. This inspired the "good idea" to raise its level to allow vehicular traffic to cross at high tide. Inadequate allowance for tidal exchange caused the water in the upper estuary to desalinate and accelerated sedimentation took place in the lower estuary. The estuary was given a temporary reprieve when freshwater floods breached the causeway in 1976, and again in the winter of 1979. Two meetings (in 1979 and 1980) were called to investigate the problems of the Seekoei estuary. Both meetings were attended by local inhabitants, by representatives of central, provincial and local government, and by specialists in the fields of estuarine ecology, hydrodynamics and sedimentation. Consensus among the specialists was that the causeway was undesirable and should be removed or suitably modified. The local authority chose repair the flood breach. The ecology of the estuary returned from estuarine to one which was much more freshwater tolerant.

Apart from causing increased sedimentation both upstream and downstream from it, the causeway is an unsightly structure. It is poorly designed causing it to be breached by virtually every

fluvial flood that passes through the estuary. Furthermore, it does not have a future as a permanent structure: on the Paradise Beach bank it lies on private ground and can thus not be proclaimed as a public road.

The repair of the June, 1979 breach in the causeway generated some criticism (Esterhuysen, 1983a, 1983b). During the severe fluvial flood of July, 1983 the causeway was breached again. This presented an opportunity to allow the estuary to return to a natural state. The local authority, disregarding the accumulated evidence militating against doing so, allowed the causeway to be repaired within months. Each time the breach was repaired, heavier riprap was used in an attempt to reinforce the flood-fragile structure. When the structure will eventually have to be removed, such unwieldy material will complicate the operation, making it even more expensive.

An ironical twist underlies the entire management fiasco. The birds that disappeared when the estuary was first drained were swans. These impressive birds are not indigenous to South Africa and were probably not worth the bother of altering the estuary. It seemed afterwards that the missing swans did not migrate under stress from the changing environment, but were apparently poached. Swans are freshwater birds and would in any event not have been influenced by desalination of the estuarine water.

4.4 Discussion

The fundamental difference between the Seekoei and Kabeljous estuaries is that, whereas at the Seekoei entrepreneurs developed land adjacent to its banks, the Kabeljous remained practically unaffected.

The problems that have become evident in the Seekoei resulted from a lack of planning and a disregard for the effects of natural processes. That local authorities are allowed to continue such practices results from a legal loophole. The South African coast is administrated under at least eleven acts and ordinances (South African National Scientific Programmes, 1983). At the time when these regulations were promulgated both Seekoei and Kabeljous estuaries were privately owned. When the Seekoei later became public ground by development of the towns on its banks its administration was taken over by local authorities.

The errors initially made at the Seekoei estuary can be excused but that this is perpetuated indicates that a basic grasp of environmental management is lacking. The present owner of the largest section of the Kabeljous estuary preserves it in its natural state. This may not be the policy of a possible future owner who under present regulations could "develop" it in virtually any manner. It would seem that control over estuaries should be contained in a single set of regulations that provide unified norms of estuarine management applicable to all estuaries. Such regulations must provide for controlled

development without compromising or degrading the natural estuarine environment.

A further, less obvious, aspect of estuarine management is illustrated in the case of the Seekoei estuary. The estuary was undoubtedly the primary attraction for the initial development and proclamation of the two adjoining resort towns. During the development of the infrastructure, the developers and local authorities actually made the estuary less attractive. The original recreational value of the development depended largely on the scenic attraction of the estuary, and making the estuary less attractive does not make economic sense. The recreational value of the estuary can only be restored by reversing the deleterious effects of past management. Such recreational devaluation has not taken place at the Kabeljous estuary as the degree of development is less than at the Seekoei estuary. Should the Kabeljous estuary be developed in any way the mistakes made at the Seekoei must be avoided.

5. CONCLUSIONS

The state of the Kabeljous estuary is sound. Private ownership has not adversely affected the sedimentary ecology of the estuary. Owing to the absence of development or other extraneous influences, the management of the Kabeljous estuary is superior to that of the Seekoei estuary, 10 km farther south.

Whether the Kabeljous inlet should be artificially opened after extended closure depends on prevailing priorities. If the environment is to be preserved the inlet should be left in its natural state. If people wish to bathe in the water it would probably be safer to open the inlet occasionally to prevent the water from becoming stagnant.

Comparison between two estuaries indicates that an all-encompassing estuarine management strategy is required on a national basis.

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ACKNOWLEDGEMENTS

Mr LC du Toit allowed the investigators to cross his land during field work. Likewise the Humansdorp Divisional Council gave permission to enter land under its control. David Cohen and Anni Tonin assisted in the field. Anni Tonin, Sharon Walsh and Sheva de Jong assisted in the laboratory. Professor IC Rust made useful suggestions for the improvement of the original text and diagrams. The project was financed by SANCOR through the Cooperative Scientific Programmes of the CSIR.

Section

Esterhuysen

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APPENDIX I

This section lists the distribution data of sediment samples collected in the Kabeljous estuary. The sample lines are marked on fig. 3.1. The position of the sample stations can be found from the coded station numbers. For example G 5;4T originates from the Kabeljous ("KB" in the code) and was collected on line number 5 ("5", see fig. 3.1). It was taken at the bed surface ("T" denotes TOP) at position 4 on that line. This sampling spot (indicated as a dot, fig. 3.1) is the fourth from the LEFT, looking up-estuary. Samples were also collected 0,5 m below the 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.
($\text{PHI} = -\log_2 (\text{grain size in mm} / 1 \text{ mm})$)

This appendix has three sections: A, B and C. Section A lists the grain size class distributions of the samples. Section B gives the corresponding statistical parameters and section C lists the respective contents of bioclastic carbonate and of organic material.

APPENDIX I A

This section lists the grain size class distributions.

The parameters listed below are as follows:

- VCS - Very coarse sand (grain diameters 1 mm to 2 mm)
- CS - Coarse sand (grain diameters 0,5 mm to 1 mm)
- MS - Medium sand (grain diameters 0,25 mm to 0,5 mm)
- FS - Fine sand (grain diameters 0,125 mm to 0,25 mm)
- VFS - Very fine sand (grain diameters 0,063 mm to 0,125 mm)
- Mud - Silt and clay (grain diameters less than 0,063 mm)

Sample no	%VCS	%CS	%MS	%FS	%VES	%Mud
KB 2; 1T	0.29	0.29	10.56	86.51	1.17	1.17
1B	0.29	0.59	23.60	73.45	0.88	1.18
2T	0.29	0.57	37.82	58.74	0.29	2.29
2B	0.92	0.31	18.77	79.08	0.62	0.31
3T	3.04	1.30	23.48	70.00	0.43	1.74
3B	0.60	1.19	28.06	68.96	0.30	0.90
4T	0.74	0.74	27.78	64.07	4.81	1.85
4B	0.93	2.31	14.81	63.89	4.63	13.43
5T	2.46	0.70	23.51	66.32	3.86	3.16
5B	0.35	0.70	24.65	71.83	0.70	1.76
6T	1.08	0.72	23.47	70.76	1.81	2.17
6B	0.33	0.33	24.10	71.99	0.33	2.93
7T	2.05	1.23	26.23	65.98	1.23	3.28
7B	1.10	0.74	23.90	71.69	0.74	1.84
8T	0.95	0.48	20.48	73.33	3.81	0.95
8B	1.04	1.04	23.61	72.57	0.69	1.04
KB 3; 1T	0.40	0.40	23.20	66.40	7.20	2.40
1B	1.15	0.77	21.46	72.41	1.15	3.07
2T	1.56	3.13	19.14	62.50	8.59	5.08
2B	1.26	3.78	17.23	61.76	6.30	9.66
3T	0.90	3.60	18.92	54.50	9.91	12.16
3B	2.34	3.27	15.89	64.02	5.61	8.88
4T	0.63	2.19	25.71	58.62	7.84	5.02
4B	1.95	1.95	19.53	49.22	5.86	21.48
5T	1.47	1.47	25.74	61.03	6.25	4.04
5B	1.75	1.75	24.02	54.59	6.99	10.92
6T	0.71	3.20	22.78	65.12	4.63	3.56
6B	13.55	5.13	24.54	47.25	3.66	5.86
KB 4; 1T	0.95	1.90	17.14	63.33	6.19	10.48
1B	1.21	2.02	19.03	59.51	6.88	11.34
2T	3.00	3.37	16.48	34.08	10.11	32.96
2B	3.14	3.66	13.61	25.13	14.66	39.79
3T	1.95	7.42	40.62	40.62	2.73	6.64
3B	4.05	11.84	40.19	31.78	5.92	6.23
4T	3.59	9.42	40.36	38.12	2.24	6.28
4B	2.27	9.42	37.01	40.26	3.90	7.14
5T	1.11	7.01	38.75	47.23	1.48	4.43
5B		Solid	bottom			
KB 5; 1T	2.76	1.57	16.54	51.97	11.02	16.14
1B	6.11	0.76	5.73	26.34	6.11	54.96
2T	7.09	6.03	28.01	35.46	9.57	13.83
2B	1.97	6.56	27.87	41.64	8.85	13.11
3T	2.29	6.88	16.51	31.19	7.80	35.32
3B		Solid	bottom			
4T	2.50	11.07	38.21	32.50	5.36	10.36
4B	3.08	11.69	38.77	36.62	2.77	7.08
5T	1.28	9.29	39.74	41.99	3.85	3.85
5B	5.00	10.36	33.57	45.36	2.14	3.57

Sample no	%VCS	%CS	%MS	%ES	%VES	%Mud
KB 6;1T	1.81	4.23	35.35	31.12	9.97	17.52
1B	4.08	5.64	29.15	33.23	9.72	18.18
2T	2.41	4.22	13.25	25.60	9.34	45.18
2B		Solid	bottom			
3T	1.60	15.06	52.24	24.04	2.56	4.49
3B	17.43	14.80	40.13	17.43	4.93	5.26
4T	4.15	6.79	16.60	22.26	15.09	35.09
4B		Solid	bottom			
KB 7;1T		Solid	bottom			
1B		Solid	bottom			
2T	4.20	15.32	43.24	27.03	2.40	7.81
2B		Solid	bottom			
3T	12.33	6.33	14.00	37.67	13.67	16.00
3B		Solid	bottom			
4T	4.45	5.48	14.73	41.10	13.70	20.55
4B		Solid	bottom			
KB 8;1T		Solid	bottom			
1B		Solid	bottom			
2T	1.54	19.31	44.02	19.69	3.47	11.97
2B		Solid	bottom			
3T	2.70	8.88	37.45	29.73	10.42	10.81
3B		Solid	bottom			

APPENDIX I B

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

Statistical formulae were obtained from Buller and McManus (1979). The parameters listed below are as follows:

- Med. - The distribution median in PHI-units ($Md = P_{50}$) *
- Mean - The mean grain size in PHI-units ($M = (P_{16} + P_{84})/2$)
- Sort - Grain sorting in PHI-units ($So = (P_{84} - P_{16})/2$)
- Ske. - Distribution skewness in PHI-units ($Sk = (M - Md)/S$)
- Kurt - Distribution kurtosis in PHI-units
($Ku = (((P_{95} - P_5)/2) - S)/S$)

* P_x is the Xth percentile of the relevant distribution.

Sample no	Med.	Mean	Sort	Ske.	Kurt
KB 2; 1T	2.44	2.44	0.39	0.00	0.99
1B	2.34	2.21	0.58	-0.21	0.52
2T	2.17	2.06	0.67	-0.16	0.35
2B	2.38	2.30	0.51	-0.16	0.71
3T	2.30	2.13	0.65	-0.26	0.47
3B	2.29	2.14	0.64	-0.23	0.43
4T	2.31	2.17	0.66	-0.21	0.42
4B	2.39	2.29	0.57	-0.19	0.75
5T	2.33	2.17	0.65	-0.24	0.47
5B	2.33	2.19	0.60	-0.22	0.49
6T	2.33	2.20	0.61	-0.23	0.50
6B	2.33	2.20	0.59	-0.22	0.50
7T	2.29	2.12	0.66	-0.24	0.43
7B	2.33	2.19	0.61	-0.23	0.50
8T	2.38	2.27	0.57	-0.19	0.60
8B	2.33	2.19	0.60	-0.23	0.51
KB 3; 1T	2.37	2.26	0.62	-0.19	0.74
1B	2.35	2.22	0.58	-0.22	0.55
2T	2.38	2.22	0.67	-0.23	0.82
2B	2.37	2.21	0.66	-0.25	0.83
3T	2.38	2.21	0.71	-0.23	0.82
3B	2.38	2.21	0.65	-0.25	0.94
4T	2.32	2.18	0.70	-0.21	0.66
4B	2.32	2.15	0.71	-0.24	0.64
5T	2.32	2.17	0.68	-0.22	0.58
5B	2.31	2.16	0.71	-0.22	0.64
6T	2.33	2.17	0.66	-0.24	0.47
6B	2.08	1.53	1.23	-0.45	0.47
KB 4; 1T	2.39	2.27	0.60	-0.20	0.81
1B	2.37	2.23	0.65	-0.22	0.76
2T	2.31	2.12	0.86	-0.22	1.07
2B	2.39	2.28	1.07	-0.10	0.80
3T	1.92	1.92	0.78	0.00	0.66
3B	1.77	1.82	0.89	0.05	0.76
4T	1.84	1.86	0.81	0.02	0.74
4B	1.94	1.91	0.82	-0.04	0.66
5T	2.02	1.95	0.76	-0.10	0.58
5B		Solid bottom			
KB 5; 1T	2.41	2.25	0.70	-0.22	0.93
1B	2.38	2.01	0.95	-0.39	1.24
2T	2.06	1.95	0.93	-0.11	1.12
2B	2.17	2.04	0.84	-0.16	0.87
3T	2.21	1.99	0.92	-0.24	0.87
3B		Solid bottom			
4T	1.82	1.87	0.85	0.06	0.75
4B	1.82	1.84	0.83	0.02	0.69
5T	1.94	1.92	0.80	-0.03	0.62
5B	1.98	1.85	0.85	-0.15	0.75

Sample no	Med.	Mean	Sol. t	Ske.	Kurt
KB 6; 1T	2.00	2.05	0.85	0.06	0.79
1B		Solid bottom			
1B	2.06	2.01	0.89	-0.06	1.01
2T	2.29	2.11	0.95	-0.19	0.91
3T	1.60	1.69	0.78	0.12	0.73
3B	1.38	1.14	1.27	-0.19	0.48
4T	2.22	2.11	1.20	-0.09	0.67
4B		Solid bottom			
		Solid bottom			
KB 7; 1T		Solid bottom			
1B		Solid bottom			
2T	1.61	1.62	0.93	0.00	0.56
2B		Solid bottom			
3T	2.25	1.60	1.42	-0.46	0.53
3B		Solid bottom			
4T	2.37	2.13	0.94	-0.25	1.03
4B		Solid bottom			
		Solid bottom			
1T		Solid bottom			
1B		Solid bottom			
2T	1.53	1.56	0.91	0.03	0.55
2B		Solid bottom			
3T	1.88	1.97	0.90	0.10	0.88
3B		Solid bottom			

APPENDIX I C

This section lists the respective contents of CaCO_3 and of H_2O_2 leachable organic material.

Carbonate content of the samples was determined using a "carbonate bomb" (Schink et al., 1979). The organic content was determined by H_2O_2 leaching (McCave, 1979). This method does not determine all the organic material in the sediment but gives an approximation of the material that is likely to influence the redox potential of the sediment. 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.

Sample no	%Carb.	%Org C
KB 2;1T	35.80	1.22
1B	30.00	1.46
2T	31.00	1.13
2B	34.60	1.27
3T	31.40	1.58
3B	34.20	1.65
4T	31.70	1.53
4B	30.70	5.85
5T	34.00	1.89
5B	32.50	1.49
6T	32.00	1.67
6B	31.80	1.69
7T	32.80	1.82
7B	31.60	1.43
8T	34.50	1.46
8B	35.10	1.40
KB 3;1T	29.00	1.59
1B	24.30	1.13
2T	20.90	1.39
2B	28.00	2.43
3T	35.00	3.47
3B	32.90	3.31
4T	15.10	1.22
4B	10.00	2.12
5T	17.70	1.07
5B	17.20	1.86
6T	10.70	1.25
6B	22.40	1.88
KB 4;1T	0.00	1.03
1B	0.00	1.20
2T	6.40	2.54
2B	7.30	3.41
3T	0.00	0.90
3B	0.00	0.76
4T	0.00	0.88
4B	0.00	0.72
5T	0.00	0.89
5B	Solid bottom	
KB 5;1T	0.00	1.50
1B	0.00	3.65
2T	0.00	1.28
2B	0.00	1.02
3T	0.00	3.05
3B	Solid bottom	
4T	0.00	1.36
4B	0.00	0.93
5T	0.00	0.83
5B	0.00	0.65

<u>Sample no</u>	<u>%Carb.</u>	<u>%Org C</u>
KB 6;1T	0.00	1.60
1B	Solid	bottom
2T	0.00	3.29
2B	Solid	bottom
3T	0.00	0.92
3B	0.00	1.07
4T	0.00	3.87
4B	Solid	bottom
KB 7;1T	Solid	bottom
1B	Solid	bottom
2T	0.00	1.67
2B	Solid	bottom
3T	0.00	3.38
3B	Solid	bottom
4T	0.00	2.99
4B	Solid	bottom
KB 8;1T	Solid	bottom
1B	Solid	bottom
2T	0.00	2.31
2B	Solid	bottom
3T	0.00	1.92
3B	Solid	bottom