SURFICIAL SEDIMENT DISTRIBUTION IN THE MIRAMICHI ESTUARY AND IMPLICATIONS FOR DREDGING

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INTRODUCTION

This report, which comprises a surficial-sediment survey of Miramichi Estuary, was prepared at the request of the Miramichi Channel Study. Under an agreement between K. Philpott , Manager, Miramichi Channel Study (MCS) and Environmental Marine Geology (EMG), EMG undertook to provide MCS with a bottom-sediment distribution map and a report on the interpretation of this distribution. MCS in turn provided EMG with 2½ man-months technical support. With the support provided by MCS, Mr. B. Eastwood, a geology student at St. Mary's University, was hired, and ably assisted EMG during all phases of this study.

A number of bottom-sediment sampling surveys were conducted in the early 1970's in the Miramichi, but have heretofore never been compiled into a detailed bottom-sediment distribution map. Prior to the 1970's the works of Bousfield (1955), Bartlett (1966) and Tapley (1969) were the only data existing on the sediment distribution in the Miramichi. Although Bousfield's work is of high quality, it is outdated and therefore inadequate for depicting the contemporary sediment distribution. The works of Bartlett and Tapley contain too little information on sediment-sample data, and their sampling density is far too low, to be of any use for depicting sediment distribution, or even for incorporation into the sediment surveys of the 1970's.

Of the recent sediment-sampling surveys (the ones that were considered for incorporation into the surficial-sediment map), three were conducted by authority of MCS, and two directly by BIO scientific personnel under two separate and independent projects (Table 1). Some of the samples from these various surveys were analyzed for grain-size by various laboratories using different procedures, but for many of the samples no size-analysis data was available at all (Table 2).

TABLE 1 - Recent Bottom Sediment Surveys

DATE CONDUCTED	CONDUCTED BY	SAMPLER USED	AREA SAMPLED
May-July, 1974	ADI Ltd. for MCS	Unknown	Shipping channel from Outer Bay to Chatham.
October 1974	ComDev Marine Ltd. for MCS	Shipek	Outer Bay (nearshore), plus Portage Channel and Portage Gully.
June-July 1975	CHS for M.O.T. and MCS	VanVeen	Entire estuary including Outer Bay, on a 1.6 Km grid.
Sept.-Oct. 1973	Kranck, BIO	VanVeen	Entire Estuary, low density of sampling points.
Sept., 1975 May, 1976	EMG-BIO	Eckman	1975 - Low density throughout estuary, pilot study 1976 - Areas with insufficient sample data.

TABLE 2 - Sediment-Size Analysis

SURVEY	EXISTING ANALYTICAL DATA (ANALYTICAL LAB)	SAMPLES PROCESSED FOR THIS STUDY (ANALYTICAL LAB)	METHOD OF ANALYSIS	SAMPLES USED IN THIS STUDY
ADI Ltd. 1973	yes, all samples (ADI Ltd.)	none	sieve	not used
ComDev Marine Ltd. 1974	yes, 51 of 103 samples (Geocon Ltd.)	none	sieve	all used
M.O.T. 1975	yes, 1) Every second sample (NBRPC)		sieve-pipette (pipette in salt water)	sand analyses used, mud analyses not used.
	2) All samples (K.Kranck, AOL)		Coulter Counter	most not used because of comparability problems
		3) Those samples containing mud that were not analyzed by conventional methods (MacLaren-Atlantic for EMG)	sieve-pipette	all used
Kranck 1973	none	All samples provided courtesy of K.Kranck (EMG Lab and MacLaren-Atlantic)	sieve-pipette	all used
EMG 1975	none	All samples (EMG Lab)	sieve-pipette	all used
EMG 1976	none	All samples (MacLaren-Atlantic, still being Processed)	sieve-pipette	all used

This made the problem of evaluating the sediment-survey data a two-fold one: 1) determining whether the various surveys could be compared with respect to sampling procedure; 2) determining whether the various surveys could be compared with respect to size-analysis procedure.

In order to evaluate sampling procedures of the various surveys I had to be largely subjective, and decide intuitively which sampling surveys were most reliable. The size-analysis data, if one knows it is accurate, can help to some degree in determining poor sampling methods. All surveys used conventional grab samplers, apart from ADI Ltd., in which case there is no information of what was used. Loss of fine material from some samplers can occur, when water depth is relatively great and the sediment being sampled contains material ranging in size from gravel to mud. However, in a relatively shallow area such as the Miramichi where none of the sediments are extremely heterogeneous or bimodal, I felt that the Eckman, Van Veen and Shipek grab samplers could be reliably compared.

The completion of this report was slowed considerably because a lot of the samples from the 1975 M.O.T. survey had to be analyzed by our laboratories, and we had to utilize a lot of our own samples which were just collected in May (Table 2). Coulter counter analyses (done by K. Kranck) of the MOT 1975 samples, apart from the well-sorted sand samples, were not easily compared to conventional methods, so they were redone by conventional means. In addition, samples from the 1973 Kranck survey had to be size-analyzed because no analysis had been done on them previously. ComDev size analysis data were all usable, but the ADI Ltd. data was rejected completely, because as far as can be determined, the analyses were not performed completely or properly. The ADI analyses all showed a bias toward high sand and gravel content even in the case of samples collected from mud areas.

The distribution of samples from the various surveys utilized in this report are given in Map #1. The coverage is adequate throughout the estuary save for the borderline areas such as Neguac Bay and Baie St. Anne. In these areas bottom sediment distribution is largely interpretative.

The ideas presented here are based on my own interpretations of the bottom-sediment distribution, combined with field and photographic interpretations of morphological features and dynamic processes presently existing in the estuarine system of the Miramichi. Since I will be conducting a detailed investigation of sediment distribution (grain-size statistical analysis, mineralogical analysis) within the on-going Miramichi multi-disciplinary project of EMG, I anticipate that a number of the ideas presented here regarding sediment dynamics and dredging problems, will be substantiated and/or revised in the months ahead. These results (combined with data herein) will form the basis for a publication on bottom sediments of the Miramichi, and will be available to MCS when it is completed. I feel that the agreement between EMG and MCS has been of mutual benefit to both organizations, because this synthesis was the logical first step to my intended research work on sediments of the Miramichi, and it provides MCS with a much needed preliminary documentation of the surficial-sediment distribution of the Miramichi.

DESCRIPTIVE MORPHOLOGY AND SEDIMENTARY ENVIRONMENTS

The Miramichi estuary is a typical funnel-shaped estuary, and with regard to geomorphological type, would fall into the "bar-built" estuary type in the classification of Pritchard (1967). Pritchard considers the bar-built type to be a composite system, consisting of an outer embayment enclosed by a coastal barrier, and an inner major drowned river valley. He also considers that estuaries of this type are usually shallow and affected considerably by winds. The Miramichi fits this description almost perfectly.

Five major sedimentary environments can be recognized in the Miramichi estuarine system: river channel, inner bay, tidal-delta complex, coastal barrier and outer bay. These environments are delineated on the basis of physiography and water depth, and the boundaries between them are chosen arbitrarily for descriptive purposes (Fig. 1). The distribution of sedimentary environments closely parallels the hydrodynamic system in the estuary and the physical characteristics of the sediments from each environment are a reflection of this system (Table 3).

River Channel

This environment is a typical river, it has downcut into bedrock forming a confined channel, the lower reaches of which have been submerged by rise in sea level following glacial retreat. Water depth in the river is variable; maximum depths occur near the shore on the outside of meander bends, and minimum depths occur on the inside of meander bends near the opposite shore. Point bar deposits are the cause of this cross-channel shallowing. Flat-lying Paleozoic sandstones form a low-cliffed shoreline along most of the river channel except on the inner side of meander bends where Pleistocene(?) to Holocene alluvial deposits occur.

Inner Bay

This environment is relatively unrestricted geomorphologically compared to the river channel, and has a rather constant water depth and smooth submarine topography. It is more or less a shallow basinal area which formed through the drowning of the alluvial valley and plain adjacent to the river mouth. Very low cliffs of flat-lying Paleozoic sandstone rim the north and south shores.

TABLE 3 - Some Physical Characteristics of Sediments from Various Depositional Environments

ENVIRONMENT	SUBENVIRONMENT	TEXTURE	COLOUR	ORGANIC CONTENT	PRIMARY STRUCTURES
Outer Bay	-	Sand to gravelly sand, (sandy gravel)	light brownish grey to light yellowish brown	low	Not observed
Coastal Barrier	Beach and foredune	sand	brownish-yellow	low	Laminations, planar beds, ridge-and-runnel systems, ripples, swash marks, etc.
Tidal-Delta Complex	Tidal deltas	sand	light brownish grey to light yellowish brown	low	Sand waves, various ripples, some megaripples
	Tidal inlets	sand to gravelly sand			Not observed
Inner Bay	Basinal	sandy mud to mud, (muddy sand)	olive gray to grayish brown	inter-mediate to high	Color mottling to color-laminated occasionally
	Nearshore	sand	light olive-brown to pale olive	low	ripples, occasionally mega-ripples, current laminations
River Channel	Shallows	gravelly sand to sand	pinkish grey to yellow gray	inter-mediate to low	Not observed
	Deeps	sandy mud to mud	dark grayish brown to black and dark olive-gray	high	Not observed

These outcrops often occur as sandstone pavement extending well into the nearshore zone below low-water mark. A good deal of the nearshore sands are supplied by erosion of these shoreline outcrops. Pleistocene(?) and Holocene alluvial deposits form the shoreline in the vicinity of tributary river-mouths, and deposits of peat occur in a number of areas (in particular at Cheval Point).

Tidal-Delta Complex

The tidal-delta complex is the term used for the shallow sand-dominated area, which is present on both sides of the coastal barrier. Three sub-environments make up the tidal-delta complex; the tidal inlets (Portage Channel, Portage Gully, Huckleberry Gully), coalescing flood-tidal deltas (including Horseshoe Shoal), and ebb-tidal deltas. The terms "flood-tidal delta" and "ebb-tidal delta", as used here, are defined respectively as, "sediment accumulation formed inside an inlet by flood-tidal currents", and "sediment accumulation seaward of a tidal inlet, deposited by ebb-tidal currents"(Coastal Research Group, 1969, p. 456).

The relatively continuous, shallow north-south trending belt of sand banks and shoals which extend well into the estuary at Baie Ste. Anne and Horseshoe Shoal, and to a lesser extent in the Neguac Bay region, are actually coalescing flood-tidal deltas. The extent of the flood-tidal delta complex as compared to the small shoal areas (ebb-tidal deltas) seaward of Portage Gully and Portage Channel (Map #2), indicate that the predominant, or net, movement of marine detritus is landward, or into the estuary. An ebb-tidal delta is not present at Huckleberry Gully, and the flood-tidal delta extends farthest into the estuary in this region. This suggests that net landward movement of sand is more pronounced in this region than in the tidal-deltaic areas farther north.

Coastal Barrier

The term "coastal barrier" as used here, is defined by Bird (1964) as "a strip of depositional land extending above high-tide level, and standing offshore or across the mouths of inlets or embayments". The coastal barrier at Miramichi extends between the bedrock headland at Escuminac, and the headland at Pointe Au Terra Noir, which is located well north of Neguac Lagoon. It is broken by three main inlets (Portage Gully, Portage Channel, Huckleberry Gully). The barrier complex is thus divided into four segments known, from south to north, as Preston Beach, Fox Island, Portage Island, and Neguac Island-Barrier. These coastal-barrier segments consist essentially of two major zones: 1) the contemporary foredune and beach environment, which forms the present shoreline, and is actively changing in response to waves, winds and tidal currents, and 2) the ancient vegetated barrier tract which is a succession of parallel beach ridges with intervening swales consisting of marsh, swamp and small lagoons. The ancient barrier is being modified to some degree at present, but its overall morphology is generally the result of progradational accretion during the Holocene.

Outer Bay

This environment is a typical shallow arcuate, open marine bay. The bottom slopes gently in a seaward direction, and because of this configuration, wind-generated swell and tidal currents are rarely dissipated before they reach well into the inshore areas.

DISTRIBUTION OF SURFICIAL SEDIMENT

Sediment types and their distribution are depicted in Map #3. The textural classification used for construction of this map is that of Folk (1968). There are six major sediment types depicted on the map; sandy gravel, gravelly sand, sand, muddy sand, sandy mud, and mud. These six types are derived from grouping of classes (on the triangular diagram) such that their distribution illustrates most meaningfully the varying depositional regimes existing in the estuary. For example, the gravelly sand boundary is extended below the 5% cutoff to include the slightly gravelly sand category because the two classes, when considered together, are more meaningful in illustrating that sands containing gravel occur more often in the high energy zones such as Portage Channel and the outer bay region.

The distribution of sand plus gravel (weight percent of material coarser than 0.0625 mm) is depicted in Map #4. This distribution complements the distribution of textural types as depicted in Map #3. From these two maps, a number of observations and interpretations can be made concerning sediment distribution in the Miramichi.

The variations in distribution of textural types correspond closely with the various depositional environments. In the outer bay gravelly sand and sand are the predominant sediment types. The gravelly sand facies occur seaward of the sand facies suggesting that onshore transport of sediment is occurring. The predominance of flood-tidal deltaic sand deposits over their ebb-tidal counterparts, combined with the presence of gravelly sand, as channel-lag deposits in the regions of the tidal inlets, indicates that net transport of marine sand is directed into the estuary.

The sediments in the river channel are characterized by extreme textural variability, ranging from mud to sandy gravel. The upper reaches of the channel are dominated by moderately- to poorly-sorted, medium- to coarse-grained sands of fluvial origin. Further downstream, similar sands occur as broad shoaler areas on the inside of meander bends. In fact, sand dominates areally in the river, and mud deposits occur only along the thalweg of the channel, and in local off-channel deep areas.

The inner bay environment is characterized by muddy sediments with a paucity of sand. This area is the main depositional sink for fine-grained fluvial detritus coming downstream. It is my opinion that very little coarse-grained fluvial detritus is carried as far down as the inner bay region. Similarly, very little coarse-grained marine detritus is transported farther into the estuary than the inner bay region. The sandy mud and muddy sand facies between the flood-tidal delta and the inner bay basin represent mixed deposits of fine-grained fluvial material and marine sand.

It can be inferred, from the dispersal pattern displayed by the mud facies in the inner bay, that current velocities are probably always consistently lower (over a given time interval) in this region than in other regions of the estuary. This interpretation is substantiated by the recent work of R.R. Johnson, NRC, who constructed a two-dimensional numerical model of velocity distribution in Miramichi Bay. The drop in transport energy due to the interaction of tidal and river forces causes the deposition of clay, silt, and fine sand. Deposition of flocculated clay-size particles probably occurs in this region even though the flocculation front may occur farther upstream. Flocculation of clay-size material would not necessarily mean immediate deposition especially if current velocities were high enough to transport such material a short distance before it settles through the water column. It is also inferred, from the distribution of mud, that the zone where advective and diffusive mixing is at a maximum, is located in the vicinity of the lower river-estuary on the upstream side of the mud basin.

Turbulence at this diffuse fresh water-seawater boundary, could account for the lag between flocculation and deposition.

The hydrodynamic circulation in the estuary is related to bottom topography, lateral physical dimensions of the estuary, and to the wind. The splayed pattern of mud deposits reflects these controls. The seaward moving water, as it leaves the river channel will tend to follow the direction of the submarine shipping channel adjacent to the northern shore. As it moves over Grand Dune Flats it will follow the path of least resistance, which is along the north shore, where water depths are greatest in the inner bay region. The incoming sea water serves to deflect outflowing water toward the northwest also, because it is initially directed inward toward the southwest through Horseshoe Bar, and then due west and west-northwest as it progresses farther upstream. The intrusion of marine sand farther into the southern half of the estuary, and the tongue of mud farther seaward in the northern half of the estuary seems to substantiate this interpretation. A tongue of marine sand extends into the inner bay along the shipping channel reflecting the region through which the maximum volume of sea water intrudes. Apparently some "ponding-up" of water occurs in the Bay du Vin region, (as evidenced by the presence of bottom mud there), due to the interaction of circulation forces described above. In addition, wind may play a dominant role in the "ponding" of water in the Bay due Vin region; this situation is indicated in the numerical model of R.R. Johnson (personal comm.), especially when prevailing winds are from the northeast.

The bottom sediment distribution points to a circulation and depositional energy model such as depicted in Figure 2. Dominant transporting energies are directed inland in the tidal delta region, seaward at the river channel, and laterally in the inner bay region, where currents are lowest in terms of overall transporting energy, and where the effects of winds on circulation are highest.

The estuarine system can be divided into three depositional realms; marine, fluvial, and mixed, on the basis of bottom sediment distribution (Fig. 3). This division suggests that there are two main sources of estuary sediments, marine and fluvial. In fact, there is a third source, shoreline erosion of sandstone bedrock. It is as yet unknown how important shoreline erosion is in supplying sediment to the estuary, but in the inner bay region, a significant part of the nearshore sand which extends as a belt along the north and south shores, is supplied directly from erosion of adjacent shoreline outcrops. At numerous shoreline localities friable sandstone debris, and bedding-plane outcrops can be seen to extend a considerable distance below low-water mark. The low-cliffed shore at these same localities appears to have receded considerably in recent years. It is hoped that shoreline recession can be investigated further to ascertain the amount of material which is being supplied to the nearshore zone through such erosion.

CONSEQUENCES FOR DREDGING AND DREDGE-SPOIL DISPOSAL

Channel Dredging and Realignment Proposals

The present shipping channel and the proposed new routes are depicted on Map #1. Historically the problem areas for channel maintenance were, and still are: the Outer Bar ("The Lump"), located in the outer bay adjacent to Fox Island; Horseshoe Bar, the southern extremity of Horseshoe Shoal, just inside the coastal barrier; and Grand Dune Flats (Working Group Report, 1974).

In my opinion, the problem areas within the inner bay region will not be alleviated by choosing any of the alternate routes depicted on Map #1. The shipping channel, where it presently exists, is probably the best possible location. Where it crosses at Horseshoe Bar, is the narrowest part of Horseshoe Shoal, and in this position, it is maintained to some degree by tidal channel currents. To dredge a channel through the northern part of Horseshoe Shoal would be a major undertaking, combined with the fact that this new channel would be less likely to be maintained naturally by tidal currents. The pre sent channel is located in the axis of maximum water movement. Siltation rates are bound to be much higher behind the barrier, than adjacent to a tidal inlet.

With regard to the Grand Dune leg of the shipping channel, it may be advisable to change the route to a NNW direction through the centre of the inner bay to the point where Grand Dune Flats is narrowest, and then traverse the flats as proposed. However, again the cost and effort to change the channel may be far greater than to deepen and maintain the channel where it is presently located. Siltation rates will still be a problem wherever Grand Dune Flats is traversed.

One possible area for rerouting the shipping channel in the river section is located at Lower Newcastle, where it traverses north of a mid-river shoaler area, through a sand bottom. Adjustment of the channel to the south of this shoal where mud bottom is present would make it more compatible with the natural hydrology of the river. However, in this instance again, to change a small portion of the shipping channel from a relatively deep area to a shallow area which initially has to be dredged, may not be as economical as periodic maintenance of the present shipping lane in this region. Apart from this one questionable area, the present shipping channel in the river section of the estuary is probably situated in the best possible place already.

In the outer bay area siltation will always be a problem because on-shore transport of sediment from the Gulf prevails, combined with a westerly longshore drift west of Point Escuminac, and a southerly longshore drift along Neguac Barrier and Portage Island. "The Lump" at the southern end of the Outer Bar is located at the limit of the ebb-tidal delta which is deflected southward by longshore drift (Map #2). An ebb-spit occurs on the south side of Portage Channel which indicates the orientation of the ebb tidal channel and the direction in which ebb-tidal sand is being transported. The ebb-tidal channel probably supplies sediment to the southern half of the Outer Bar, which in turn terminates where westerly longshore movement meets ebb-migrating sand. It is here where sand accumulation will be greatest, in the region of "The Lump".

The proposed alternative shipping-channel route to the present one (via "The Lump"), is located immediately east of Portage Channel extending easterly through the Outer Bar (Map #1). This area was experimentally dredged in June, 1965 by DPW, to a depth of 22 ft. below LWOST, width of 200 ft., and 322.675 yd^3 of dredge-spoil was removed (Working Group Report, 1974). DPW resurveyed this area through to 1968, and concluded that maintenance of an alternative channel through the Outer Bar, would be hopeless because of rapid siltation. It is interesting to note that the 1974 hydrographic surveys indicate that this channel is still well over 18 ft. deep for most of its length (Map #2). I would suggest that this alternate routing be given serious consideration. It is obvious that this channel has been maintained naturally by tidal and wave-generated currents, and that siltation has not been as rapid as expected, or as rapid as it was when the channel was dredged in the midsixties. If the morphology of this channel is approaching stable conditions, at its present depth and width, then it may approach stabilization at a navigable state if it is redredged to a much larger width and depth than it was during initial dredging of 1965. To maintain a 26 foot deep channel via "The Lump" would require an estimated annual removal of 400,000 yd^3 (Working Group Report, 1974). Only 323,000 yd^3 were removed from the proposed alternate channel during initial dredging of 1965, so it is worth investigating the possibility of utilizing the proposed alternate route, and bypassing "The Lump". It is possible that the dredging of the channel through the Outer Bar in 1965, may have increased siltation rates in the vicinity of "The Lump", and certainly will do so if this alternate route is made navigable for shipping. The reason for this is that the newly dredged channel serves as a direct route for ebb-tidal channel flow coming from within the Miramichi barrier. The naturally-existing southward ebb-tidal channel is now partially bypassed in terms of original flow volume and the effective transporting energy originally occurring in this channel has been reduced accordingly.

Dredge-Spoil Disposal

It is difficult to suggest really ideal areas for disposal of dredge-spoil in estuaries such as the Miramichi. The choice of suitable areas depends on what the dredged material is, whether it is sand or mud. An obvious suitable location, in terms of minimizing environmental hazards to the estuary, is on land, but this is not economical, nor aesthetically pleasing to the public who prefer to have it dumped where it is not visible, that is, under water.

In the area of ~~Grand~~ Dune Flats, dredge spoil would be mud. So the best locality in the estuary to dispose of it would be to spread it over a wide area in the inner-bay mud basin immediately south of the shipping channel.

It would then remain where it was dumped because the same such material is being deposited there at present; that is, it would remain there provided the amount of dredge-spoil would not be great enough to greatly decrease the water depth and alter the hydrodynamics of the region. This could be determined beforehand, possibly experimentally on the NRC model.

Dredged material from Horseshoe Bar, "The Lump", and the proposed alternate channel through the Outer Bar, would consist mainly of clean sand. If such spoil is dumped anywhere in the outer bay, it will eventually end up back in the dredged areas, or in the inner estuary. No environmental hazards are likely from this type of dumping, and it is difficult to estimate how rapidly such material would return to the nearshore zone. Another, but probably uneconomical place to dispose of such sand would be in the Gulf south and east of Point Escuminac. If dumped there, it would supply additional sand to the southerly longshore drift along the New Brunswick coast of Northumberland Strait.

A third and probably best method of disposal of dredge-spoil consisting of clean sand, would be to barge it to Chatham, Newcastle or Escuminac, and stock-pile it for use by the municipality, public,or provincial government, for building construction, either as fill or in concrete, or for road construction and maintenance. There is a general scarcity of fine aggregate for construction in southeastern New Brusnwick (ADI Ltd., 1975), so this could be one way of easing this shortage and avoiding the problems involved in disposing of such large volumes of material into the ocean.

One fact puzzles me about the history of maintenance dredging in the Miramichi, that is, Horseshoe Bar and Grand Dune Flats are apparently of grave concern because of siltation problems. The last maintenance dredging to occur at Horseshoe Bar and Grand Dune Flats, was in 1930 and 1940, respectively (Working Group Report, 1974). After such intervals of time, siltation problems are not surprising and should be expected. I would suggest that these dredged areas approached stable conditions quite some time ago, that siltation occurred rapidly soon after the dredging, that the rate of siltation has been slow since then and that the dredged channel has been relatively stable for a number of years. Ships navigating the channel 10 to 15 years ago probably have experienced the same problems, with regard to channel depth and width, as they do today. The continued passage of ships through these dredged areas probably has contributed considerably to the maintenance of a navigable waterway.

"The Lump" was last dredged, for maintenance purposes, in 1956. It is here that siltation probably has been occurring at a relatively high and constant rate since dredging and it is here, in the Outer Bar region, that siltation problems will be most pronounced in the future.

Summary

1) The present shipping channel is located in almost the best position possible in both the river section and the inner bay section of the estuary. The alternate routes proposed will not alleviate any of the present siltation problems.

2) The siltation problems at Horseshoe Bar (Horseshoe Shoal) and Grand Dune Flats cannot be alleviated because both these high siltation areas extend laterally across the estuary. Where the present channel crosses Horseshoe Bar, is the area where siltation rates on Horseshoe Shoal are the lowest. Any dredged channel across Grand Dune Flats will encounter siltation problems, so if it is left in its present location, then dredging does not have to start back at "square-one", so to speak.

3) MCS should explore thoroughly the possibility of changing the shipping channel, via "The Lump", in the outer bay, to the proposed alternate route which traverses in an east-west direction, directly through the Outer Bar.

4) The disposal site of mud-spoil from Grand Dune Flats, should be located in the inner-bay mud basin to the south of the dredged area. It is likely the spoil would remain there if the quantities were not sufficiently large enough so as to alter the bottom topography to any great extent.

5) Sand dredge-spoil from Horseshoe Bar and the Outer Bar can be dumped in the outer bay and will present no immediate environmental hazard. However, since the dominant movement of sand is shoreward, this spoil can be expected to increase the landward sand supply and thereby end up once again in the nearshore region.

6) The possibility of utilizing the sand dredge-spoil as construction aggregate or fill should be explored. Provincial, municipal or private concerns may be interested in studying the feasibility of using this spoil for such purposes.

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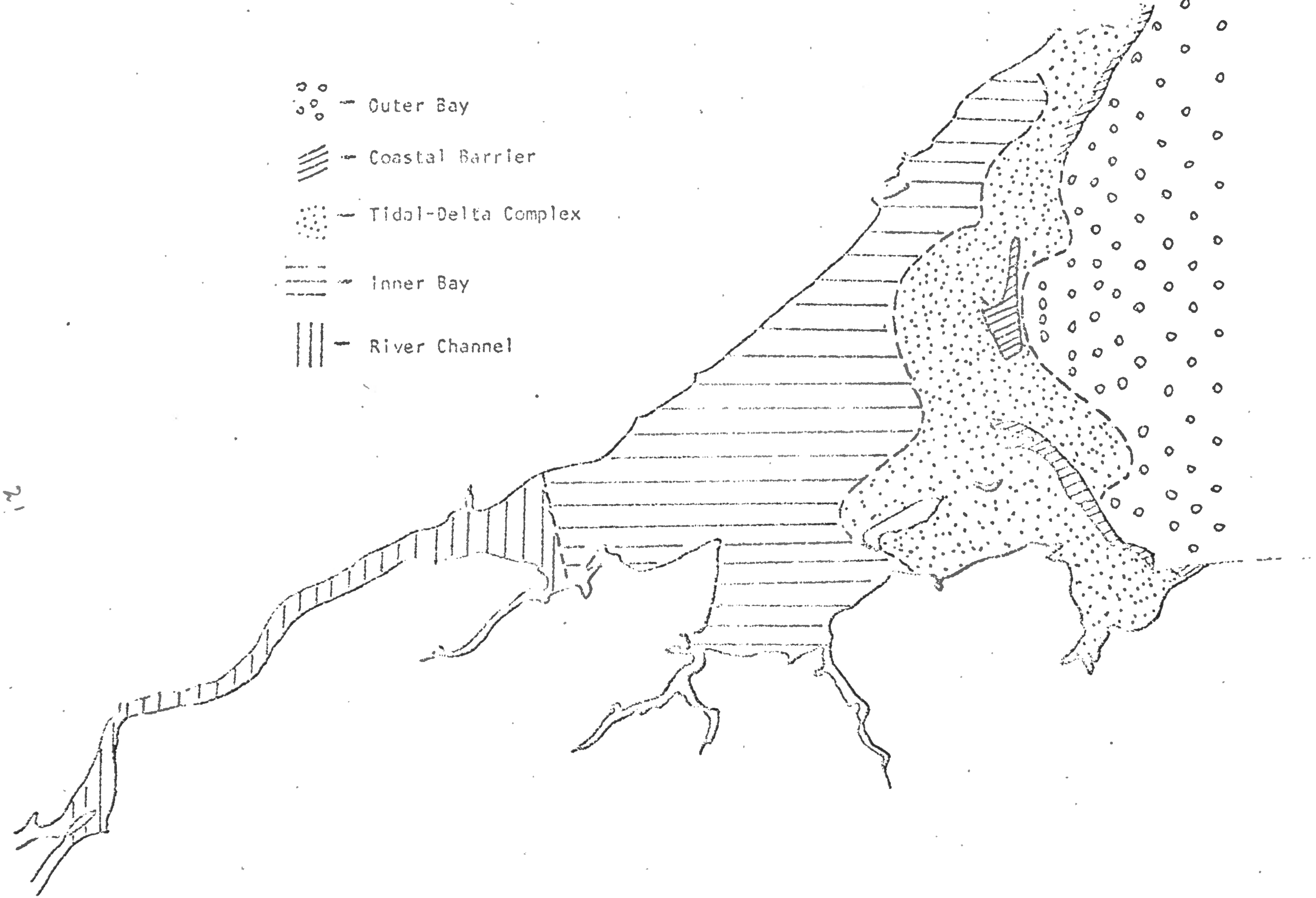

Figure 1 - Distribution of major sedimentary environments.

Figure 2 - Distribution of dominant [illegible] energies in the estuary.

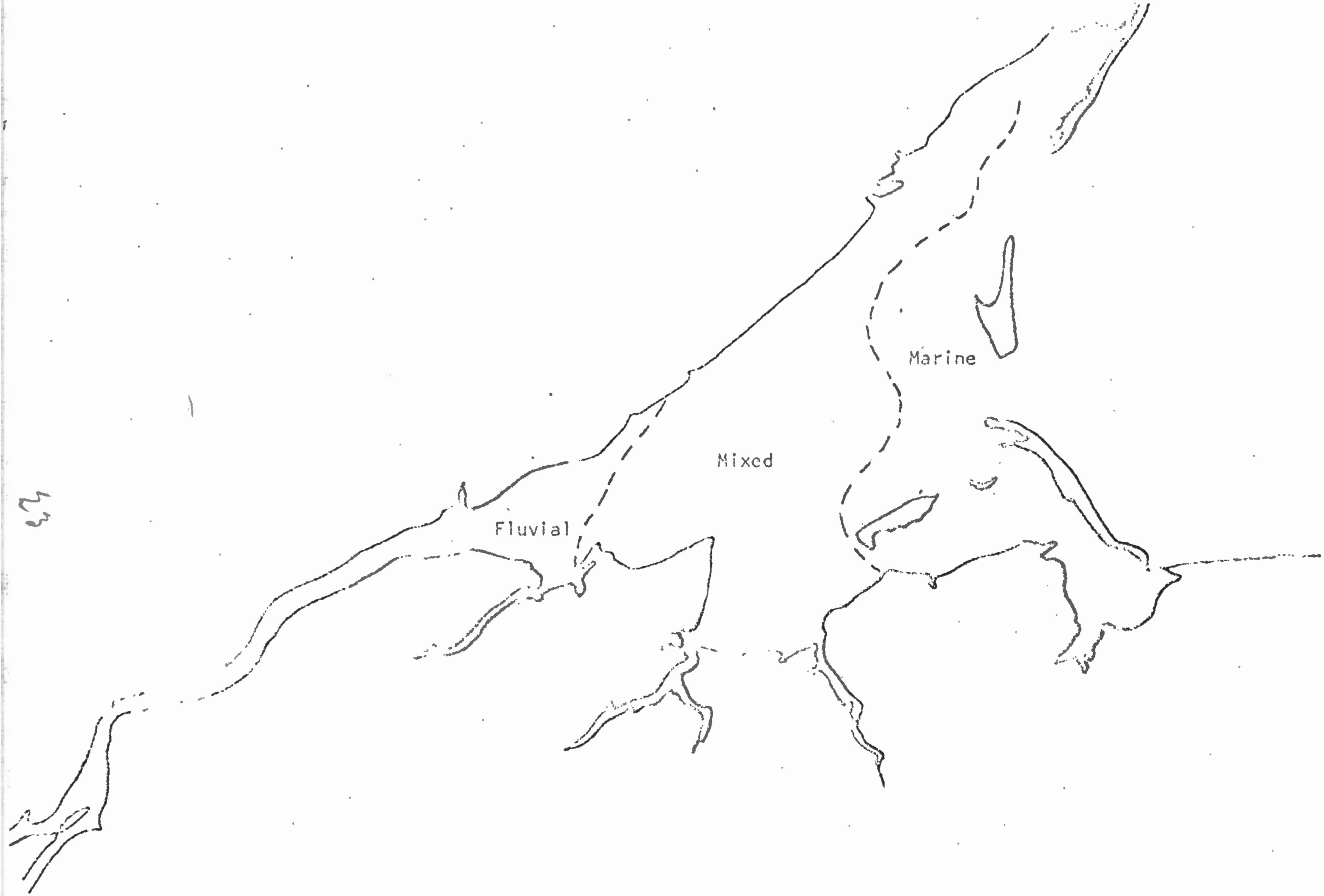

Figure 3 - Distribution of depositional realms in the estuary.