INLETS/ESTUARIES DISCHARGING INTO SHELTERED WATERS

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SUMMARY

Tidal prism - cross sectional area relationships and tidal velocities have been measured for inlet entrances and along the length of the estuary for four creeks entering the sheltered waters on the South East Queensland coast, Australia. It has been found that the inlet entrance tidal prism - cross-sectional area relationship is controlled by the magnitude of littoral drift. The tidal prism - cross-sectional area relationship along the estuary is believed to be common to all tidal estuaries landward of the region where littoral drift has an influence.

For tidal inlets on sheltered coasts with tidal prisms of the order of $10^6 m^3$, the mean maximium velocity during spring tides at the inlet entrance is about 0.3 to 0.4 m/s.

1. INTRODUCTION

For the design of a new international airport at Brisbane, it was necessary to reclaim an existing stable creek and to divert flood-waters to an artificial inlet. In order to design an artificial inlet which would be stable, or at least have predictable characteristics, a study was undertaken by and for the design authority, the Australian Government Department of Housing and Construction, to investigate the characteristics of inlets and estuaries discharging into sheltered waters.

The site for the airport is shown in Figure 1 where Serpentine Creek will be reclaimed and an artificial inlet excavated about two kilometres to the north. Both Serpentine Creek and the artificial inlet discharge into Moreton Bay which is approximately 30 km wide by 50 km long. It follows that the wave climate at the inlet entrance will be mild with wave periods and heights rarely exceeding 5 seconds and 1.5 metres respectively. Littoral drift rates are consequently low, probably less than 10,000 m^3 per annum. With these considerations, it was thought that the economic design of an artificial inlet should not be based on relationships derived for tidal inlets on open coasts; e.g. O'Brien (1969), Bruun (1978), Jarrett (1976).

In order to obtain relationships upon which the design of a predictable inlet and estuary may be based, field studies were undertaken to measure the characteristics of inlets in protected waters.

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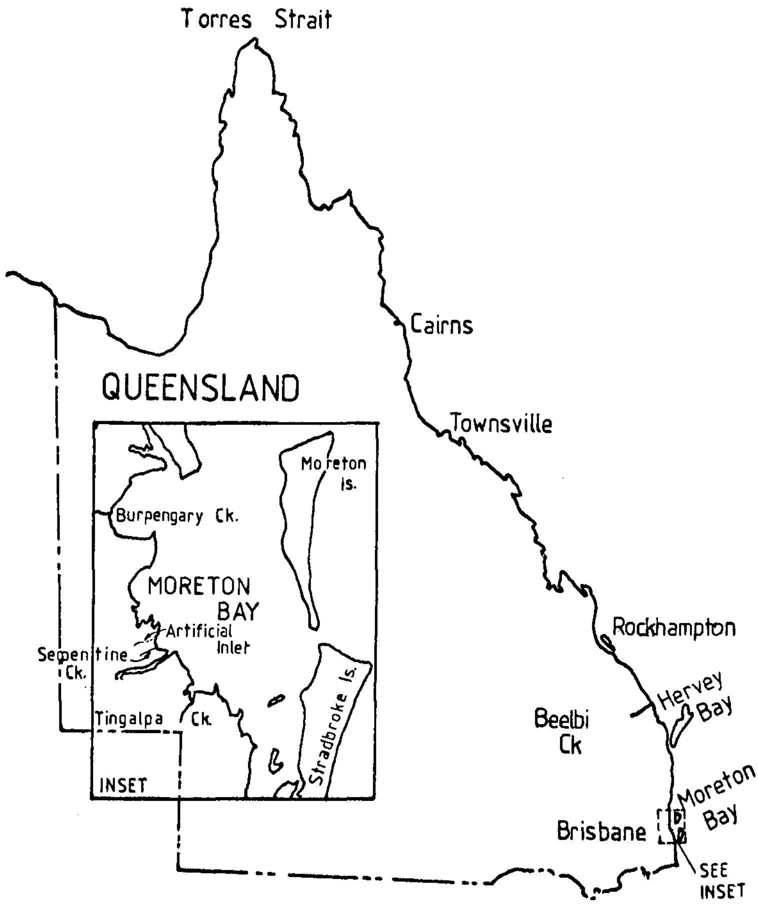

FIGURE 1 Locality Plan

Comparisons were also made with data obtained by others. Geomorphological and sedimentological studies of Serpentine Creek and adjoining areas were also undertaken to obtain an understanding of the recent (Holocene) geological history and sedimentation processes; Gourlay (1979).

2. PREVIOUS STUDIES

An understanding of the stability of inlets/estuaries must be based on a sound understanding of the tidal hydraulics, flood flows, wave mechanisms and sedimentary aspects. However, the degree of importance of each of these influences depends to some extent on the exposure of the inlet to the open ocean.

There have been numerous studies of tidal inlets on exposed coasts. Summaries of these studies and the factors controlling these inlets have had wide publication, in particular those of O'Brien (1969) and Bruun (1978). These studies relate mainly to inlets between the ocean and bays, rather than inlets and an associated tidal estuary. Information on tidal inlets and estuaries discharging into bays or a sheltered section of the ocean is fairly scarce, and there is little published data. Very recently, Byrne et al (1980) have obtained a comprehensive set of data for inlets in Chesapeake Bay. Also, because of the variability possible in bay shape and bathymetry, the generalisations possible for the open coast may not be possible for sheltered inlets.

For Australian inlets/estuaries discharging into relatively sheltered waters very few publications have been found which are quite relevant to this study. Many of these publications are internal to their relevant organisations, which indicates that there may be other data obtained by others which has not been reported in an accessible form. It is possible that a similar situation exists in other countries where, because the studies for small inlets tend to be small scale, the results are not readily accessible. Consequently, a literature search of data obtained outside Australia has not been attempted for sheltered inlets.

Perhaps the most relevant study to this investigation is that published by Apelt (1977) which investigates the existing Serpentine Creek. Figure 2 shows a plot of tidal prism vs cross-sectional area along the Serpentine estuary. It also includes the data from other relatively sheltered estuaries for which information was available, namely Georges River, N.S.W. (Munro et al 1967), Mooloolah River, Qld. (Nittim 1974) and Pine River, Qld. (Cameron McNamara 1978). The Mooloolah River in South East Queensland discharges into the ocean at a rather sheltered location on an exposed coastline about 150 km north of Brisbane where the littoral drift is relatively small. The Georges River, N.S.W., discharges into Botany Bay south of Sydney. The Pine River discharges into Moreton Bay, but is a much larger estuary than the other estuaries in Moreton Bay considered in this paper.

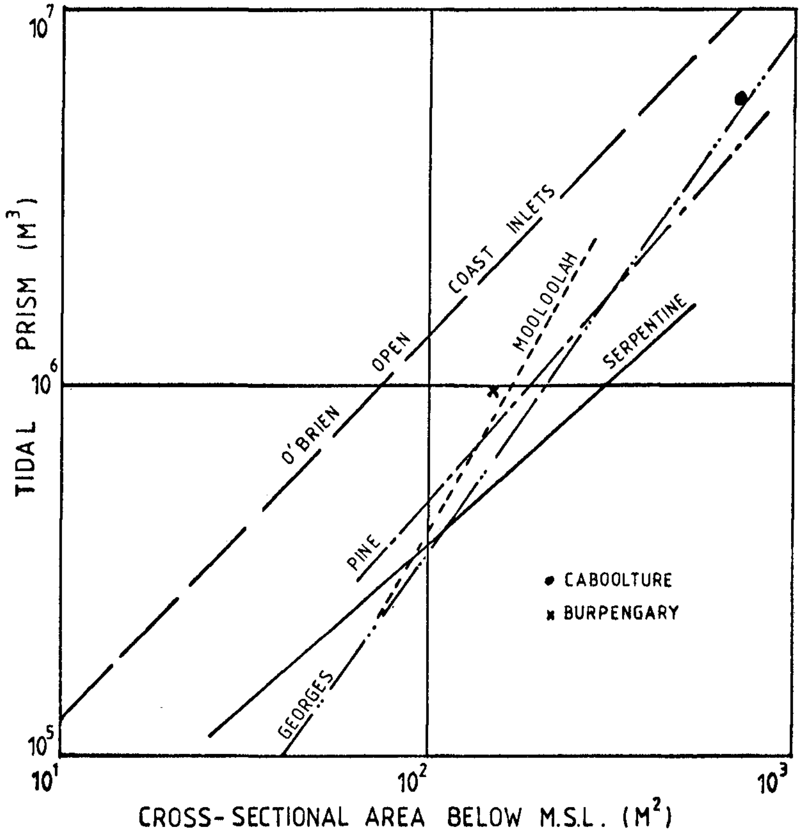

FIGURE 2 AUSTRALIAN INLET - ESTUARY DATA
SHELTERED LOCATIONS

For reference, O'Brien's line for exposed inlet entrances has been included. Figure 2 shows that for each of these Australian inlets the tidal prism characteristics at the entrance and along the estuary fall well below the open coast inlet line.

Figure 2 also shows tidal prisms for the entrance to Burpengary Creek and the Caboolture River in Moreton Bay which also fall well below the open coast line. These sets of data do show quite a wide scatter and were considered inadequate for the purposes of designing an artificial inlet and estuary. Much of the scatter may be attributed to a large variation in scale of the estuaries, and to river flows that may dominate tidal flows. For the system under study, it was expected that tidal characteristics would control the long term shape of the inlet and estuary.

3. FIELD MEASUREMENTS

Tide, current and limited hydrographic data were obtained for four inlets and associated estuaries in South East Queensland. Chosen were:

Beelbi Creek in Hervey Bay, and
Tingalpa, Serpentine and Burpengary Creeks in Moreton Bay.

Each inlet was selected because its scale, tidal range and exposure were similar to that of the proposed artificial inlet. For each creek the spring tidal range is about 2 metres outside the entrance, and the tidal prisms ranged from $0.8 \times 10^6 m^3$ for Burpengary Creek to $1.4 \times 10^6 m^3$ for Beelhi Creek.

The prevailing wind system for this section of coast is south easterly, as typified by the wind rose for Cape Moreton in Figure 3. The wind rose for Cape Moreton may give an exaggerated impression of the dominance of the south east wind, because the recording station has direct exposure to this wind direction. Winds within Moreton Bay and Hervey Bay would be slightly modified by the adjacent land masses.

From Figures 1 and 3 it is apparent that each of these creek entrances is well protected from swell waves, as well as receiving a large degree of protection from short period waves generated from the dominant south east wind direction.

Perhaps the most variable factor between the selected creeks was the nature of the sediments. All the creeks entering Moreton Bay have similar sediments, with silts and clays on the banks and fine sand on the creek bed. In the downstream areas the depth of these fine materials is generally in excess of 1.5m. The upstream reaches show more variability, with Tingalpa Creek crossing several rock bars within the region of tidal influence.

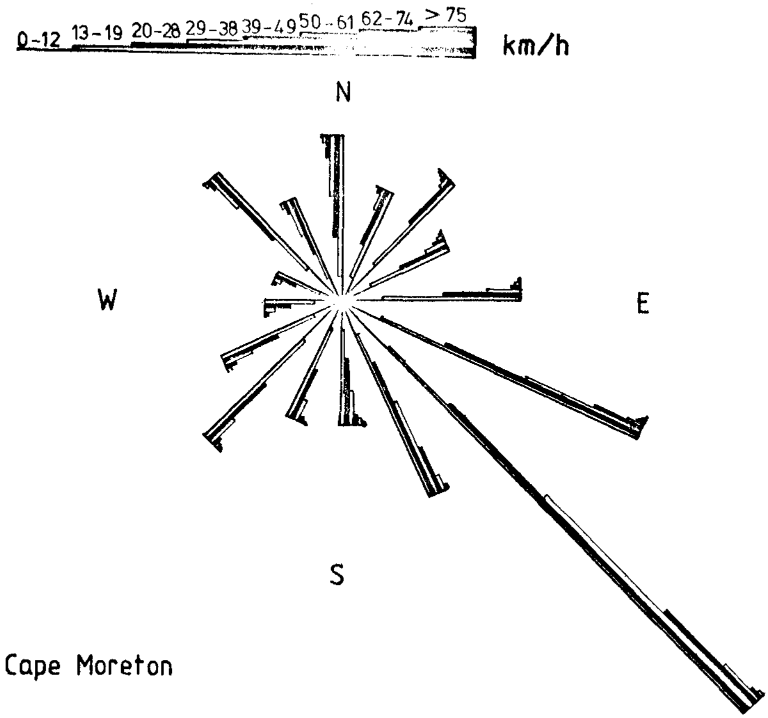

FIGURE 3 WIND ROSE

Beelbi Creek has much coarser sediments throughout its length. Areas showing fine sand or silt on the bed are only superficial deposits and much of the creek hed is underlain with gravel. Silt or fine sand thickness rarely exceeds 0.5m within the creek bed. There are quite coarse sediments at the downstream end of Beelbi Creek, particularly in the flood channel. A detailed sedimentological study of these creeks was beyond the scope of this paper, although this type of study has been completed for the Serpentine Creek (Gourlay 1979).

4. DATA

The data obtained consisted of:

(a) Tide records at three or four stations along each creek during at least one spring tide.
(b) Tidal velocities at up to four sections along each creek during the period for which tidal records were made.
(c) Hydrographic survey of each creek sufficient to define cross-sectional areas and tidal prisms along the length of the estuary.

The data was reduced to give mean maximium velocity across each section monitored over a mean spring tidal range (V mean max.), and the cross-sectional area (A) and tidal prism (P) at sections every 0.5 to 1 kilometre along the estuary. Figure 4 shows the V mean max. for both flood (F) and ebb (E) tides for each creek as a function of distance upstream from the creek mouth. With the exception of the flood data point at the 5 km mark of Beelbi Creek, the data points show a consistent picture, with velocities at the creek entrance of about 0.3 to 0.4 m/s dropping to 0.2 to 0.3 m/s at the upstream limit of tidal influence. There was negligible rainfall (river flow) before or during all the measurement periods.

Figure 5 shows the data for tidal prism vs cross-sectional area for the length of the estuaries to the limit of the tidal influence. The data for Serpentine Creek has been modified from that shown in Figure 2. A correction has been made by deducting the tidal prism of Schultz canal - an excavated channel at the upstream end of Serpentine Creek. This correction has heen justified on the basis that the lower reaches of the Serpentine have not had time to readjust to the extra tidal prism introduced by the Schultz channel. This correction results in a hetter agreement between the four sets of data.

5. DISCUSSION

It is quite clear from the data presented that tbe stability cbaracteristics of small inlets discharging into sbeltered waters are quite different from those for large systems connected through an exposed shoreline.

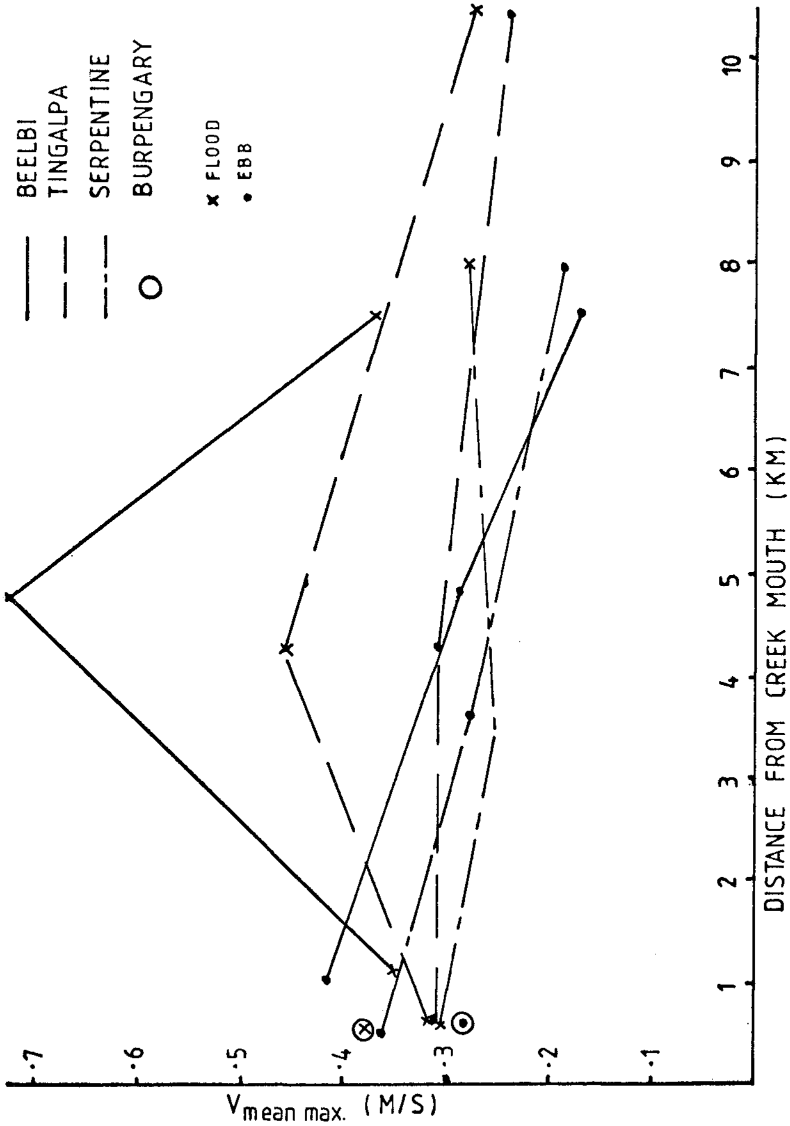

FIGURE 4 INLET/ESTUARY TIDAL VELOCITIES

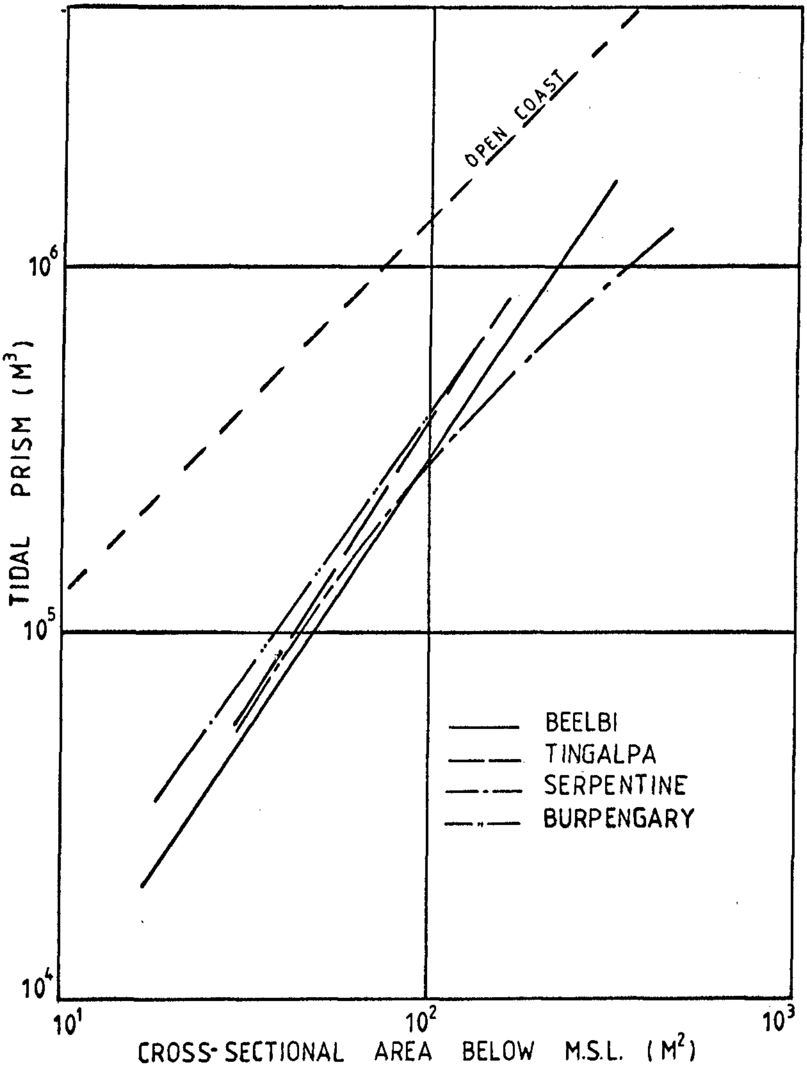

FIGURE 5 S.E. QUEENSLAND INLET/ESTUARY DATA SHELTERED LOCATIONS

However, it is suggested that the difference is purely in terms of scale. The mechanisms are the same in both instances.

5.1 Inlet Only

Table 1 summarises the velocity at the inlet entrance for each of the four creeks considered.

TABLE 1

V mean max. : FOR CREEKS ENTERING SHELTERED WATERS ON THE SOUTH EAST QUEENSLAND COAST

Creek	V mean max. (m/s)	
	Flood Tide	Ebb Tide
Serpentine	0.30	0.31
Tingalpa	0.31	0.32
Burpengary	0.37	0.29
Beelbi	0.35	0.42

By comparison, for about 50 inlets on exposed coasts on the U.S.A. and in Europe, Bruun (1978) reports that in almost all cases $0.8 < V$ mean max. < 1.2 m/s. In a similar manner, Figure 5 shows that for a given cross-sectional area of the inlet entrance, the tidal prism for exposed coast inlets is roughly 2 to 3 times those of the sheltered inlets reported herein.

An explanation for the marked difference between the four creeks and those reported for open coasts is that the littoral drift is on order of magnitude lower for the shorelines across which the South East Queensland creeks discharge.

The effect of the littoral drift is to try to infill the entrance of the inlet, whereas the tidal flow through the inlet entrance combats this by moving at a velocity fast enough to scour any material deposited in the entrance. If the tidal velocity is not large enough, the entrance will reduce in size until either the velocity increases to a sufficiently high scouring velocity, or the entrance is closed. With the large littoral drift on exposed shorelines, it follows that a large quantity of sediment must be moved by tidal velocities each tidal cycle, and this velocity for a stable inlet is of order of 1 m/s.

In contrast, for sheltered inlets the littoral drift rate is small and, consequently, a much smaller volume of material needs to be moved out of the entrance each tidal cycle. Figure 5 shows that the tidal cross-sectional area of the entrance to sheltered tidal inlets is much larger than for exposed inlets for a given tidal prism, and, it follows that velocities will be much lower. The measured velocities of 0.3 to 0.4 m/s are sufficient to initiate sediment motion for the sediments encountered, and, although the velocities are low, they are sufficient to counteract the low littoral drift rates.

Confirmation of the consistency of the P - A relationships of the inlets reported here, and those of others, is strengthened by the results reported hy Byrne et al (1980). Figure 6 shows the inlet P - A relationships for exposed coasts, sheltered coasts, very small natural inlets and model scale inlets.

5.2 Estuary

Confirmation of the influence of littoral drift upon inlet tidal prism - cross-sectional area relationships is found when the relationship between P and A along the estuaries is considered. Figure 7 combines data from Figures 2 and 5 and includes the Yaquina River in Oregon, U.S.A., which discharges into the ocean on an exposed coast. Goodwin et al (1970).

For all these estuaries the P - A relationship is approximately the same as the P - A relationship for the entrances of the four small estuaries studied here, and this relationship is very different from that for inlet channels on exposed coastlines. The entrance channel data of Byrne et al (1980) for inlet entrances are an order of magnitude smaller than these South East Queensland entrances, and are consistent, as can he seen on Figure 6 . All the estuaries have entrance cross-sections with greater areas than indicated by the open coast line, except the Yaquina River whose cross-section falls on the O'Brien line. This is consistent with its exposed location. The inference is that for estuaries where tidal flow, rather than flood discharge, determine the form, a stable P - A relationship may be predicted, provided the littoral drift rate is known. The littoral drift rate effectively controls the entrance cross-sectional characteristics, but upstream from the limit of influence of littoral drift all the estuaries investigated have a similar P - A realationship.

As previously proposed by Nelson (1977) this inference can be taken one step further by postulating on Figure 6 a generalised estuary (tidal) P - A line for the estuary outside the region of littoral drift influence. See Figure 8. The underlying assumption, which is validated by the data examined for inlet estuary systems, is that any littoral drift tends to choke the entrance area. Field data for a range of tidal estuaries would be required to completely test this hypothesis.

6. CONCLUSIONS

(A) Tidal prism - cross-sectional area (P - A) relationships may be used for describing tidal inlets, provided a distinction is drawn between the entrance and locations along the length of the estuary.

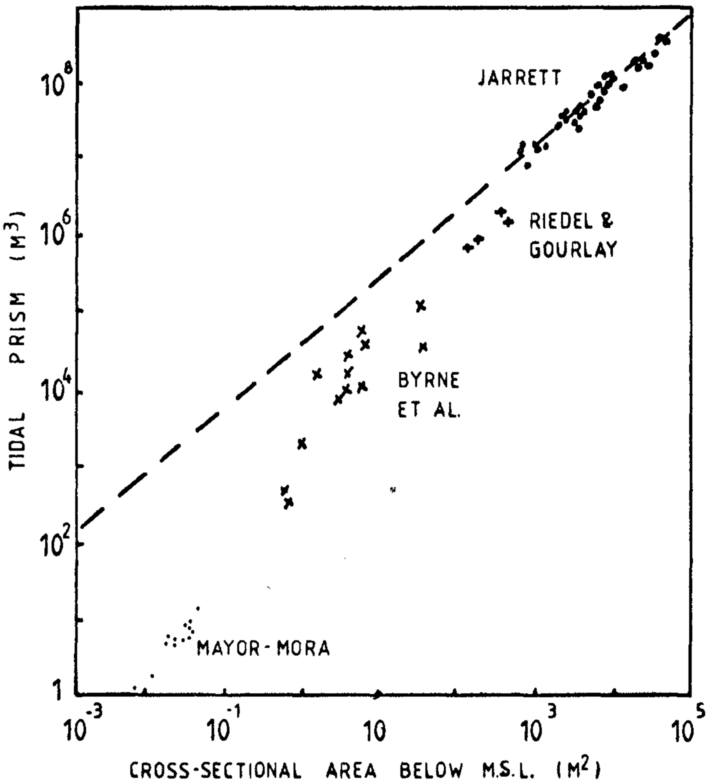

FIGURE 6 INLET ENTRANCES
ALL SCALES

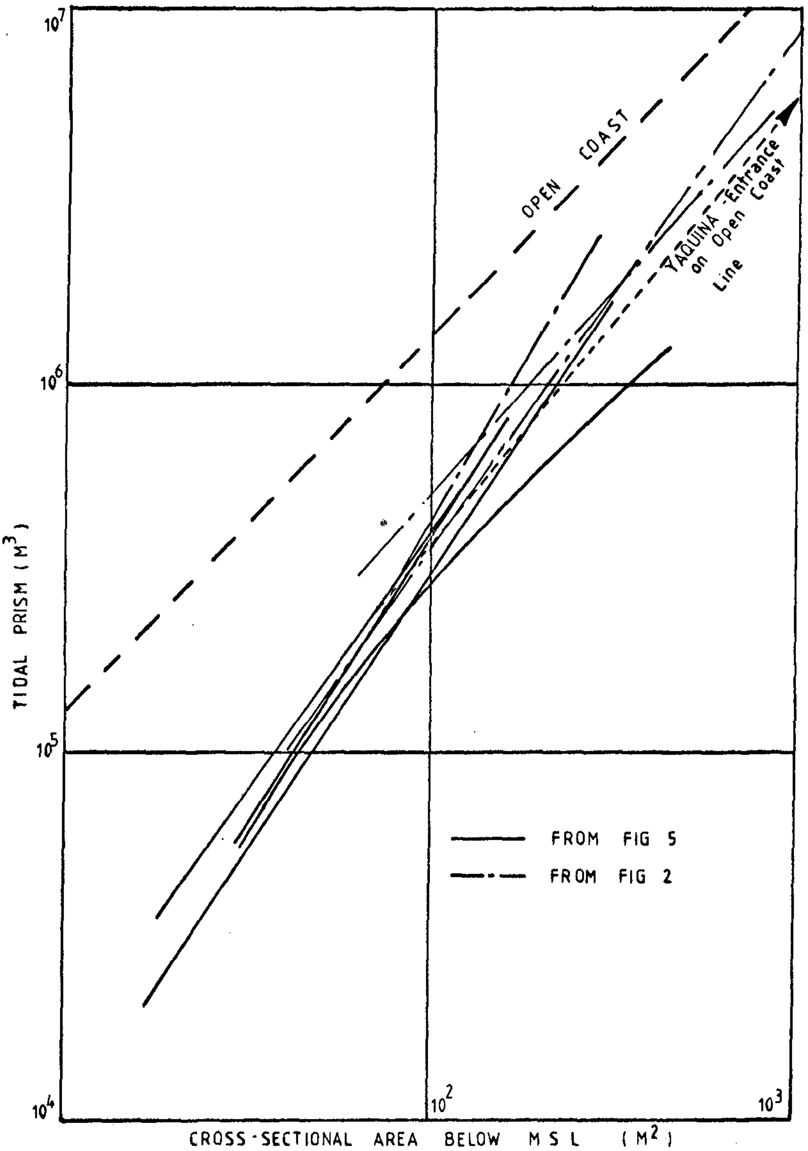

FIGURE 7 INLET - ESTUARY COMPARISON

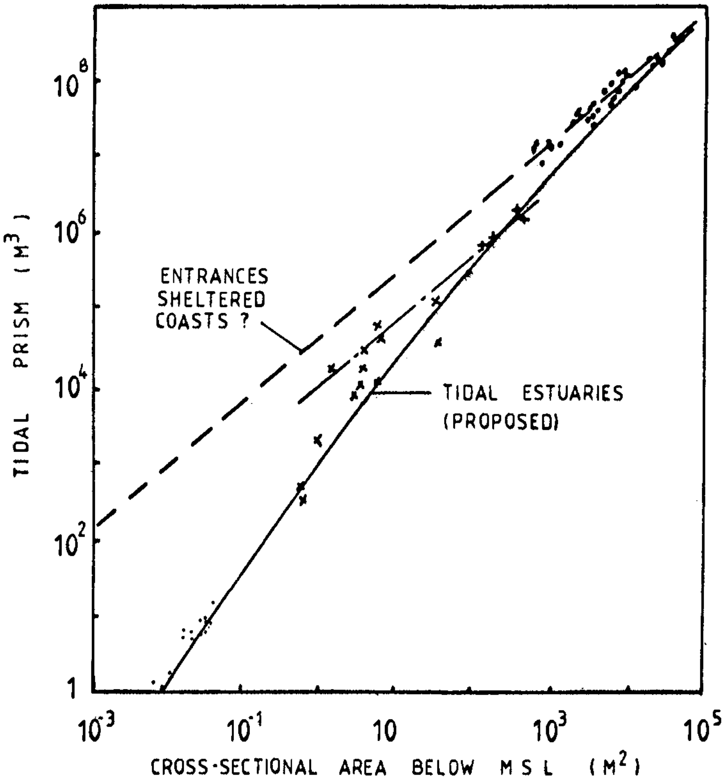

FIGURE 8 PROPOSED TIDAL ESTUARY LINE

(B) The O'Brien P - A representation holds for exposed coasts where there is a large littoral drift. At the other end of the scale are inlets with small littoral drift which fall on a P - A line well below the exposed coast line.

(C) The P - A line for inlet entrances lies above the P - A line for the length of the estuary. As littoral drift reduces for smaller inlets which are permanently open, the estuary line approaches the inlet more closely.

7. ACKNOWLEDGEMENTS

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