CHAPTER 72

MODEL TESTS AND STUDIES FOR PORT RASHID, DUBAI

ERIC LOEWY

Partner
Sir William Halcrow & Partners
Consulting Engineers, London

ABSTRACT

This paper is a factual account of studies carried out for the design of a new deep water harbour As so often happens construction work had to be begun before many of the conclusions of the study were available so that alterations to the initial designs had to be made while work progressed The studies comprised tidal and wave recordings and analysis, model studies to determine residual wave conditions at the quays, studies to determine the extent of littoral drift, the effect of the proposed works upon this and possible measures to counter downdrift erosion In addition studies were made of the stability of the adjacent creek channel which had previously been the harbour and a mathematical model study was carried out of the effects on the creek regime of various proposed entrance works including the construction of an entirely new creek entrance channel through the new deep water harbour

INTRODUCTION

The State of Dubai is situated on the southerly coast of the Strait of Hormuz which forms the seaward entrance of The Gulf (sometimes called the Persian or Arabian Gulf - see fig 1) The Capital Town of Dubai consists essentially of the twin towns of Dubai proper and Daira (fig 2) which lie astride the mouth of a tidal creek which has up to now formed its harbour This harbour was used by country craft (dhows), lighters and other small vessels, with only very minor works on jetties and wharves up to approximately 1958 The combination of littoral drift towards the north east and the creek tidal flow resulted in a gradual migration of the creek entrance in the direction of the drift and, in the years after the last war, to a reduction in the depth of water available at the entrance Starting in 1959 entrance training works were constructed and the channel dredged out to 8 feet below chart datum These works caused an interruption of the littoral drift with consequent erosion of the downdrift site (figs 3 and 4)

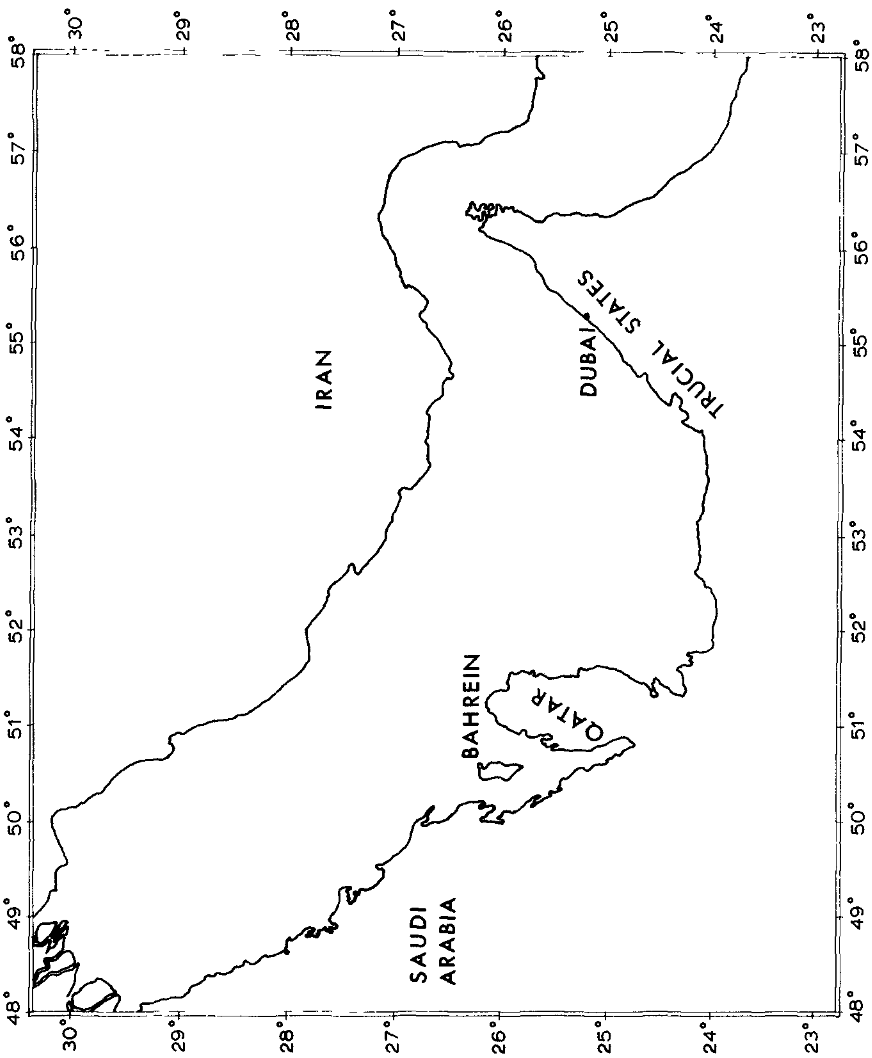
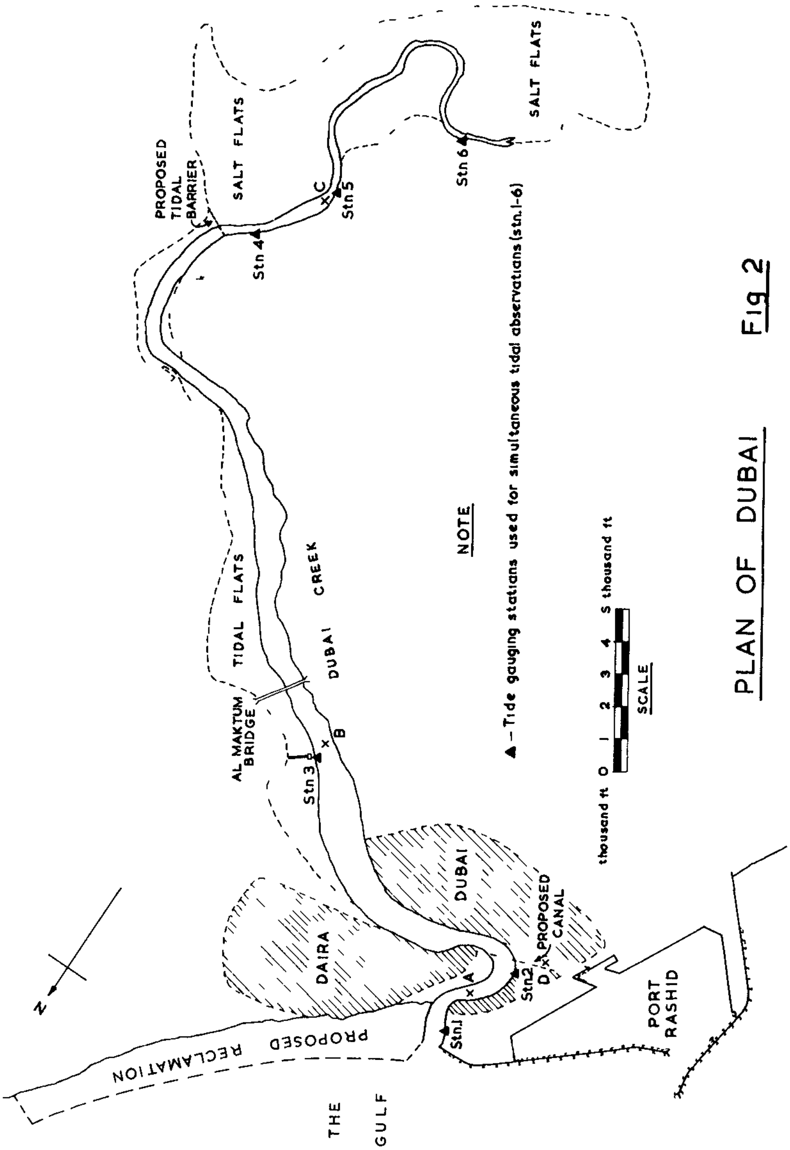


Fig 1 Plan of THE GULF



PLAN OF DUBAI

Fig 2

Fig. 3 DUBAI CREEK

Fig. 4 CREEK ENTRANCE

In 1966, as a result of oil being found in Dubai waters, His Highness the Ruler was enabled to embark upon the construction of a new deep water harbour, to be known as Port Rashid, immediately south-east of the creek entrance (fig 2) The new harbour, which will enclose a water area of approximately 350 acres and will provide 15 deep water berths each approximately 600 ft, long, is still in course of construction It will have a bed level at its entrance approximately 36 ft below chart datum and will be dredged to 30 5 feet below chart datum throughout Since the harbour works will form a solid barrier to the littoral drift for approximately one mile out to sea from the previous shore line it is clear that these are likely to have an even greater effect on the coastal regime than the creek entrance works

There are proposals to close or partly close the existing creek entrance and form a new canal link from the creek to the new harbour There is also a proposal to reclaim a coastal strip of land north east (downdrift) of the new harbour and protect this with a heavy sea wall which would have the effect of preventing further erosion there and transferring the erosion to less valuable land further along the coast

Model Tests and Studies were initiated to consider various aspects of the works The majority of these were carried out at the Hydraulics Research Station at Wallingford, England

INVESTIGATIONS

A tide recorder was set up on the side of a small jetty built out across the beach into the sea An analysis of the first year's tidal records was carried out by the Institute of Coastal Oceanography and Tides at Birkenhead, England The analysis demonstrated the extent of the "set up" which can occur at the south-east end of the Gulf On 25th January 1969 this was 12-18 inches continuously for a period of 12 hours Shorter period seiches up to 17 inches have also been recorded The tides are subject to a large diurnal inequality Their normal range is between MHHW + 5 5 ft (chart datum), MLHW + 4 4 ft ,MHLW + 2 6 ft and MLLW + 1 3 ft

An O S P O S wave recorder was installed This type of self-contained recorder was chosen in place of an instrument which would record on shore to avoid the danger of the connecting cable being broken by small vessels achoring offshore For most of the recording period the O S P O S instrument was anchored approximately $\frac{3}{4}$ mile offshore in 36 ft of water (below chart datum) with the recorder tethered 8 to 10 ft below chart datum so as to be approximately 3 ft below what was anticipated to be lowest wave trough level The relationships and equations used in the analysis of the wave records were reduced to forms suitable for the Olivetti Programma 101 Desk Top Computer The analysis was carried out in accordance with Draper's procedure (ref 1) using the empirical corrections for attenuation worked out by Draper and Maxted (ref 2)

Since no commercially-available, proven, wave direction recorder of reasonable cost appeared to be available wave directions were estimated visually, normally twice daily Twice daily observations were the most which could be expected from the already overbusy Resident Engineer's Staff but as the height recordings occurred 8 times per day (every 3 hours) it is obvious that considerable interpolation of wave directions had to be estimated with corresponding risks of error There is no doubt that the development of a reliable, commercially-available, reasonably-inexpensive wave direction recorder would be very greatly welcomed

WAVE ANALYSIS

To date six month's wave records have been analysed The data has been adequate and sufficiently representative for wave height frequency prediction graphs to be drawn for "all directions" waves and for waves from 300°, the dominant direction, and from 330°, but not other directions The "all directions" prediction (fig 5) drawn on probability graph paper, extended upwards to obtain a Once in 100 Years wave value, indicates a maximum deep water wave height of 34 5 ft in 100 years, 31 5 ft in 50 years, and 26 0 ft in 10 years Using Darbyshire and Draper's relationships (ref 3) between wind speed and duration for the maximum possible fetch of approximately 500 nautical miles these maximum wave heights would require wind speeds of respectively 44, 43 and 36 knots for a period in each case of approximately 33 hours, or equivalent combinations of speed and duration

In the restricted area of The Gulf the majority of wave patterns are composed of short-period waves The recording of such waves led to difficulties which were not sufficiently appreciated at the beginning of the analysis The first was locational, in that the record tended to be increasingly flattened the deeper the pressure-actuated instrument was tethered below the water surface This was overcome in large measure but still required an attenuation factor adjustment before feeding the data into the computer The second was instrumental, in that a considerable number of the 12 minute duration records were of waves about 1 foot in height, shown on the trace as 1 mm The difficulty of classifying these in wave height steps was such that the analysis proved unreliable in the smaller ranges and in fact only derived maximum waves over 7 feet in height were plotted, the linear results being extended to cover predictions for lesser waves and extrapolated for waves beyond the scope of the instrument readings

Estimation of the likely frequency of stated wave heights has so far been assessed only by reference to the British Ministry of Technology's statistical survey of wave characteristics estimated visually from Voluntary Observing Ships on their normal shipping passages (ref 4) It is interesting to note, however, the confirmation provided by maximum heights up to 25 feet being estimated at points a little further west in The Gulf during a storm in 1964

The relationship between maximum wave height and maximum significant wave height was found during this analysis of six-months' recordings to be approximately 2 to 1, for the range of wave periods of between 4 and 9 seconds which was of principal interest and occurrence

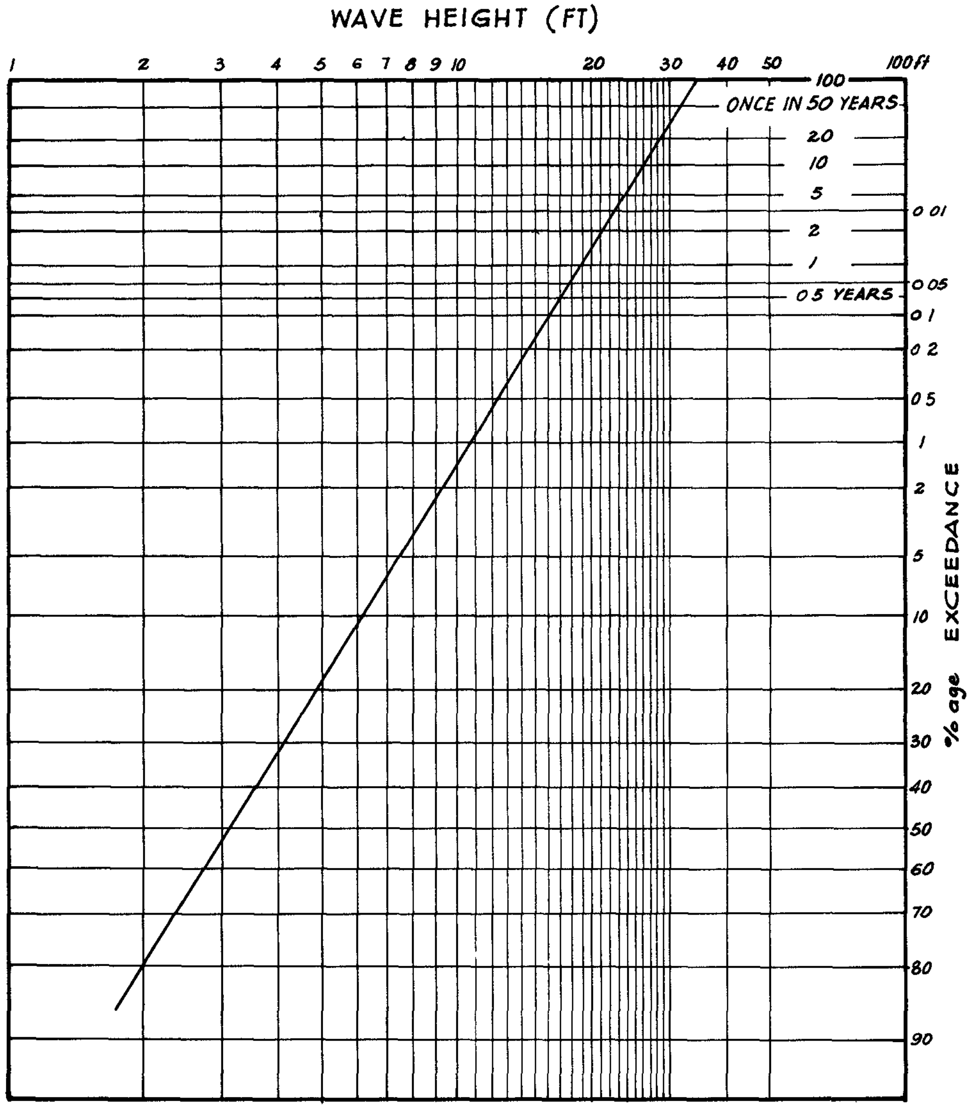


FIG 5 WAVE HEIGHT PREDICTION (all directions)

HYDRAULIC MODEL TESTS

A rigid bed hydraulic model of Port Rashid was constructed to a scale of 1 150 Waves of different equivalent heights, periods and directions were generated and directed on to the harbour and their residual heights along the quays were measured for a number of harbour layouts A final harbour layout was chosen by this means These model tests had to be carried out before any results could be obtained from the wave recorder The waves used for the tests were therefore estimated from wave recordings taken further west in the Gulf and an assessment, using synoptic charts, of the corresponding waves off Dubai

Idealised ship movement tests, using the same equivalent waves, were also carried out using models representing 10,000 dwt and 4,000 dwt vessels at the quays The results of these model tests were satisfactory, except in the case of two berths when waves were from the north direction This is in fact the direction in which the harbour entrance points so that there is virtually no obstruction to these waves Although no prediction for waves from the north has been possible from wave recordings at Dubai for reasons mentioned previously it has become clear that considerable wave activity from that general direction is rare This conclusion has since been confirmed by an analysis of the wave records from Voluntary Observing Ships steaming in the vicinity of Dubai These records were kindly supplied by the British Meteorological Office

In connection with the wave model a study was carried out of the extent to which waves could be generated within the enclosed harbour area over the greatest fetch of approximately 1 3 miles by strong winds blowing from approximately south west or north east Although it was appreciated that these conditions would only occur infrequently, experience with the model showed that the resulting waves would not significantly hamper the working of ships alongside the quays

No evidence was obtained that the natural period of oscillation of the harbour basin would give rise to seiches having periods or length of range which could affect moored vessels in Port Rashid, providing of course that such mooring lines and fenders were in appropriate combination of stiffness and softness which previous model and full-scale tests had shown to be suitable

LITTORAL DRIFT

The coastal regime at and in the vicinity of Dubai was studied particularly in order to assess the effects of the construction of Port Rashid As has been mentioned, training works were carried out between 1959 and 1962 at the entrance to Dubai Creek These involved the construction of steel sheet-piled training walls to stabilise and maintain the creek channel into the sea out to approximately the seabed contour 8 0 ft below chart datum, this being a sufficient depth of channel for the country craft and lighter traffic at that time (fig 3)

Since the net littoral drift is south west to north east along the coast the effect of these training walls had been to cause accretion on the south west side and erosion on the north east side By 1968 the downdrift erosion, which affected the densely-populated town of Daira, had begun to cause serious concern, though by about that time some natural sand by-passing of the creek had just begun to occur There were therefore naturally fears of the effect of the very much bigger barrier of Port Rashid Comparison of regular measurements of beach and bed levels on a number of lines perpendicular to the coast updrift of the training walls early led to the conclusion that the natural net rate of littoral drift was approximately 70,000 cu yds per year In 1969 a further calculation was made based upon the relationship -

$$Q = 210\, E^{0\ 8}$$

where Q = intensity of littoral drift in cu yds per day
and E = longshore wave energy in millions of food-pounds per foot of beach per day

The net littoral drift per year calculated from this amounted to 79,000 cu yds Again, because wave data from the wave recorder was not available when this calculation was made, the same assumptions as have been mentioned before were made regarding the waves However since the two calculations showed such close agreement it was considered justified to assume a net littoral drift of the order of 80,000 cu yds per year from south west to north east and no further calculations have been undertaken using the results of the analysis of the first 6 months of actual wave records

Based upon such an assessment of annual volume, it will be at least 20 years before any significant by-passing of sand across the entrance of Port Rashid is likely to occur The form which this natural by-passing may take is uncertain and may well be unacceptable During this time corresponding erosion of the downdrift coast of Daira will occur unless remedial measures are taken Since this township is densely populated to the coastline this is obviously not a result which can be accepted and the Ruler is at present considering the adoption of one of several alternative solutions proposed to him Artificial nourishment is one course, another,more favoured, is to concentrate the erosion length further downdrift, where the coastal strip is devoid of use or habitation, by carrying out protection and reclamation works from the creek entrance to beyond the downdrift end of Daira

DUBAI CREEK

The influence of the creek flow upon the situation has not so far been mentioned because it does not appear that there is any significant outflow or inflow of bed material associated with it As far as is known the creek has remained remarkably stable of recent years in these respects though there has undoubtedly been a gradual migration of the entrance towards the north east

Normal sand by-passing did not apparently produce the formation of sand bars which cause navigational difficulties But when the channel began to follow a course leading over a coral reef an unacceptable reduction in natural entrance depth resulted The works carried out between 1959 and 1962 successfully relocated the entrance by a system of sheet piled training walls with dredging to restore and deepen slightly the channel linking the creek port with the sea

With the firm proposal taken to construct the deep water port on the coast off Dubai, there followed naturally the suggestion of a connection by water between the already-flourishing Creek port, with its winding and restricted entrance, and the new harbour enabling cargo liners to discharge and export freight in security from wind and sea conditions It was evident that the sediment loads and tidal velocities through the creek port had a large effect on the success of such a scheme to direct the flow into and out of the tidal basin upstream of the port and to close, wholly or partially, what would become the former entrance Examination of this proposal could only be through model analysis, unfortunately time and cost limited the study to a mainly qualative rather than a quantative one, but nevertheless the results were instructive

INVESTIGATION AND MATHEMATICAL MODEL

The creek is not fed by anysurface streams, even intermittent ones, but there is a small amount of sub-surface seepage of water into the upper reaches and this seepage is very highly saline In addition there are very extensive tidal flats at the head of the creek which are covered at high water and dry out at low water These large areas of generally very shallow water are of course areas where high evaporation leads to increasing salinity For these two reasons, therefore, the water at the head of the creek is considerably more saline than the sea and the water lower down the creek This reverses the more usual situation in which fresh water flows into the head of a tidal inlet and the salinity decreases as the distance from the sea increases A natural corollary of the situation at Dubai is that the highest salinities occur at low water The result of this salinity pattern is that there is a net drift of water near the bed of the creek towards the sea, but the velocities involved are so low that this is not of significance as regards the transport of bed material

No measurements are available to show up any areas of accretion or erosion either permanent or temporary in the creek or to indicate quantitatively any natural changes in the entrance channel However it seems clear that there is a negligible transport of solids to the creek through sub-surface flows The most likely sources are from wind-blown material and erosion of the bed or banks Erosion does not appear to provide any overall change in the quantity of solid material entering or leaving the creek though there are local movements within it Wind-blown sand undoubtedly does provide an input source, but such calculations as have been possible in this respect suggest that the quantity is small and that it is confined to the upper reaches Due to a large diurnal inequality in the tides at Dubai the maximum ebb flows in the creek are greater than the maximum flood flows so that bed material from the creek tends to be flushed out into the sea rather than the reverse, and oonsequently the entrance channel remains open

A large number of cross-sections of the creek were surveyed and tidal observations carried out simultaneously at six stations (fig 2) over a high spring tide cycle on 13/14 May 1968, with an extensive series of current velocity measurements taken during this cycle The mathematical model of tidal flows in the creek, with the view to assessing the effects of various proposed schemes, was proved against this set of tide levels and flows Because of the large diurnal inequality, which results in velocities and discharges on the fall of the major tide being much greater than the velocities and flows during any other period, subsequent analyses were directed towards determining the maximum velocities and volumes of water (tidal prism) leaving the creek on the ebb of the major tide under the conditions of 13th/14th May 1968

Once the model had been satisfactorily proved the effects of proposed engineering works could be studied These proposed works are indicated on Figure 2 and they comprised -

(a) Construction of a canal link between Port Rashid and the creek and the closure or partial closure of the by-passed seaward end of the latter

(b) Construction of a tidal barrier near tide gauging station 4 to close off the salt flat area at the head of the creek The object of the barrier would be primarily to reduce the tidal flow by eliminating the large storage volume contained in the tidal flats at the head of the creek As a secondary object it would serve as a barrage to increase water level permanently above the barrier in a reach to which vessels would have access through a lock Such a barrier might indeed be valuable but would probably be better sited further towards the sea so that the locked area would be able to serve the towns and the ships

RESULTS AND CONCLUSIONS

The mathematical model quickly demonstrated that the tidal regime in the creek is at present dominated by two factors These are the throttling effect of the narrow channel through the Town and the presence of the large inter-tidal flats storage volume at the head of the creek As a result schemes to vary the entrance to the creek cannot alone greatly affect the regime except locally The only practical scheme examined which caused an appreciable change in the whole regime was that to construct a tidal barrier blocking off the major portion of the inter-tidal flats storage volume

The model was able to calculate water level, velocity and flow at any time at a number of selected points in the creek and proposed canal for the conditons resulting from the various schemes under the open-sea ebb tidal conditions of the 13/14 May 1968 Volumes of tidal prisms could also be calculated for the various tide levels

Some actual mathematically-calculated figures may be of interest here At present the creek channel tidal maximum velocities vary greatly along its length Peak maximum velocity is 5 2 ft/sec at Section A (fig 2), reducing to 1 33 ft/sec at Section B and increasing again to 2 5 ft/sec at Section C Incipient sediment movement was calculated to correspond to a water surface velocity of 1 4 ft/sec for a 0 1 mm sand (taken as representative of the finer fractions of bed material) This means that at present some sediment movement towards the sea probably takes place in the upper reaches but not in the middle reaches In the lower reaches between the towns quite extensive movement would take place were it not for the fact that the bed here mainly consists of coral with limestone boulders and the quantity of sand is small It would appear therefore that there is probably some accumulation of bed material in the middle reaches though there are no indications that this is of serious proportions The bed sand lost in the upper reaches appears to be approximately made good by the wind-blown sand previously mentioned

When the proposed canal was introduced into the model, with varying proportions of the existing creek entrance channel remaining as well, it was found that the effect of such new entrance proposals on the tidal prism was limited to a maximum increase of 6 6 per cent because of the throttling effect of the reach through the town A large change in the entrance channel conveyance produced only a small change in the tidal prism As a result it was possible to work out a simple method of calculating the performance of any combination of entrance channels (so long as their combined conveyance exceeded the value of the existing entrance channel) This no longer required the use of the mathematical model

Provisionally it was considered that a canal link having a 340 ft wide rectangular section and a bed level 12 ft below chart datum, with the existing creek entrance completely closed off, would result in a peak maximum velocity of 4 4 ft/sec (at Section D, fig 2) This would be acceptable provided that the bed material was found to be suitable or was suitably protected Peak maximum velocities somewhat higher than 1 4 ft/sec would also be present within part of Port Rashid under the conditions of this arrangement

The effect of the tidal barrier was to decrease the tidal prism (major ebb tide 13th/14th May 1968) by causing a reduction in the canal peak maximum velocity from the 4 4 ft/sec quoted above to approximately 3 4 ft/second Policy on both these matters remains to be decided, as there are many other factors of a non-hydraulic kind to be taken into account

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