MAJOR PORT DEVELOPMENTS AT RICHARDS BAY WITH DUE REGARD TO PRESERVING THE NATURAL ENVIRONMENT

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SYNOPSIS

Since World War II South Africa has experienced a considerable industrial growth and this has resulted in the need for more and better harbour facilities. Particularly in view of the transport of bulk materials Richards Bay was chosen as the most suitable site for the establishment of a deep water port to serve the existing and future industrial areas of the Transvaal, the Northern Free State and Natal. Richards Bay consists of a large shallow bay connected to the sea by a shallow estuary channel through which tidal flow and marine organisms can move freely. The Umhlathuzi River flows into the bay and its flood waters are discharged to sea through the existing estuary channel.

Since only about half the bay area will be required for harbour development in the foreseeable future the Natal Provincial Administration proposed the idea of preserving the southern half of the bay as a nature reserve. This suggestion was made possible by the inclusion in the harbour scheme of a levee separating the harbour area from the southern half of the bay, which at the same time would provide access to the bluff area on the south side of the harbour entrance channel and reduce siltation in the harbour basins.

Time limitations precluded the model testing of an estuarine flood relief channel direct to the sea and thus in the tender documents provision was made for both tidal exchange between the nature reserve and the harbour, and for flood discharge, by the inclusion of a large flood relief structure in the levee. An alternative, ecologically much more attractive solution of a new estuary channel excavated through the dunes directly to the sea became an economically feasible proposition.

SAMEVATTING

Sedert die tweede wereldoorlog het Suid-Afrika aansienlike nywerheidsgroei ondervind wat tot behoeftte aan meer en beter hawefasiteite gelei het. Met die oog op veral die vervoer van massastowwe is Richardsbaai gekies as die geskikste plek vir die vestiging van 'n diepwater-hawe om die bestaande en toekomstige nywerheidsgebiede van die Transvaal, Noord-Vrystaat en Natal te bedien. Richardsbaai bestaan uit 'n groot vlak baai, met die see verbind deur 'n vlak uitmondingskanaal waardeur getystrone en seelwwe vrylik kan beweeg. Die Umhlathuzi-rivier mond in die baai uit en sy vloedwater loop ook die see in deur die bestaande uitmondingskanaal.

Aangesien slegs ongeveer helfte van die baai gebied benodig sal word vir hawe-ontwikkeling in die voorsienbare toekoms het die Natalse Provinsiale Administrasie die bewaring van die suidelike helfte van die baai as natuurreservaat voorgestel. Hierdie voorstel is moontlik gemaak deur die insluiting van 'n dyk in die haweskema wat die hawegebied van die suidelike helfte van die baai skei en terselfdertyd toegang tot die oewer gebied aan die suidekant van die hawe-toegangs-kanaal verleen en toesteliking van die hawekomme verminder.

Tydperkings het modeltoetsing van 'n uitmondingsvloedafvoerkanaal registreer na die see verhoed en dus is daar in die tenderdokumente voorsiening gemaak vir beide getwysseling tussen die natuurreservaat en die hawe asook vir vloedafvoer deur die insluiting van 'n groot vloeddeurvoer-structuur in die dyk. 'n Alternatiewe oplossing, ekologies veel aantrekkeliker, van 'n nuwe uitmondingskanaal direk deur die duine uitgegraaf na die see, het 'n ekonomies gangbare proposisie geword.

INTRODUCTION

The existing harbours in South Africa have been hard pressed to meet the demands of shipping ever since the sudden closing of the Suez Canal, brought about by the 'Seven-Day War' in the Middle East in June 1967. Moreover, requirements for the bulk handling of coal, oil and ore could not be met by extending the existing ports and it was therefore decided by the government in 1965 to develop a new deep-water harbour at Richards Bay.

Need for additional harbour facilities

Since World War II the country has experienced an almost unprecedented industrial growth as well as a general rise in the population's standard of living. As a

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result the demand for capital and consumer goods has increased, bringing about a corresponding increase in foreign trade as the Republic's manufactur­ing industry cannot as yet meet the demand for all such goods.

The steady increase in foreign trade has caused existing facilities at the major harbours to be strained. Furthermore the present indications are that the mass export of basic raw materials and agricultural products will continue to expand, increasing the load on existing harbour facilities.

Apart from the fact that space in the country's harbours for storage and handling bulk materials is extremely limited, the existing harbours are not designed to accommodate the bigger ships now in use with their cheaper shipping tariffs. Adaptation to handle the big ships of the future is not an economic proposition. From the above it is clear that an additional deep-water harbour is required to cater for future needs.

**Location of new harbour**

In deciding on the location of a new deep-water harbour, both economic and technical factors had to be taken into account. For economic reasons the complex had to be situated where it could have the greatest possible impact on the economy, i.e., to be in a suitable position to serve the highly industrialized Pretoria, Johannesburg, Vereeniging triangle and to provide relief to Durban, South Africa's busiest port. At the same time, it had to be able to serve other industrialized areas in the Transvaal, Natal and the Northern Free State, all of which have considerable potential for further industrial and other growth.

Richards Bay fulfilled these requirements and had the additional advantage that it could be easily connected to the existing railway network at a relatively low cost (Fig 1). Moreover, at Richards Bay there is an adequate supply of unskilled labour available and an established town (Empangeni) with an existing infra-structure suitable to support the early development of the area is situated close by.

All the possible suitable sites for a large deep-water harbour are situated north of Durban as indicated in Fig 1. The possible sites which were considered included Kosi Bay, Sondwana Bay, St Lucia and Richards Bay. Of these Richards Bay is technically by far the best suited. The bay has excellent natural protection from the sea by a very substantial bluff. It has a water area of some 3 315 ha, far larger than any of the other possible sites.

The lagoon, fed by the Umhlatuzi, Nsez and Manzamyana rivers, is itself well suited for development although the existing water depths are on average less than one metre. The material in the lagoon is soft and easily dredged. Hard material (cretaceous) exists at depths suitable for the founding of deep-water berths. It has also been established that a natural gorge filled with loose sediments consisting of a hard base material and well suited for opening into an approach channel for large ships to enter the lagoon exists in the coastline. However, in certain areas, particularly near the centre of the lagoon, the founding material is of very doubtful quality. The originally-envisioned flood control structure had to be re-sited after detailed sub-soil investigations had been carried out. While much of the surrounding countryside is marshy, its general topography is flat and therefore ideal for industrial development. There is also a plentiful supply of good fresh water, readily available, to support a large developed area.

**Planning and research**

Extensive research and planning preceded the harbour works at Richards Bay. An aerial survey of the areas surrounding Richards Bay and soundings of the lagoon were made in 1987. At the same time wash-borings on
the shores of the bay were carried out under contract to establish the depths of silt and sand layers. The CSIR was also commissioned in 1967 to study the area. The latter included field and hydraulic model studies by the CSIR’s Hydraulics Research Unit at Stellenbosch aimed at providing the required data for the optimum design of the harbour entrance and to establish its effect on the adjacent coastline.

This research showed that the harbour entrance could be adequately protected against heavy seas by the construction of relatively short breakwaters and that the siting of the entrance channel seaward of the breakwaters could be controlled by the use of suitable dredging craft. Tests were also carried out on models to establish a safe and reliable breakwater design and it was possible to arrive at a relatively simple cross-section.

At a later date model studies were also undertaken of the necessary flood relief works, including a study of a new estuary, which appeared to be the most attractive alternative solution to the flood relief structure, particularly from the ecological point of view.

**RICHARDS BAY**

Richards Bay obtained its name from one Commodore Richards who later became Sir Fredrick William Richards. In the year 1879 he compiled a report on the sea conditions off the Natal Coast. The first historical reference to Europeans entering the Richards Bay area relates to Portuguese seamen who were shipwrecked off the coast and absorbed by the local inhabitants. They gave it the name Rio-dos-Piexes (river of fish). The colour and features of the local natives gave positive evidence to later settlers that this early European intrusion had taken place.

The idea of a harbour at Richards Bay dates back as far as 1902 when consideration was first given to the construction of a port. Cathcart W. Methven, then Harbour Engineer of Durban, or rather Port Natal as it was then known, carried out a detailed survey for this purpose and in his report dated 1903 to the Prime Minister of Natal, Sir Albert Hime, indicated that Richards Bay was even more suitable for the establishing of a harbour than Durban.

**Description of bay**

Richards Bay consists of a sedimentary basin of more than 3 000 ha with a narrow outlet to the sea (Fig 2). Due to the narrow estuary channel which connects the bay to the sea, the sea tides, which at the estuary mouth have a range between 0.5 m and 2.1 m, are reduced to much smaller water level variations in the bay of between 0.03 m and 0.5 m.

The bay is fed by two main rivers, the Umhlatuzi and Nsezi, and one stream, the Manzamyana. All discharging into a deltaic area on the north-west side of the bay. Over the years the run-off from these rivers has deposited considerable quantities of alluvial material and silt in the lagoon. The average estimated silt load varies between 20 000 to 120 000 tons per annum and this results in a possible average siltation of some 0.5 mm to 3 mm per annum.

Coral has been located offshore in water depths of some 18 m indicating that in the past, the sea level off the Natal coast must have been much lower. This caused the rivers to cut deep gorges in the underlying cretaceous material overlying basic granite rock. As the sea level rose, probably due to the melting of the polar ice caps, the gorges were filled with sea sand and alluvial deposits. The filling-in of the basin and gorges has resulted in some areas of the bay having good foundation material whilst material in other areas is virtually colloidal silt.

**Ecological value of Richards Bay**

Richards Bay with its over 3 000-ha water surface area undoubtedly is one of the most important Natal lagoons for the breeding of many species of fish and crustacea. In Natal, only the St Lucia Lake has a considerably larger area of about 30 000 ha, whereas Kosi Bay is of similar size to Richards Bay. Durban Bay has about
half the water area of Richards Bay but its productivity regarding fish life has been drastically reduced by harbour works and industrial development. As may be seen from Fig 3, in its present natural state Richards Bay is of considerable importance as a nature reserve and for sport fishing, boating and general recreation.

Ecological surveys by Wallace² and Hemens³ show the presence of many species of fish such as salmon, grunter, bream and springer. A most interesting finding was the virtual absence of adult angling fish and the abundance of juveniles which indicates that, of the Natal lagoons, Richards Bay plays a very special role in that it provides the ideal habitat for breeding. This nursery function of Richards Bay is dependent on the existence of extensive beds of eel grass (Zostera capensis) in the estuary area between the mouth and Spinach Point shown in Fig 2. This vegetation supports and shelters a large colony of shrimps, prawns, crabs and other small organisms which in turn provide the food for the larger game fish. Although there is no eel grass in the southern muddy parts of the bay, various species of soft bodied organisms such as worms which provide food for the juvenile fish thrive in these areas.

Fig 3 — Sunset over the bay

Fig 4 — Richards Bay harbour — initial development
Richards Bay thus plays a very significant role in supporting Natal’s marine fish stocks and although the construction of a deep-water harbour at Richards Bay must be accepted as an economic necessity everything possible is being done to protect, reinstate or even improve the natural environment in those parts of the bay which are not required for initial harbour development.

RICHARDS BAY HARBOUR

The first stage of development, which provides for 150 000 dwt ships using the port by April 1976, is shown in Fig 4. Provision has been made in the design for ships of up to 250 000 dwt using the harbour at some future date.

In planning a major harbour it is essential that in the early stages a basic framework which allows for the anticipated future extensions be prepared. This was done in the case of Richards Bay and the work now to be undertaken fits into the framework which allows considerable flexibility. The initial harbour development will be confined to the northern part of the bay and the southern part will as far as possible be left undisturbed at this stage. However, if the need arises at some future date, the southern section will be available for further development.

A prominent feature in the first stage of development is a levee dividing the bay into a commercial harbour and a nature reserve. This arrangement has the added advantage of providing a silt trap which avoids siltation of the harbour when floods occur in the Nsezi and Umhlatuzi rivers.

The harbour entrance was designed to provide entry to the harbour by 150 000 dwt vessels for 99 per cent of the time. Under design conditions loaded vessels will enter the harbour with a speed of about 3.5 m/s (7 knots) and will need the full 6 km available stopping length provided inside to be brought to a complete standstill in the turning circle area shown in Fig 4.

An important feature taken into consideration in the design of the inner harbour layout is separation of the berths to ensure considerable flexibility. The initial harbour development will be confined to the northern part of the bay and the southern part will as far as possible be left undisturbed at this stage. However, if the need arises at some future date, the southern section will be available for further development.

NATURE RESERVE

As already mentioned only about half the bay area will be required in the foreseeable future for harbour development. Moreover, both for the construction of the harbour works and for the operation of the bulk material dirty cargoes (coal) from the clean cargoes (Fig 4). Provision has also been made for possible future containerized traffic. Berthing for harbour craft, a berth and small slipway to carry out maintenance and repairs to harbour craft, as well as adequate space for small commercial launches required for operational purposes in the harbour have all been provided for.

Provision has been made for a berth for the harbour maintenance dredger which is required for pumping clean dreged and onto the northern beaches to compensate for the disturbances in the natural littoral drift conditions brought about by the construction of breakwaters.

Tidal flow

By constructing the levee as a continuous dyke the nature reserve would have been completely sealed off from the sea and, although it could have developed into an inland natural eco-system, its special value for the ecology of the Natal coast would have been lost. It was therefore decided to include a tidal inlet structure in the levee adjacent to or incorporated in the 'original flood relief works’ shown in Fig 4 which would allow an exchange of lagoon and sea water and also provide access to the nature reserve for marine organisms.

Although it was realized that a more direct link to the sea would be desirable from the ecological point of view, tidal openings in the levee connected by a dredged channel to the harbour entrance channel as shown in Fig 4 appeared to be the only economic solution at the time (1971). However, gates were to be provided in the tidal openings which could be closed in case of heavy pollution in the harbour area to protect the nature reserve.

Flood relief

The combined flow of the Umhlatuzi and Nsezi rivers, which discharge on the nature reserve side of the proposed levee, reaches 4 300 m³/s with a recurrence interval of 100 years. Various possibilities to reroute the floods to sea were considered but time limitations for inviting tenders for harbour works precluded the model testing of a flood relief channel direct to the sea. The accepted scheme included an overflow spillway structure in the lagoon joined to a lined channel through the levee and a dredged channel to connect the flood relief structure to the harbour entrance channel. More detailed soil investigations later necessitated a 2-km seaward shift of the original flood relief works, as shown in Fig 4.

The flood relief works could not be built as a simple opening in the levee because of the need for tidal control in the lagoon. Large gated openings involve certain operational risks: thus a simple overflow spillway appeared to offer the best solution. To avoid any uncontrolled return flow from the harbour into the lagoon the crest of the spillway had to be above high water which gave a crest level of + 2 m to LWOST.

Because of the extensive areas of low lying ground around Richards Bay the maximum backing up level in the lagoon was not allowed to exceed the value experienced in 1956, when a flood of similar magnitude to the 100 year design flood occurred. This level was generally accepted to be about + 3 m above LWOST which would result in a maximum overtopping of the spillway by 1 m and a required length of spillway of some 2 km to accommodate the 4 300 m³/s flood.

Although the head difference over the spillway was small (maximum 1 m at high and 3 m at low tide) and its crest level was only 2 m above the existing lagoon bottom, due to the considerable spillway length the flood relief works became a structure of major proportions.

NEW ESTUARY FOR RICHARDS BAY NATURE RESERVE

Although the construction of a direct link between the nature reserve and the sea, by cutting a channel through the southern bluff, was considered in the

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1Low Water Ordinary Spring Tide.
earlier stages of planning, the idea was dropped because of the high cost involved (excavation of some 9 million $m^3$ of material was involved) and the uncertainty of keeping the new mouth always open to the sea.

However, when the details of the flood relief and tidal structures became available and it was found that because of the abundance of silty material in the bay area several million cubic metres of sand would probably have to be borrowed from the east corner of the nature reserve, for the construction of the levee, it became apparent that the construction of a new estuary channel could be an economic proposition after all if its technical feasibility could be established.

The new estuary channel (Fig 5) thus had to provide for tidal exchange between the sea and the nature reserve and, in addition, it had to be able to discharge a flood of 4 300 $m^3/s$ to sea with a maximum flood level in the lagoon $+3 \text{ m}$ above LWOST.

Ecological considerations

The construction of a direct link between the nature reserve and the sea has considerable ecological advantages over the original scheme. In the first place the possibility of contamination of the lagoon water with polluted harbour water is greatly reduced because the lagoon will draw its water directly from the sea.

Also, as was mentioned above, the estuary portion of the Richards Bay system, lying between the mouth and Spinach Point, forms the most important part of the existing marine eco-system. With the construction of the new estuary ideal conditions will be created for the re-establishment of new eel grass beds to replace those in the existing estuary areas.

From the ecological point of view the estuary channel should preferably always be open to sea, although closure for a few days up to about two weeks would probably not harm the ecology significantly. The tidal variations in the lagoon should be of the same order as the existing ones (average about 0.2 m) and to avoid large shallow areas of the lagoon becoming exposed the low water level should not drop below $+0.7 \text{ m}$ to LWOST.

Stability of new estuary

Before the new estuary scheme could be considered the stability of the new mouth had to be investigated. Although the existing estuary mouth, as far as is known, has always been open, this provides no guarantee that the new estuary will never close, particularly since the lagoon area is less than half the existing bay area.

The stability of a tidal inlet depends on a balance between tidal action, which causes scour, and wave action which causes deposition in the channel by littoral sand drift. O’Brien established an empirical relationship between the tidal prism of estuaries and the minimum flow cross-section of the estuary mouth. O’Brien’s data, together with some local data and additional information from work by Johnson and Giese are plotted in Fig 5. In this figure the shaded area between the two parallel lines marked ‘no jetties’ represents stable estuary conditions in a natural state.
Compared with estuaries in other parts of the world the South African estuaries are quite small. In the period November 1969 to March 1970 the Richards Bay mouth had a cross-sectional area of about 300 m² at MSL which was larger than the maximum stable area. By July/August 1970 the area had been reduced to 150 m² which was somewhat smaller than the minimum stable condition and as a result a new mouth scoured out on 14 October 1970 which had a considerably larger area (about 450 m²) resulting in greater tidal variations in the bay, as may be seen from Fig 5.

Whereas the existing bay area is 27.5 km², the area of the nature reserve will be only 13.2 km². Assuming similar tidal variations of 0.2 m in the bay and the lagoon the stable estuary area will become about 150 m² according to Fig 5. Since tidal variations in the nature reserve cannot be predicted with certainty the cross-sectional area of the new mouth is expected to fall within the range of 100 m² to 200 m² with corresponding tidal variations in the lagoon of 0.1 m to 0.3 m.

Considering these reasonably large mouth areas and the short length of the estuary (about 1 km, see Fig 4), it is unlikely that a new mouth would close except under very unfavourable littoral drift conditions. It was therefore decided to adopt a new estuary configuration approximately as shown in Fig 4 with a tidal channel of 100 m wide and a depth of between —0.5 m and —1.0 relative to LWOST.

**Flood discharge**

To provide both room for the expected natural sideward movements of the estuary channel and to make allowance for the discharge to sea of the combined Umhlatuzi and Nsco river flood of 4 300 m³/s a 700-m wide flood channel to a level of 0.5 m above LWOST was found necessary in addition to the tide channel. This required a total width of 800 m for the cutting through the bluff (Fig 4).

Detailed hydraulic model tests have shown that this channel width is sufficient to accommodate a flood of 4 300 m³/s without raising the lagoon level above 3 m relative to LWOST.

**Tidal gates in the levee**

As a safeguard against possible closure of the new estuary mouth the effects of tidal gates in the levee, in addition to the new estuary channel, were investigated.

For a tidal variation in the sea of 1.8 m the lagoon tidal variation should be only about 0.2 m. Since the full 1.8 m tidal range will be experienced in the harbour area during high tide the water level on the harbour side will rise above the water level on the lagoon side of the levee. Thus by providing gates in the levee, which are opened only during high tide, water can be let into the lagoon to assist scouring of the estuary mouth.

Computer calculations and model tests showed that with two tidal gates, each 40 m wide and with a bottom level at 2 m below LWOST, outflow velocities in the estuary mouth were increased by about 10 per cent, whereas inflow velocities were reduced by about 30 per cent (Fig 6). Calculations showed that the total flow into the lagoon over one tidal cycle through two gates amounted to 3.8 million m³ and through the estuary to 4.1 million m³, and that the outflow amounted to 7.4 million m³.

Compared with the case without gates in the levee when the inflow and outflow through the estuary mouth are balanced (5.3 million m³), the two tidal gates are seen to provide an additional quantity of water for flushing the mouth of 40 per cent of the normal tidal exchange. Since the flushing action of a single 40 m gate was considerably less and the increase in flushing action for three 40 m gates was not significant, provision was made for two tidal gates in the levee.

It is expected that flushing of the estuary would be necessary under exceptional conditions only and the fact that harbour water would be used for this is therefore not serious.

Apart from the possibility of bringing water into the lagoon, the gates will also be used for flood discharge providing an extra safety margin against excessive flood levels in the nature reserve. By opening the two tidal gates about a quarter of the 4 300 m³/s flood discharge may be routed through these gates. This would effect a considerable reduction in the lagoon flood level from 3.1 m to 2.6 m above LWOST.

**Additional investigations**

Further investigations are in progress to study various aspects of the new estuary scheme shown in Fig 4 in more detail. These studies include, inter alia, movable
bed model tests to check the above tidal and flood channel dimensions and to determine the effectiveness of the tidal gates for flushing the mouth. The model studies should also indicate how close the estuary channel must be dredged to the theoretical cross-section and healing ability of the new estuary after a large flood when the estuary can scour up to 5 m in depth and the tidal variations in the nature reserve can temporarily increase to an 0.8-m range compared with the normal range of 0.2 m.

CONCLUSIONS

As a result of continued industrial development and the world trend towards increased ship sizes to reduce overall transportation costs, harbour facilities to handle these mammoth ships have to be provided. The preservation of fauna and flora has, of necessity, to take second place at this stage.

For this reason the planning at Richards Bay makes provision for the development of a harbour as big as or even bigger than Durban. At some future date it may be found necessary to sacrifice the remaining nature reserve to expand the harbour into the southern part of the bay.

On the other hand there is an increasing awareness of the need to protect and improve the environment. Those parts of Richards Bay which are not needed for harbour development in the foreseeable future should therefore, if possible, be preserved in their natural state. By implementing the new estuary scheme, which now appears to be an economic proposition, in preference to the flood relief works through the levee, the southern half of Richards Bay will not only remain untouched but its value to the marine ecology of the Natal coast will be much improved by the possibility of completely restoring estuarine conditions in it.

In the planning of the Richards Bay harbour complex flexibility was considered of prime importance because of, firstly, the unpredictability of future shipping trends and, secondly, the relative importance of further harbour development as against nature conservation which may well change in the distant future. The aim has therefore been to allow for both possibilities; either the harbour can be extended into the southern half of the bay or the southern half of the bay can be maintained and possibly even further improved as a nature reserve.

The work at Richards Bay was started in May 1972 and to date (December 1973) considerable progress has already been made with this gigantic project, as can be seen from Fig 7.

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