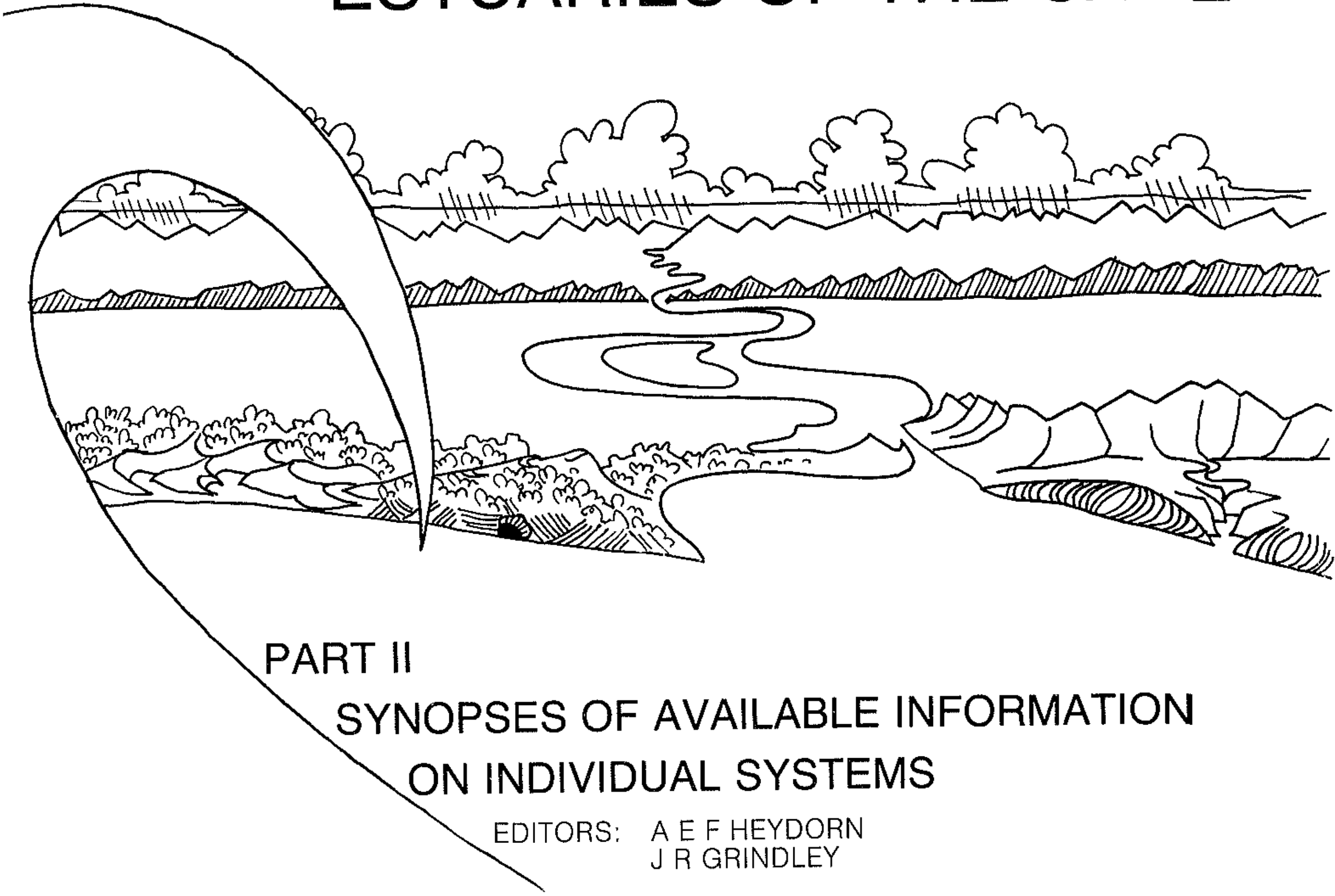
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY
ESTUARINE AND COASTAL RESEARCH UNIT – ECRU

ESTUARIES OF THE CAPE



PART II
SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

EDITORS: A E F HEYDORN
J R GRINDLEY

REPORT NO. 11
HARTENBOS (CMS1)

CSIR RESEARCH REPORT 410

Stellenbosch, South Africa
June 1982

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PART II: SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

REPORT NO. 11: HARTENBOS (CMS1)

(CMS1 — CSIR Estuary Index Number)

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PREFACE

The Estuarine and Coastal Research Unit (ECRU) was established by the National Research Institute for Oceanology (NRIO) of the CSIR in 1979 with the following aims:

- to contribute information relevant to the development of a cohesive management policy for the South African coastline;
- to compile syntheses of all available knowledge on the 167 estuaries of the Cape between the Kei and the Orange rivers;
- to identify gaps in information, to conduct research to fill these and to stimulate Universities, Museums and other institutions to become involved in this kind of work;
- to contribute to *ad hoc* investigations carried out by NRIO on the impacts of proposed developments in the coastal environment, and especially in estuaries.

The Unit was established at the request of the Government, and the Department of Environment Affairs contributes substantially to the running costs.

In 1980 the Unit published its first report under the title "The Estuaries of the Cape, Part I - Synopsis of the Cape Coast. Natural Features, Dynamics and Utilization" (by Heydorn and Tinley)*. As the name of the report implies, it is an overview of the Cape Coast dealing with aspects such as climate, geology, soils, catchments, run-off, vegetation, oceanography and of course, estuaries. At the specific request of the Government, the report includes preliminary management recommendations.

The present report is one of a series on Cape Estuaries being published under the general title "The Estuaries of the Cape, Part II". In these reports all available information on individual estuaries is summarized and presented in a format similar to that used in a report on Natal estuaries which was published by the Natal Town and Regional Planning Commission in 1978. It was found however, that much information is dated or inadequate and that the compilation of Part II reports is therefore not possible without brief prior surveys by the ECRU. These surveys are usually carried out in collaboration with the Botanical Research Institute and frequently with individual scientists who have special interest in the systems concerned. One of these is Prof JR Grindley of the University of Cape Town who is co-editor of the Part II series.

These surveys are however not adequate to provide complete understanding of the functioning of estuarine systems under the variable conditions prevalent along the South African coastline. The ECRU therefore liaises closely with Universities and other research institutes and encourages them to carry out longer-term research in selected estuarine systems. In this way a far greater range of expertise is involved in the programme and it is hoped that the needs of those responsible for coastal zone management at Local-, Provincial and Central Government levels can be met within a reasonable period of time.

Finally, it has been attempted to write the Part II reports in language understandable to the layman. However it has been impossible to avoid technical terms altogether. A glossary explaining these is therefore included in each report.

FP Anderson
DIRECTOR

National Research Institute for Oceanology
CSIR

*CSIR Research Report 380

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HARTENBOS

1. HISTORICAL BACKGROUND

1.1 Synonyms and derivations

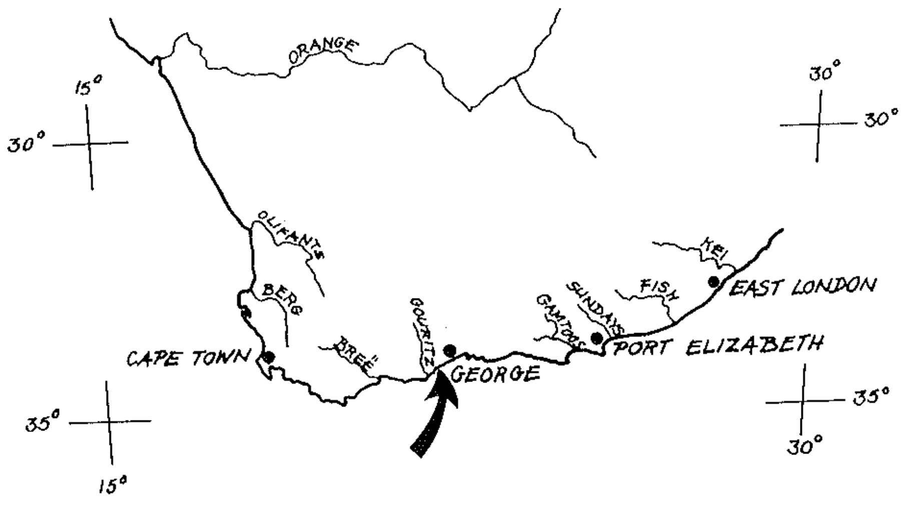
Hertinbosch:	According to Messrs Lamprecht and Kellerman (Hartenbos Municipality) and Mr De Lange (Afrikaanse Taal en Kultuur Vereniging - ATKV), the name originates from the Dutch: hert (buck), in (in) and bosch (bush) or more literally means "buck in bush". The name probably derives from the occurrence of bushbuck in the natural forest areas around the Hartenbos Estuary.
Hartenbosch:	The name of the original farm as given on the 1:50 000 Sheet 3422 AA.
Hartenbos:	The existing name of the river and holiday resort (1:50 000 Sheet 3422 AA).

1.2 Historical aspects

In 1936 the ATKV bought a portion of the original farm Hartenbosch, lying to the south of the Hartenbos Estuary. This portion was sub-divided with some erven being sold to private owners, others being leased on a lease-hold agreement and the remainder being developed as the ATKV Holiday Resort.

2. LOCATION

The mouth of the Hartenbos is situated at 34°07'S, 22°07'E, about 7,5 km north-west of Mossel Bay harbour (1:50 000 Sheet 3422 AA).



2.1 Accessibility

The new national road from Cape Town and Mossel Bay to George crosses the Hartenbos about 1,5 km upstream of its mouth. The turn-off to Hartenbos from the national road is signposted and access to the mouth of the estuary is via roads running through the ATKV Holiday Resort situated on the southern bank.

2.2 Local authorities

The Hartenbos is situated within the area administered by the Outeniqua Divisional Council. The holiday resort and lease-hold properties are owned and controlled by the ATKV. The Hartenbos Municipality administers the area made up of the privately owned properties.

The dunefields lying to the north of the mouth of the Hartenbos, between the railway line and beach, have in the past been controlled by the Directorate of Forestry of the Department of Environment Affairs. This area has been taken over by the ATKV for further development, but a condition is that driftsand must be adequately controlled and prevented from blowing onto the railway line.

3. ABIOTIC CHARACTERISTICS

3.1 River Catchment

3.1.1 Catchment characteristics

The area of the Hartenbos catchment is given as 207 km^2 by Midgley and Pitman (1969), Noble and Hemens (1978) and Day (1981). The Directorate of Water Affairs Publication, River Flow Data (1978) gives the catchment area as 144 km^2.

River length

The total river length of the Hartenbos from its source to the mouth is approximately 32 km. (1:50 000 Sheets 3421 BB and 3422 AA.)

Tributaries

Approximately 20 unnamed watercourses enter the Hartenbos along its length. The two tributaries named on the 1:50 000 Sheet 3422 AA are the Goedemoedrivier and Melkboomrivier in the upper catchment above the Hartebeeskuil Dam. According to Messrs Lamprecht, Kellerman and De Lange, the Matjiesdrif River runs into the Hartebeeskuil Dam.

Geology

The following description is based on information obtained from the 1:250 000 Geological Map 3322 Oudtshoorn. The Hartenbos riverbed, from the mouth to about 10 km upstream of the mouth, lies on Tertiary[1] to Quaternary[2] alluvial valley deposits. To the north and south of these deposits, Cretaceous[3] to Tertiary deposits of conglomerate, sandstone, siltstone and clay outcrops are found.

Just downstream of the Hartbeeskuil Dam wall the river runs through an area of whitish-weathering quartz sandstone described as medium to coarse grained quartzitic and massive, of the Table Mountain Series.

Immediately to the south of the estuary lies an area dominated by Dwyka[4] tillite and subordinate shale, on which the town of Hartenbos is situated. To the north and south of the mouth of the estuary, aeolian sands overlie the earlier geological formations in a narrow strip along the coast.

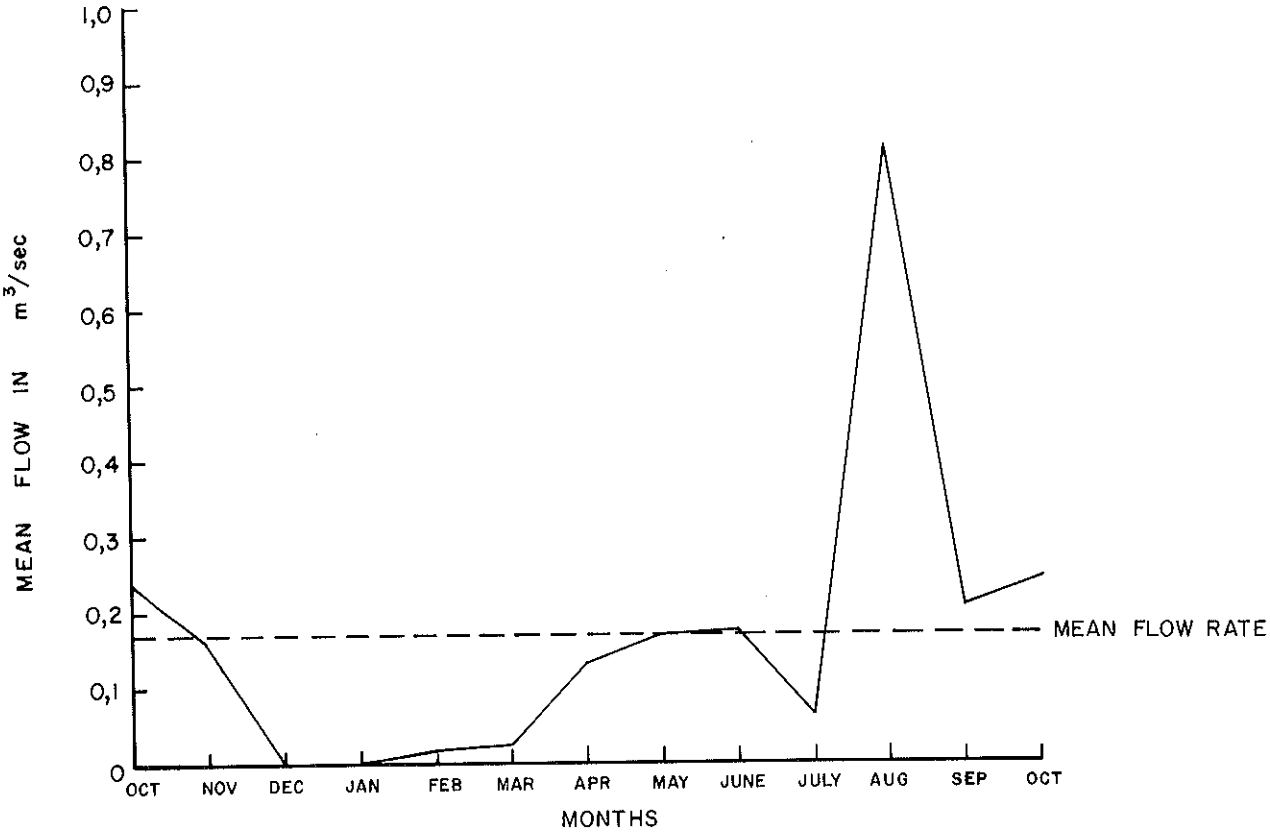


FIG. 1 : Monthly mean flow rates for the Hartenbos River for the period October 1953 to October 1970 (before construction of the Hartebeeskuil Dam). Flow rates calculated from data given in Monthly Flow Records (1968) and River Flow Data (1978). The mean flow rate for the 17 year period is indicated.

[1] *Tertiary:*	*a division of geological time generally recognized as lasting from 65 million to 2,5 million years ago.*
[2] *Quaternary:*	*the division of geological time generally recognized as lasting from 2,5 million years ago to the present.*
[3] *Cretaceous:*	*geological period from 136 to 65 million years ago.*
[4] *Dwyka tillite:*	*boulder clay deposited during the Dwyka glaciation which occurred about 300 million years ago.*

Rainfall and run-off

Midgley and Pitman (1969) give the mean annual precipitation for the Hartenbos catchment as 462 mm to 509 mm. According to Heydorn and Tinley (1980) (p 27) the catchment of the Hartenbos falls between the 400 and 500 mm mean annual isohyets.

The mean annual run-off is given as 2 072 morgen feet (5,4 x 10^6 m^3) (Midgley and Pitman, 1969) and 5 x 10^6 m^3 (Noble and Hemens, 1978). From flow records in the publications Monthly Flow Records (1968) and River Flow Data (1978), the mean annual run-off for the seventeen-year period from October 1953 to September 1970, was calculated to be 5,3 x 10^6 m^3. The flow measurements were made at a gauging station K1M01 situated approximately 5 km upstream of the mouth.

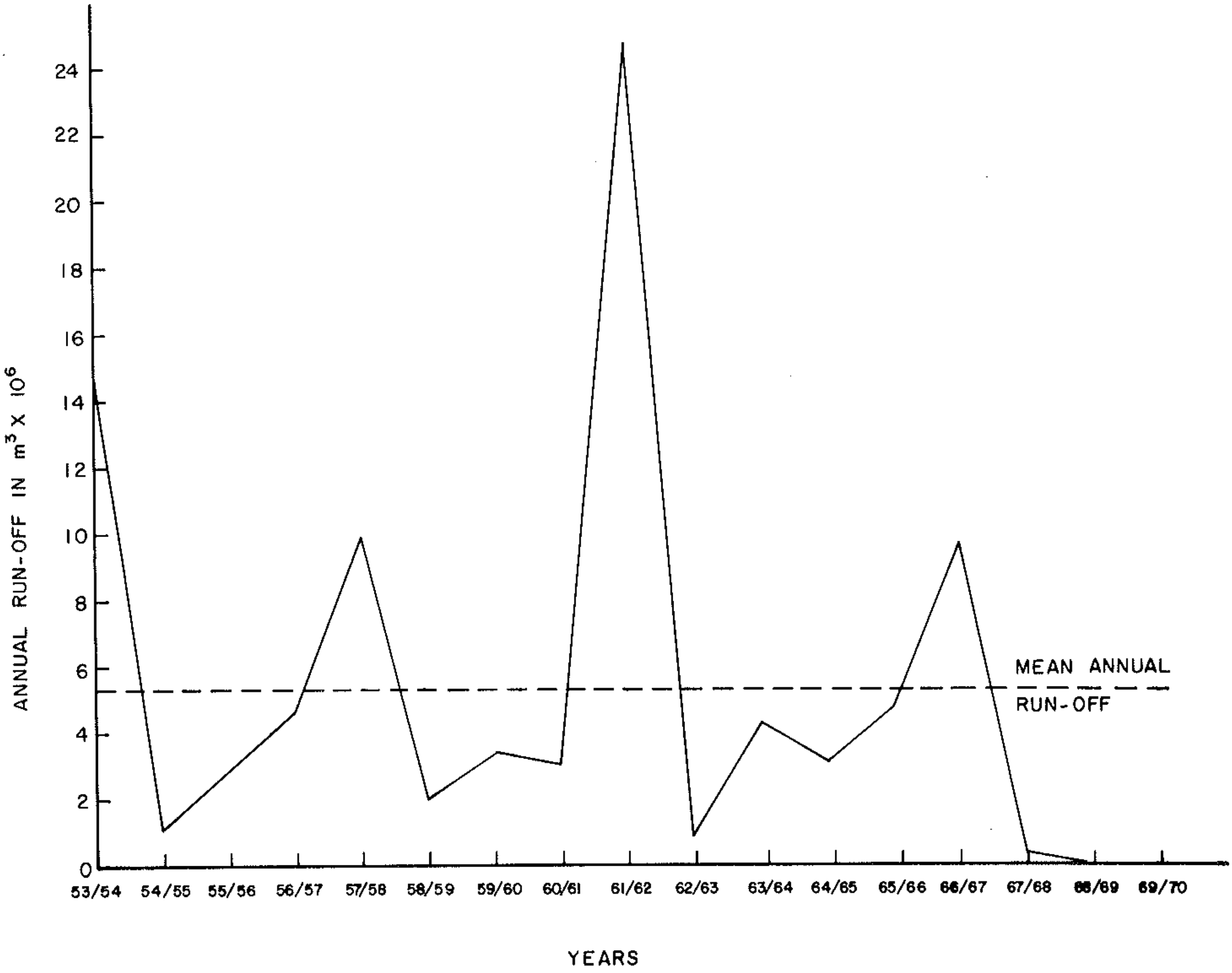


FIG. 2: Total annual run-off for the Hartenbos River for the period October 1953 to October 1970 (before construction of the Hartebeeskuil Dam). Yearly run-off calculated from data given in Monthly Flow Records (1968) and River Flow Data (1978). The mean annual run-off is indicated.

Flow records from the above-mentioned gauging station indicate that before construction of the Hartebeeskuil Dam, the river flowed intermittently. No-flow periods generally occurred from the summer to early winter months. During the seventeen-year period, October 1953 to October 1970, the highest total run-off was recorded during the months of April (5,79 x 10^6 m^3), June (7,71 x 10^6 m^3), August (37,0 x 10^6 m^3), September (9,14 x 10^6 m^3) and November (6,99 x 10^6 m^3). However, the measuring capacity of the gauging station was exceeded in August 1962 when floods occurred. The August peaks in monthly total run-off (above) and monthly mean flow (Figure 1) were largely due to these floods. The above data include a one-year period of no-flow from January 1960 to January 1961 and a two-year period of no-flow from October 1968 to September 1970. The latter was completed in 1970. The graph in Figure 1 depicts the mean flow rate per month at the gauging station (K1M01) for the period October 1953 to September 1970 and Figure 2 the trends in annual run-off over the same period.

The Hartenbos and its catchment lie within a region of bimodal (spring and autumn peaks) rainfall (Heydorn and Tinley, 1980). This would explain the flow peaks in April - June and August - November in Figure 1.

Flow measurements for the gauging station (K1M01) were continued after construction of the Hartebeeskuil Dam until September 1973 when the station was closed down due to the effects of the dam. During this period, run-off occurred only from July to November 1971 and from April to July 1973.

3.1.2 Land Ownership/Uses

According to Messrs Lamprecht, Kellerman and De Lange the catchment consists of privately owned farms. In the upper parts of the catchment grain and wheat are farmed, whilst the lower reaches are used for grazing of cattle and sheep, etc. (J Blomerus, Agricultural Technical Services, pers. comm.).

The State-owned Hartebeeskuil Dam is situated in the upper catchment approximately 12 km upstream of the mouth. The water from the dam cannot be used for irrigation as it is brackish and would give rise to mineralization problems (J Blomerus, pers. comm.).

During the ECRU survey (9 - 11 November 1981) a brickworks on the southern bank of the river, about 4 km upstream of the mouth was noted.

3.1.3 Obstructions

The major obstruction in the catchment is the Hartebeeskuil Dam, situated approximately 12 km upstream of the mouth. The dam, which totally impounds run-off from the upper reaches of the catchment, was completed in 1970. The purpose of this dam was to supply water for the ATKV Holiday resort at Hartenbos. After it was constructed, it was found that the water was not potable due to brackishness. According to Department of Agricultural Technical Services (ATS) Memorandum of 4 July 1975, the brackishness is due to springs in the catchment which have a high salt content.

Because of its salinity, the water in the dam is also unsuitable for irrigation purposes and ATS have advised against its use by farmers (J Blomerus, pers comm). The water is, however, minimally used for the watering of livestock by farmers in the catchment. The dam, which has a substantial water surface area, is not used for recreational purposes.

Since its construction, the Hartebeeskuil Dam has taken eleven years to reach overflow level, with a minimal amount of water being released to maintain a steady reading on the gauge plate at the water level recorder immediately below the dam wall.

Upstream of the dam wall there are several minor dams built on farms, for the watering of livestock (J Blomerus, pers comm).

The gravel road from the Mossel Bay/Oudtshoorn road to Herbertsdale crosses the Hartenbos immediately below the Hartebeeskuil Dam wall. The Mossel Bay/Oudtshoorn road crosses the Hartenbos via a concrete bridge approximately 6 km upstream of the mouth. Upstream and downstream of this bridge, the riverbed was clogged with reeds at the time of the ECRU survey. There is also a narrow gravel road across the river opposite the brickworks approximately 4 km upstream of the mouth (1:50 000 Sheet 3422 AA).

There are several fences demarcating farm boundaries, which cross the Hartenbos in the lower parts of its catchment.

3.1.4 Siltation

As the land is largely protected by soil conservation works, there is minimal loss of topsoil in the catchment. Besides this, the Hartebeeskuil Dam retains any silt brought down during floods or otherwise (Department Agricultural Technical Services Memorandum of 4 July 1975).

3.2 Estuary

3.2.1 Estuary characteristics

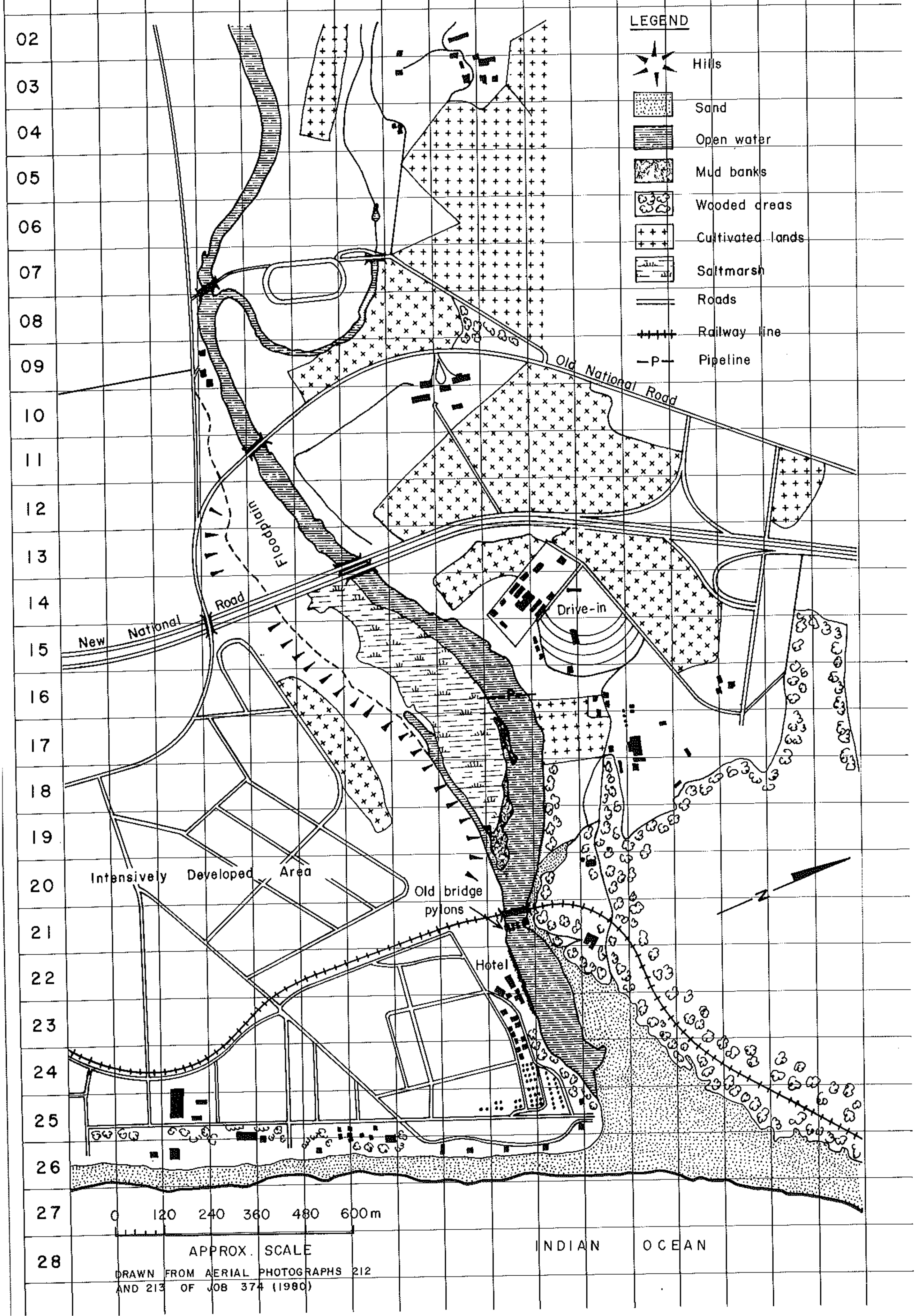
This section is contributed by Dr GAW Fromme of the Sediment Dynamics Division, NRIO.

Estuary type and area

Type: The Hartenbos is a double-sandspit estuary (Heydorn and Tinley 1980, p 53). The major sandspit lies on the south-western bank and a secondary short sandspit on the opposite north-eastern bank. The mouth is open periodically and its configuration is variable (see Figures 3, 4, 5 and 7).

Area: According to planimeter measurements, the water surface area in Figure 3, taking the limit of the estuary to be at the drifts (Grid Refs 0704 and 0707) is 18 ha. If the saltmarsh area is included, the estuarine area is 31 ha.

FIG. 3 : Hartenbos Estuary



DRAWN FROM AERIAL PHOTOGRAPHS 212 AND 213 OF JOB 374 (1980)

Geomorphology

Downstream of the open floodplains of the upper estuary, the river enters the mouth area by breaking through a massive 20 to 30 m high barrier dune belt which carries the ATKV Holiday development on the south-western bank, and dune vegetation on the north-eastern bank of the river.

Here the estuary forms a funnel-shaped steep valley which opens asymetrically out to sea in a north-easterly direction. The estuary mouth is characterized by a large flat sandbar, elevated 1 to 2 m above mean sea level, which fits into the valley of the Hartenbos River mouth, in this way blocking the inlet most of the time.

Bathymetry

During the ECRU survey on 11 and 12 November 1981, conditions were found to be as follows (see Figure 7):

A deep water channel of 1 to 2 m depth, depending on the conditions of the tide, ran along the south-western bank from the Riviera Hotel down to the parking area on the south-western sandspit. From there the channel turned sharply across the estuary towards its north-eastern bank, and then broke out to sea in an S-shaped bend, where the water depths decreased to approximately 1 m. All the other areas of the lower estuary are dominated by relatively shallow areas and sand shoals, of less than 0,5 m water depth. From the railway bridge upstream to the southern drift (Grid Ref 0704) depths varied from 1,3 to 1,2 m on a high spring tide (ECRU survey).

Bottom material

The bottom material in the estuary mouth consists chiefly of fine to medium grained marine sand. Terrestrial sediments (black mud and silt) are found upstream of the railway bridge in the meanders and channel system of the upper estuary.

Flood History

According to Messrs Lamprecht, Kellerman and De Lange the river used to come down every year before construction of the Hartebeeskuil Dam in 1970. Since 1970 the river has come down about every two to three years. Major floods occurred in 1963 and 1981, the former being the biggest. Flow data for the Hartenbos in River Flow Data (1978) suggest that the river in fact flooded in August 1962 with a maximum flow peak of more than 81,0 cumecs. However, during this flood the measuring capacity of the gauging station (K1M01) was exceeded. This may be the same flood as that referred to by Messrs Lamprecht, Kellerman and De Lange as having occurred in 1963. Photographs taken by Mr GJ Lamprecht at the time, show that the floodwaters overtopped the rock embankment in front of the Riviera Hotel (see Figure 3) and flooded through the hotel to the bottle store situated behind it. The Drive-In Cinema situated on the northern bank of the estuary (see Figure 3), was also inundated during this flood, which occurred during a high spring tide (GJ Lamprecht, GP Kellerman and GL de Lange, pers. comm.).

In 1981 floods occurred on 25 January, 26 March and again in April (GJ Lamprecht, GP Kellerman and GL de Lange, pers. comm.). In the January flood, farmlands upstream of the drifts across the upper reaches of the estuary were flooded and the road bridge for the Mossel Bay/Oudtshoorn road which crosses the Hartenbos about 6 km from the mouth, was under water and impassable.

3.2.2 Mouth Dynamics

(This section is contributed by Dr GAW Fromme of the Sediment Dynamics Division, NRIO.)

History of mouth behaviour

Characteristic changes in the estuary mouth are documented by historical aerial and terrestrial photographs housed in the ECRU Documentation Centre (NRIO, Stellenbosch). Three typical conditions are shown in Figure 4.

(a) After a flood, the channel along the north-eastern bank is widened and straightened into a well-developed funnel shaped tidal inlet. This situation existed in 1963, during the ECRU survey in November 1981 and also probably throughout most of 1981 after the floods earlier that year. During such conditions the tidal inlet is close to the north-eastern bank, causing heavy erosion just below the railway line.

(b) Narrow channel meandering from the deep water area at the south-western side of the lagoon towards the north-eastern bank and to sea via a sand delta at the foreshore. The south-western sandspit is fully developed, pushing the channel towards the north-eastern bank (without causing erosion). The lagoon is apparently not tidal and the channel is merely an overflow of lagoon water. These conditions existed in 1957 and also during a visit to the Hartenbos by ECRU personnel at the beginning of December 1981.

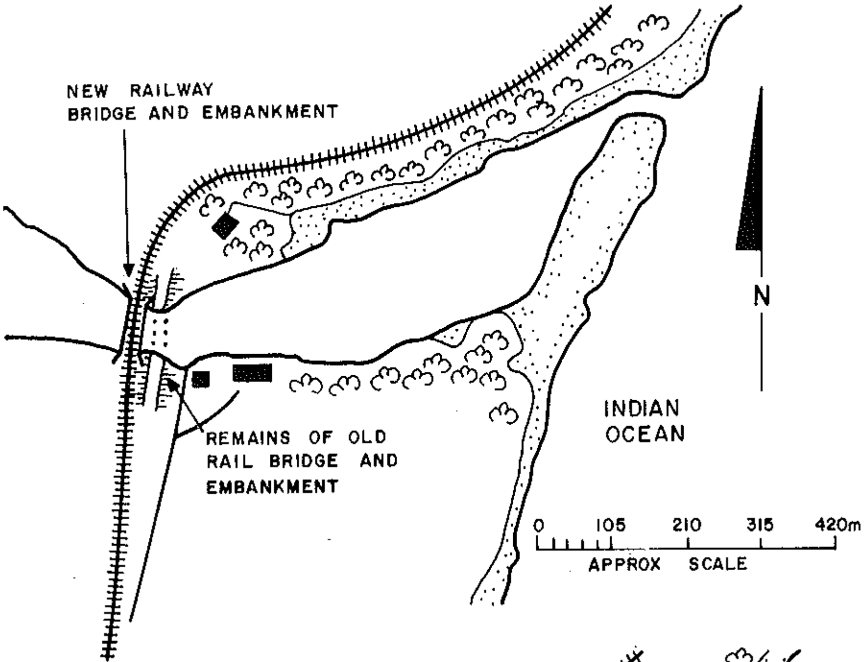
(c) Mouth closed with a large sandbank on the north-eastern side and deep water on the south-western side. There is a solid beach bar across the entire mouth area. This closed-mouth condition existed when aerial and terrestrial photographs were taken in January 1940, December 1968, June 1969 and April and October 1977. It has been the typical situation in the Hartenbos since construction of the Hartebeeskuil Dam in 1970.

Although the above three conditions are based on limited photographic evidence and field observations, they illustrate the dynamic and changeable nature of the estuary mouth and illustrate the danger of human interference with these dynamic processes.

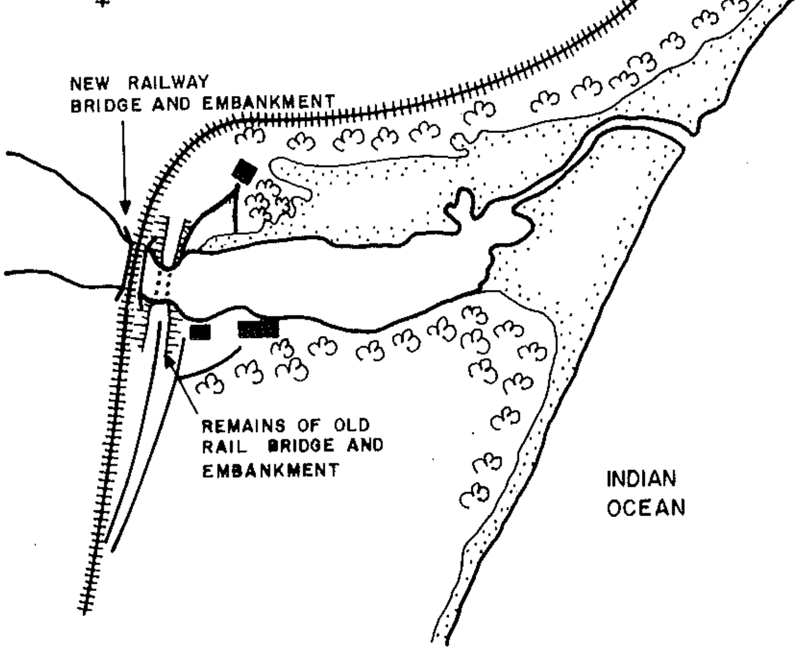
At times when the water level in the estuary has risen without breaking through at the mouth (usually at the end of winter), the sandbar at the mouth has been artificially breached. Motivation for artificial breaching usually emanates from people wanting to gain access to "Die Bult" holiday facilities situated on the floodplain on the northern bank of the estuary, just downstream

FIG 4 : CHANGES IN CONFIGURATION OF HARTENBOS ESTUARY MOUTH

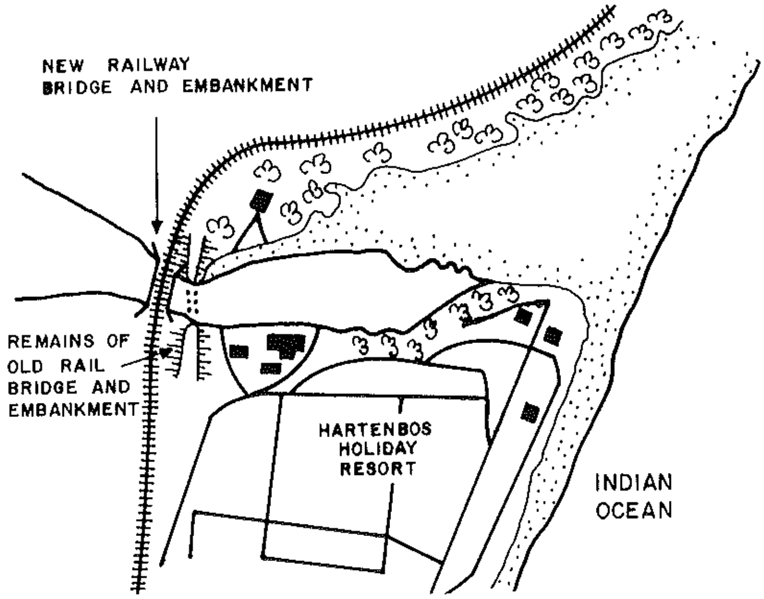
(ALL MAPS DRAWN TO SAME SCALE USING A BAUSCH AND LOMB STEREO ZOOM TRANSFERSCOPE)



(a) COMPILED FROM AERIAL PHOTOGRAP (TRIG. SURVEY) TAKEN IN 1963, JOB NO. 492 AT AN APPROX. SCALE OF 1:30 000, SOME TIME AFTER FLOO SANDSPIT BUILDING UP ON SOUTH-WESTERN SIDE OF MOUTH AND TIDAL INLET BEING PUSHED AGAINST NORTH-EASTERN BANK.



(b) COMPILED FROM AERIAL PHOTOGRAPHS (TRIG. SURVEY) TAKEN IN 1957, JOB NO. 403 AT AN APPROX. SCALE OF 1:30 000. MOUTH CONSISTING OF NARROW CHANNEL MEANDERING FROM DEEPWATER AREA ON SOUTH-WESTERN SIDE OF LAGOON, TOWARDS NORTH-EASTERN BANK. SOUTH-WESTERN SANDSPIT FULLY DEVELOPED. LAGOON NOT TIDAL AND CHANNEL MERELY AN OVERFLOW OF LAGOON WATER.



(c) COMPILED FROM AERIAL PHOTOGRAPHS (UNIV OF NATAL, SURVEY DEPT.) TAKEN IN 1979, JOB NO. 326 AT AN APPROX. SCALE O 1:10 000 TYPICAL MOUTH CLOSE CONDITION, WITH SUBSTANTIAL SANDBAR ON NORTH-EASTERN SIDE AND DEEP WATER ON SOUTH-WESTERN SIDE OF MOUTH.

of the railway bridge (Figure 3, Grid Ref 2112). The access path passes under the northern side of the railway bridge and it is here that the path first becomes inundated. After being breached the mouth usually remains open for about a week before it is closed by marine sediments again (GJ Lamprecht, GP Kellerman and GL de Lange, pers. comm.).

FIG. 5: Mouth of the Hartenbos Estuary just after closure at the end of 1981 (ECRU 81-12-05)

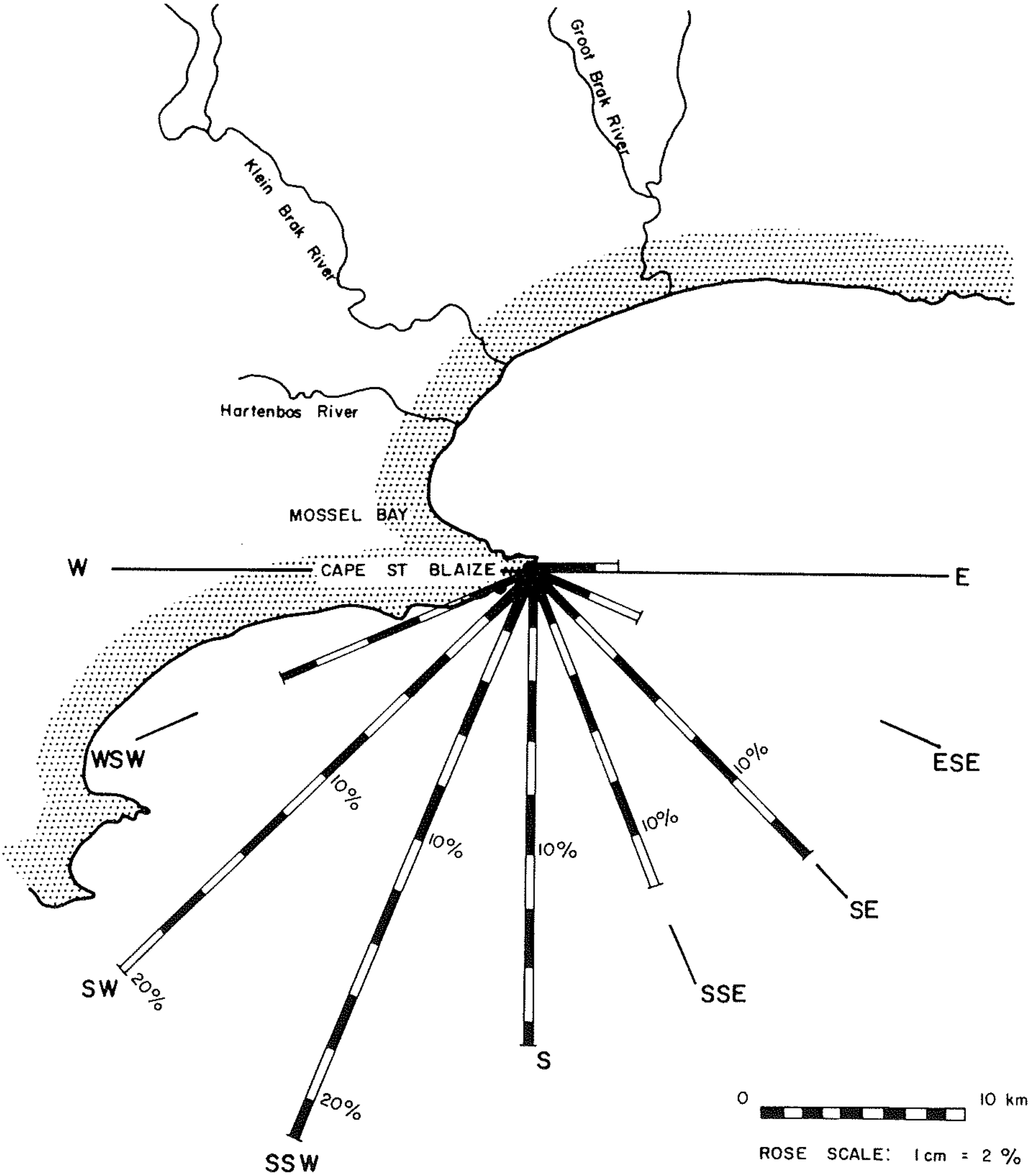
Inshore oceanography

The current and circulation patterns off the coastline in the Mossel Bay area are not well understood (Harris, 1978). This is due to the scarcity of data for the area and also, the complexity of the circulation patterns that occur there. Since the Agulhas Current follows the edge of the Agulhas Bank (some 130 km off the coastline at Mossel Bay), its influence over the bank is sometimes apparent but it is intermittent and may form vortices (Harris, 1978). Harris also points out that the diminished influence of the Agulhas Current over the Agulhas Bank means that wind-induced currents become more important. The predominant winds blow from the south-east in summer and the north-west in winter (Heydorn and Tinley, 1980).

In a review of the data on coastal currents in South African waters, Harris (1978) furthermore makes note of the relatively high percentage frequencies of both slack water and onshore currents, off the coast respectively west and east of Mossel Bay. He also highlights the fact that oil from the *Venpet/Venoil* collision in December 1977, moved inshore and was deposited along

FIG. 6 : WAVE ROSE FOR DEEP SEA WAVES (CLINOMETER) AT CAPE ST BLAIZE.

FROM 1968 TO 1972 (AFTER ASHBY ET AL, 1973). THE PERCENTAGE DISTRIBUTION IS SHOWN. APPROXIMATE MAP SCALE 1:300 000.



the coastline east of Mossel Bay. For four days prior to the deposition of the oil, the wind had a strong onshore component.

Of importance for an analysis of the littoral sediment movement influencing the mouth dynamics of the Hartenbos, is an assessment of the wave climate in the region between Mossel Bay and the Great Brak River mouth. The results of an analysis of wave clinometer measurements collected at Cape St Blaize Lighthouse over a period of five years (Ashby et al, 1973) are summarized in the wave rose in Figure 6. Deep-sea wave data from voluntary observing ships (Swart and Serdyn, 1981) support these results.

The wave rose shows that the promontory of Cape St Blaize largely shelters the half-heart-shaped Mossel Bay from the prevailing swells. Hence the mouth of the Hartenbos River lies in an area which theoretically can receive only direct deep sea waves originating from the south south-east to the east. Waves approaching from a direction to the the west of south south-east do, however, also enter Mossel Bay because they are diffracted in an anti-clockwise direction around Cape St Blaize.

From Figure 6 it can be seen that all waves from the south-east, east south-east and east, approach the coast at Hartenbos undisturbed in an easterly direction. All waves from the south south-east, south, south south-west and south-west, after being diffracted around Cape St Blaize to a lesser or greater degree, also run up on the Hartenbos coastline in an easterly direction.

Because the diffracted waves that reach the Hartenbos coastline are low-energy waves and because there is a low percentage of deep-sea waves from the south-east that reach the Hartenbos coastline undisturbed, wave-generated east-bound longshore drift is minor or non-existent. In a diffraction area, the longshore currents are normally more complex and contain a component due to longshore variation in wave height within the diffraction area, which in turn gives rise to a longshore variation in wave set-up (wave set-up is the build-up of a higher mean water level inside the surf zone than outside, which is associated with the momentum flux in progressive waves). In the instance of Mossel Bay, this means that the water level in the surf-zone is higher at the mouth of the Great Brak than it is at Hartenbos. A gradient from east to west is created which results in a westward flowing surf-zone current and accordingly in a net longshore sediment displacement towards the west. Although it is possible that the net longshore drift at the mouth of the Great Brak River may change in direction, the longshore drift to the west of it and at Hartenbos is predominantly towards the west. This is because of the weakening of the east-bound component.

The *in situ* observations during the ECRU surveys also indicate that the west-bound component is predominant (see Figure 7).

The tidal range for Mossel Bay as calculated from the South African Tide Tables (1981) is 1,75 m between MLWS and MHWS. The tidal range at the pipe causeway (Figure 3, Grid Ref 1610) was approximately 0,5 m at the time of the ECRU survey. During the survey the estuary was tidal to above the road causeways (Figure 3, Grid Refs 0704 and 0707) with an approximately two-hour time lag from the mouth.

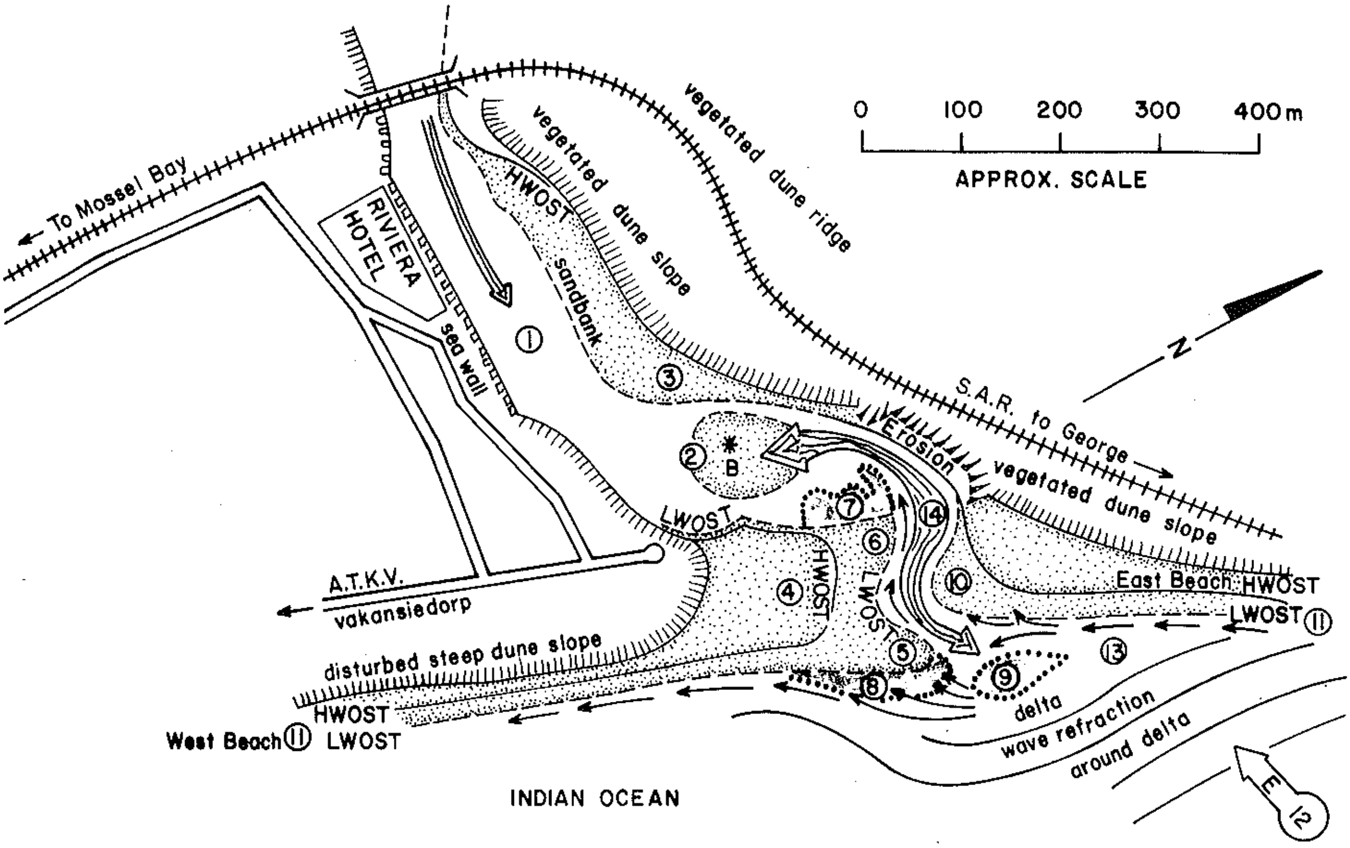


FIG: 7 Sediment dynamics of the Hartenbos Estuary mouth as on 12 November 1981.

LEGEND TO FIGURE 7: Hartenbos River mouth, 12 November 1981

①	River course.
②	Inner tidal delta, formed by the influx of marine sand during incoming tide ⑭ .
③	Tidal sandbank on north-eastern bank of estuary.
④	North-easterly sandspit above HWOST.
⑤	Outer (seaward) tip of south-western sandspit below HWOST.
⑥	Inner (landward) tip of south-western sandspit below HWOST.
⑦	Submerged prograding sandbank at inner tip of south-western sandspit, mainly caused by sand migration along north-easterly face of south-western sandspit, and by wash-over during HW-tides.
⑧	Submerged prograding sandbank at outer tip of south-western sandspit, receiving material from delta ⑨ .
⑨	Delta formation in front of estuary mouth, caused by sand movement in mouth channel during outgoing tide.
⑩	North-easterly sandspit below HWOST.
⑪	Beach (between LWST and backshore).
⑫	North-easterly swell breaking obliquely against the beach, generating a south-westbound sand movement along the shore ⑬ .
⑬	Longshore (littoral) sand transport moving in a south-westerly direction (under the influence of an north-easterly swell ⑫ .
⑭	Deep section of estuary mouth channel, scoured by tidal currents, ending seaward at the tidal delta ⑨ .
LWOST, HWOST	Low and high water ordinary springtide water edges.
B	Dune bush slumped down from erosion on north-eastern bank and being washed upstream by tidal current.

Conclusions on mouth dynamics

The sediment movement and basic dynamics at the Hartenbos River mouth as could be established by the study of historical photographs, aerial photographs, the geomorphology, inshore oceanography, and relevant local information and the observations carried out on 12 November and 5 December 1981, led to the following conclusions:

(1) Before 1970 the estuary mouth underwent characteristic changes and three typical conditions are shown in Figure 4.

(2) The typical situation since the construction of the Hartebeeskuil Dam in 1970 was the solid beach bar across the entire mouth area (Figure 4c).

(3) The mouth of the Hartenbos Estuary opens naturally only during major floods.

(4) During closure of the mouth the south-western sandspit grows from the south-west to the north-east with the result that the river course is diverted to the north-eastern bank causing severe erosion of the bank.

(5) In the light of the observations, any proposed developments such as the construction of a roadbridge across the estuary near the mouth and a road running below and parallel to the railway line must be discouraged.

3.2.3 Land Ownership/Uses

The township of Hartenbos consists largely of the Hartenbos Holiday Resort situated on the southern bank of the lower reaches of the estuary. The Holiday Resort was established in 1936 with 998 erven which are owned by the ATKV and various plotholders (CPA: A preliminary survey and report of Cape Coastal Townships and Resorts. Report no. 1, 1969). The holiday accommodation at the resort consisted of 280 beach cottages with 1 350 beds and 370 tent/caravan sites, in 1970 (CPA Cape Coastal Survey Report No 2, 1973). According to this report, the permanent population of the Hartenbos Holiday Resort in 1970 was 455 with an influx of 4 250 holidaymakers during peak holiday periods. By 1981, this influx had increased to up to 9 000 during peak periods (GL de Lange, ATKV, pers comm). The ATKV also own the registered township of Hartenbos Extension No 4 consisting of 868 erven. This township is situated just inland of the new national road to the south of the Hartenbos Estuary and has yet to be developed (CPA Report no. 1, 1969). A part of the floodplain on the southern bank of the estuary between the new national road bridge and the railway bridge (see Figure 3) known as Lot C is soon to be taken over by the ATKV. This area was under the control of the Outeniqua Divisional Council at the time of the ECRU survey (GL de Lange, pers comm). The Riviera Hotel is situated on the southern bank of the estuary, just downstream of the railway bridge. The remainder of the Hartenbos Township to the south of the estuary consists of privately owned properties.

Between the northern bank of the estuary and the boundary of the farm Vaale Valley are the Hartenbos Drive-In Cinema and eleven registered plots, of which four had been built upon and three permanently occupied by 1969 (CPA Report No 1, 1969). Most of the developments on the northern bank are situated on the floodplain, in particular, a holiday camp, the Drive-In Cinema and the holiday cottages. The two holiday cottages (Figure 3, Grid Refs 2012 and 2112) are situated one upstream and one downstream of the railway line respectively, the latter being below the 25-year flood line, as shown on a map obtained from Geustyn, Forsyth and Joubert Inc., Consulting Civil and Structural Engineers. The Seashells Motel (Established in 1962) is situated on the northern bank of the estuary, alongside the old national road.

North-west of the Hartenbos mouth, between the railway line and high water mark, lies the Hartenbos Forest Reserve stretching northwards to the mouth of the Klein Brak Estuary and having an area of 40 morgen (34 ha) (CPA Report No 1, 1969). The ATKV has taken over this dune area (see Plate I) in order to extend its present holiday developments, but a strict condition is that driftsand must be prevented from reaching the railway line (GL de Lange, pers comm). Inland of the railway line lies the farm Vaale Valley.

Before construction of the Hartebeeskuil Dam, the estuary was used for pleasure boating and waterskiing (GJ Lamprecht, GP Kellerman and GL de Lange, pers comm). Since dam construction, the estuary has usually been stagnant with high salinities and dense mats of algae, due to eutrophication. This has made it unattractive for recreational purposes. The banks and floodplain of the middle and upper reaches of the estuary are used for the grazing of cattle.

3.2.4 Obstructions

In the upper reaches of the estuary, approximately 2,5 km from the mouth (Grid Refs 0704 and 0707) road causeways cross the two main watercourses of the Hartenbos. The southern causeway is a low-lying concrete structure with several pipe culverts for the passage of water. At the time of the ECRU survey, this causeway had recently been damaged (probably during the 1981 floods) and repaired. The northern causeway (Plate III) had been completely washed away on its southern side and could no longer be traversed by vehicles at the time of the ECRU survey. The banks of the channel on the southern side of the causeway had also been badly eroded by floodwaters. Attempts to curb this have been made by filling in the eroded part with derelict vehicles (Plate III).

The old national road single span bridge (Grid Ref 1105) built before 1940 (Aerial Photography Job No 14039) crosses the Hartenbos about 2 km upstream of the mouth. It has substantial supporting embankments built across the floodplain on either side of the estuary. The main pipeline for the fresh water supply (dams on the Klein Brak and Groot Brak to the north-east of the Hartenbos) to Mossel Bay, is attached to the old national road bridge.

The new national road bridges (Grid Ref 1307) were constructed in 1973 and are situated about 1,6 km from the mouth. They are also supported by embankments across the floodplain on either side of the estuary. At the time of the ECRU survey, construction rubble was present on the bottom of the estuary, under the bridges, making boating hazardous.

About 1,2 km from the mouth a causeway (Grid Ref 1610) supporting the old pipeline for freshwater supply (from the catchment of the Groot Brak to the north-east) to Mossel Bay and Hartenbos, crosses the estuary. The pipe is buried in the floodplain on either side of the causeway. At the time of the ECRU survey this pipeline, which was constructed in 1940 (GL Lamprecht, GP Kellerman and GL de Lange, pers. comm.) was still in use. The northern side of its causeway had recently been damaged (probably during the 1981 floods) and repaired. According to Messrs Lamprecht, Kellerman and De Lange, this old causeway and pipeline are to be removed soon.

The present railway bridge (Grid Ref 2110), constructed in 1956 and carrying the main Cape Town/Port Elizabeth line, is situated about 800 m from the mouth of the Hartenbos. It has a substantial supporting embankment across the floodplain on the northern side. Immediately downstream of it are the remains of the old railway bridge. These consist of disused embankments on either side of the constriction in the estuary at this point and the remains of the old pylons situated in the main channel. The old railway bridge was made of steel and due to rust, became unsafe by the early 1950's, necessitating its replacement. The old bridge pylons, instead of being removed were dynamited and capped with concrete cylinders, creating both a hazard to boats and an obstruction to the flow of water.

There are also developments on the floodplain of the Hartenbos, both on the northern and southern banks, which obstruct floodwaters. Of particular note is the Riviera Hotel on the southern bank, situated about 200 m downstream of the railway bridge (Grid Ref 2210). Floodwaters are channelled directly towards the hotel and in the past have flooded it and the buildings behind it (see Section 3.2, Abnormal flow patterns and Plate II).

3.2.5 Physico-chemical Characteristics

(This section incorporates unpublished reports on the chemistry of the Hartenbos Estuary by Dr PD Bartlett of the Marine Chemistry and Biology Division, NRIO.)

Before the ECRU survey on 10 and 11 November 1981, available information on the physico-chemical characteristics of the Hartenbos Estuary comprised data by Eagle *et al* (1979), Watling and Watling (1980) and Day (1981). The data by Day (1981) were collected during a visit by a group of biologists from the University of Cape Town in May 1950. Those by Eagle *et al* (1979) and Watling and Watling (1980) were collected in July 1978 as part of the Marine Pollution Monitoring Programme. Physico-chemical data for the estuary were also collected during the ECRU survey and during a follow-up survey by the Marine Pollution Monitoring Group of the NRIO on 31 January 1982. As there has been a proposal to site a sewage effluent outfall in the upper reaches of the Hartenbos, the water chemistry of the estuary was extensively investigated during the ECRU and follow-up surveys. The data from these two surveys are on record in the ECRU Documentation Centre (NRIO, Stellenbosch) and for the sake of conciseness, only a summary of the trends is given in this report.

Salinity records for the Hartenbos suggest that hypersaline (more than 35 parts per thousand) conditions have occurred from time to time, even before the advent of the Hartebeeskuil Dam in 1970. In May 1950, the salinity near the mouth was 38 parts per thousand and near the head of the estuary, 41,8 parts per thousand (Day, 1981). These salinities suggest that there was little, if any, tidal exchange at the time. In July 1978, during a period of prolonged drought, the Hartenbos was flowing very weakly and the mouth was closed (Eagle et al, 1979). At the time, salinities in the estuary decreased from 33 parts per thousand at the mouth to 29 parts per thousand at the southern causeway (Grid Ref 0704), with a mean of 31 parts per thousand. Of note was a salinity of 4 parts per thousand in the main channel (Grid Ref 0305) 500 m upstream of the southern causeway.

At the beginning of August 1980 when the mouth of the Hartenbos was closed, the salinity in the estuary at the new national road bridge (Grid Ref 1307) was 50 parts per thousand and dense mats of algae on the surface indicated stagnant eutrophic conditions (TJE Heinecken, pers. comm.)(see Figure 8).

At the time of the ECRU survey in November 1981, during a high spring tide and open-mouth conditions, surface salinities ranged from 36 parts per thousand at the mouth to 24 parts per thousand at the southern causeway (Grid Ref 0704). The equivalent bottom salinities, however, ranged from 36 to 33 parts per thousand. This indicated stratification and a probable salt wedge effect in the upper reaches of the estuary even though the depth was only 1,2 m. The mean salinity for the estuary was 34 parts per thousand and tidal exchange extended to well above the southern causeway (Grid Ref 0704) and proposed sewage effluent outfall point for Mossel Bay (Grid Ref 0707) where a salinity of 24 parts per thousand was measured on the high tide.

By the end of January 1982, the mouth had closed again and salinities had increased to 41 parts per thousand in the lagoon just upstream of the sandbar and to 44 parts per thousand at the southern causeway (Grid Ref 0704) and the proposed sewage effluent outfall site (Grid Ref 0707) below the northern drift. The salinity above this drift was 35 parts per thousand, indicating sea water penetration to above this point. An unusual feature of the Hartenbos is that its run-off is brackish due to leaching of salts from the catchment (salinity in the Hartebeeskuil Dam was 2 parts per thousand at the time of the ECRU survey). The diluting effect of run-off on the saline water of the estuary is therefore, not as great as would be the case if the run-off were completely fresh. As shown by the above salinity data, the evaporative loss in the estuary often exceeds riverine inflow, particularly during the summer months when the inflow is minimal (Figure 1).

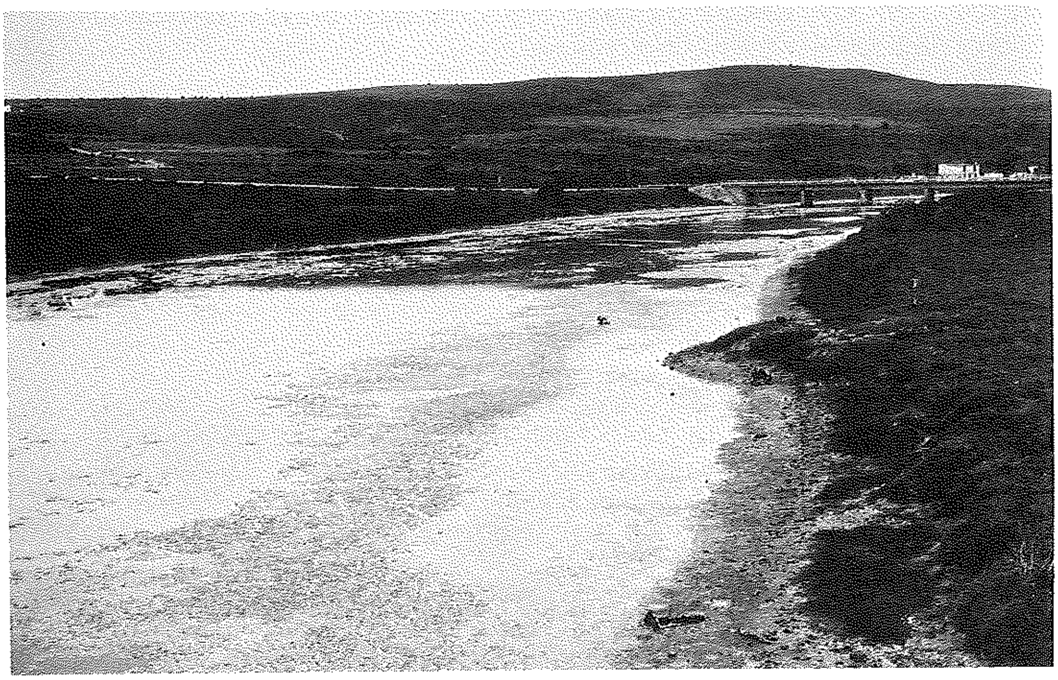


FIG. 8: Middle reaches of the Hartenbos Estuary showing dense mats of algae, indicative of stagnant eutrophic conditions. The salinity was $50^{o}/_{oo}$ at the time (ECRU 80-08-01).

Temperatures in the estuary are of the order of 18°C in May (Day, 1981). In July 1978, when the mouth was closed, temperatures increased from the mouth (12°C) to the upper reaches of the estuary (17°C), with a mean of 15°C (Eagle et al, 1979). In November 1981, tidal action was evident throughout the estuary and temperatures increased from 20°C at the mouth to 26°C in the shallow upper reaches. The mean temperature was 22°C. At the end of January 1982 when the mouth was closed and there was no tidal influence, temperatures in the estuary varied less. From the mouth to the upper reaches, the range was 25 - 26°C with a mean of 25,6°C.

Water transparency, measured using a Secchi disc, ranged from more than 1,3 m at the mouth, to 0,6 m at the southern causeway (Grid Ref 0704) during the ECRU survey in November 1981.

Dissolved oxygen levels decreased from 7,7 milligrams per litre at the mouth to 4,9 milligrams per litre in the upper reaches of the estuary with a mean of 6,4 milligrams per litre in July 1978 (Eagle et al, 1979) when the mouth was closed. With the good tidal circulation throughout the estuary in November 1981, oxygen levels near the mouth were close to saturation. On the surface they decreased from 7,7 milligrams per litre at the mouth to 5,7 milligrams per litre 100 m upstream of the new national road bridge (Grid Ref 1307) and 6,1 milligrams per litre near the southern causeway (Grid Ref 0704). The lowest values of 5,2 and 4,2 milligrams per litre were recorded on the bottom in the middle reaches of the estuary at Grid Refs 1610 and 1306, respectively. From the morphology of the estuary, siltation and the deposition of debris might be expected to occur in this region. At the end of January 1982, oxygen levels were even lower, but consistent, and ranged from 5,0 to 4,67 milligrams per litre in the estuary. The higher temperature and hypersaline conditions at the time were probably the reason for these low levels.

pH in the estuary varied from 8,29 to 9,01 with a mean of 8,6 at the end of July 1978 (Eagle et al, 1979). In November 1981 when the mouth was open, the values were normal for sea water and ranged from 8,0 to 8,2 (mean 8,1). There was no change in pH in January 1982, although the mouth was closed.

Nitrate levels were high in July 1978 and ranged from 146,80 micromoles per litre (a standard chemical concentration unit) in the middle reaches, to 50,45 micromoles per litre in the upper reaches of the estuary (Eagle et al, 1979). The mean value for the estuary was 105,90 micromoles per litre. These high levels indicate eutrophication and with the mouth being closed at the time, could have originated from decomposing algae (PD Bartlett, pers. comm.). In 1981, nitrate levels were within the normal range for a clean estuary (PD Bartlett, pers. comm.), with a mean value of 2,75 micromoles per litre. In January 1982, these levels were even lower, with a mean value for the estuary of 0,87 micromoles per litre.

Nitrite levels were low in July 1978 with a mean value of 0,24 micromoles per litre. In both the November 1981 and January 1982 surveys, nitrite levels were so low as to be undetectable, indicating that the estuary was well oxygenated at the time.

Phosphate levels were essentially consistent throughout the estuary in November 1981 with a mean value of 0,81 micromoles per litre. The values were lower than might normally be expected in an estuary (PD Bartlett, pers. comm.). In January 1982, the phosphate levels were even lower with a mean of 0,49 micromoles per litre for the estuary. Total phosphorus levels in July 1978 were considerably higher with a mean value of 2,29 micromoles per litre. The reason for this was probably that the closed mouth allowed the accummulation of algal degradation products (PD Bartlett, pers. comm.).

Silicate levels, in November 1981 were typical for a Cape estuary (mean value of 15,55 micromoles per litre). The lowest levels were in the lower reaches of the estuary and the highest levels in the upper reaches. As silicates are leached from the catchment, this can be expected when the mouth is open. With the mouth being closed in July 1978 and January 1982 silicate levels were less variable. The mean values at those times were 20,75 micromoles per litre and 27,19 micromoles per litre respectively.

In November 1981 levels of ammonia were extremely low (mean value of 1,19 micromoles per litre) indicating a healthy, well-oxygenated system (PD Bartlett, pers. comm.). By January 1981, low levels of dissolved organic *carbon* were found at sampling stations under direct marine influence. At stations further upstream, dissolved *inorganic carbon* increased due to geological carbonate being brought down in the river water. The dissolved *organic carbon* levels were extremely low (mean value of 1,6 milligrams per litre) and indicated no source of organic pollution (PD Bartlett, pers. comm.).

By January 1982 dissolved organic carbon levels had increased to a mean for the estuary of 8,9 milligrams per litre. Dissolved inorganic carbon levels, however, declined from a mean of 28,6 milligrams per litre in November 1982 to 17,5 milligrams per litre in January 1982.

3.2.6 Pollution

(This section incorporates information from an unpublished report on the chemistry of the Hartenbos Estuary by Dr PD Bartlett of the Marine Chemistry and Biology Division, NRIO.)

At present there are no direct sewage discharges into the Hartenbos Estuary. However, the town of Hartenbos relies heavily on septic tank systems. There may therefore be some ground seepage from these, especially after peak holiday periods when up to 9 000 holidaymakers converge on the area. This would lead to some bacterial and nutrient contamination of the system.

Sewage from Mossel Bay Municipality enters the sea near the harbour to the south of the Hartenbos in two ways. Firstly roughly-screened macerated waste is discharged via a steel pipe. Secondly, night soil from Coloured townships is emptied into a small rocky embayment (Fricke et al, 1981).

Industrial effluent from the Langeberg Co-op Canning Factory and the Nestlé Factory enters the sea via an open canal at Voorbaai, about 3 km to the south of the Hartenbos mouth.

The bulk of the effluent is from the Langeberg Cannery which has a peak operation season coinciding with the processing of fruit (peaches and pears) from January to mid-April. The strength of this waste during the main canning season is some 10 000 milligrams per litre COD (Chemical Oxygen Demand), while the daily load from the Nestlé Factory is 300 kilograms COD with a hydraulic flow of 150 cubic metres per day (GA Visser, pers comm).

The proposed Mossel Bay/Hartenbos sewage works site is on the northern bank of the upper reaches of the Hartenbos Estuary with the outfall point at the northern drift (Grid Ref 0707) and is scheduled to come into operation in 1986. These works will handle the industrial and domestic effluent which presently enters the sea (GA Visser, pers comm). Based on predictions for the year 1990, the daily volume of combined industrial and domestic effluent to be handled by the works, will range from an average of 5,95 megalitres out of season to an average of 7,45 megalitres in season with a maximum through-flow of 7,83 megalitres (17 845 kilograms COD) per day (GA Visser, pers comm). At the time of writing, the proposed sewage works had been designed for treatment to the general standard, as set out in the Government Gazette of 5 April 1962 (W. Malan, pers. comm.). This level of purification does not require the removal of phosphates and nitrates.

The release of sewage effluent into a normally closed estuary already affected by eutrophication is not to be recommended. However the Directorate of Water Affairs of the Department of Environment Affairs may be able to maintain the estuary in an ecologically viable condition by controlled release of water from the Hartebeeskuil Dam. With a view to this, the Sediment Dynamics Division of the NRIO is conducting an investigation of the hydrological requirements of the estuary.

In December 1977, the coastline north of Mossel Bay was subjected to *oil* pollution from the *Venpet/Venoil* tanker collision offshore. The mouth of the Hartenbos was closed at the time, so that little or no oil penetrated the estuary (GJ Lamprecht, GP Kellerman and GL de Lange, pers. comm.) but did cause beach pollution. No oil was observed anywhere within the estuarine system during the ECRU survey in November 1981.

A *metal* survey of the Hartenbos Estuary in July 1978 revealed indications of other than natural metal build-up in sediments in the upper reaches of the estuary. Copper, lead, zinc, cobalt, nickel, cadmium, chromium and mercury levels, although not high, were significantly elevated above background levels (Watling and Watling, 1980).

An analysis of metal levels in the tissue of mussels *(Perna perna)* and limpets *(Patella longicosta)* from the rocky shore and snails *(Bullia rhodostoma)* from the sandy beaches, near the mouth of the Hartenbos, revealed no significantly elevated concentrations (Watling and Watling, 1982).

Pesticide utilization in the catchment of the Hartenbos is low as bolworm is the only significant pest to the wheat farmers (J Blomerus, pers. comm.).

The only *herbicides* used in the catchment are hormonal types. These cause minimal pollution (J Blomerus, pers. comm.).

3.2.7 Public Health Aspects

Records of the *bacteriology* of the Hartenbos Estuary were obtained from Mr JA van der Walt, the Health Inspector for Mossel Bay Municipality and Mr G Streicher, the Health Inspector for the Outeniqua Divisional Council. The data can be seen in Appendix I.

The data do indicate a degree of faecal pollution, but whether this is of human or animal origin is not entirely clear. The *E. coli* and coliform counts do not constitute a serious public health hazard. However, they are based on infrequent sampling. Since the estuary is often closed for long periods and in view of its use for recreational purposes, the bacteriology should be monitored more regularly.

4. BIOTIC CHARACTERISTICS

4.1 Flora

(This section is contributed by Mr M O'Callaghan of the Botanical Research Institute.)

The general configuration of the Hartenbos estuary is shown in Figure 3. Figure 9 shows the spatial distribution of the semi-aquatic and terrestrial vegetation mapping units while Appendix II shows some of the species and physical features of each unit, as established during the ECRU survey of November 1981.

4.1.1 Phytoplankton/Diatoms

Although no specific data are available concerning this aspect of the estuarine flora, phytoplankton blooms have been reported from the estuary when water levels are low and/or the river mouth is closed. The possible reasons for this are numerous. JR Grindley (pers. comm.) reports that *Potamogeton* dies when the salinity of the water rises with the closure of the mouth. The decay of this and other plant material could enhance the nutrient levels of the estuarine waters, thus causing excessive phytoplankton growth.

Similarly, if nutrients are enhanced by artificial means, e.g. seepage from septic tanks, cattle excrement or sewage effluent (as from the proposed sewage works), excessive phytoplankton growth, eutrophication and eventually stagnation, could result. The tendency for the mouth to close has already been discussed and an increase in the river flow from the Hartebeeskuil Dam, could keep the river mouth open for longer periods and thus offset some of the problems mentioned above.

4.1.2 Algae

Nearshore: JR Grindley (pers. comm.) reports that the macrophytic algae on the rocks near the mouth of the estuary include:

Porphyra capensis
Codium duthieae
Zonaria subarticulata
Pterosiphonia cloiophylla
Corallina sp
Lithothamnium sp
Gelidium pristoides
Caulerpa filiformis
Plocamium cornatum
Ulva sp
Arthrocardia sp

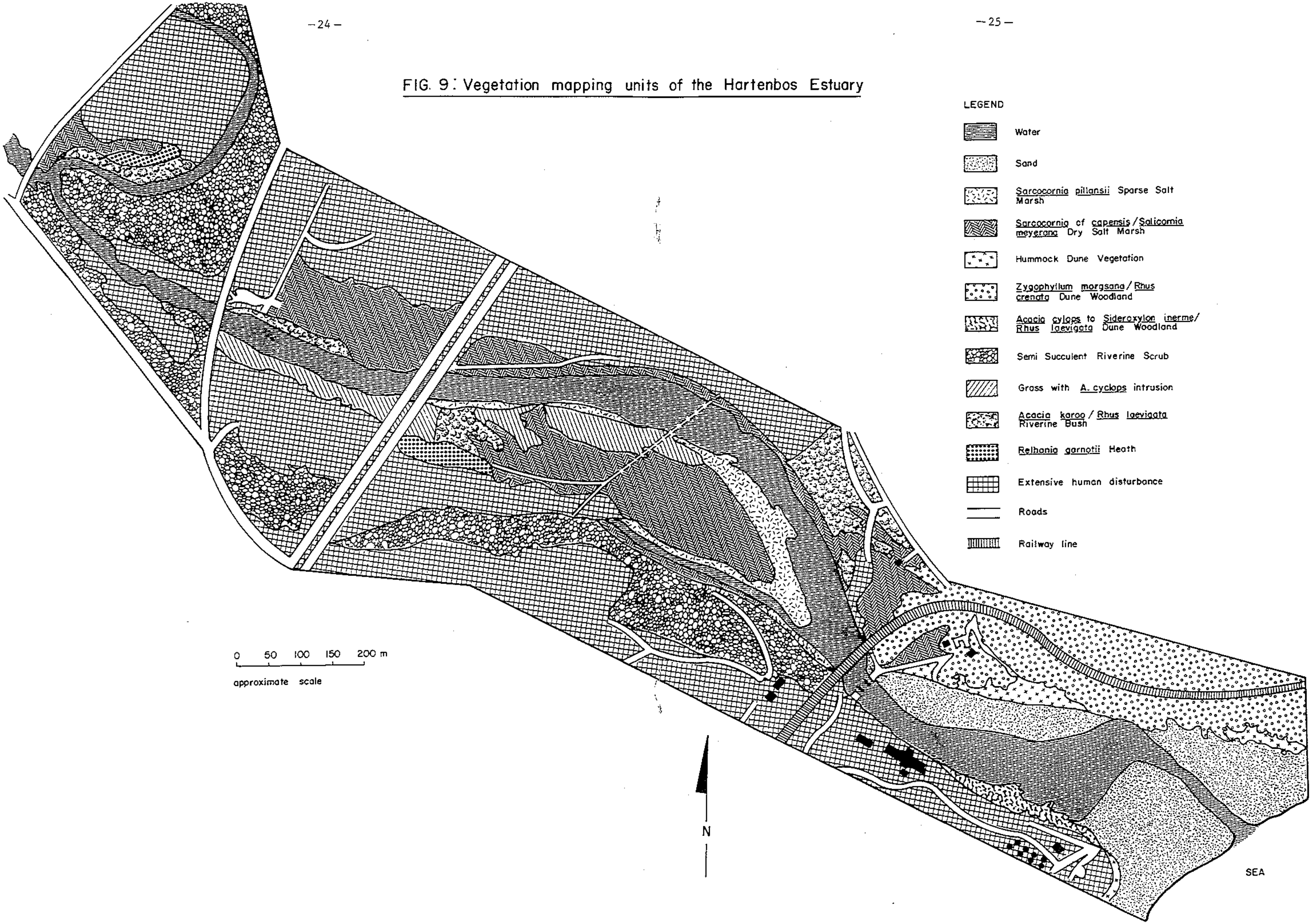
From this it would seem that the species composition of the rocky shore algae of this area has a great affinity to that of the Western Cape. However, Eastern Cape species are not uncommon e.g. *Caulerpa, Plocamium, Gelidium* (see Simons, 1976).

Few algal data are available for this estuary, although the presence of *Enteromorpha* has been reported (ECRU 80-08-01) and algal problems do occur near the mouth when water levels are low (JR Grindley, pers. comm.).

4.1.3 Aquatic Vegetation

Although Day (1981) reports that no submerged vegetation is found in the Hartenbos estuary, *Ruppia* (ECRU 80-08-01) and *Potamogeton*

FIG. 9: Vegetation mapping units of the Hartenbos Estuary



(JR Grindley, pers. comm.) have been reported from the lower and upper parts of the estuary respectively. During the ECRU survey, floating strands of *Zostera* were noted between the pipe and rail bridges, but no attached plants were seen.

4.1.4 Semi-aquatic Vegetation

The salt marshes between the rail bridge and the new freeway (see Figure 9) seem to be well developed and stratified from a sparse *Sarcocornia pillansii,* through *Sarcocornia* cf *capensis* to a dense *Salicornia meyerana* community. Here *Chenolea diffusa* (soutbossie), *Eragrostis* sp (Parsons 352)[1] and *Spergularia marginata* have become established in the drier areas.

Landward of the new freeway and seaward of the old rail bridge, similar *Sarcocornia/Chenolea* communities are found. However, these communities show signs of disturbance, possibly from grazing activities. *Ehrharta delicatula, Bromus* sp (Parsons 334) and *Plantago lanceolata* (lamb's tongue) are common.

4.1.5 Terrestrial vegetation

Seven main terrestrial vegetation mapping units were recognized, namely:

(a) Hummock Dune Vegetation;
(b) *Zygophyllum morgsana/Rhus crenata* Dune Woodland;
(c) *Acacia cyclops* to *Sideroxylon inerme/Rhus laevigata* Dune Woodland;
(d) Grass with *Acacia cyclops* intrusion;
(e) *Acacia karroo/Rhus laevigata* Riverine Bush;
(f) *Relhania garnotii/Cynodon dactylon* Heath.

(a) Hummock Dune Vegetation: The east facing dune to the south of the river is well covered with *Tetragonia decumbens* (klappiesbrak) and *Cynodon dactylon* (Bermuda quick grass) while *Galenia secunda* (vanwyksbossie) and *Chenolea diffusa* are common.

The hummock dunes to the north of the river have a sparse covering of *T. decumbens* and *Senecio elegans* (strandblommetjies). Nearer the river, cover is poor and *Acacia cyclops* (rooikrans) becomes dominant.

(b) *Zygophyllum morgsana/Rhus crenata* Dune Woodland: Although much of the dunes to the north of the river are covered with *A. cyclops,* remnants of the natural vegetation, in the form of *Rhus* spp (kliptaaibos), *Zygophyllum morgsana* (leeubos), *Ehrharta villosa* (pipe grass) and *Pelargonium peltatum* (kolsuring) are to be found.

(c) *Acacia cyclops* to *Sideroxylon inerme/Rhus laevigata* Dune Woodland: The southern banks near the mouth of the river are dominated by *A. cyclops*. However, natural trees and

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[1] *Parsons species numbers e.g. Parsons 352 refer to specimens unidentified by the Botanical Research Institute at the time of writing.*

shrubs such as *Azima tetracantha* (bee-sting bush), *Sideroxylon inerme* (milkwood) and *Rhus laevigata* are present.

Sporobolus viginicus (brakgras), *Tetragonia decumbens* and *Chenolea diffusa* are found toward the fringes with *Galenia secunda* and *Pentzia pilulifera* (beesbossie) in the more disturbed areas.

(d) Semi-succulent Riverine Scrub: The steep north-facing slope above the rail bridge is covered with a relatively diverse riverine scrub. Although true dominance is absent, common shrub species are *Rhus glauca* (blinkblaartaaibos), *Azima tetracantha, Diospiros dichrophylla* (bloubos) and *Carissa bispinosa* (lemoenbessie). Grasses such as *Eragrostis curvula* (blousoetgras), *Ehrharta villosa, Phalaris arundinacea* (reed canary grass) and succulents such as *Crassula* spp, *Aloe* spp and decumbent plants: *Blepharis capensis* (rankklits), *Senecio radicans* (bobbejaantoontjies) are also found.

Although a number of alien plants such as *A. cyclops, Opuntia ficus-indica* (prickly pear), *Nerium oleander, Lantana camara* and *Adromischus* sp are present in this area, their cover has not yet reached epidemic proportions.

(e) Grass with *A. cyclops* intrusion: At the north-east, the dense *Salicornia meyerana* salt marsh has become dominated by *Ehrharta erecta* and *Bromus* sp (Parsons 334), although salt marsh plants are still present. A number of shrubs, *Heteroptilis suffructicosum, Limonium scabrum* (sea lavender) and *Drosanthemum* sp (Parsons 332) are also to be found.

Where *A. cyclops* dominates, *Chironia baccifera* (aambeibossie), *Solanum rigescens* (wildelemoentjie) and *Gnidia squarosa* are also present.

(f) *Acacia karroo/Rhus laevigata* Riverine Bush: This vegetation unit is dominated by *A. karroo* and *R. laevegata* with *Carissa bispinosa, Aloe ferox, Bromus* sp (Parsons 332), *Carpobrotus edulis* (Hottentots fig) and *Maytenus heterophylla* (common spike thorn). This bush-type community is, however, endangered by the enroachment of adjacent *A. cyclops*.

(g) *Relhania garnotii/Cynodon dactylon* Heath: This community has a number of elements similar to coastal renosterveld. It has, however, been extensively disturbed in areas and is endangered by encroaching *A. cyclops*.

Although the vegetation around this river is described as 'Valley Bushveld' by Acocks (1975), this veld type, in a relatively undisturbed state, occurs only in the upper reaches of the river while renosterveld and fynbos are also found in some areas in the catchment.

4.2 Fauna

4.2.1 Zooplankton

No available information.

4.2.2 Aquatic invertebrates

During the ECRU survey 20 intertidal invertebrate species were recorded as living on the rocks of the shoreline adjacent to the mouth of the Hartenbos. Two species of mussel and a snail were found to be living on the adjacent sandy beach. A species list of the above-mentioned invertebrates can be seen in Appendix III.

As part of a pollution survey in July 1978, the meiofauna of the beach at Voorbaai, 3 km to the south of the mouth of the Hartenbos, was sampled. The populations were made up chiefly of nematodes and harpacticoid copepods, with smaller numbers of flatworms, polychaetes, oligochaetes, archiannelids, mystacocarids and others (Eagle et al, 1979). After a follow-up survey in November 1979, the numbers of the three dominant groups, nematodes, harpacticoid copepods and flatworms, were found to be significantly lower (Fricke et al, 1981). However this was attributed by Fricke et al (1981) to be the result of seasonal differences in the activity of the canning factory at Voorbaai (see Section 3.2 Pollution).

In the estuary itself, colonies of tube worms *Ficopomatus enigmatica* were found on the supports of the pipe causeway (Grid Ref 1610) during the ECRU survey. The amphipod *Grandidierella* sp was found in association with these colonies.

A survey of bait organisms in the Hartenbos was carried out in November 1981 (when the mouth was still open) by CM Gaigher of the CPA Department of Nature and Environmental Conservation. The recorded densities of the burrowing sand prawn *Callianassa kraussi,* the dominant benthic bait organism in South African estuaries, are shown in Appendix IV.

Adult prawns appeared to be most concentrated on the sand banks on the northern side of the estuary a few hundred metres upstream of the mouth. They occurred on both banks up to the pipe causeway (Grid Ref 1610).

C. kraussi became sparse upstream of the pipe causeway on the northern bank, but continued up to the eroded northern drift (Grid Ref 0707) on the northern tributary. On the southern bank, *C. kraussi* concentrations were dense up to the new national road bridge (Grid Ref 1407) but sparse above that. The data indicate extensive distribution of *C. kraussi* throughout the estuary, particularly where suitable substrates occurred. The distribution of juvenile burrows suggested that there was a breeding population at the mouth (CM Gaigher, pers. comm.).

The observation of a fresh moult of the mud prawn *Upogebia africana* and shells of pencil bait *Solen capensis,* suggested the occurrence of these bait organisms in the estuary although no holes of the former were seen (CM Gaigher, pers. comm. and ECRU survey). Sandprawns are collected for bait on the northern bank near the mouth, at times (GJ Lamprecht, GP Kellerman and GL de Lange, pers. comm.).

An eight-minute "D" net haul in the middle reaches of the estuary (Grid Ref 1810) yielded 7 crown crabs, *Hymenosoma orbiculare* and more than 100 sandshrimps *Palaemon pacificus*, during the ECRU survey.

4.2.3 Insects

Day (1981) reports that a species of water beetle was collected at the Hartenbos in May 1950.

4.2.4 Fish

(Common names of fishes are according to Smith, 1975).

According to Messrs Lamprecht, Kellerman and De Lange, a 16 kg kob *Argyrosomus hololepidotus* was caught in front of the Riviera hotel in earlier days. They also mentioned that in the past, mullet mortalities have occurred when the mouth has been closed and that *Tilapia* have occurred in the lower estuary with freshwater conditions. Day (1981) records the collection of the flathead mullet *Mugil cephalus* from the Hartenbos in May 1950.

During the ECRU survey, fish were sampled using a "D" net and gill net in the middle reaches of the estuary and a scoop net in the shallower upper reaches. A checklist of the fish species recorded during the ECRU survey is given in Appendix V and the quantitative gill net catch data in Appendix VI.

All twelve fish species recorded during the ECRU survey are considered by Day (1981) as being common in estuaries. Of the twelve species, two breed only in estuaries, two breed in both estuaries and the sea, and seven are marine migrants using estuaries as nursery areas only. The breeding biology of the outstanding species is unknown (Day, 1981).

Fish were generally abundant in the estuary during the ECRU survey. This may be attributed to the fact that there was good tidal exchange at the time and that the mouth had been open for most of 1981. It is notable that specimens of virtually all the species collected were juvenile or immature, indicating recent recruitment to the estuary. With closure of the mouth and the onset of salinities of the order of 50 parts per thousand (as recorded in August 1980) few of the recorded fish species would be able to survive. According to the salinity ranges given by Whitfield, et al (1981), of the fish species recorded in the Hartenbos, only *R. holubi, A. hololepidotus, M. cephalus and L. dumerili* would be able to survive salinities of 50 parts per thousand. This further emphasizes the serious ecological consequences of reduced run-off due to the Hartebeeskuil Dam.

4.2.5 Reptiles and Amphibians

According to Messrs Lamprecht, Kellerman and De Lange, puff-adders *Bitis arietans* have been seen on the banks of the estuary.

No specimens of reptiles or amphibians were collected during the ECRU survey. However, a checklist (excluding lizards) of species recorded from the area covered by the 1:50 000 Sheet 3422 AA Mosselbaai, in which the Hartenbos is centrally situated, was obtained from AL de Villiers (pers. comm.) of the CPA Department of Nature and Environmental Conservation. The species list can be seen in Appendix VII.

Two species of tortoise, eight snake species and eight frog species have been recorded in the area. Lizards have been excluded in these records as lizard taxonomy is presently under review (AL de Villiers, pers. comm.).

4.2.6 Birds

Bird counts for the Hartenbos amount to those in Underhill and Cooper (1982, unpublished) done on 16 January 1981 and casual observations made during the ECRU survey. As such, the latter was not a fully representative bird count. The species recorded and numbers thereof are given in Appendix VIII.

In January 1981 a total of 91 water-associated birds consisting of 16 species was counted. Of these, 11 species were recognized waders making up a total of 73 birds. The waders consisted of 4 resident species (25 birds) and 7 migrant species (48 birds).

At the time of the ECRU survey a total of 31 water-associated birds consisting of 12 species was counted. Of these, 5 species were recognized waders making up a total of 14 birds. There were 4 resident species (10 birds) and 1 migrant species (4 birds).

The Hartenbos does not seem to be a particularly important estuary for waders. This is borne out by the relatively low counts mentioned above.

4.2.7 Mammals

According to Messrs Lamprecht, Kellerman and De Lange, Grysbok *Raphicerus melanotis* and Bushbuck *Tragelaphis scriptus* are found in the area. During the ECRU survey, water mongoose *Atilax paludinosus* tracks were seen on the banks of the estuary.

Mammal records for the area covered by the 1:50 000 Sheet 3422 AA Mosselbaai were obtained from Stuart et al (1980) and Stuart (1981). The checklist is given in Appendix IX.

Of the total of 14 mammal species recorded, 3 have been listed in South African Red Data Books as being rare or threatened. These are the Honey badger and Cape greater gerbil (Meester, 1976) and Leopard (Skinner et al, 1977).

5. SYNTHESIS

The state of knowledge of the Hartenbos is fair. However, the bulk of the information originates from the ECRU survey and surveys carried out as part of the National Programme for Marine Pollution.

The Hartenbos has a relatively small catchment (207 km^2) which receives most of its annual rainfall (400 - 500 mm) in the spring and autumn months. Peak flows therefore occurred from August to

November and April to June, before construction of the Hartebeeskuil Dam in 1970 (see Figure 1). The mouth used to close during dry periods (particularly in the summer months) even before the main impoundment was constructed on the river. This is evidenced by aerial photographs of the estuary taken before 1970. As indicated by the salinity records in Day (1981), stagnant hypersaline conditions did develop from time to time, with evaporative water loss from the closed estuary. The brackishness of the river water probably also contributes to the salinity in the estuary when it is closed. With the mouth fully open, the whole estuary becomes tidal, water circulation is good and recruitment of marine organisms occurs (as seen during the ECRU survey). When the estuary is tidal, it is aesthetically pleasing and attractive to holiday makers, thereby becoming an asset to the holiday resort.

The primary effect of the Hartebeeskuil Dam on the estuary has been the closure of the mouth for extended periods. This has been due to reduction of the hydraulic force which used to open the mouth and maintain it that way during spring and autumn. In essence, the dynamic balance between flow tending to open the mouth and the build-up of marine sediment tending to close it, has been tipped towards the latter, resulting in consolidation of the sandbar. Further, the natural scouring force necessary to keep the river channel and estuary free of silt, has been reduced except during times of heavy floods.

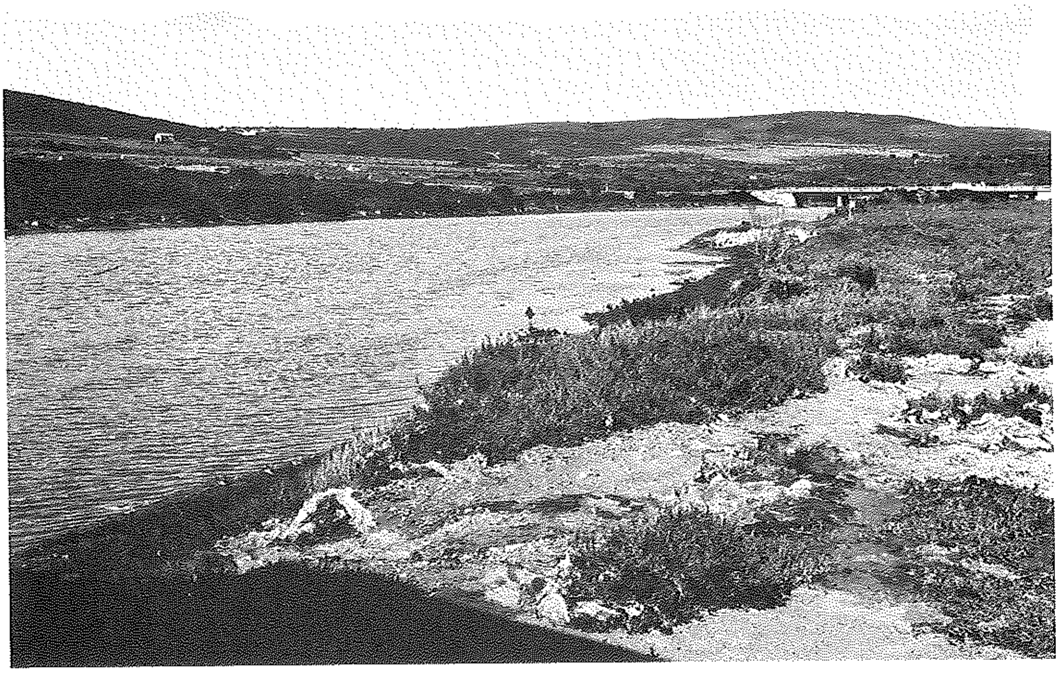

FIG. 10: Middle reaches of the Hartenbos Estuary after floods in January 1981. The photograph was taken from the new national roadbridge looking upstream towards the old national roadbridge. The improvement in the state of the estuary can be seen on comparison of Figure 8 with Figure 10 (ECRU 81-01-27).

A secondary effect of the Hartebeeskuil Dam has been the establishment of hypersaline and eutrophic conditions in the estuary (see Figure 8). This has been due to evaporative water loss exceeding riverine replenishment when the estuary has been closed, particularly in the summer months. It must therefore be accepted that the Hartenbos has changed from being an estuary which opened to the sea during peak flow periods, to a closed lagoon, primarily as a result of the Hartebeeskuil Dam. Although the hypersaline lagoon condition did occur in the summer months before impoundment, it has been the predominant state since 1970. As most estuarine organisms are unable to tolerate excessive salinities for extended periods, such conditions place a severe environmental constraint on the biological and recreational viability of the Hartenbos.

The Hartenbos was rejuvenated by the floods in 1981 (*cf* Figures 8 and 10). Evidence for this can be seen from the sizes of the marine migratory fish species collected during the ECRU survey. Virtually all the specimens collected were either juvenile or immature, indicating recruitment into the system during 1981. Marine migratory species spend up to three years in estuaries before returning to sea to spawn as adults. Hence a total lack of adult marine fish suggests that there had been no recruitment for several years before 1981.

Floodplain developments around the Hartenbos Estuary have degraded the estuarine environment. The extensive road and rail bridge embankments have given rise to several obstructions to the passage of floodwaters. Of particular note in this respect are the old and new railway bridge embankments. These obstructions channel floodwaters directly towards the Riviera Hotel just downstream on the southern bank (see Figure 3 and Plate II). With the hotel being situated at a low level on the floodplain, floodwaters tend to overtop the sea wall in front of it and flood the buildings behind it, as occurred in August 1962. Low-lying developments on the northern bank on the outer bend near the pipe causeway are also prone to flooding, although in the case of the Hartenbos Drive-In Cinema, this does not cause serious damage. The holiday cottages on either side of the northern railway bridge embankment are both situated on the floodplain and are also prone to flooding. In particular "Die Bult" holiday cottage (Grid Ref 2112), is situated below the 25-year floodline as shown on a map obtained from Geustyn, Forsyth and Joubert Inc. (Consulting Civil and Structural Engineers). Motivation for the artificial breaching of the mouth usually emanates from people wishing to gain access to this cottage. Such action is ecologically deleterious as it not only prevents the water from spreading naturally amongst the wetland fringe areas, but also from building up to a level which would enable scouring to take place (Heydorn and Tinley, 1980). A solution would be to build a subway through the embankment behind the cottage, for access by vehicles.

It is ironical that the motivation for the construction of the Hartebeeskuil Dam was to supply water to the Hartenbos Holiday Resort, situated alongside the estuary and that a part of the aesthetic appeal which initially attracted development should have been destroyed by it. The Hartenbos used to be used for recreational purposes (e.g. water skiing) but since the advent of the dam has become unattractive to holidaymakers because it is frequently in a stagnant condition. As the dam water is not used for any other purposes due to its brackishness, it would seem appropriate that it should be used to maintain the estuary in a viable condition. This could be done by either simulating the natural flow regime of the river before dam construction or by release of water on an *ad hoc* basis to cater for the needs of the estuary at the time. It should be borne in mind that the economic value of properties adjacent to the Hartenbos will increase if the estuary is maintained in a good condition with greater aesthetic appeal.

The old railway bridge pylons and their concrete cappings, should be removed as soon as possible. Besides being an obstruction to the flow of water, they are a hazard to boating and are aesthetically displeasing. If the estuary is to be rehabilitated to improve its recreational value this will be even more important.

During the ECRU survey, erosion of the fore-dune region of the shoreline to the south of the mouth of the Hartenbos during high spring tides was noted. This was causing damage to beach access walkways and efforts had been made to protect the fore-dunes from erosion using wooden sleepers. In the light of this and also because of the sensitivity of fore-dune areas to human disturbance, the proposed ATKV development between the railway line and the beach to the north of the mouth of the Hartenbos is not advisable. As can be seen in Figures 3 and 5 and Plate I, this is the sensitive barrier dune zone and development of it is directly contrary to the land use recommendations stated on pages 54 and 55 of Heydorn and Tinley (1980); (Refer to Figure 21; Diagram IV of the report for the recommended land use of this type of dune environment.) Accordingly, any development of this dune area should take place well above the railway line, leaving the intrinsically unstable area free of human disturbance. This would ensure the stability of the area and protection of the railway line from erosion and wind-blown sand. Even at present the area just to the north of the mouth is very prone to erosion (see Plate I and Figure 7) when the mouth of the Hartenbos meanders northwards. Construction of an access road to the proposed development further north must therefore be strongly discouraged.

As the low-lying floodplain area on the southern bank, between the new national road bridges and the railway bridge, is the only remaining undisturbed saltmarsh area, no development should be allowed to take place there. Besides being vulnerable to flooding, it is an important biologically productive wetland fringe area.

The proposed sewage works effluent outfall is to be situated at the northern drift (Grid Ref 0707) in the upper reaches of the estuary. Provided that the level of treatment will be of the highest possible standard, the expected hydraulic input of about 6 to 8 megalitres per day could benefit the estuary. However, this would require that nutrient levels, particularly of phosphates and nitrates in the effluent be kept to an absolute minimum, so as to prevent eutrophication. This is particularly important when considering that the peak outfall rate of 7,83 megalitres per day will occur during the December/January holiday period. With the Hartenbos being situated in a region of bimodal rainfall (peaks in spring and autumn), the months of December and January fall into the middle of the dry period when run-off is minimal. Hence the estuary is likely to be closed during this period and the dilution of sewage effluent by river water will be minimal.

The Sediment Dynamics Division (SDD) of the NRIO is at present investigating the hydrology of the Hartenbos Estuary. It is hoped that the recommendations of the SDD and the information contained in this report will form a basis for the future management of the Hartenbos. With a view to this, the Scientific Services Division of the Directorate of Water Affairs has been engaged to formulate a management plan for the Hartebeeskuil Dam in an effort to rehabilitate the estuary.

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As the collection of data for this report was essentially a team effort, the assistance of all members of the ECRU is acknowledged.

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GLOSSARY OF TERMS USED IN PART II REPORTS

abiotic: non-living (characteristics).
aeolian (deposits): materials transported and laid down on the earth's surface by wind.
alien: plants or animals introduced from one environment to another, where they had not occurred previously.
alluvium: unconsolidated fragmental material laid down by a river or stream as a cone or fan, in its bed, on its floodplain and in lakes or estuaries, usually comprised of silt, sand or gravel.
anaerobic: lacking or devoid of oxygen.
anoxic: the condition of not having enough oxygen.
aquatic: growing or living in or upon water.
arcuate: curved symmetrically like a bow.
barchanoid (dune): crescent-shaped and moving forward continually, the horns of the crescent pointing downwind.
bathymetry: measurement of depth of a water body.
benthic: bottom-living.
berm: a natural or artificially constructed narrow terrace, shelf or ledge of sediment.
bimodal: having two peaks.
biogenic: originating from living organisms.
biomass: a quantitative estimation of the total weight of living material found in a particular area or volume.
biome: major ecological regions (life zones) identified by the type of vegetation in a landscape.
biotic: living (characteristics).
breaching: making a gap or breaking through (a sandbar).
calcareous: containing an appreciable proportion of calcium carbonate.
calcrete: a sedimentary deposit derived from coarse fragments of other rocks cemented by calcium carbonate.
Chart Datum: This is the datum of soundings on the latest edition of the largest scale navigational chart of the area. It is -0,900 m relative to land levelling datum which is commonly called Mean Sea Level by most land surveyors.
coliforms: members of a particularly large, widespread group of bacteria normally present in the gastro-intestinal tract.
community: a well defined assemblage of plants and/or animals clearly distinguishable from other such assemblages.
conglomerate: a rock composed of rounded, waterworn pebbles 'cemented' in a matrix of calcium carbonate, silica or iron oxide.
cusp: a sand spit or beach ridge usually at right angles to the beach formed by sets of constructive waves.
"D" net: a small net attached to a "D" shaped frame riding on skids and pulled along the bottom of the estuary, used for sampling animals on or near the bottom.
detritus: organic debris from decomposing plants and animals.
diatoms: a class of algae with distinct pigments and siliceous cell walls. They are important components of phytoplankton.
dynamic: relating to ongoing and natural change.
ecology: the study of the structure and functions of ecosystems, particularly the dynamic co-evolutionary relationships of organisms, communities and habitats.
ecosystem: an interacting and interdependent natural system of organisms, biotic communities and their habitats.
eddies: a movement of a fluid substance, particularly air or water, within a larger body of that substance.
endemic: confined to and evolved under the unique conditions of a particular region or site and found nowhere else in the world.
enon: most striking formation in the Cape. Crammed with pebbles and boulders, phenomenally embedded and massive, yellow or brilliantly red in colour, producing remarkable hills. Curiously carved into crags and hollows.

epifauna: animal life found on the surface of any substrate such as plants, rocks or even other animals.

epiphyte: a plant living on the surface of another plant without deriving water or nourishment from it.

episodic: sporadic and tending to be extreme.

estuary: a partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with fresh water derived from land drainage (Day 1981).

eutrophication: the process by which a body of water is greatly enriched by the natural or artificial addition of nutrients. This may result in both beneficial (increased productivity) and adverse effects (smothering by dominant plant types).

flocculation (as used in these reports): the settlement or coagulation of river borne silt particles when they come in contact with sea water.

fluvial (deposits): originating from rivers.

food web: a chain of organisms through which energy is transferred. Each "link" in a chain feeds on and obtains energy from the preceding one.

fynbos: literally fine-leaved heath-shrub. Heathlands of the south and south-western Cape of Africa.

geomorphology: the study of land form or topography.

gill net: a vertically placed net left in the water into which fish swim and become enmeshed, usually behind the gills.

habitat: area or natural environment in which the requirements of a specific animal or plant are met.

halophytes: plants which can tolerate salty conditions.

HAT (Highest Astronomical Tide) and LAT (Lowest Astronomical Tide): HAT and LAT are the highest and lowest levels respectively, which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; these levels will not be reached every year. HAT and LAT are not the extreme levels which can be reached, as storm surges may cause considerably higher and lower levels to occur (South African Tide Tables 1980).

hummock (dune): a low rounded hillock or mound of sand.

hydrography: the description, surveying and charting of oceans, seas and coastlines together with the study of water masses (flow, floods, tides etc.).

hydrology: the study of water, including its physical characteristics, distribution and movement.

indigenous: belonging to the locality; not imported.

intertidal: generally the area which is inundated during high tides and exposed during low tides.

isohyets: lines on maps connecting points having equal amounts of rainfall.

isotherms: lines on maps joining places having the same temperature at a particular instant, or having the same average, extremes or ranges of temperature over a certain period.

lagoon: an expanse of sheltered, tranquil water. (Thus Langebaan lagoon is a sheltered arm of the sea with a normal marine salinity; Knysna lagoon is an expanded part of a normal estuary and Hermanus lagoon is a temporarily closed estuary (Day 1981)).

limpid: clear or transparent.

littoral: applied generally to the seashore. Used more specifically it is the zone between high- and low-water marks.

longshore drift: a drift of material along a beach as a result of waves breaking at an angle.

macrophyte: any large plant as opposed to small ones. Aquatic macrophytes may float at the surface or be submerged and/or rooted on the bottom.

marls: crumbly mixture of clay, sand and limestone, usually with shell fragments.

matrix: medium in which a structure is embedded.

meiofauna: microscopic or semi-microscopic animals that inhabit sediments but live quite independently of the macrofauna, or benthos.

metamorphic: changes brought about in rocks within the earth's crust by the agencies of heat, pressure and chemically active substances.

MHWS (Mean High Water Springs) and MLWS (Mean Low Water Springs): the height of MHWS is the average, throughout a year when the average maximum declination of the moon is 23°, of the height of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is greatest. The height of MLWS is the average height obtained by the two successive low waters during the same periods (South African Tide Tables 1980).

morphometry: physical dimensions such as shape, depth, width, length etc.

osmoregulation: the regulation in animals of the osmotic pressure in the body by controlling the amount of water and/or salts in the body.

pathogenic: disease producing.

photosynthesis: the synthesis of carbohydrates in green plants from carbon dioxide and water, using sunlight energy.

phytoplankton: plant components of plankton.

piscivorous: fish eating.

plankton: microscopic animals and plants which float or drift passively in the water.

quartzite: rock composed almost entirely of quartz recemented by silicon. Quartzite is hard, resistant and impermeable.

riparian: adjacent to or living on the banks of rivers, streams or lakes.

rip current: the return flow of water which has been piled up on the shore by waves, especially when they break obliquely across a longshore current.

salinity: the proportion of salts in pure water, in parts per thousand by mass. The mean figure for the sea is 34,5 parts per thousand, written 34,5°/oo.

secchi disc: a simple instrument used to measure the transparency of water.

sheet flow: water flowing in thin continuous sheets rather than concentrated into individual channels.

slipface: the sheltered leeward side of a sand-dune, steeper than the windward side.

teleost: modern day bony fishes (as distinct from cartilaginous fishes).

trophic level: a division of a food chain defined by the method of obtaining food either as primary producers, or as primary, secondary or tertiary consumers.

trough: a crescent shaped section of beach between two cusps.

wetlands: areas that are inundated or saturated by surface or ground water frequently enough to support vegetation adapted to life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

zooplankton: animal components of plankton.

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APPENDIX I: Bacteriological records for the Hartenbos Estuary. See Figure 3 for grid references

Date	State of month	Sampling Site Grid Ref and locality	*E. coli* per 100 ml	Total coliforms per 100 ml
78-01-04	Closed	2210 In front of hotel	0	0
78-01-04	Closed	2210 In front of house near hotel	900	1 800
79-11-13	Closed	2210 In front of hotel	0	0
79-11-13	Closed	2210 In front of hotel	0	8
81-04-07	Open	1105 Old national roadbridge	140	140
81-06-02	Open	1105 Old national roadbridge	1 600	16 000
81-07-28	Open	1105 Old national roadbridge	40	45
81-08-30	Open	1105 Old national roadbridge	250	250

APPENDIX II: Species composition and physical features of the vegetation mapping units of the area studied at the Hartenbos Estuary

Mapping Unit	*Area	% of area studied	Cover (%)	Average Height (m)
Sarcocornia pillansii Sparse Salt Marsh	2,04	1,66	20	0,10
Sarcocornia cf *capensis/ Salicornia meyerana* Dry Salt Marsh	13,62	11,08	85	0,15
Hummock Dune Vegetation	0,94	0,76	70	0,30
Zygophyllum morgsana/Rhus laevigata Dune Woodland	7,36	5,99	65	3,00
Acacia cyclops to *Sideroxylon inerme/Rhus laevigata* Dune Woodland	1,06	0,86	90	1,50
Semi-Succulent Riverine Scrub	16,61	13,51	60	1,40
Grass with *Acacia cyclops* intrusion	3,66	2,98	90	0,30
Acacia karroo/Rhus laevigata Riverine Bush	2,78	2,26	90	1,50
Relhania garnotii Heath	0,94	0,76	70	0,70
Water	15,72	12,79		
Sand	9,21	7,49		
Extensive Human Disturbance	49,01	39,86		
Total	122,95			

(*estimated areas)

APPENDIX II: (Cont.)

Sarcocornia pillansii Sparse Salt Marsh

Cotula coronopifolia (1); *Eragostia* sp (Parsons 352)(+); *Sarcocornia pillansii* (3); *Spergularia marginata* (1).

Sarcocornia cf *capensis*/*Salicornia meyerana* Dry Salt Marsh

Chenolea diffusa (2); *Crassula expansa* (+); *Cynanchum* cf *obtusifolium* (r); *Disphyma crassifolia* (+); *Eragrostis* sp (Parsons 352)(1); *Mesembryanthemum* sp (Parsons 349)(r); *Phragmites australis* (+); *Salicornia meyerana* (5); *Sarcocornia* cf *capensis* (5); *S. pillansii* (5); *Sporobolus virginicus* (1); *Triglochin bulbosa* (r).

Also found in disturbed areas:

Bromus sp (Parsons 334)(1); *Ehrharta delicatula* (2); *Plantago lanceolat* (+); *Solanum rigescens* (+); *Sutera campanulata* (r).

Also found landwards of the freeway bridge:

Disphyma crassifolia (2); *Chenolea diffusa* (1); *Eragrostis* sp (Parsons 352) (+); *Ficinia lateralis* (2); *Limonium scabrum* (+); *Lolium* cf *perenne* (+); *Oxalis pes-caprae* (r); *Pentzia pilulifera* (r); *Phalaris arundinacea* (+); *Pseudoschoenus inanis* (2); *Relhania garnotii* (2); *Scirpus costatus* (+); *Senecio burchellii* (1); *Spergularia marginata* (+); *Sphalmanthus* cf *calycinus* (r).

Hummock Dune Vegetation

Agropyron distichum (+); *Arctotheca populifolia* (r); *Chenolea diffusa* (+); *Cynodon dactylon* (1); *Disphyma crassifolia* (r); *Galenia secunda* (+); *Limeum africanum* (r); *Tetragonia decumbens* (5).

Also found to north of river:

Ammophila arenaria (1); *Heteroptilis suffruticosa* (r); *Passerina paludosa* (r); *Senecio elegans* (1).

Zygophyllum morgsana/*Rhus crenata* Dune Woodland

Acacia cyclops (3); *Asparagus* sp (1); *Azima tetracantha* (+); *Carpobrotus edulis* (+); *Cissampelos capensis* (r); *Cynanchum* cf *obtusifolium* (+); *Ehrharta villosa* (1); *Lycium afrum* (r); *Maytenus heterophylla* (r); *Pelargonium peltatum* (r); *Pollichia campestris* (r); *Rhus crenata* (2); *R. longispina* (+); *R. undulata* (+); *Sideroxylon inerme* (r); *Solanum rigescens* (+); *Tetragonia decumbens* (+).

Acacia cyclops to *Sideroxylon inerme*/*Rhus laevigata* Dune Woodland

Acacia cyclops (5); *Aloe ferox* (r); *Anagillis arvensis* (1); *Asparagus* sp (2); *Azima tetracantha* (2); *Chrysanthemoides monolifera* (r); *Cotyledon orbiculata* (r); *Eragrostis* sp (Parsons 354)(r); *Euphorbia* sp (Parsons 513) (3); *Galenia secunda* (r); *Malephora luteola* (r); *Oxalis pes-caprae* (r); *Pelargonium odoratissimum* (1); *Pentzia pilulifera* (+); *Rhus laevigata* (2); *Senecio* sp (Parsons 354)(+); *Sideroxylon inerme* (2); *Stenotaphrum secundatum* (+); *Tetragonia decumbens* (r); *T. fruticosa* (1); *Zygophyllum morgsana* (2).

APPENDIX II: (Cont.)

Grass with *A. cyclops* intrusion

Anagillis arvensis (+); *Bromus* sp (Parsons 334)(3); *Carpobrotus edulis* (+); *Chenolea diffusa* (1); *Crassula expansa* (+); *Disphyma crassifolia* (+); *Drosanthemum* sp (Parsons 332)(r); *Ehrharta delicatula* (3); *Eragrostis curvula* (+); *Euphorbia burmannii* (1); *Galenia secunda* (+); *Limonium scabrum* (1); *Oxalis pes-caprae* (r); *Pentzia pilulifera* (+); *Salicornia meyerana* (+).

Also found with *A. cyclops* canopy:

Acacia cyclops (3); *Aloe ferox* (2); *Bonatea fruticosa* (r); *Carpobrotus edulis* (2); *Chironia baccifera* (+); *Cynodon dactylon* (1); *Felicia fascicularis* (r); *Galenia secunda* (1); *Gnidia squarosa* (1); *Heteroptilis suffruticosa* (1); *Maytenus heterophylla* (+); *Opuntia ficus-indica* (r); *Pteronia* sp (Parsons 336)(r); *Rhus crenata* (1); *R. laevigata* (1); *Senecio radicans* (1); *Solanum rigescens* (r); *Stenotaphrum secundatum* (3); *Tetragonia fruticosa* (+).

Acacia karroo/Rhus laevigata Riverine Bush

Acacia cyclops (+); *A. karroo* (3); *Aloe ferox* (2); *Bromus* sp (Parsons 334)(2); *Carissa bispinosa* (1); *Carpobrotus edulis* (2); *Chironia baccifera* (r); *Cynanchum obtusifolium* (1); *Disphyma crassifolia* (1); *Euphorbia burmannii* (+); *Galenia secunda* (1); *Limonium scabrum* (+); *Maytenus heterophylla* (+); *Pelargonium alchemilloides* (r); *Rhus laevigata* (3); *Stenotaphrum secundatum* (1); *Tetragonia fruticosa* (+).

Relhania garnotii Heath

Acacia cyclops (2); *Aloe ferox* (1); *Carpobrotus edulis* (+); *Chironia baccifera* (1); *Cynodon dactylon* (3); *Disphyma crassifolia* (+); *Elytropappus rhinoceratus* (r); *Eragrostis curvula* (+); *Ficinia lateralis* (r); *Limosella aquatica* (3); *Lycium afrum* (3); *Mariscus grantii* (+); *Oxalis pes-caprae* (1); *Pelargonium peltatum* (r); *Phalaris arundinacea* (+); *Phylica purpurea* (3); *Relhania garnotii* (4); *Rhus laevigata* (+); *R. longispina* (+); *Solanum rigescens* (r); *Sutera companulata* (r).

Note: The symbols in brackets following each species name represent adapted Braun-Blanquet Cover-Abundanc Classes as follows:

r - 1/few individuals, cover less than 0,1% of area
+ - occasional plants, cover less than 1% of area
1 - abundant, cover 1 - 5% of area
2 - any number, cover 6 - 25% of area
3 - any number, cover 26 - 50% of area
4 - any number, cover 51 - 75% of area
5 - any number, cover 76 - 100% of area.

APPENDIX III: Invertebrate species list for the shoreline adjacent to the mouth of the Hartenbos as recorded during the ECRU survey on 81-11-11.

Substrate	Common name		Scientific name
Rocky shore	Crumb-of-bread sponge	-	*Hymeniacedon perlavis*
	Sea anemones	-	*Pseudactinia flagellifera*
			Actinia equina
	Tube worm	-	*Pomatoleios kraussii*
	Common scale-worm	-	*Lepidonotus semitectus*
	Barnacles	-	*Balanus algicola*
			Tetraclita serrata
			Chthalamus dentatus
			Octomeris angulosa
	Gammarid amphipod	-	*Ceradocus rubromaculatus*
	Shore spider	-	*Amaurobioides africanus*
	Cape oyster	-	*Crassostrea margaritacea*
	Brown mussel	-	*Perna perna*
	Limpets	-	*Patella cochlear*
			P. granularis
			P. barbara
			Siphonaria capensis
			S. oculus
	Whelk	-	*Mayena gemmifera*
	Redbait	-	*Pyura stolonifera*
Sandy beach	Cape sand mussel	-	*Donax serra*
	Mussel	-	*Tellina trilatera*
	Plough shell	-	*Bullia rhodostoma*

APPENDIX IV: Densities of *Callianassa kraussi* in the Hartenbos Estuary on 27 November 1981 (Mr C Gaigher, pers. comm.). See Figure 3 for Grid References.

Position of Sampling Site	ECRU Grid Ref.	No. of Burrow Openings		No. of Prawns Per 10 Cores with a Prawn pump
		Adults	Juveniles	
On southern bank at mouth	2251	16	28	2
On northern bank 200 m upstream of mouth	2512	120	0	15
On northern bank 200 m downstream of railway bridge	2211	56	0	12
On northern bank 100 m upstream of railway bridge	2010	56	0	6
On southern bank 250 m upstream of railway bridge (Approx. 250 m downstream of pipe causeway)	1810	72	0	8

APPENDIX V: Fish species recorded for the Hartenbos Estuary during the ECRU survey.

Common name	Scientific name	State of maturity and where recorded
Blacktail	*Diplodus sargus*	Juveniles at mouth
Estuarine round-herring	*Gilchristella aestuarius*	Many juveniles in shallow upper reaches
Leervis	*Lichia amia*	Juveniles in middle reaches
White steenbras	*Lithognathus lithognathus*	Juveniles in middle reaches
Groovy mullet	*Liza dumerili*	Immature specimens in middle reaches
Southern mullet	*Liza richardsoni*	Immature specimens in middle reaches
		Juveniles in upper reaches
Cape moony	*Monodactylus falciformis*	Immature specimens in middle reaches
		Juveniles in upper reaches
Flathead mullet	*Mugil cephalus*	Juveniles in upper reaches
Knysna sandgoby	*Psammogobius knysnaensis*	Small specimens in middle reaches
Cape stumpnose	*Rhabdosargus holubi*	Juveniles in middle reaches
Blackhard sole	*Solea bleekeri*	Immature specimens in middle reaches
Sea-catfish	*Tachysurus feliceps*	Immature specimens in middle reaches

APPENDIX VI: Gill net catch data collected during the ECRU survey. The variable-mesh gill net was set at the pipe causeway (Grid Ref 1610) for the 12 hour period from 19h00, 81-11-10 to 07h00, 81-11-11.

Common name	Scientific name	No. caught	Fork length (cm) Min.	Mean	Max.
Southern mullet	*Liza richardsoni*	11	14,3	20,9	25,5
Groovy mullet	*Liza dumerili*	8	13.2	16,7	21,0
Cape moony	*Monodactylus falciformis*	8	7,0	10,5	11,6
Leervis	*Lichia amia*	5	26,5	27,7	29,0
Sea-catfish	*Tachysurus feliceps*	4	11,7	12,3	13,5
White steenbras	*Lithognathus lithognathus*	1	-	17,5	-

APPENDIX VII: A checklist of reptiles (excluding lizards) and amphibians recorded for the area covered by the 1:50 000 Topocadastral Sheet 3422 AA Mosselbaai (AL de Villiers, pers. comm.).

Tortoises: Records from Greig and Burdett (1976)

Common name		Scientific name
Angulated Tortoise	-	*Chersina angulata*
Padlopertjie or Parrots-beak Tortoise	-	*Homopus areolatus*

Snakes: Records from Fitzsimons (1962)

Common name		Scientific name
Brown House Snake	-	*Boaedon fuliginosus*
Natal Green Snake	-	*Philothamnus natalensis*
Southern Shovel-snout	-	*Prosymna sundevallii*
Herald Snake	-	*Crotaphopeltis hotamboeia*
Rhombic Skaapsteker	-	*Psammophylax rhombeatus*
Cross-marked Grass Snake	-	*Psammophis crucifer*
Southern Dwarf Garter Snake	-	*Elaps lacteus*
Cape Cobra	-	*Naja nivea*

Frogs: Records from Poynton (1964) and Greig, Boycott and De Villiers (1979)

Common name		Scientific name
Sand Toad	-	*Bufo angusticeps*
Raucous Toad	-	*Bufo rangeri*
Cape Sand Frog	-	*Tomopterna delalandii*
Cape River Frog	-	*Rana fuscigula*
Striped Grass Frog	-	*Rana fasciata*
Spotted Rana	-	*Rana grayii*
Common Caco	-	*Cacosternum boettgeri*
Bronze Caco	-	*Cacosternum nanum*

APPENDIX VIII: Water bird counts for the Hartenbos Estuary. The dates of the counts and sources of the data are indicated.

Roberts No.	Species	Number seen 81-01-16 Underhill & Cooper (1982)	 81-11-10 ECRU Survey
47	White-breasted Cormorant	1	3
50	Reed Cormorant		1
54	Grey Heron	5	
59	Little Egret		1
88	Spur-winged Goose		1
98	Cape Teal	4	
231	Black Oystercatcher		2
233	Ringed Plover	16	
235	White-fronted Sandplover	8	5
237	Kittlitz's Sandplover	12	
238	Three-banded Sandplover	3	1

APPENDIX VIII: (Cont.)

Roberts No.	Species	Numer seen 81-01-16 Underhill & Cooper (1982)	81-11-10 ECRU Survey
241	Grey Plover	4	
242	Crowned Plover		2
245	Blacksmith Plover	2	
253	Little Stint	16	
258	Common Sandpiper	2	
262	Marsh Sandpiper	1	
263	Greenshank	8	4
264	Wood Sandpiper	1	
275	Cape Dikkop		1
287	Southern Black-backed Gull	5	4
689	Cape Wagtail	3	6
	TOTALS	91	31

The bird recordings made during the ECRU survey originate from casual observations and probably do not reflect a fully representative count.

APPENDIX IX: A checklist of mammals recorded for the area covered by the 1:50 000 Topocadastral Sheet 3422 AA Mosselbaai. Records from Stuart et al (1980, unpublished research report) and Stuart, 1981)

Common name		Scientific name
Horse-shoe bat	-	*Rhinolophus capensis*
Chacma baboon	-	*Papio ursinus*
Cape greater gerbil	-	*Tatera afra*
Cape pouched mouse	-	*Saccastomys campestris*
Striped mouse	-	*Rhabdomys pumilio*
Brown rat	-	*Rattus norvegicus*
Black rat	-	*Rattus rattus*
Cape dune-mole rat	-	*Bathyergus suillus*
Honey badger	-	*Mellivora capensis*
Cape grey mongoose	-	*Herpestes pulverulentus*
Yellow mongoose	-	*Cynictis penicillata*
Cape wild cat	-	*Felis lybica*
Caracal	-	*Felis caracal*
Leopard	-	*Panthera pardus*

APPENDIX X: Summary of available information

BIOTIC		Food Webs	Summary of available information																		
	Fauna	Mammals														*					
		Birds																			
		Reptiles & Amphibians								*		*	*							*	
		Fish						*													
		Fauna on soft substrates									*										
		Fauna on hard substrates																			
		Insects						*													
		Other invertebrates																			
		Zooplankton																			
	Flora	Terrestrial		*																	
		Phytoplankton																			
		Halophytes						*													
ABIOTIC	Other	Historical																			
		Utilization				*	*				*										
		Conservation																			
		Modelling																			
		Aquaculture																			
		Management				*	*								*						
	Bacteriology																				
	Chemistry	Pesticide residues																			
		Metal residues																			
		Eutrophication																			
		General chemistry						*	*												
	Geomorphology	Sediment transport & deposition																			
		Paleoenviroment																			
		Geology																			
	Physics	Circulation & mixing												*							
		Density variations																			
		Hydrology			*									*	*		*	*	*		*
	Physiography	Morphology													*						
		Catchment characteristics															*		*		*
YEAR (DATE OF INFORMATION)				1975	1973	1969	1973	1981	1979	1962	1981	1976	1979	1978	1980	1976	1969	1968	1978	1964	1978
ESTUARY / RIVERMOUTH / LAGOON	HARTENBOS (Estuary/Lagoon)		Sources of information	Acocks	Ashby et al	Cape Provincial Administration	Cape Provincial Administration	Day	Eagle et al	Fitzsimons	Fricke	Greig and Burdett	Greig, et al	Harris	Heydorn and Tinley	Meester	Midgley and Pitman	Monthly flow records	Noble and Hemens	Poynton	River flow data

APPENDIX X: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON	HARTENBOS (Estuary/Lagoon)		Sources of information	Roberts	Simons	Skinner et al	Smith	South Africa Dept. Agr. Techn. Services	South Africa Dept. of Planning	South African tide tables	Stuart	Stuart et al	Swart and Serdyn	Underhill and Cooper	Watling and Watling	Watling and Watling	Whitfield et al		P.D. Bartlett (pers. comm.)	J. Blomerus (pers. comm.)	G.L. de Lange (pers. comm.)
YEAR (DATE OF INFORMATION)				1978	1976	1977	1975	1975	1971	1981	1981	1980	1982	1982	1980	1982	1981		1981	1981	1981
BIOTIC		Food Webs	Summary of available information																		
	Fauna	Mammals				*					*	*									
		Birds		*										*							
		Reptiles & Amphibians																			
		Fish					*										*				
		Fauna on soft substrates																			
		Fauna on hard substrates																			
		Insects																			
		Other invertebrates																			
		Zooplankton																			
	Flora	Terrestrial																			
		Phytoplankton																			
		Halophytes			*																
ABIOTIC	Other	Historical																			*
		Utilization							*											*	*
		Conservation																			
		Modelling																			
		Aquaculture																			
		Management																		*	*
	Bacteriology																				
	Chemistry	Pesticide residues																		*	
		Metal residues													*	*					
		Eutrophication																	*		
		General chemistry																	*		
	Geomorphology	Sediment transport & deposition						*													*
		Paleoenviroment																			
		Geology																			
	Physics	Circulation & mixing								*											
		Density variations																			
		Hydrology								*			*								*
	Physiography	Morphology																			
		Catchment characteristics						*												*	*

APPENDIX X: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON	HARTENBOS (Estuary/Lagoon)		Sources of Information	A.L. de Villiers (pers. comm.)	C.M. Gaigher (pers. comm.)	Geustyn, Forsyth & Joubert Inc. (pers. comm.)	J.R. Grindley (pers. comm.)	T.J.E. Heinecken (pers. comm.)	G.P. Kellerman (pers. comm.)	G.J. Lamprecht (pers. comm.)	W. Malan (pers. comm.)	G. Streicher (pers. comm.)	J.A. van der Walt (pers. comm.)	G.A. Visser (pers. comm.)		ECRU Survey		S.A. 1:50 000 Sheet 3422AA	S.A. 1:50 000 Sheet 3421BB	S.A. 1:250 000 Geol. Series 3322	
YEAR (DATE OF INFORMATION)				1982	1981	1981	1981	!980	1981	1981	1981	1981	1981	1981		1981		1977	1973	1979	
BIOTIC		Food Webs	Summary of available information																		
BIOTIC	Fauna	Mammals														*					
		Birds														*					
		Reptiles & Amphibians		*																	
		Fish														*					
		Fauna on soft substrates			*											*					
		Fauna on hard substrates														*					
		Insects																			
		Other invertebrates																			
		Zooplankton																			
	Flora	Terrestrial														*					
		Phytoplankton																			
		Halophytes					*									*					
ABIOTIC	Other	Historical							*	*											
		Utilization				*			*	*	*			*		*					
		Conservation																			
		Modelling																			
		Aquaculture																			
		Management							*	*						*					
		Bacteriology										*	*								
	Chemistry	Pesticide residues																			
		Metal residues																			
		Eutrophication						*													
		General chemistry						*								*					
	Geomorphology	Sediment transport & deposition					*		*	*						*					
		Paleoenviroment																			
		Geology																		*	
	Physics	Circulation & mixing														*					
		Density variations														*					
		Hydrology				*	*		*	*						*					
	Physiography	Morphology														*		*	*		
		Catchment characteristics							*	*						*		*	*	*	

APPENDIX X: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON	HARTENBOS (Estuary/Lagoon)		Sources of Information	Aerial Photography	Trig Survey	Job No. 14039	Job No. 403	Job No. 492	Job No. 621	Land Survey Dept. Univ. of Natal	Job No. 326	Job No. 349	Job No. 374	Job No. 391							
YEAR (DATE OF INFORMATION)						1940	1957	1963	1968		1979	1980	1980	1981							
BIOTIC		Food Webs																			
	Fauna	Mammals	Summary of available information																		
		Birds																			
		Reptiles & Amphibians																			
		Fish																			
		Fauna on soft substrates																			
		Fauna on hard substrates																			
		Insects																			
		Other invertebrates																			
		Zooplankton																			
	Flora	Terrestrial																			
		Phytoplankton																			
		Halophytes																			
ABIOTIC	Other	Historical				*	*	*	*		*	*	*	*							
		Utilization																			
		Conservation .																			
		Modelling																			
		Aquaculture																			
		Management																			
		Bacteriology																			
	Chemistry	Pesticide residues																			
		Metal residues																			
		Eutrophication																			
		General chemistry																			
	Geomor-phology	Sediment transport & deposition				*	*	*	*		*	*	*	*							
		Paleoenviroment																			
		Geology																			
	Physics	Circulation & mixing				*	*	*	*		*	*	*	*							
		Density variations																			
		Hydrology				*	*	*	*		*	*	*	*							
	Physiography	Morphology				*	*	*	*		*	*	*	*							
		Catchment characteristics				*	*	*	*			*	*	*							

Notes:

PLATES I, II AND III OVERLEAF

PLATE I: Hartenbos Estuary mouth in an open condition during high spring tides. Erosion of the northern bank can be seen. The proposed ATKV development is to be sited on the fore-dune area from the northern bank northwards. (ECRU 81-11-11)

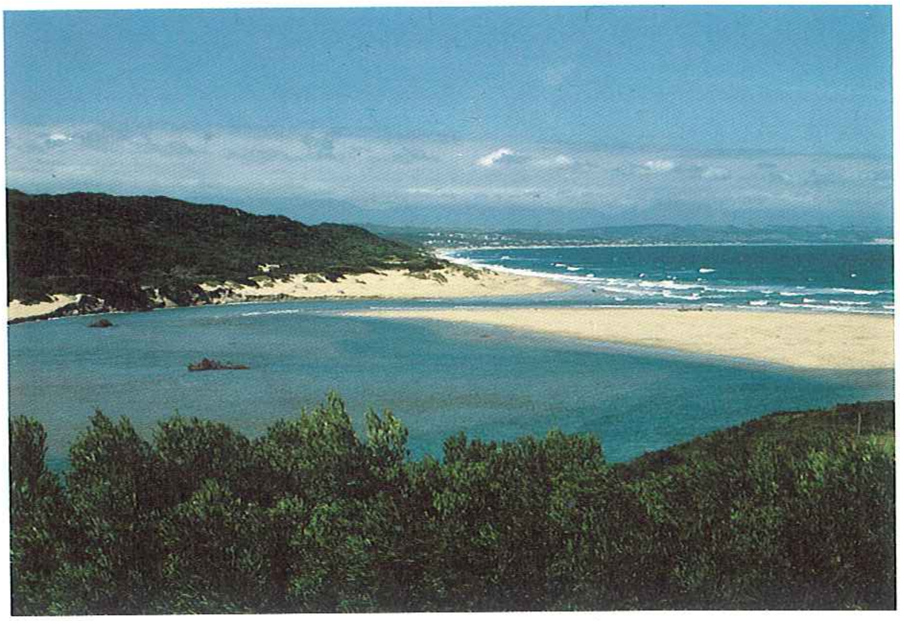

PLATE II: Old railway bridge remains with the Riviera Hotel in the background looking downstream from the base of one of the new railway bridge pylons. The orientation of the pylons such that exit flow from the bridge, is directed towards the hotel, can be seen (ECRU 81-11-11)

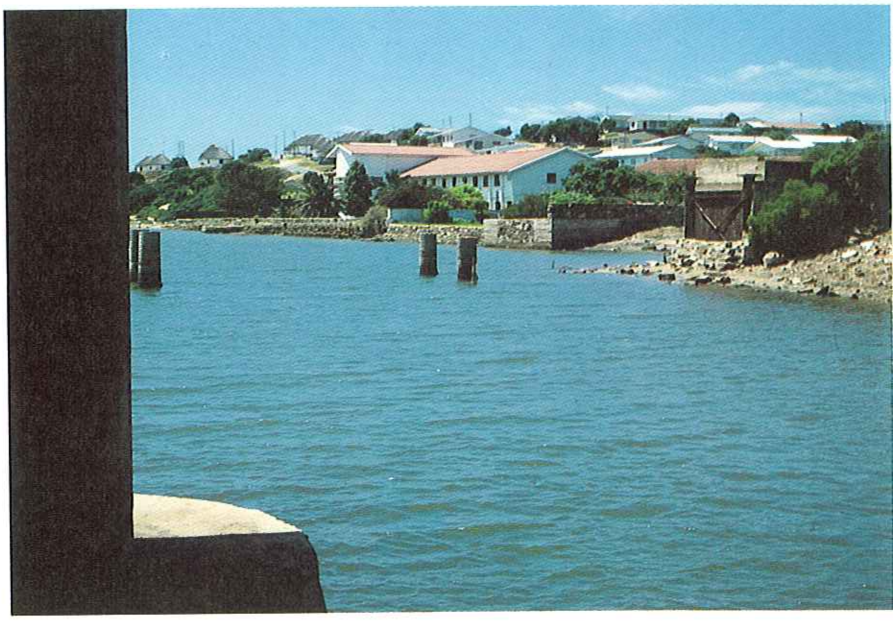

PLATE III: Northern drift in the upper reaches of the estuary (Grid Ref 0707) showing flood damage and attempts to prevent erosion using derelict vehicles. The proposed sewage effluent outfall is to be sited just downstream of this point. (ECRU 81-11-11)