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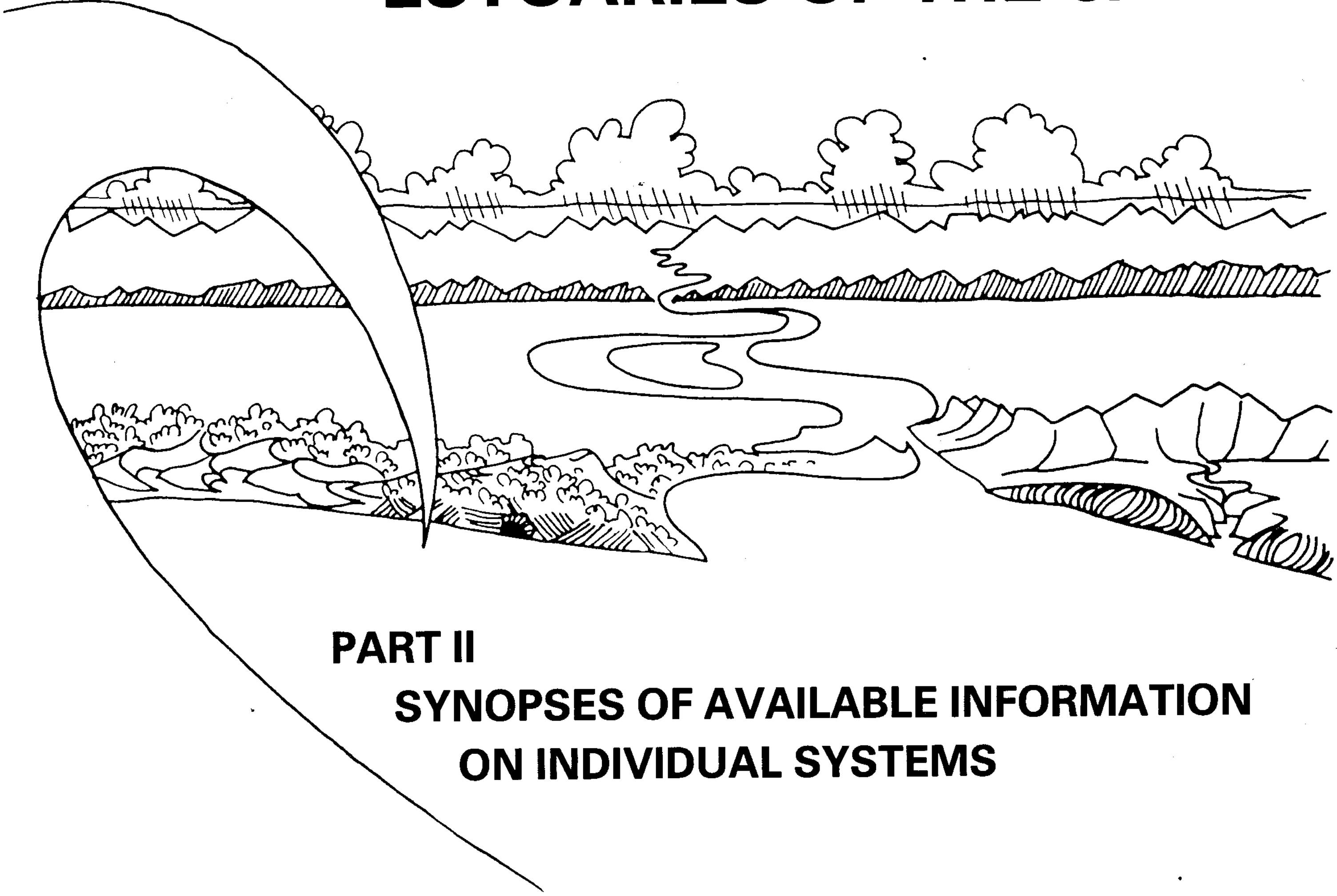
ESTUARIES OF THE CAPE



PART II

SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

REPORT NO. 28

RIETVLEI (CW 24) AND DIEP (CW 25)

CSIR RESEARCH REPORT 427

Stellenbosch, South Africa
May 1988

ESTUARIES OF THE CAPE

PART II: SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

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FRONTISPIECE: THE DIEP ESTUARY (MILNERTON LAGOON) – ECRU 87-11-01

REPORT NO. 28: RIETVLEI (CW 24) AND DIEP ESTUARY (CW 25)

(CW 24 and CW 25 – CSIR Estuary Index Numbers)

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ESTUARINE AND COASTAL RESEARCH UNIT – ECRU
DIVISION OF EARTH, MARINE AND ATMOSPHERIC SCIENCE AND TECHNOLOGY
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PREFACE

The Estuarine and Coastal Research Unit was established by the National Research Institute for Oceanology 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 from the Kei to 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 undertake investigations 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 "Estuaries of the Cape, Part I - Synopsis of the Cape Coast. Natural Features, Dynamics and Utilization" (by Heydorn and Tinley, CSIR Research Report 380). The report 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 "Estuaries of the Cape, Part II". These reports summarize, in language understandable to the layman, all available information on individual estuaries. 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, 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 on 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.

On 1 April 1988 the National Research Institute for Oceanology was incorporated into the new Division of Earth, Marine and Atmospheric Science and Technology (DEMAST) of the CSIR. In the process of restructuring, the Estuarine and Coastal Research Unit (ECRU) ceased to exist as an entity. However, the tasks undertaken by the ECRU continue to be performed by the Coastal Processes and Management Advice Programme of DEMAST.

D H SWART
MANAGER, COASTAL PROCESSES AND MANAGEMENT ADVICE PROGRAMME
DIVISION OF EARTH, MARINE AND ATMOSPHERIC SCIENCE AND TECHNOLOGY

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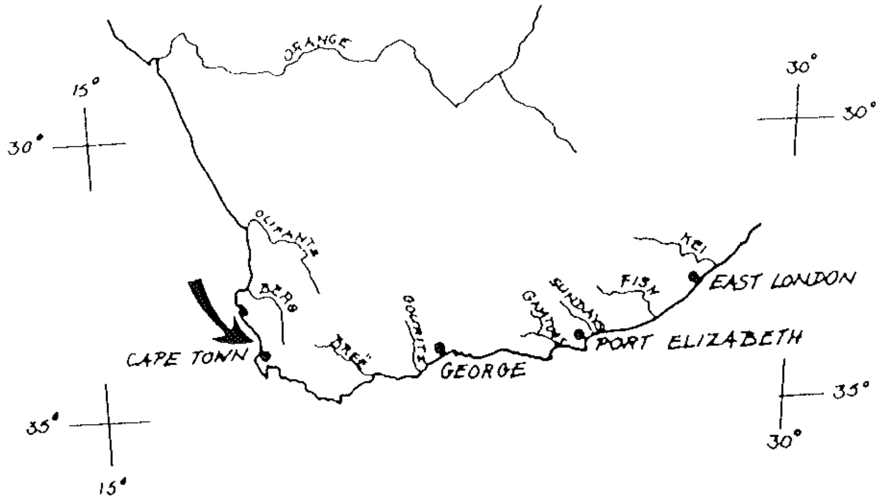
DIEP/RIETVLEI

1. LOCATION

The mouth of the Diep River is located at 33° 54,5´S; 18° 28´E and Rietvlei is at 33° 51´S; 18° 29´E.



1.1 Accessibility

The Rietvlei/Milnerton Lagoon area is readily accessible by road, particularly via the Otto du Plessis Drive from Cape Town, which becomes the R27 to Langebaan/Saldanha (approximately 5 km from Cape Town). There are numerous other minor access routes through the surrounding developed areas. There is no passenger rail service at present although the Milnerton Municipality has maintained rail corridors (Hill Kaplan Scott (HKS), 1971). It is conceivable that the development of the Mamre/Atlantis area to the north may justify the establishment of a passenger service in the future. There is no direct sea access because of the sandbar across the mouth of Milnerton Lagoon.

1.2 Local Authorities

Catchment: The catchment area lies within four magisterial districts; Cape Town, Bellville, Paarl and Malmesbury. Local authority boundaries include those of the divisional Councils of the Cape, Malmesbury and Paarl. At the time of writing the boundaries of the new Regional Services Councils, which will supersede the Divisional Councils, had not been delineated.

Rietvlei and Milnerton Lagoon lie within the Cape Town Metropolitan Area, although outside the municipal boundary of Cape Town and come under the jurisdiction of the Milnerton Municipality. The municipal limit is the Vissershok Bridge on the N7 to Malmesbury.

The beaches are controlled in terms of the Seashore Act No. 21 of 1935 and the Sea Fisheries Act No. 58 of 1973. The area immediately adjoining the beach is referred to as the Admiralty Reserve and is controlled by separate legislation. Control of the beaches adjoining the harbour has been delegated to South African Transport Services.

Between 1974 and 1976 South African Transport Services (SATS) undertook the dredging of an area of about 70 hectares in the north-west of Rietvlei. This area was dredged to an average depth of 9 m to provide fill for the development of the container berths (Ben Schoeman dock) for Cape Town harbour. These deeply dredged basins and the surrounding land are still owned by SATS. (See Centre-spread and Figure 2).

A site immediately south of the mouth of Milnerton Lagoon was allocated to the Chief Directorate Marine Development for new laboratories for the Sea Fisheries Research Institute. This plan has been abandoned and the future of the site remains to be decided.

2. HISTORICAL BACKGROUND

2.1 Synonyms and Derivations

Diep River is the name used on the 1:50 000 sheet and the name used by most authors (Bulpin, 1980) and on early plans and maps (Barbier, 1786). Riet Vlei (or Rietvlei in the Afrikaans format) is the name generally used for the shallow vlei between the river and its estuary at Milnerton. Van Riebeeck referred to Rietvlei as the Zout Pan in a 1653 diary entry but by 1670 the name had changed to Riet Vallei. The estuarine channel of the Diep River between the mouth and Riet Vlei is commonly referred to as Milnerton Lagoon and this term has been used by Millard and Scott (1954) and Beaumont and Heydenrych (1979). Some of the earlier maps and plans used archaic forms of the above names such as Riet Valley (for the Riet Vlei in the sketch plan by Bell and Michell (1845)), Riet-Vley in the plan from Mr Kuy's survey (1874), and Diepe River in an early map used in Burman (1970). John Jourdain who visited the Cape in 1608 wrote of Riet Vlei while the adjoining Salt River was known as the Jacqueline River in 1601 (Green, 1961).

2.2 Historical Aspects

References to Rietvlei date back to as early as 1608, with Jourdain describing elephant spoor adjacent to a fish filled river which flowed into the vlei (Raven Hart, 1967). At the time of Van Riebeeck's arrival in the Cape in 1652 the Diep River entered the sea through two mouths, one probably a little to the south of the present mouth and another further south at the present Salt/Black River mouth. The channel linking the Diep River to the Salt/Black River cut off a piece of land called Paarden Eiland or Horse Island.

Although firewood was collected along the banks of the Diep River, and cattle were grazed in the area, it was not until about 1690 that farms began to be established (Burman, 1970). The present day suburb of Milnerton was known as Vissers Hok until the 18th Century although today the name is used for a place further north on the Diep River.

In 1786 Barbier produced a map of the Diep River estuarine system showing the connection between the Diep and Salt Rivers, and the Diep River mouth about 3 km south of its current position (Beaumont and Heydenrych, 1980; Grindley and Heydorn, 1979). It appears that both the vlei and the river were considerably deeper than they are today. A map by Fanshawe, drawn in 1806, shows crossing points for guns and cavalry. Unsubstantiated reports claim that sailing ships were able to navigate upstream as far as the current Vissershok, approximately 13 km from the river mouth but these were probably shallow barges or ships' boats.

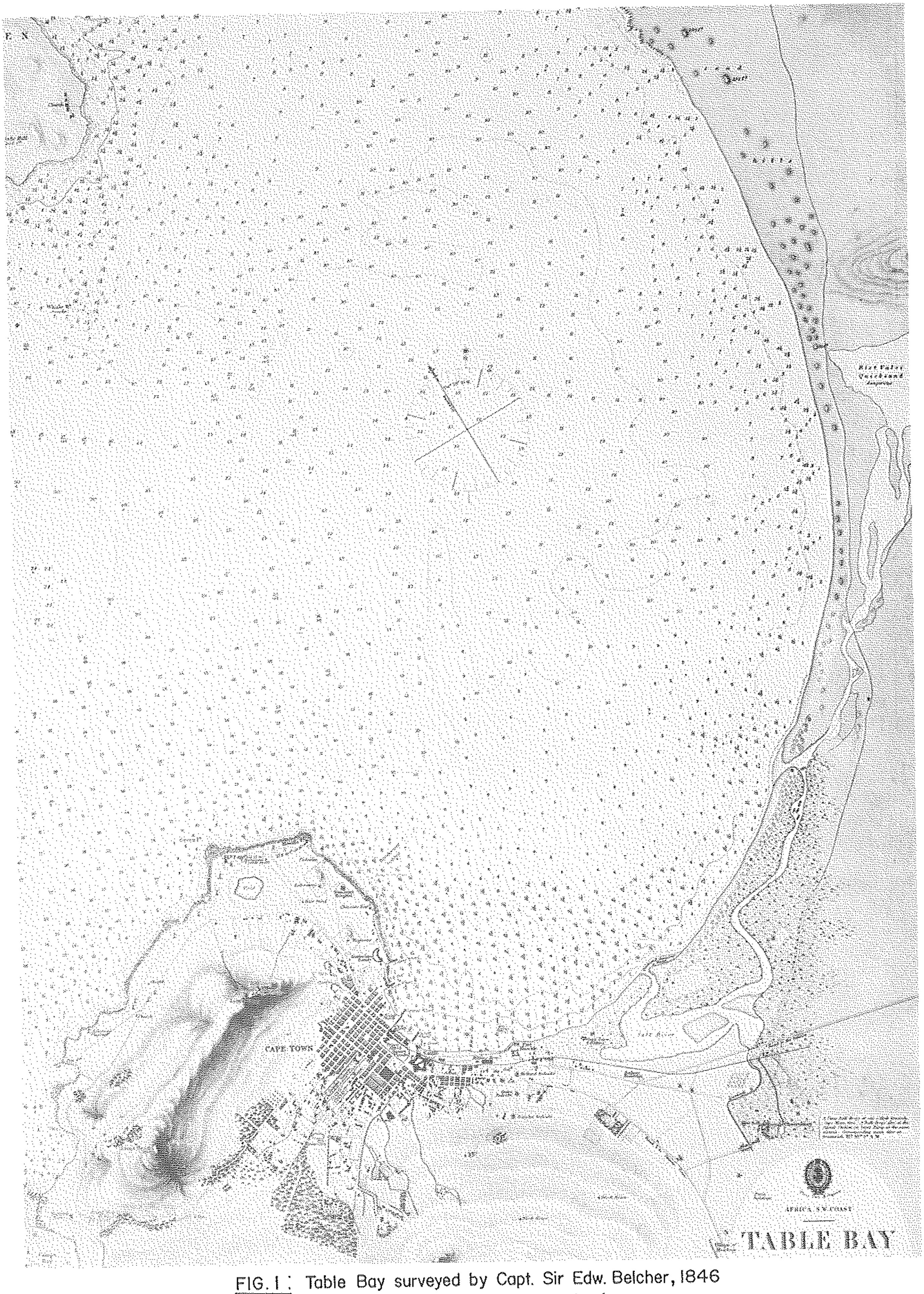


FIG. I : Table Bay surveyed by Capt. Sir Edw. Belcher, 1846
(note the two mouths of the Diep River)

Survey plans drawn in 1846 (Figure 1) and 1860 indicate that Rietvlei was silting up, with areas previously described by Fanshawe as being too deep for cavalry to cross, now labelled as quicksands. The plans also show the existence of a new mouth close to where it is today. Beaumont and Heydenrych (1980) believe that the deterioration of the channel isolating Paarden Eiland began at this time. This was assisted by periodic closure of the new mouth and accelerated in recent times, by local road and rail construction in the early 20th Century. A railway line built in 1904, provided access to Milnerton from Cape Town, until its closure in 1938. In the same year (1904) a single carriage wooden bridge was built across the estuary, linking the mainland with the Zonnekus Peninsula. This bridge remains today and was the only means of vehicular access to Zonnekus until 1985 when a new bridge was built (Figure 19).

The founding of Milnerton Estates Limited, on August 30, 1897, under the Cape Company Act (adopted only five years previously), reflected a temporary wave of optimism and an urge towards development, which had been sweeping the whole country as the trauma of the Jameson Raid receded into the background. This led in October 1897 to a communication from the company, Milnerton Estates Limited, "notifying the purchase of the properties known as Paarden Island and Jan Biesjes Kraal respectively". The letter also informed that it was intended "to lay out the estate as a township, to be known as Milnerton and also to open up railway communications from Cape Town to the centre of the property ..." Selection of the name "Milnerton" can be linked to the news of the day namely the arrival in Cape Colony of the new High Commissioner for South Africa, Sir Alfred Milner, afterwards Lord Milner (Rosenthal, 1980).

Steam dredgers were employed in 1905 to deepen parts of Milnerton Lagoon for rowing regattas. It is unlikely that this was related to increasing siltation in Rietvlei which was probably due to poor agricultural practice in the catchment. This siltation would have reduced the flow and scouring action of tidal waters (Beaumont and Heydenrych, 1980). In 1928 a weir was constructed across the river mouth in an attempt to counter the effects of siltation by increasing the water depth. The build-up of water behind the weir resulted in the flooding of adjacent residential areas and after two particularly severe floods in 1941 and 1942, the weir was demolished. The remains near the west bank were still visible in 1985.

The Otto du Plessis Drive bridge was built across the Diep River in 1961 separating Riet Vlei from Milnerton Lagoon.

In the 1960s proposals were submitted for the building of a fishing harbour and oil-tanker berth in the area (Vissery Ontwikkelingskorporasie van Suid-Afrika Beperk, 1967). Site investigations were carried out by Ocean Science and Engineering South Africa (1965) including investigations of the thickness of the offshore sediments and the configuration of the bedrock surface. The effects of a proposed new fishing harbour on the Table Bay Coastline were considered by Zwamborn in the CSIR report "Effect of proposed new fishing harbour ..." (1964). Further studies of the engineering geology and geophysics of the proposed site were described by Pike and Saayman (1966). Fleischmann (1967) analysed the fishing fleets of South and South West Africa and the significance of a fishing harbour in Table Bay. Plans for the Rietvlei Harbour were prepared by Niehaus (1967). The proposals were considered by the Advisory Committee for the planning of the Rietvlei Harbour in Cape Town in 1967 and 1968 (CPA, 1967-68). In more recent times a report on sediments in this area appears in Rogers (1980) and Woodburne (1983) describes the bathymetry, solid geology and Quaternary sedimentology of Table Bay. This harbour development would have radically altered the river characteristics, with the river being channelled around the harbour (Beaumont and Heydenrych, 1980).

Sir de Villiers Graaff and his family through Graaffs' Trust and later through Milnerton Estates were largely responsible for the development of the Milnerton area including the adjoining areas of Table View Township, and Metro Township. The original plans were set out by J H C Hofmeyr (Town Planner). In 1970 during the development of Marina Da Gama at Muizenberg interest was expressed in the development of a comparable marina at Rietvlei. A preliminary progress report was prepared by Rosenthal (1970), an engineering feasibility report (Rosenthal, 1971) and a book of drawings illustrating the proposals (Rosenthal, 1971). Flooding problems were considered by Beaumont (1971) and Beaumont and Rosenthal (1971). Plans for Table Bay Harbour Extensions to include container berth facilities were put forward by South African Railways (1971) which lead to Beaumont (1972) preparing a report on coastal morphology and Rossouw (1972) a report on effects on the Table Bay coastline. In the early 1970s Milnerton Estates, the major landowner of the vlei area, commissioned a detailed feasibility study of the various marina development proposals (Milnerton Estates Development, 1972, 1972, 1973).

FIG. 2: The area of Rietvlei (Flamingo Vlei) that was dredged to a depth of 9 m during the 1970s to provide fill for the construction of the new container berths at Cape Town Harbour has become popular for recreation. (Photo: ECRU, 87-11-01).

In 1978 Mr Kent Durr, MP for Maitland, proposed that Rietvlei should be declared a Nature Area in terms of Article 4 of the Physical Planning Act (No. 88 of 1967), as a preliminary to use as a nature reserve. He instructed that a feasibility investigation be carried out as to whether the area could be reserved as a natural area for nature conservation and limited recreation.

Grindley, Cooper and Hall (1976) and Grindley and Cooper (1979) had already proposed that Rietvlei be classified a Category A conservation area, meaning that it should be rigidly protected with limited public access but they proposed that the dredged area (Figure 2) in the north-western corner of the vlei and the lower estuary be classified Category B, implying prevention of exploitation but with unrestricted public entry. Heydorn and Tinley (1980) suggested Category C reserve status for the entire area, implying controlled development and allowance of recreational activities including fishing and bait collecting.

Thus the situation at the beginning of 1980 was that two mutually exclusive schemes were proposed for the area; one the development of a residential marina and the other the establishment of a Nature Area. An exhaustive environmental evaluation study was implemented under the auspices of the then School of Environmental Studies at the University of Cape Town, to assess the relative effects of the two proposals (Stauth, 1983). However, while the study was still under way the Cabinet took a decision to declare Rietvlei/Milnerton Lagoon a Nature Area. On 22 June 1982 the Cabinet approved, in principle, that a defined area of the Rietvlei system be reserved as a Nature Area in terms of Section 4 of the Physical Planning Act, 1967 (Act 88 of 1967) and after acquisition through purchase, transferred to the Cape Provincial Administration.

The region of the Milnerton Peninsula south of the golf course is being developed as a residential area. The developers commissioned a preliminary environmental assessment the results of which were favourable. In addition, the CSIR and the author were asked to assess the stability of the seaward and estuarine extremities of the area and also to comment on possible environmental impact (Swart, 1983; Grindley, 1983).

Aspects of the history of the area are included in Raven-Hart (1967), Burman (1970), Green (1961), Ripp (1977) and Beaumont and Heydenrych (1980).

2.3 Archaeology

Gill (1928) reports the discovery of whale bones, possibly those of a Sei Whale *(Balaenoptera borealis)*, in a quarry at Yzerplaats (present-day Ysterplaat), near Maitland. While the exact location remains vague, this was probably three or four kilometers south-east of the mouth of the Diep River. Kensley (1975 and 1985) describes the exposure by heavy seas of a late Pleistocene raised beach deposit situated about 100 m to the north of Milnerton lighthouse. Miocene fossil deposits, including shark and penguin remains have been located at the Ysterplaat Air Force Base (33°55'S, 18°30'E) (Simpson, 1973). Tankard (1975) refers to fossils of the middle Miocene Saldanha Formation being located both at Ysterplaat and in submerged deposits just offshore from Milnerton. Pollen deposits located by Schalke (1973) adjacent to Milnerton Lagoon indicate the presence of *Podocarpus* forests in the area during the Late Quaternary. Grindley *et al.* (in press) describe palaeoenvironmental conditions on the basis of fossil molluscs in sediments revealing marine conditions.

3. ABIOTIC CHARACTERISTICS

3.1 River Catchment

Area

The Diep River rises in the Riebeek Kasteel mountains 65 km north-east of Cape Town (Day and King, *in press).* The Diep River catchment covers the Malmesbury district and the area west of Paarl, including Durbanville. Estimates of the catchment area include 246 km^2 (Noble and Hemens, 1978) (too low), 1 408 km^2 (Millard and Scott, 1954), 1 125 km^2 (Heydorn and Tinley, 1980) and 1 434 km^2 (HKS, 1971). The Department of Water Affairs gives the catchment area above

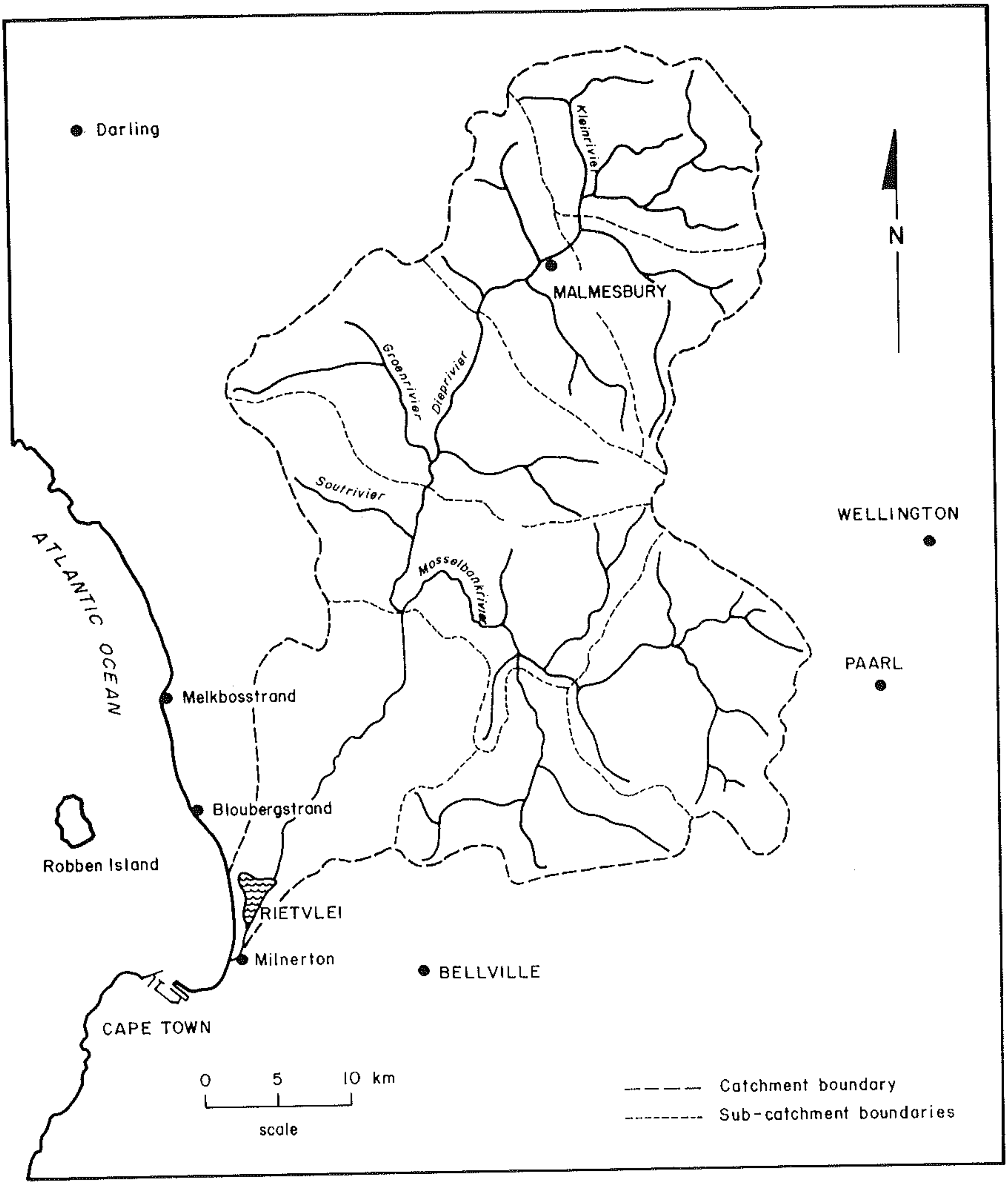


Fig. 3: Diep River Catchment Area

gauging station G2M14 at Vissershok[1] as 1 360 km^2. Cox (1971) gives this area as 525 square miles and according to Pitman *et al.*, 1981b it is 1 495 km^2 (Figure 3).

River length

Beaumont and Heydenrych (1980) give the length of the river as approximately 60 km, and Millard and Scott (1954) as approximately 64 km.

Tributaries

Tributaries include the Riebeek, Platklip, Swart and Sout. The major tributary is the Mosselbank which drains the Durbanville/Kraaifontein area, and which itself has the Klapmuts as a tributary, draining the Agterpaarl area.

3.1.1 Rainfall and Run-off

The Diep River and its tributaries lie within the winter rainfall region. The mean annual precipitation over the northern half of the catchment area is 515 mm and over the southern half 527 mm (Pitman *et al.*, 1981b). Of this about 63 percent falls in the four-month period May-August. The river tends to dry up in summer.

Rainfall records may be found in Pitman *et al.* (1981b).

Flow records

Noble and Hemens (1978) cite a mean annual run-off (MAR) of 43 x 10^6 m^3 whereas Beaumont and Heydenrych (1980) give the MAR for the Diep River as nearly 40 x 10^6 m^3, although they do not name their source of reference. Pitman *et al.* (1981b) provide an estimate of 81 x 10^6 m^3 for virgin MAR, based on synthetic flow data. The Directorate of Water Affairs have three gauging stations on the system; G2M12 on the Diep River near Malmesbury, G3M13 on the Mosselbank River at Klipheuwel and G2M14 on the Diep River as Vissershok. Flow records are available for G2M12 since 1965 and for the other two stations since 1966, although those for G2M14 are incomplete. For the 11 full years within the period 1965-1981 that records are available for G2M14, the mean annual run-off is 29,80 x 10^6 m^3, lower than all three of the published estimates for the Diep River. The above records all ignore any flow entering the system below Vissershok such as the tributary draining Tygerberg and including some storm drainage inflows.

Measured monthly flow at station G2M14 ranges between zero (most years, midsummer) and 53,3 x 10^6 m^3 (August, 1974) (Figure 4). Simulated run-off for the catchment area ranges between zero (April 1924, February, March 1928) and 164 x 10^6 m^3 (August 1973) (amended from Pitman *et al.*, 1981b). The apparent discrepancy between measured and simulated run-off may be due to extraction of water upstream for irrigation purposes, although only about 34 km^2 of the catchment is under irrigation (Pitman *et al.*, 1981b).

Details of flow records at the three gauging stations are published by the Division of Hydrology (River Flow Data, 1978) for the period up to 1970. Post 1970 data are available on request from the Department of Water Affairs (Hydrology) in Pretoria.

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[1] Gauging station G2M14 is at 33°47'30"S, 18°33'E.

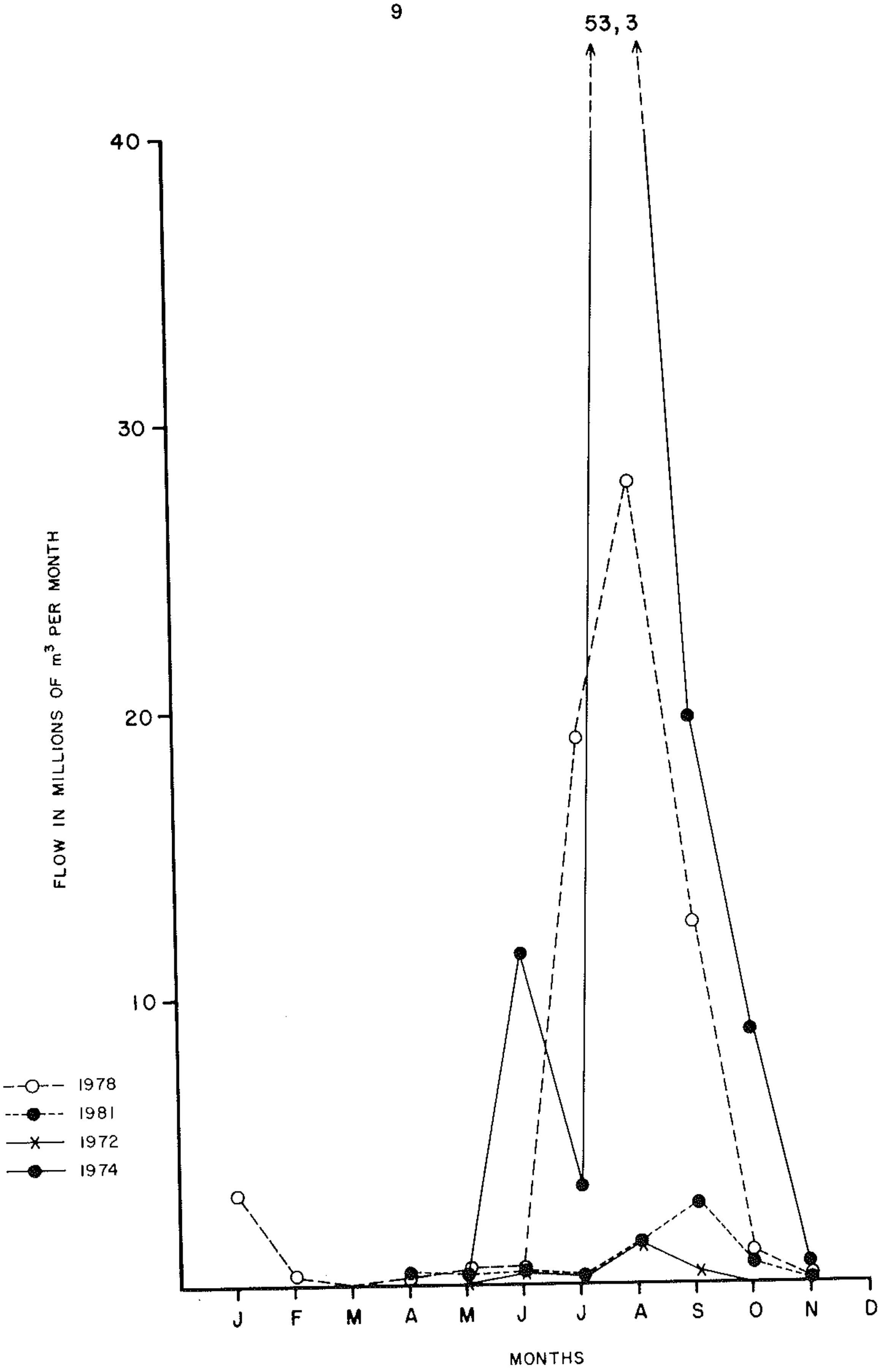


Fig. 4: Variations of monthly flow of the Diep River at Vissershok in millions of cubic metres

(flow data from gauging station G2M14)

(a selection of years to show variation)

The Diep River catchment area is bounded by Table Bay on the western side and the Diep River flows into Table Bay after passing through Rietvlei and Milnerton Lagoon (Talbot, 1971). During the winter months, the rainy season in the south-western Cape, the mouth is open but during the summer the mouth of the lagoon is closed by a sandbar. The river between the bridge near Vissershok and Rietvlei does not flow at all during droughts. The Milnerton Lagoon itself and Rietvlei have been described by Millard and Scott (1954). The actual volume of the water in the lagoon is dependent on the rainfall figures for the previous rainy season (Beaumont and Heydenrych, 1980).

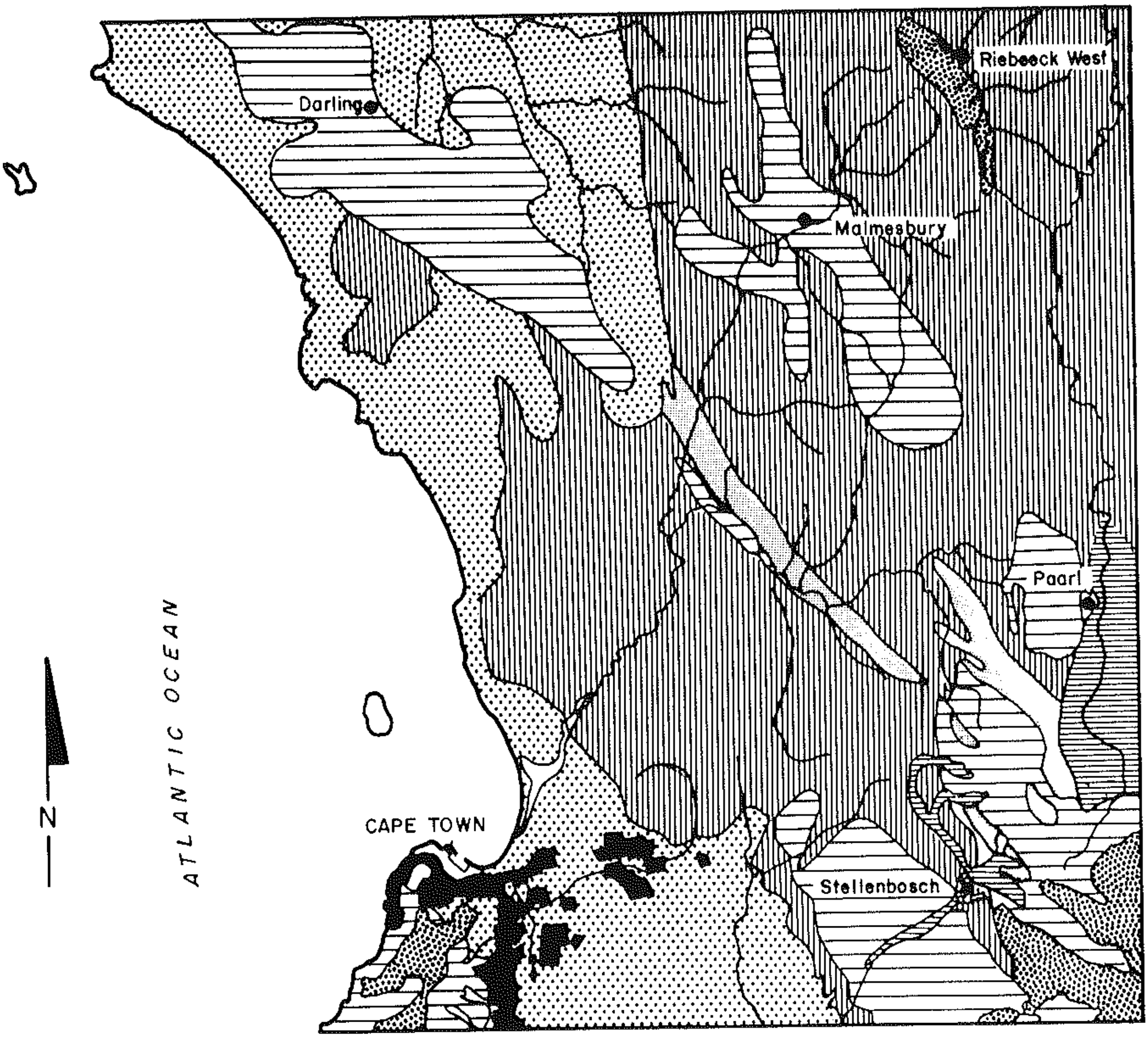
3.1.2 Geology, Geomorphology and Soils

The predominant geological formation in this area is the Malmesbury Formation but Cape Granite and what are thought to be Klipheuwel Beds are also present, though to a lesser extent. The approximate geological boundaries and distribution of these formations may be seen in Figure 5. The Malmesbury rocks are dark, medium-grained, sub-greywackes with interbedded blue and sometimes purplish shales. Graded bedding is not uncommon in the greywackes and may be suggestive of a turbidate origin (Geology Department Handout, UCT *in litt.*). There is evidence of multiple folding and late shearing at Blaauwbergstrand a few kilometres north of the lagoon. In the Gran Sasso Quarry, jointing and folding appear in the working face. The Malmesbury sediments have been dated at 595 million years (Alsopp and Kolbe, 1965).

The Cape Granite is characteristically light grey, porphyritic and intrudes into the sediments of the Malmesbury Formation and has been dated at 553 million years (Alsopp and Kolbe, 1965). Large microcline microperthite phenocrysts are plentiful and form a cospicuous feature of the granite. The Klipheuwel Beds outcrop at the village of Klipheuwel and the contact with the Cape Granite is visible in a large disused quarry. At this intensive contact the feldspar of the granite is almost completely altered to kaolinite. However, due to the small areas of outcrop of the Cape Granite and Klipheuwel Beds their contribution to the lagoon sediments is small in comparison to that of the Malmesbury Formation.

The Malmesbury Formation rocks are poorly exposed, consisting of low rolling hills, and have been subject to low grade regional metamorphism never proceeding beyond the biotite stage (Truswell, 1977). The sediments of the Malmesbury Formation consist of a variety of shales, greywackes, quartzites and grits, with occasional bands of conglomerate, limestone, dolomite, chert, basic lavas and tuffs. In the catchment of the Diep River, arenaceous slates (greywackes) alternate with more argillaceous shales. Excellent exposures of the greywackes and shales are provided by quarries, where the arenaceous rocks are being quarried for building material.

Some aspects of the geochemistry of the weathering products of the rocks of the Diep River catchment have been studied by Lawless (1972) and Smith (1972). The dominant source of clay minerals in Milnerton Lagoon sediments is most likely to be the Malmerbury Formation rocks which crop out or are present under the soil of most of the catchment area of the Diep River (Figure 5). Some clay minerals could be derived from the small areas of Cape Granite and Klipheuwel Formation, but these are not expected to be important when compared with the contribution from the Malmesbury Formation. The clay fraction of the sediments in the lagoon is detrital and not authigenically formed. There is no 'halite' problem. The argillaceous Malmesbury rocks are preferentially depleted in potassium relative to rubidium on weathering. Further depletion of potassium in the weathered product occurs due to desorbtion of this element probably from illite while in



(horizontal lines, closely spaced)	Alluvium	(blank)	FRANSCH HOEK AND KLIPHEUVEL BEDS: arkoses, grits, phyllites, sandstones and shales
(fine dots)	Unconsolidated sands	(vertical lines)	MALMESBURY BEDS: slates, phyllites and quartzites
(dense stipple)	TABLE MOUNTAIN GROUP: sandstones with subordinate shale bands	(horizontal lines, widely spaced)	IGNEOUS ROCKS: granites, diorites and felsites

Fig. 5: Generalized Geological Map (after Union Geological Survey, Sheet 247, 1933)

contact with interstitial water. There are marked seasonal and spatial variations within the supernatant waters of Milnerton Lagoon. It appears that strontium is selectively lost at the site of weathering, (Cox, 1971). Further geochemical analyses are provided in UCT Geochemistry Honours projects by De Swardt (1970), Smith (1972), Lawless (1972) and Cornell (1970).

Milnerton Lagoon during the summer months acts rather like an evaporite system. The concentration of most elements was found to decrease from Rietvlei to the mouth of the Lagoon. This could possibly be due to the precipitation of $CaSO_4$ relative to $MgCl_2$ with higher rate of precipitation in Rietvlei. In the Malmesbury Rocks the feldspars and illite weather to kaolinite. The chemical changes that accompany this alteration are a decrease in Ca, Mg, Na, K, Rb and possibly Sr. K is being removed ahead of Rb resulting in a decrease in the K/Rb ratio with increasing degree of weathering.

Palynological (fossil pollen) investigations of the Rietvlei area revealed a maximum thickness of 23,5 m of Upper Quaternary sediments over the basement of Precambrian and Palaeozoic rocks (Schalke, 1973). The sediments were studied on the basis of cores from boreholes drilled for the purpose. Fossil pollen, fossil molluscs, sediments and ^{14}C determinations were carried out. The outlet of the Diep River was found to have been to the north of its present position opposite the north-west corner of the vlei. During the middle of the last glacial period a rise of sea level to a maximum of -18 m below present mean sea-level took place. During this time interval two extensions of *Podocarpus* (Yellow wood) forest took place on the Cape Flats. In the Rietvlei basin local erosion and deepening of the river beds were associated with the lower sea-level. The sea-level rise during the later part of the last glacial period and Holocene resulted in renewed deposition of sediments which filled the northern opening. The formation of coastal dunes started, the vegetation came to resemble the present flora, and the river outlet finally took its present position.

An account of the sediments in the Rietvlei basin is provided by Pike and Saayman (1966) who undertook a comprehensive engineering geological and geophysical investigation for the proposed harbour. Further, more recent accounts are provided by Rogers (1980) and Grindley *et al.* (in press). Information on the offshore sediments are provided in reports by Ocean Science and Engineering SA (Pty) Limited (1965) and Woodborne (1983).

3.1.3 Land Ownership and Uses

The catchment falls within the area of the Cape Province described by Talbot (1947) as the western lowland. Talbot subdivides the area into the Swartland in the east and the Sandveld in the west. The Swartland is described as a region of undulating lowland with locally level areas but with relatively steep slopes along the river courses. The Sandveld is flatter, the river valleys being wide and shallow with gentle slopes.

Virtually the entire catchment is under cultivation with only a few patches of natural vegetation remaining. Talbot (1947) has provided a detailed analysis of erosion in the area as related to land use. A relatively small proportion of the cultivated land consists of vineyards and orchards, and erosion is not particularly serious on most of these farms. Grain farming dominates the agriculture, and it is to this that Talbot (1947) attributes 90 percent of the soil losses of the region during this century. Talbot paints a very bleak picture of chronic erosion due to criminally bad land management. "The gullied hillsides, the wind-eroded lands, and the abandoned fields of today are a monument and an indictment of men who could stabilize wheat prices but were powerless to stabilize the soil" (Talbot, 1947). Talbot estimated that in the western lowland region (of which the Diep River catchment forms a substantial part), a total of approximately 2 527 square kilometers were affected by gully erosion, and of this 573 square kilometers were severely gullied.

While the predominant land-use in the Diep River catchment area remains wheat farming, a considerable amount of industrial development has taken place in the Milnerton area and at Atlantis to the west of the catchment. A large fertilizer factory, a petroleum refinery, and the Milnerton Sewage Works have been developed near Rietvlei.

During the 1960s and early 1970s various proposals were advanced which would have altered the Rietvlei system completely. The first of these involved the building of a fishing harbour for which the river would have been diverted around the harbour area by means of a new channel. Entirely different proposals concerning marina and waterfront housing development were also put forward. The proposals ranged from developments in which large-scale dredging of Rietvlei and the Milnerton Lagoon was planned, to various lesser schemes. Fortunately changes in economic circumstances and property markets allowed the natural system to survive. However, extensions to Cape Town harbour (Ben Schoeman Dock) did require the dredging of deep basins in the north-western area of the Rietvlei basin to supply fill material for the new container berths (see Centre-spread). An area (now known as Flamingo Vlei) was dredged to a depth of nine metres for this purpose.

This deep water area has become an important recreation area which is now under the control of the Milnerton Aquatic Club. Their management committee fosters a range of aquatic activities but with a strong conservation emphasis. Extensive residential development has taken place particularly in Table View north of Rietvlei and various further extensions to the Milnerton Municipal area are developing in surrounding regions. The golf course to the west of Milnerton Lagoon is a true links immediately adjoining the sea. The peninsula north of the mouth is being developed as a new residential township called Woodbridge Island.

3.1.4 Obstructions

There are numerous bridges over the river and its tributaries; G F van Wyk, Cape Department of Nature and Environmental Conservation *(in litt.)*, mentions a bridge on the farm Swellengift in the Kalbaskraal district which marks the furthest upstream penetration by marine fish ("springers"). There is a large number of bridges within the entire catchment but not many weirs or farm dams because high salinity renders the water of limited use to farmers. Nevertheless a dam has been proposed for the Vissershok region. Wetland vegetation communities in Rietvlei are geared to the cycle of winter flooding and summer drought. A disturbance of this natural cycle through the construction of a dam in the catchment would seriously disturb the Rietvlei ecosystem (Venter, 1979). It is essential, should a dam be built, that the design permits the release of volumes of water adequate for the maintenance of the Rietvlei wetland. According to Jezewski and Roberts (1986), the calculated flooding requirement of this estuary is 21 190 x 10^6 m^3/a and the adapted value is 5 670 x 10^6 m^3/a, that is, 7 percent of MAR.

3.1.5 Siltation

Extensive erosion in the Swartland and Sandveld has led to severe siltation problems in local rivers. Run-off from the unprotected cultivated land is virtually unimpeded, resulting in massive soil loads entering the rivers together with increased volumes of water. By contrast in undisturbed veld much of the rainfall is absorbed. The result is that the stream channels tend to be both widened by abnormal floods and choked with silt (Talbot, 1947). The sediment yield to the upper five-sixths of the Diep River is 150 tonnes/km^2/annum and to the lower one-sixth 50 tonnes/km^2/annum (Pitman *et al.*, 1981b).

3.1.6 Abnormal Flow Patterns and Flood History

The Diep River has a relatively well-documented flood history, although a number of records are based on observations by local residents. Beaumont and Heydenrych (1980) have provided a review of flood records since 1923 and a report of a flood in 1906 has been received from a local farmer. A summary of the information provided by Beaumont and Heydenrych follows:

1923: Water levels rose to within 0,85 m of the road surface of the wooden bridge. This would represent a peak flood level of MSL + 2,5 m at this site.

1927: Water level approximately 4,27 m above river bed at the Blaauwberg road bridge and submerged the structure.

1937: Water level rose to top of handrails of weir at mouth of lagoon. Peak flood level approximately MSL + 2,75 m.

1941, 1942: No details, but weir significantly damaged. Weir demolished soon afterwards (S Wood, Milnerton Town Engineer, pers. comm.).

1954: Flood of 400 m^3 per second (cumecs) at Rietvlei.

1961: Flood of estimated 340 cumecs rose to underside of bridge deck of Otto du Plessis Bridge while under construction - MSL + 2,75 m.

1974: 13 June 56 cumecs recorded at Vissershok. Peak level recorded at wooden bridge MSL + 2,11 m. Mouth initially closed, then scoured open. 21 August 87 cumecs recorded at Vissershok but only MSL + 1,81 m at wooden bridge because mouth open throughout. (According to Department of Water Affairs computer printout; 13 June 52,4 cumecs, 21 August 81,7 cumecs).

1983: 25 June MSL + 2,05 m at Otto du Plessis Bridge and MSL + 1,9 m at wooden bridge (Swart, 1983). Mouth opened artificially before flood water reached estuary (Figure 6).

The flood regime of Rietvlei has been extensively studied in connection with the various development proposals considered for the area. To this end a water level recorder was used at the Wooden Bridge between 1971 and 1975 for the purpose of monitoring water level variations. Thus, together with gauging station G2M14 established at Vissershok in 1966, recent flood data should be reasonably accurate. A recent report, making use of flow data from the three gauging stations in the catchment, estimates the 50 and 100-year flood levels at 210 and 300 cumecs respectively (Crous, 1979, in Beaumont and Heydenrych, 1980). Earlier estimates had put the 100-year flood at Rietvlei as high as 810 cumecs. It has also been estimated that the 100-year flood is attenuated by about 20 percent by the Rietvlei basin.

Beaumont and Heydenrych (1980) point out that flood regimes have changed since the early 17th Century to the extent that Rietvlei and Milnerton Lagoon differ in their flood characteristics. Flooding at Rietvlei depends simply on the volume of influent water whereas in the lagoon the extent of flooding depends largely on whether or not the mouth is open. This is well-demonstrated by the 1974 floods. The flood of 13 June (56 cumecs) did not inundate the Table View residential area but because the mouth was closed initially, levels increased in the lagoon to MSL + 2,11 m and flooded the adjacent road. A larger flood (87 cumecs) on 21 August caused extensive flooding of the Table View area but, because by then the mouth was open, only reached MSL + 1,81 m in the lagoon.

In the report Assessment of Zonnekus Development (1983), Swart points out that for most of the flood records there is no mention as to whether the quoted discharge was measured/estimated simultaneously with the given maximum levels. There is also no record in several cases as to whether the mouth was open or closed.

Mr S Wood, the Milnerton Town Engineer, has provided some further information relating to floods. Flooding is being aggravated by weed growth in the north-eastern corner of Rietvlei. It is possible that this growth is being enhanced by the input of phosphorus-rich silt, although this would represent a changed situation from that described by Marais (1973), who suggested that the Diep River was not significantly polluted. Weed growth also causes flooding in the south-eastern corner where a canal draining Edgemead residential area and Montagu Gardens industrial area enters the vlei.

FIG. 6: Rietvlei in flood in July 1983 with only the tops of trees showing above the flood waters. (Photo: J R Grindley).

A flood problem area exists at the corner of Sprigg and Hof Streets in the Table View residential area. The region is protected by dikes but nevertheless has had to be pumped out in the past. The eastern end of Sprigg Street, but not the adjoining houses, have been flooded in the past but the dike has now been raised.

S Wood, (pers. comm.) has recorded a number of flood levels, although he does not give dates. These include MSL + 4,34 m above the Blaauwberg road bridge, MSL + 4,01 m in the north-eastern corner, MSL + 3,64 m near the corner of Sprigg and Hof Streets and MSL + 3,46 m at the Otto du Plessis Drive Bridge.

3.2 Estuary

(Section includes contribution by L Barwell, Coastal Processes and Management Advice Programme, DEMAST).

The area including Rietvlei and Milnerton Lagoon (estuary) is about 900 ha in extent (Heydorn and Tinley, 1980).

3.2.1 Vlei Topography

Rietvlei is roughly triangular in shape with a maximum width of over two kilometres in an east/west direction and a length of approximately 1,5 km north/ south. The vlei area may be defined as that between the Otto du Plessis Drive Bridge and the Blaauwberg Road Bridge (see Centrespread). It is very flat, with an elevation of 1,0 to 2,0 m above MSL (MED, 1), with the exception of the north-western corner which was dredged in the mid 1970s (see Section 3.1.3). The vlei receives the Diep River at the north-eastern corner. To the north of the vlei is a ridge of undulating scrub-covered dunes with a maximum elevation of 16,0 m above MSL (MED, 1). The eastern border of both vlei and lagoon consists of a narrow shelf approximately 500 m wide at between 4,0 and 6,0 m above MSL, to the east of which the land slopes up at a gradient of 1 in 12 to a maximum elevation of 14,0 to 16,0 m above MSL.

According to Duvenage (1983) the estuary, from the mouth to the Blaauwberg Road Bridge covers an area of approximately 428 ha. This includes the area of Rietvlei and Milnerton Lagoon below the Otto du Plessis Road Bridge. To the west of the vlei and lagoon is a coastal strip less than 500 m wide over most of its length but with a maximum width of 1 000 m near the Otto du Plessis Bridge. The seaward side of the peninsula is characterized by primary dunes with a maximum elevation of approximately 10,0 m above MSL, although most of the land is relatively flat (MED, 1).

3.2.2 Lagoon Topography and Bathymetry

The lower estuary, generally called Milnerton Lagoon, follows a narrow winding channel from the southern tip of Rietvlei to the river mouth. The river bed is below Mean Sea Level and is shallow. The maximum width of the estuary is approximately 150 m (MED1). A small temporary piped flow joins the estuary close to the mouth and represents the remains of the Diep/Salt connection. This connection cannot be opened because certain Paarden Island buildings have basements below HWST and would be flooded if full tidal exchange was allowed to enter the Zoar Vlei area.

The Diep River mouth consists of a double spit, free to migrate along an unrestricted sandbank about 250 m in length but is restrained by a gabion structure and concrete wall to the north and a naturally high area, fronted by hummock dunes, to the south.

Tachymetrical surveys of the estuary, estuary mouth and beach area were carried out by the NRIO on 5 June 1986 and 26 June 1987 (Van der Merwe, 1988). At the time of the 1986 survey, the mouth was closed and the lowest point on the sand berm across the mouth was at +1,72 m (MSL). Within the lagoon, the deepest areas (-1,5 to -2,0 m MSL) were located along the NW-side. Shallower areas, following the 0,0 m MSL contour, were evident along the SE-side and at the new bridge to Woodbridge Island the deepest channel was located on the NW-side at a level of -0,90 m MSL. A similar situation existed beneath the Wooden Bridge, upstream of the new bridge, where the deepest point in the channel was at -1,5 m MSL on the NW-side and 0,0 m MSL for the greater part of the total estuary width of 110 m at this point. Little change had occurred at these points (Figure 20).

The beach on the northern side of the mouth had an average slope of 1:20 in 1986 and showed little change between surveys, as did the slope of the southern part of the beach adjacent to the river mouth. (Average slope of 1:16 in 1986 compared to 1:18 in 1987).

As a result of the mouth being open during the 1987 survey, the beach slope at the mouth had become flatter (1:100 in 1987 compared with 1:20 in 1986).

Evidence for Prehistoric Differences in Topography

Schalke (1973) provides geological evidence for two former outlets of the Diep River, stating that sea level fluctuations and sedimentation have altered the drainage patterns within the Rietvlei area. Two erosion gullies, both now filled with sediment, exist in the shale, granite and sandstone bedrock beneath the vlei. One of the gullies is at the north-western corner of the present Rietvlei and the other lies further south. Both represent past channels of the Dieprivier.

FIG. 7: The sandy mouth of Milnerton Lagoon which links the Diep River/Rietvlei system to the sea seasonally. (Photo: ECRU, 87-11-01).

Further evidence is provided by Millard and Scott (1954) who report the discovery of the shells of *Solen*, the marine razor clam, 0,6 m below the surface of the substratum in the north-western corner of Rietvlei. They suggest that these finds indicate a one-time direct connection with the sea which would mean that Rietvlei was once an estuary rather than the brackish vlei it is now.

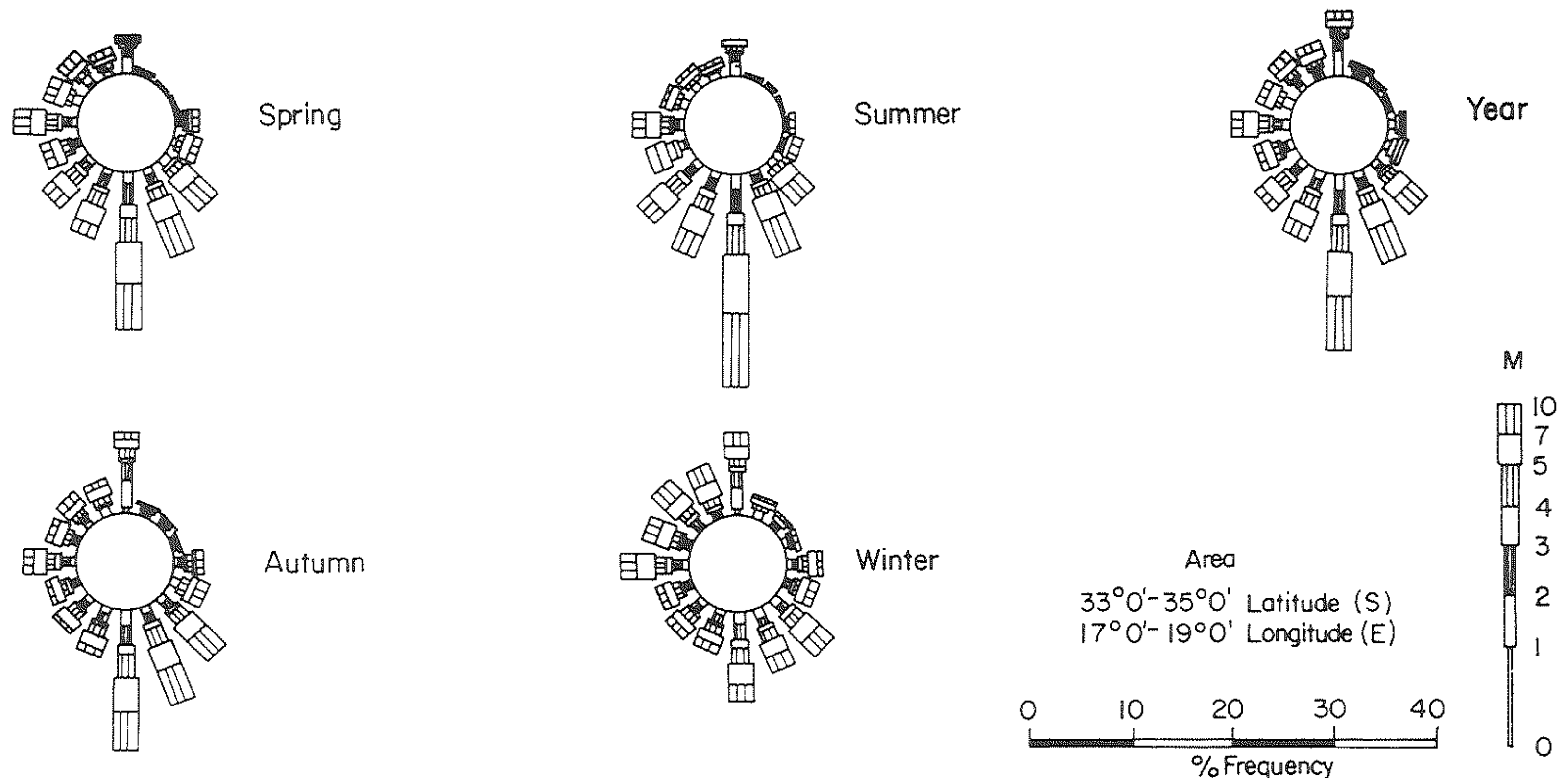


Fig. 8a: Voluntary observing ship (VOS) swell roses

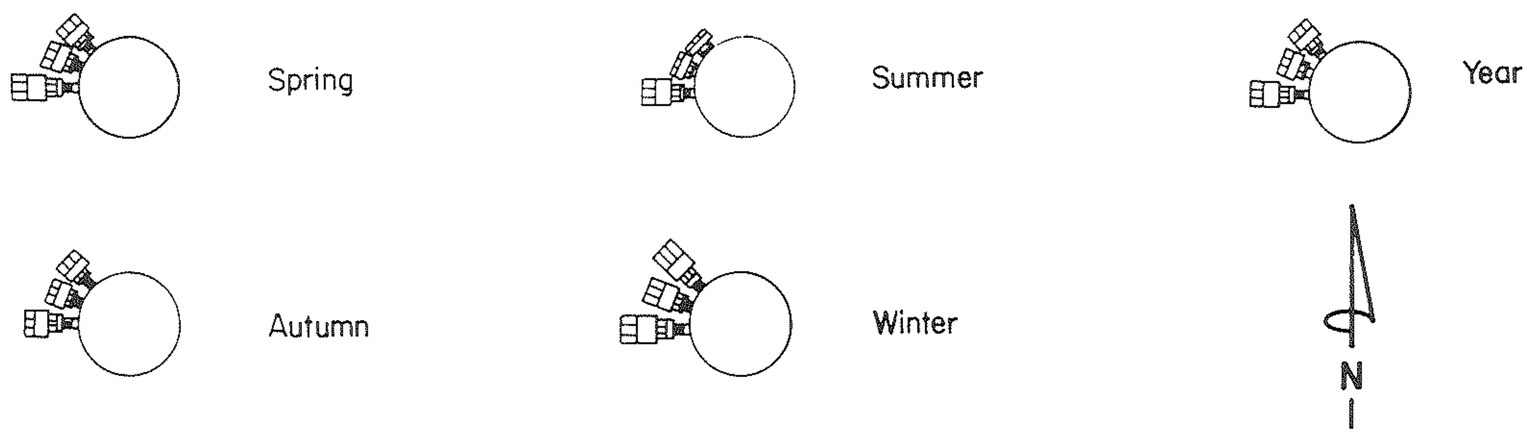


Fig. 8b: Screened voluntary observing ship (VOS) swell roses

Woodborne (1982) describes two channels crossing the floor of Table Bay, one opposite the present Diep River mouth and one opposite Rietvlei.

3.2.3 Coastal Hydraulics

The functioning of an estuary mouth and therefore the estuary as a whole is influenced by the approaching deep sea swells. Waves approaching the coast at an oblique angle are responsible for the generation of longshore sediment movement.

Geomorphological features such as the Cape Peninsula and Robben Island influence the approaching deep sea swells (Figure 8a) and as a result of the location of the Diep River mouth within Table Bay, only swells from a sector between 264o and 330o will reach the area at the river mouth with swells from the NW (315o) being influenced by Robben Island (Figure 8b). Under certain conditions, swells from a wider distribution of directions can reach the area due to wave diffraction around the Peninsula.

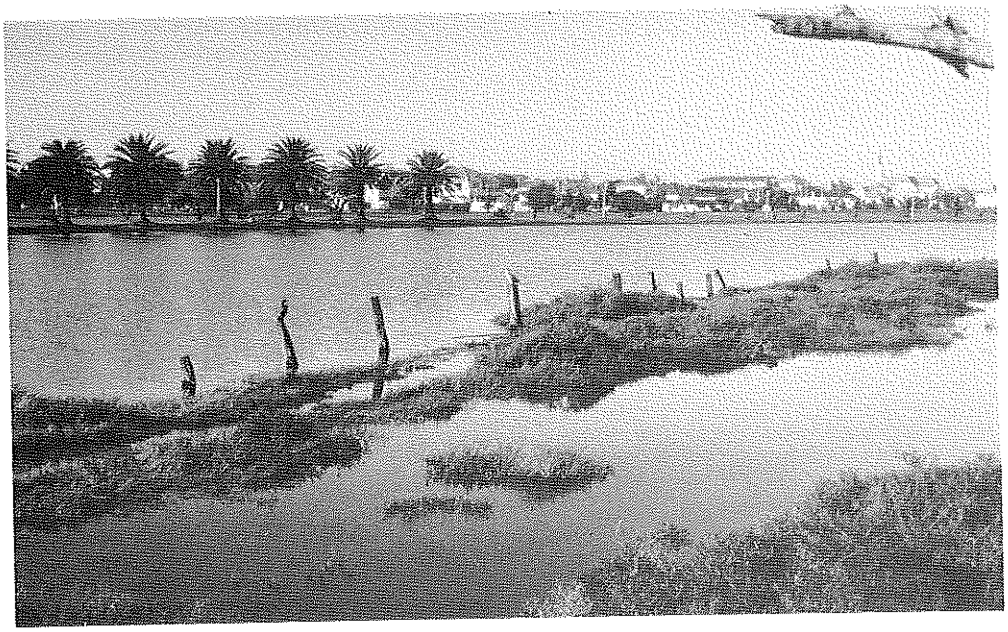


FIG. 9: A view of Milnerton across the lagoon from the Woodbridge Island Peninsula before development when natural vegetation and saltmarshes remained there. (Photo: J R Grindley).

Wind-induced currents also play a major role within Table Bay and when superimposed on the wave induced longshore currents, a variety of longshore current patterns occur. Studies of the nearshore sediment movement within Table Bay (Rossouw, 1972) reveal that waves dominate the littoral transport patterns in the area south of the Milnerton lighthouse while wind-induced currents influence the longshore movement north of the lighthouse. The net longshore sediment movement at the Diep River mouth is relatively small and is directed towards the north.

The area now known as Woodbridge Island (see Centrespread) situated on the southern end of the peninsula is flanked by Table Bay to the west and by Milnerton Lagoon to the east. Prior to development the peninsula was characterized by a 50 to 70 m wide primary dune field along its entire length, except for a small section in the centre of the coastal strip, where Zonnekus, a large mansion, was

FIG. 10: The lower reaches of Milnerton Lagoon were extensively dredged during 1985 by the dredges visible in the background to provide the sandfill for the Woodbridge Island housing development. (Photo: J R Grindley).

FIG. 11: The foundation for the development of the Woodbridge Island Development depended upon sandfill pumped from the bed of the lagoon by a dredger. (Photo: J R Grindley).

built about 65 years ago. About one-third of the total width of the peninsula was situated below the 1 in 50-year flood level for the Diep River. Consideration was given to the construction of a concrete training wall for the north bank of the Diep River as a flood control measure (Wooley, 1940). The dunes were scantily vegetated and contained numerous washovers and blow outs. This whole stretch of coast is an eroding shore, demonstrated by undercutting of the old coastal road and coastal dunes by progressive erosion. Much of this erosion is the result of Table Bay re-establishing its equilibrium following the construction of the Duncan and Ben Schoeman docks.

The original developer, Woodbridge Island Development Company, proposed the construction of more than 300 high-class dwellings on Woodbridge Island (Harry Fuchs Invest. Co., 1983). Before submitting his development plans to the local Municipality or the Department of Local Government of the Cape Provincial Administration (CPA) for approval, the developer approached the National Research Institute for Oceanology of the CSIR and Prof. J R Grindley for advice.

Maps, charts and photographs showed that the Milnerton coastline historically had been in a state of accretion between at least 1780 and 1900. In about 1900 the situation was reversed and erosion set in. Since then more than 80 m of progressive erosion took place. The change in tendency is ascribed to large-scale extensions to Table Bay harbour since the turn of the century. It was proposed that housing should be developed only above the 1 in 50-year flood level and that the estuary mouth should be opened once the water levels in the estuary exceed a certain critical level, to thus lessen the danger of flooding.

Using a predictive technique, on/offshore sediment transport rates and profile changes during simulated storms off Milnerton were calculated (Woodbridge Island Development, 1986). It was deduced that a maximum coastal recession of 30 m was possible during a storm. Allowing for a projected further 10 m of long-term coastal erosion (Rossouw, 1972) a safe set-back line of 40 m landwards of the 1986 high-water mark (HWM) was estimated for the coastline adjacent to the Diep River mouth.

On the basis of the various recommendations the developer modified his plans and submitted them for approval. The Provincial authorities altered the 37 m setback line to a 60 m building restriction line relative to the present high-water line, obviously as a compromise between the best estimate of the recession of 37 m and the maximum estimate of 107 m, in the event of harbour extensions. It is interesting to note that an average erosion of about 20 m, with a maximum of 31 m, occurred on Woodbridge Island during a severe storm in May 1984, after completion of the study. The storm waves were estimated to have a return period of 1 in 43 years. These figures substantiate the calculations done on the basis of Swart (1974), Heydorn *et al.* (1985) and Grindley (1983).

3.2.4 Estuary Hydraulics

A study of available aerial photographs (Assessment of Zonnekus Development, 1983 and Dynamics of the Diep River mouth, 1987) showed two seasonal phases, a closed lagoon phase during the dry summer months and an open estuarine phase during the wet winter months. River floods during the lagoon phase can give rise to a very high water level in the lagoon which may result in flooding of the adjacent Milnerton residential areas and in the vicinity of the bridges. Natural breachings still occur and relieve floods, but these have to be augmented by artificial breachings to prevent damage to the surrounding developments.

3.2.5 Mouth Dynamics and Tidal Currents

Currents off the mouth of Milnerton Lagoon have been studied in detail (Harris, 1978; Orren *et al.*, 1981). The main feature of the inshore currents is that

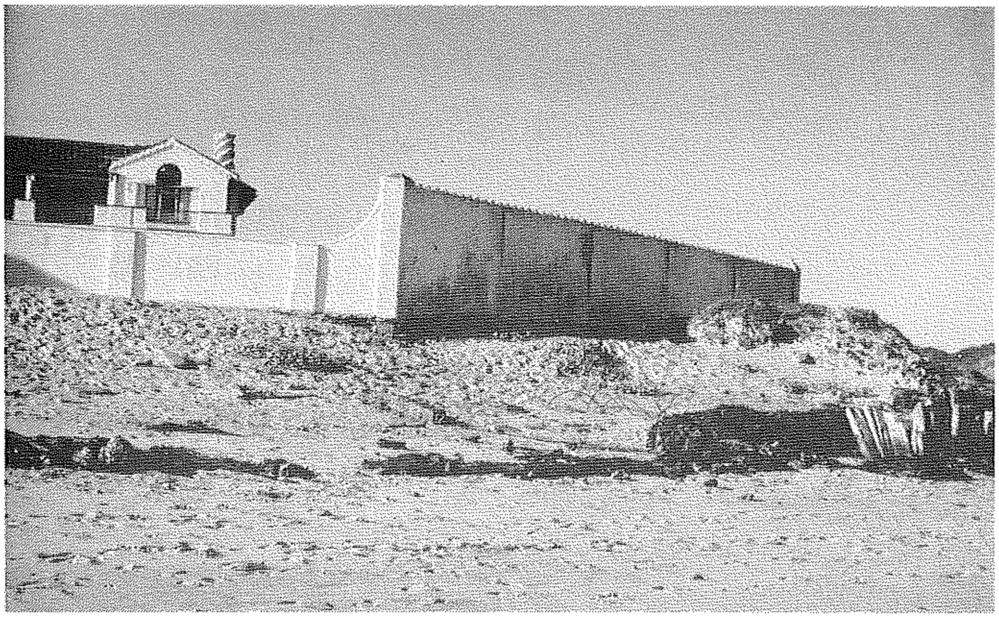


FIG. 12: The historic Zonnekus House on the sandy Woodbridge Island peninsula 400 m north of the mouth of the Diep River Rietvlei system before the great storm of May 1984. (Photo: J R Grindley).

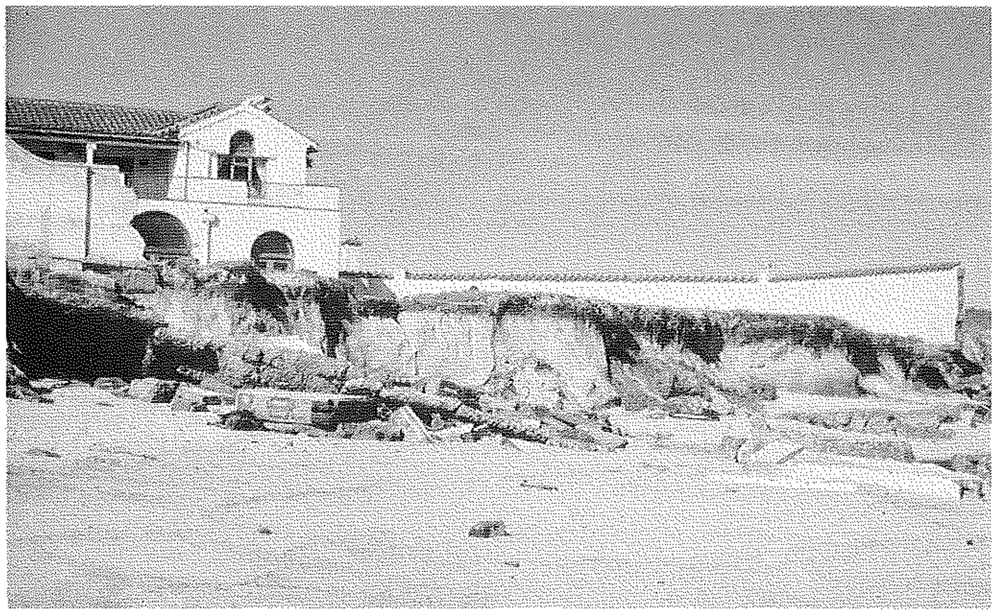


FIG. 13: Extensive marine erosion of the surrounds of the historic Zonnekus House during the great storm of May 1984. Portions of the exposed fossiliferous calcrete horizon are visible among the rubble below the eroded bank. (Photo: J R Grindley).

they are predominantly wind-driven. Tides and the Benguela Current were reported to make only a small contribution. There is an overall northward movement with water entering Table Bay between Green Point and Robben Island, and leaving between Robben Island and Melkbosstrand. However, surface currents were found to be generally weak and variable, especially in winter when the winds are less consistent than in summer. Currents were found to be even weaker at depth than at the surface; at one station off Milnerton the current velocites at 13 m depth were negligibly small (<5 cm/s) for 81 percent of the time. The residence time of the water in Table Bay thus varied considerably with the direction and speed of the wind (and hence current), and is of the order of 1-4 days. However, under certain quiescent conditions it may be longer than this (Orren *et al.*, 1981).

Historical accounts indicate that the Diep River mouth was almost permanently open to the sea (Beaumont and Heydenrych, 1980). The situation today is considerably different in that the establishment of a sandbar across the mouth isolates the river from the sea for much of the year. The actual duration of this period of closure appears to vary considerably. Local residents and officials reported in the 1970s that the mouth always closed within a matter of days after being breached by floods (Beaumont and Heydenrych, 1980), and Swart (Assessment of Zonnekus Development, 1983) agrees that this is typical behaviour. In contrast to this, Millard and Scott (1954) report that after the mouth is naturally or artificially breached in June or earlier, the system remains open to the sea, and therefore tidally influenced, throughout the rest of the winter and spring. Personal observations by Beaumont and Heydenrych (1980) during 1974 confirmed that it was possible for the mouth to stay open for several months. Shortly before the June flood of 1974 these authors measured the minimum height of the sandbar as being 1,68 m above MSL. After the flood waters broke through, the mouth remained open until November 1974. The Milnerton town engineer, reports that he opens the sandbar when the water level in the estuary reaches a particular mark (approximately 1,9 to 2,0 m above MSL)on Esplanade Road (S Wood, pers. comm.). The mouth is opened on a falling tide and the estuary virtually empties in half an hour. He also states that when opened in June the mouth never closes before December but must not be opened earlier or the estuary fails to flush adequately. It is of interest that since the estuary was dredged as part of the Woodbridge Island development the mouth has remained open (S Wood, pers. comm.). This is the result of the greater scouring effect of the increased tidal exchange.

Recent changes include an increase in the vegetated area on the southern tip of the sandspit and a setback of about 30 m along the beachfront to the north of the river mouth during the severe May 1984 storm (Dynamics of the Diep River mouth, 1988).

A maximum tidal range of 26 cm inside the mouth and 3,8 cm opposite the race course has been recorded, although the extent of tidal penetration varies with tidal phase, wind and rainfall (MED3, 1973).

Beaumont and Heydenrych (1980) believe that both littoral drift and the on/offshore movement of sand at the river mouth are of limited significance. Consequently they suggest that an activity such as dredging which would increase the volume of tidal flow in the estuary, might result in the mouth remaining permanently open.

The most detailed account of both mouth dynamics and the stability of the beach in the vicinity of the mouth is given in the report 'Assessment of Zonnekus Development' (1983). The importance of the remains of the old weir in protecting the tip of the peninsula and in restricting the influx of marine sediments was emphasized.

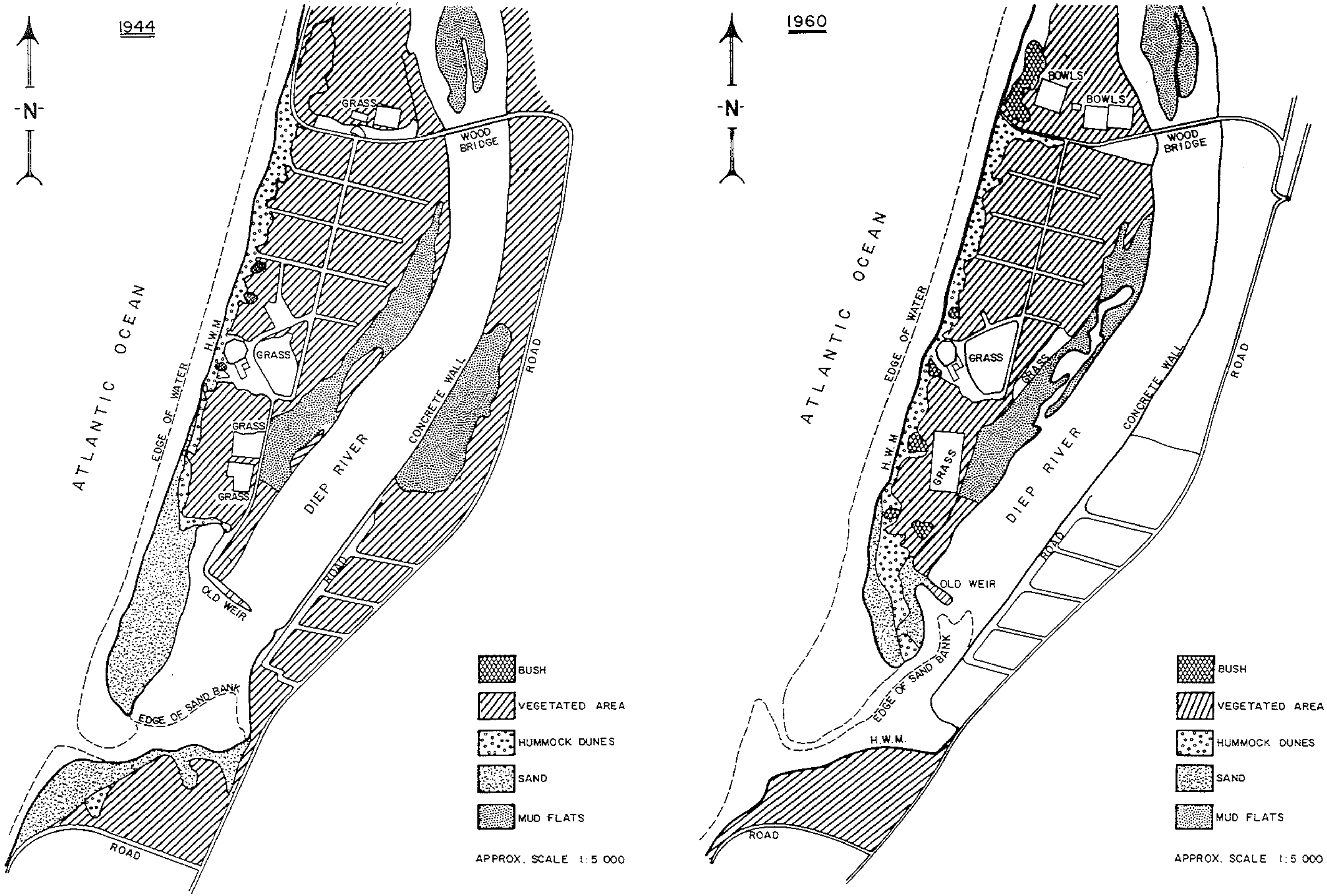


FIG. 14: Diep River mouth 1944 and 1960

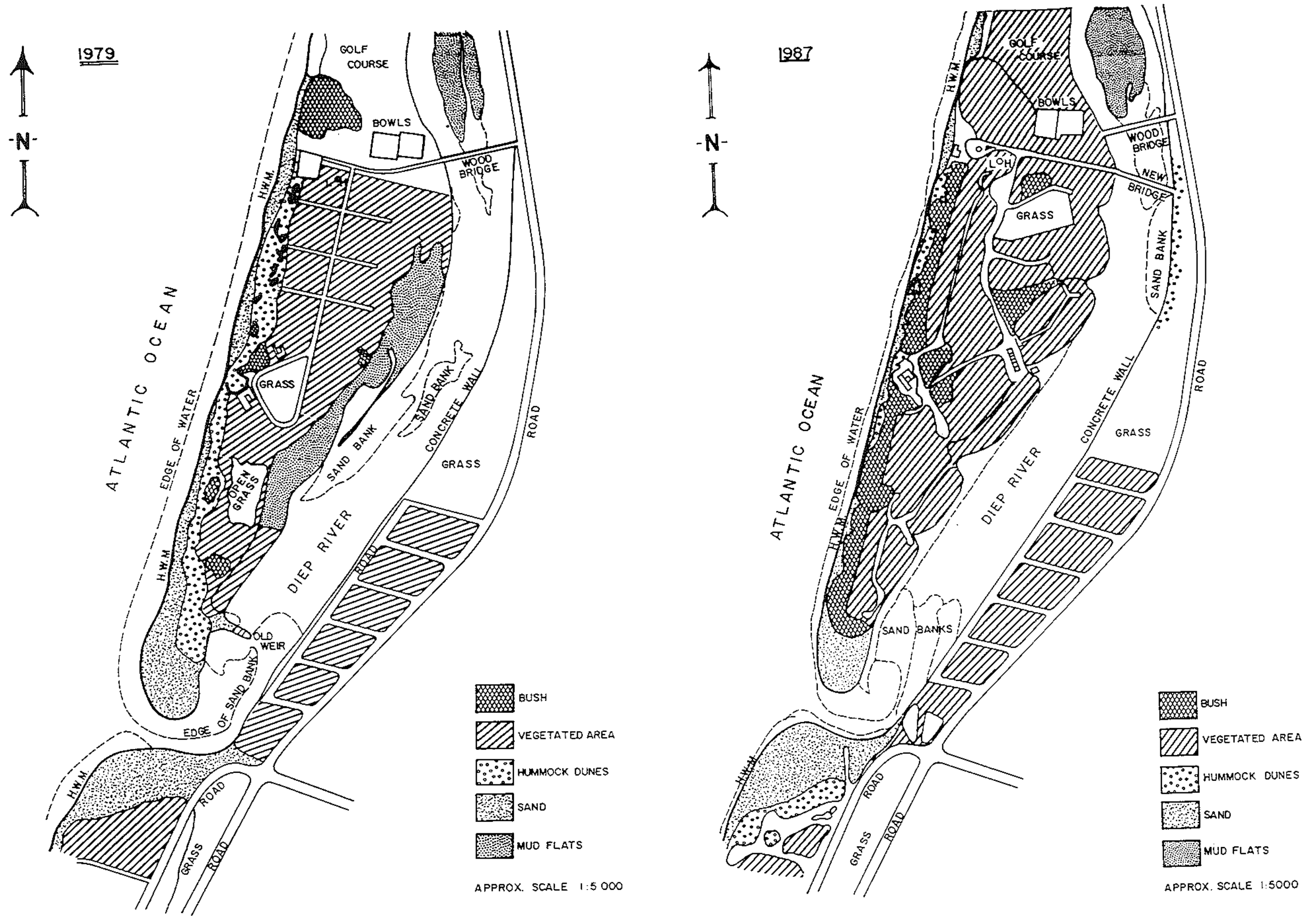


FIG. 15: Diep River mouth 1979 and 1987

3.2.6 Marine and Estuarine Sediments

Sand samples were taken in the mouth and on adjacent beach areas on three different occasions. The grain size distribution for the samples taken during 1985 indicate a non-uniform, fine sand while the samples taken on 5 June 1986 indicate poorly graded medium-coarse sand in the mouth area and well-graded medium sand to the south and north of the river mouth. Samples taken on 26 June 1987 show the sediment as being uniform, medium sand at the mouth and north of it. To the south of the mouth the sand was poorly graded and classified as medium-coarse. The difference in the sand grading and classification could be due to resorting of the sediment during stormy conditions and the added effect of sediment washed out of the estuary following the breaching of the mouth.

3.2.7 Wind and Aeolian Transport

Wind data obtained from Voluntary Observing Ships (VOS, Figure 17) indicate that south-easterly winds occur most frequently and have the highest velocity during the spring and summer months but may be as strong during autumn. During winter, north-westerly winds prevail and have the highest velocity although winds from the south/south-eastern sector occur almost as frequently but with lower average velocities. On average for the whole year south-easterly winds dominate at Milnerton.

The VOS data were analysed and an aeolian creep diagram (Figure 18) for the Diep River area deduced (Swart, 1986). These diagrams indicate how wind-blown sand would approach from different directions towards the centre of an imaginary circle on the ground.

The "all year" diagram enables the potential aeolian sand transport rate (cubic metres per year per kilometre) to be calculated for various wind directions. This indicates that during the drier spring and summer months as well as during autumn, the predominantly south-easterly winds cause a net sand movement towards the north-west. During winter the net potential aeolian sand movement occurs towards the south-east due to the prevailing north-westerly winds.

From the diagram showing the "all year" potential aeolian transport rate it can be deduced that a net movement towards the north-western sector occurs. Although a slight movement towards the north-eastern sector (inland) is indicated, the high mountains of the Cape Peninsula reduce the effect of the south-westerly winds and much less aeolian sand movement should therefore take place.

3.2.8 Land Ownership/Uses (Vlei/Estuary area)

The designated Rietvlei Nature Area (see Centrespread) is at present still owned in part by Milnerton Estates and in part by the South African Transport Services. Once established, the Nature Area will be managed by the Cape Provincial Administration's Chief Directorate of Nature and Environmental Conservation.

The eastern side of the estuary from Boundary Road to Racecourse Road is the Milnerton residential area; the area between Racecourse Road and the Milnerton Sewage Treatment Works is a designated recreational area and remains undeveloped in the immediate vicinity of the vlei. Milnerton Racecourse, a residential extension of Milnerton and the Milnerton Sports Club recreation fields border this undeveloped land; the sewage works occupy the land adjacent to the incoming Diep River, up to the Blaauwberg Bridge; east of the sewage works are a fertilizer factory and a petroleum refinery; the entire region north of the vlei

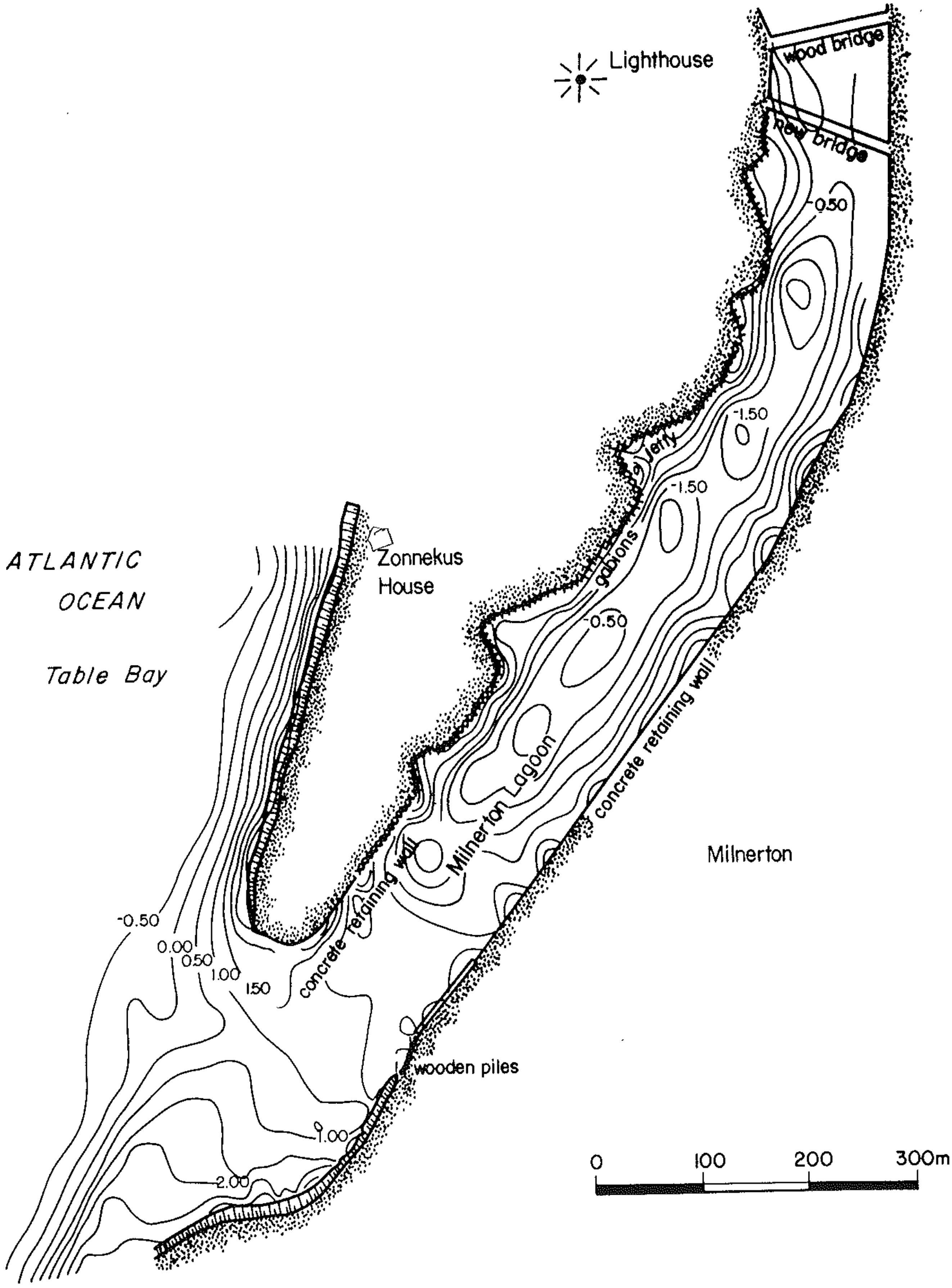


FIG. 16 : Bathymetry of Milnerton Lagoon, 26 June 1987

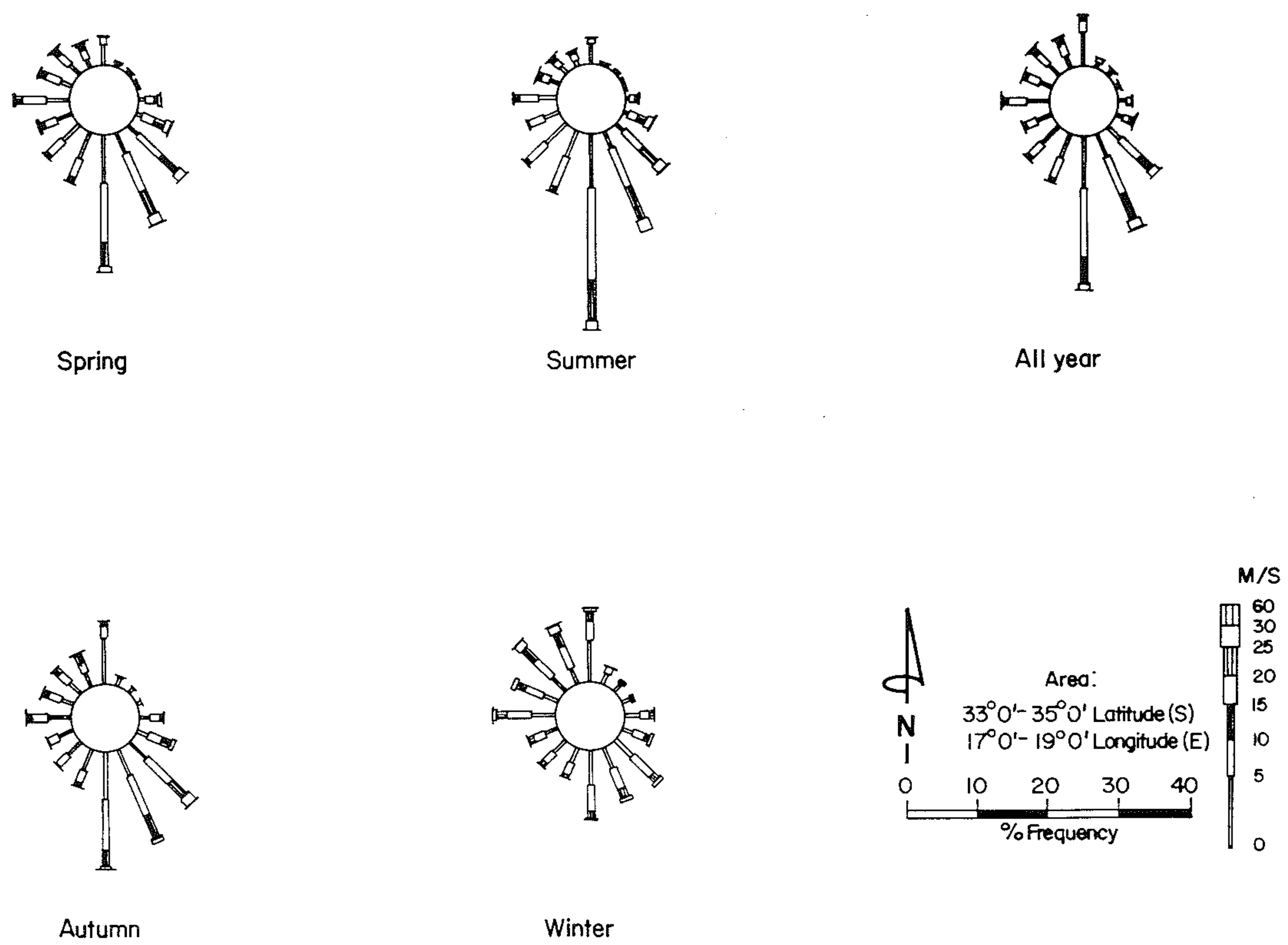
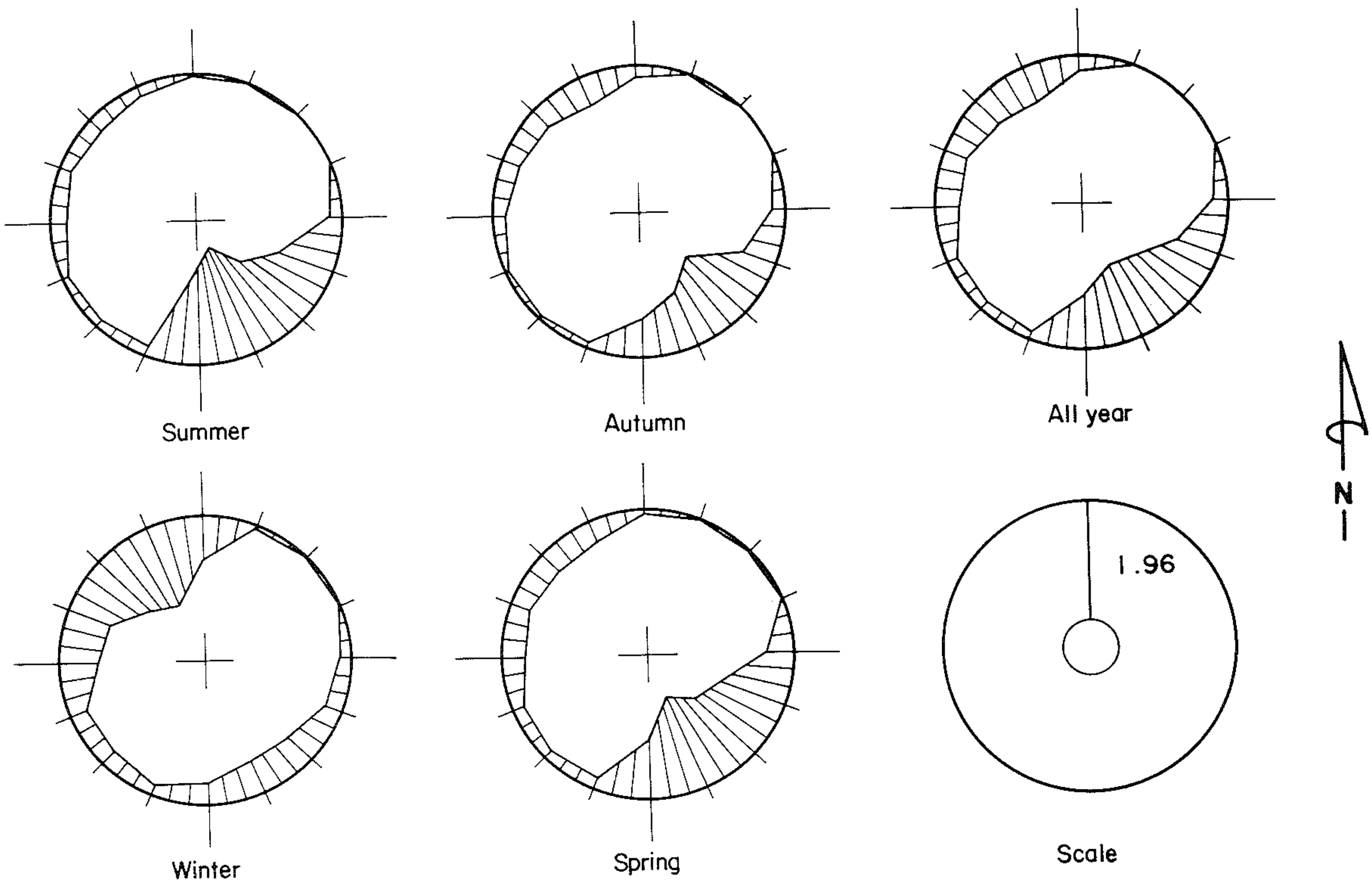


FIG. 17: Voluntary observing ship (VOS) wind roses



Aeolian transport rates are given in fractions of 10 000 cubic metres/year/kilometre with due cognizance for frequency occurence of wind events

FIG. 18: Aeolian creep diagram

consists of Table View residential area; the strip of land between the vlei and the sea southwards to the Otto du Plessis Bridge is undeveloped. The region to the west of the estuary between the Otto du Plessis Bridge and the Wooden Bridge is occupied by the Milnerton golf course; the tip of the peninsula south of the golf course, formerly known as Zonnekus, is now being developed as Woodbridge Island township (see Centrespread).

In 1971, Milnerton Estates engaged Hill Kaplan Scott (HKS), Consulting Engineers, to assess the feasibility of creating a marina at Rietvlei. HKS confirmed the technical feasibility of the general proposal, and a consortium of consultants was then appointed to investigate further the proposal and specific aspects of the design which could then be evaluated in terms of financial viability. This consortium (Hofmeyr and Leeson, Architects and Town Planning Consultants) designed five schemes and assessed their financial viability. Since some of the schemes had more than one variation, there was a total of 12 schemes to be considered (see MED Financial Viability Study, Reports 1-3, 1973).

A case study of alternative land-use options was undertaken for the Rietvlei/ Milnerton Lagoon area by Stauth (1983). The landowners, Milnerton Estates, were planning the development of an inland marina while the Government was investigating the desirability of proclaming a Nature Area to conserve the area for future generations. A decision to proclaim the Nature Area was made while the study was under way so the investigations were not completed.

Rowlands (1984), Stauth (1983) and Oberholzer (1977), have provided detailed analyses of recreational activities in the Rietvlei area. These activities include a variety of water sports in the dredged north-western part of the vlei, as well as model aircraft flying and trail bike riding on land in the vicinity. Other activities include birdwatching, walking and fishing. The estuary is used by the Milnerton Canoe Club and fishermen.

The Milnerton Municipality intends to infill a wetland area representing about 2 percent of the total area of the Rietvlei system. This is in the vicinity of the Milnerton Sewage Works and the adjoining sports foundation. The land is to be used for additional sewage maturation ponds and additional sports fields. The area in question is about 1 km long and 0,5 km wide on the landward (eastern) side of the region where the Diep River enters the Rietvlei system. Various ecologists opposed this but others, while accepting their arguments as valid, believed that there was no alternative.

3.2.9 Obstructions

The Blaauwberg Bridge crosses the Diep River upstream of Rietvlei. The Otto du Plessis Bridge crosses the lower reaches of the vlei. According to Beaumont and Heydenrych (1980) this narrow span bridge, with accompanying road embankment, forms a definite "boundary between the upstream flood absorption area and downstream channel whose flood characteristics are largely influenced by the nature of the sandbar across the river mouth" (Figures 19 and 20).

Other obstructions include the historic Wooden Bridge across the estuary recently declared a National Monument (Figure 19). The remains of the old weir were visible at the west bank of the estuary near the mouth until 1984. The weir was found to affect flow patterns at the mouth significantly (Assessment of Zonnekus Development, 1983). It had resulted in the development of a previously non-existent tip to the Zonnekus peninsula. Consequently it had caused the deflection of the mouth channel away from the peninsula towards the centre and south of the mouth area, with resultant shifting of mouth sedimentation to the east bank of the estuary and reduction in influx of marine sand.

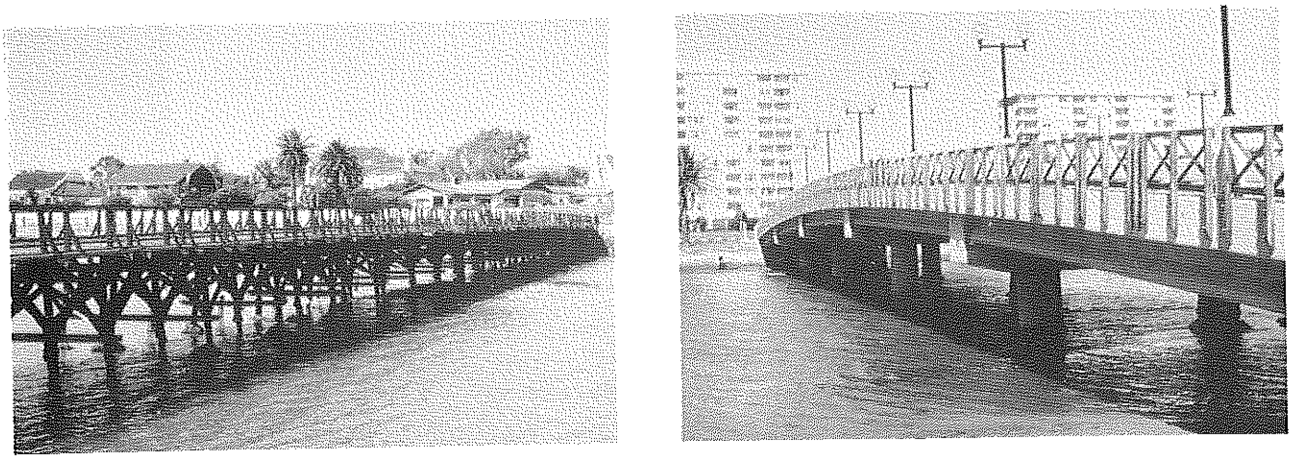


FIG. 19: The bridges linking Milnerton with the peninsula known as Woodbridge Island. **Left:** the old Wooden Bridge (now a National Monument) built by the Royal Engineers in the Nineteenth Century. **Right:** the attractive new concrete bridge built to provide access to the Woodbridge Island Development. (Photos: J R Grindley).

FIG. 20: Aerial view of the two bridges linking Milnerton with the Woodbridge Island pensinsula. The Wooden Bridge (1) lies upstream of the new concrete bridge (2). Note Milnerton Lighthouse and Golf Club in foreground. (Photo: ECRU, 87-11-01).

The new bridge (Figure 19) just downstream of the old Wooden Bridge was constructed in 1984 for the Harry Fuchs Investment Company, which initiated development of Zonnekus (now known as Woodbridge Island). This bridge should have no adverse effects on flow as the spans are larger than those of the old bridge (Assessment of Zonnekus Development, 1983).

Other possible obstructions include the proposed Atlantis railway crossing and the Diep River Dam. The dam will probably be sited near Platrug Farm above Vissershok (see Section 3.1.4).

3.2.10 Siltation

Rietvlei is flat and shallow, generally not more than 2 m deep when full. The exceptions are the artificially dredged basins in the north-west corner locally known as Flamingo Vlei north and south lakes, dredged to 9 m depth (Rowlands, 1984). The estuary (Milnerton Lagoon) is shallow and silted with the emergence of 'islands' in the summer when water levels are low (Nichols, 1977).

Millard and Scott (1954) described the bottom materials. Extensive silt deposition due to erosion in the catchment area has resulted in the substratum of both Rietvlei and most of the estuary being muddy. Cores taken from the bed show a layer of mud from 0,05 m to 0,25 m thick overlying firm, coarse sand. Towards the mouth the proportion of mud decreases, although Millard and Scott (1954) describe the substratum in the region of the weir as being a treacherous mixture of shifting sand and mud. Firm sand banks occur in the immediate vicinity of the mouth, with a delta near the east bank. A sand berm forms the mouth of the estuary. HKS (1971) provided details of soil profiles for 12 trial holes in the Rietvlei area and maps of soil types and coastal features.

3.2.11 Physico-chemical Characteristics

pH and Alkalinity

Table 1: pH values for period December 1947 to March 1951 (after Millard and Scott, 1954).

	Average	Range	No. of readings
Milnerton mouth (incl. old weir)	8,0	7,1-8,8	25
Milnerton Bridge	8,1	7,1-8,9	21
King George Fort	8,3	7,2-8,9	23
Race Course	8,2	7,1-9,2	19
Rietvlei	8,5	7,2-9,6	10
Blaauwberg Bridge	8,4	7,3-9,6	13
Vissershok	8,3	7,9-8,8	7

Maximum pH values obtained were 9,4 to 9,6 at Rietvlei and Blaauwberg Bridge when filled with reed in spring and early summer. Millard and Scott describe a general decrease in pH from 8,5 at Rietvlei to 8,0 at the mouth. They attribute this decrease partly to the buffering effect of the sea which had a pH value of approximately 8,0 near the mouth. There is a tidal variation near the mouth, with, for example, on 24 October 1950 a low/high-tide variation of 8,8/8,0. Strachan (1977) obtained pH values as low as 7,2 in the north-western corner of Rietvlei in April, and 7,1 just downstream of the sewage works.

Heydenrych (1976) measured alkalinity values (as $CaCO_3$) in Rietvlei in spring and early summer, and obtained a range from 100 mg/l to over 400 mg/l. These relatively high values, as well as the high pH, were attributed to the brackish waters of the Diep River and the geological structure of the catchment area. A drop in alkalinity appeared to occur shortly after discharge from the sewage works was stopped during the sampling period. There seemed, however, to be little effect on pH.

Table 2: Surface temperatures (oC) for the period 1948 to 1952. (N = number of records) (Millard and Scott, 1954).

	Minimum recorded	Maximum recorded	Range	Mean over total period	N
The sea	10,5	17,0	6,5	14,4	12
Milnerton Mouth	10,5	22,4	11,9	16,0	28
Milnerton Bridge	11,0	24,3	13,3	18,4	20
King George Fort	12,0	27,1	15,1	18,7	23
Race Course	12,0	31,5	19,5	21,3	19
Rietvlei	16,2	29,2	13,0	21,4	14
Blaauwberg Bridge	12,2	27,2	15,0	18,7	15
Vissershok	10,9	29,3	18,4	19,0	9

Table 3: Surface and bottom temperatures (oC) recorded between 14h00 and 15h00 in March (after Weil, 1974).

	Top	Bottom
Old weir	26	24,5
Milnerton Bridge	28	25
King George Fort	29	26
Race Course	29,5	26

Table 4: Diurnal temperature variation (oC) in Milnerton Lagoon on 10 March 1974 (after Weil, 1974).

	Time	08h00	10h00	15h00	18h00	22h00	24h00 (00h00)
Old weir	Top	20	24	26	24	23	22
	Bottom	20	22	25	24	23	23
Race Course	Top	17	25	28	25	23	19
	Bottom	16	23	24	25	23	19

The temperatures given in Table 2 were measured during daylight hours but at irregular intervals over a 4-year period. Thus while there is a general gradient between Vissershok and the mouth (with a slight increase in the vlei), this does not take into account variations according to whether the mouth is open or closed. Strachan's (1977) results show a similar trend to those of Millard and Scott (1954).

From a biotic point of view the temperature range at each site is a more significant factor than the mean temperature. The smallest ranges are found either in areas of deep water or in close proximity to the sea. This applies to both diurnal fluctuation and annual range. Diurnal variation is influenced both tidally and by atmospheric conditions. Weil (1974) measured higher surface temperatures near the mouth at low tide at 07h00 than at high tide at 13h00. This tidal effect becomes negligible in the upper reaches of the lagoon. Weil also suggests that in winter with the mouth open the lagoon water temperatures are largely influenced by the influx of marine and fresh water masses rather than by atmospheric conditions.

Both Millard and Scott (1954) (Table 2) and Weil (1974) (Table 3) measured higher temperatures at the water surface than at the bottom, with the maximum recorded difference being 4oC at the race course in March (Table 4).

Transparency

Table 5: Turbidity of the water. Figures represent the depth (cm) at which a 15 cm diameter Secchi disc disappears from sight (after Millard and Scott, 1954).

	Spring			Winter	Summer
	28.9.1949	23.10.1951		14.6.1950	4.12.1950
		LW	HW		
Vissershok	32,5	42,5		6,25	25,75
Blaauwberg Bridge	10	30		6,25	>15
Race course		25,0		10	
King George Fort	7,5	27,5	31,25	23,75	21,25
Milnerton Bridge	15	30		>55	20
Mouth area	60	45	111,25		240

Table 6: Surface chlorinities in parts per thousand.

Date		Milnerton Mouth (incl. Old Weir)	Milnerton Bridge	King George Fort	Race Course	Rietvlei	Blaauwberg Bridge	Vissershok
	12.01.48	22,7	23,4	26	45		6,0	
Mouth closed	24.02.48	27	31	32	119	dry	dry	dry
	30.04.48	30	31	32	82			
	21.06.48	19,0	4,5	1,0	0,8	0,7		
Mouth open	01.09.48	5,4	1,4	0,8	0,9		0,9	
	18.10.48	3,2	0,7	0,7	0,6		0,6	
	06.01.49	25	26	28	dry	dry	3,1	
Mouth closed	04.05.49	30	33	34	15,3		0,4	
	17.06.49	20,2						
	22.06.49	5,5	1,9	0,7	1,0	0,4	0,3	0,3
	09.08.49	4,7	0,9	0,8	0,8	0,8	0,8	0,9
Mouth open	28.09.49	19,5	3,9	0,9	0,9	0,9	0,9	0,9
	07.11.49	17,8	9,6	1,6	1,5	0,8	1,0	1,0
	05.12.49	20,0*	20,3	21,3*	11,4	dry	1,6	1,8
Mouth closed	14,02,50	31	33	38	198	dry	dry	dry
	12.04.50	31	33	33	193	dry	dry	dry
	14.06.50	10,2	6,9	2,6	1,4	1,1	0,8	1,0
	30.08.50	9,5		1,0		1,0		
	09.10.50	18,5		1,0*	0,9*	1,0		
Mouth open	24.10.50	11,9*	2,3*	1,1*	1,0*	0,8		
	26.10.50	7,4					1,0	1,1
	10.11.50					1,4		
	04.12.50	19,3	19,1	18,7	3,0	2,7	1,0	1,5
Mouth closed	14.02.51	24	25	28	138	dry		
	28.03.51	28	29	33	dry	dry	dry	dry
	04.05.51	10,1	5,4	1,7	0,9	1,1	1,0	0,9
Mouth open	10.08.51	1,2	0,7					
	17.09.51	19,0	2,3				0,7	
	23.10.51	13,4*	2,1*	0,9*	0,9*	0,9	0,8	0,9
Mouth open	20.08.52	1,5	0,5*	0,4	0,6	0,4		
Mouth closed	16.02.53			30				
Average: Mouth closed		27	29	31	113			
Average: Mouth open		11,4	5,2	3,5	1,8	1,0	0,9	1,0

* Represents a mean of low- and high-tide values, otherwise records were taken at varying states of the tide (from Millard and Scott, 1954).

Millard and Scott (1954) describe the river as being turbid and yellow-brown during the winter rains, with a Secchi disc reading of 2,5-7,5 cm. They report that the silt load is partially filtered by the reed beds and partially flocculated out by marine salts within the estuary. This explains the increasing clarity of the water towards the sea. While no recent turbidity measurements are available, siltation is reported to be steadily increasing (S Wood, pers. comm.).

Salinity

The most comprehensive survey of 'salinities' in the vlei/estuary system is that of Millard and Scott (1954). Unfortunately, since these authors measured chlorinity by means of titration with silver nitrate, conversion to salinity is not possible because of the varying proportions of different salts in the system.

The salinity/chlorinity conditions in the vlei/estuary system are highly variable, with a very large seasonal range. This is due to the opening and closing of the mouth in conjunction with the seasonal flow of the Diep River. The range is at a minimum at the mouth and increases to a maximum at the race course, where a chlorinity of 198 parts per thousand was recorded in February 1950 (Table 6).

Table 7: List of chlorinities taken at Milnerton in summer 1971/72 in parts per thousand

	22.12.1971	12.01.1972
Near Mouth	21,2	21,9
Below Old Weir	21,2	-
Above Old Weir	21,1	-
Old Road Bridge	21,5	-
Pump Station No. 2	20,5	23,1
Below Race Course	Below 19	-

Approximate conversion factor (refer to Section 3.2.11 *Salinity* for explanation)

$$\text{Chlorinity} = \frac{\text{Salinity} - 0{,}030}{1{,}805}$$

Remarks·
These values show no change from those of a comparable period of the previous survey (1948-51).

Table 8: Average surface chlorinities in parts per thousand taken at varying states of tide over four year-period (after Millard and Scott, 1954).

Mouth	Mouth (incl. Old Weir)	Wooden Bridge	King George Fort	Race Course	Riet Vlei	Blaauwberg Bridge	Vissershok
Closed	27	29	31	113	Dry	Dry	Dry
Open	11,4	5,2	3,5	1,8	1,0	0,9	1,0

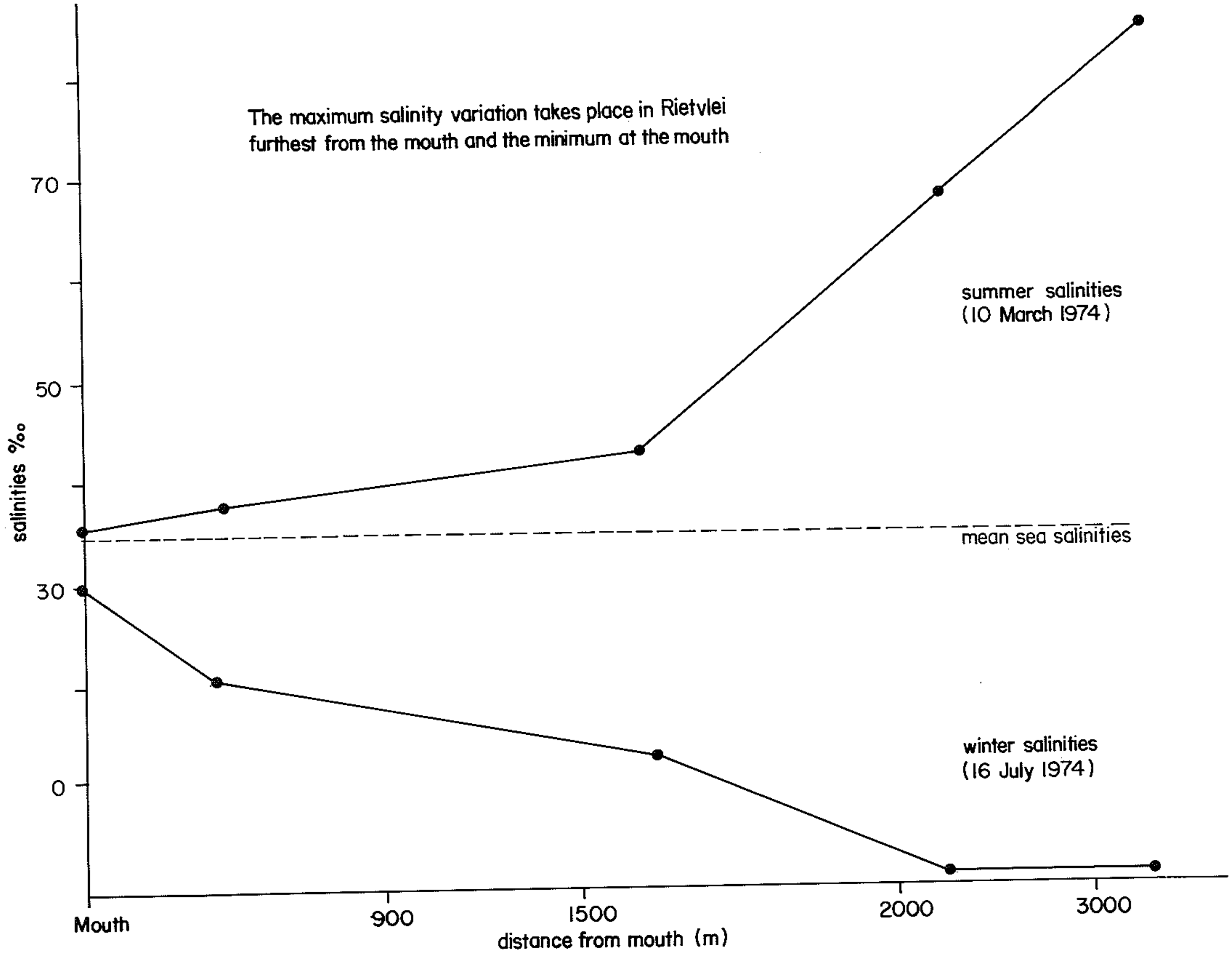


Fig. 21: Salinity values for Milnerton Lagoon showing seasonal changes (From Weil, 1974)

A maximum tidal rate of change in salinity was measured at 4,8 parts per thousand/hour within the estuary, although no tidal change occurred upstream of King George Fort. Seasonal rate of change is small, with the change from a winter minimum to a summer maximum being measured at 0,2 parts per thousand/hour (salinity).

During winter and spring the system shows a normal salinity gradient from fresh water at the head of the vlei to sea-water at the mouth. The picture is complicated slightly by the fact that salinities at Vissershok may be higher than those at the Blaauwberg Bridge (Table 8). This is due to two factors; firstly the Diep River itself is relatively high in sodium and chloride derived from the Malmesbury Shales of the catchment. Secondly, a low-salinity tributary enters the Diep River between Vissershok and Blaauwberg Bridge, thereby diluting the water. Millard and Scott (1954) suggest that the salt content of the Diep River and Rietvlei does not have a marine origin but comes rather from the catchment, although this situation may have changed somewhat in that sea-water was pumped into the dredged area to fill it (Strachan, 1977).

As the Diep River and Rietvlei dry up during summer, salinities rise due to evaporation, with a maximum chlorinity of 6 parts per thousand measured at Blaauwberg Bridge. Strachan (1977) records a salinity of 13 parts per thousand in April for the newly-formed permanent water bodies in the north-eastern corner of Rietvlei, although Rowlands (1983) measured only 2,5 parts per thousand in May.

A reversed salinity gradient develops in the estuary in summer (Figure 21). Evaporation leads to very high salinities, to the extent that occasional influxes of sea-water over the sandbar at high tide actually have a diluting effect. Maximum salinities occur in the race course region where salt crystalizes out in February and March.

Both Millard and Scott (1954) and Weil (1974) have measured vertical salinity gradients within the estuary in winter. The more dense sea-water tends to flow in along the bottom and the less dense fresh water flows out on the surface. This vertical gradient was only measured between the mouth and the Wooden Bridge; upstream of the bridge the salinity becomes homogeneous. This homogeneity is probably due to the shallowness of the water and to mixing by wind (Millard and Scott, 1954). No stratification occurs in the estuary in summer.

Chlorinity of Substratum

Millard and Scott (1954) surveyed the chlorinity of the substratum at representative sites within the vlei/estuary system. The chlorinity of the sandy substratum in the region of the mouth lay between the high and low tide values of the water. The maximum value recorded was 19,0 parts per thousand and minimum 8,0 parts per thousand, with chlorinity increasing with depth. In the muddy substratum of the upper estuary (King George Fort and the race course), salt crystalizes out on the surface in the late summer. Although chlorinities drop with the onset of the rains they are too high for much of the year to enable normal estuarine animals to survive.

Exceptionally high chlorinities (156 parts per thousand) have been measured in the substratum in Rietvlei itself. This seems to be restricted to the surface crust, with the underlying mud having a measured maximum of 11,3 parts per thousand, that is, within the tolerence range of brackish water species. During the winter the chlorinity of the substratum in the vlei tends to drop to 1-2 parts per thousand, similar to that of the water.

Dissolved Oxygen (DO) and Nutrients

Dissolved oxygen:

Heydenrych (1976) measured dissolved oxygen in Rietvlei over a 2-month period in September/October 1972. Initial values were in excess of 10 mg/l and represented levels of 150 percent of that of saturated water. Values then dropped to 5-10 mg/l, approximately 50 percent saturation. Heydenrych suggested that the high values indicated intense photosynthetic oxygen production, but no records are available of the time of day when tests were carried out. Another suggestion was that increasing summer temperatures caused an increased release of nutrients from the fermenting sludge layer on the bottom of Rietvlei. This would stimulate growth of aerobic bacteria causing a resultant drop in oxygen concentration (Marais, 1973 in MED3). According to Marais local increases in Heydenrych's oxygen data correspond to rainfall periods, suggesting increased turbulence and the inflow of well-oxygenated water.

A survey by Strachan (1977) in April revealed an area of oxygen-saturated water downstream of the sewage outfall while oxygen levels elsewhere in Rietvlei were below saturation. In the same region Strachan measured higher pH values and lower salinities than elsewhere. Furthermore a marked diurnal fluctuation was recorded in this area; 17,8 mg/l by day and 4,0 mg/l at night. Strachan suggests that this may be due to sewage effluent leading to excessive growth of algae.

Extensive records at the Milnerton Sewage Works show Chemical Oxygen Demand (COD) values ranging from 34 to 68 mg/l in various parts of Rietvlei and values varying from 35 to 74 mg/l opposite the sewage treatment works (Mr K Kenmuir, Milnerton Sewage Works, *in litt.*).

Table 9: Oxygen concentrations in Milnerton Lagoon (mg/l) (Weil, 1974).

	10 March (2-3 pm)		16 July (2-3 pm)	
	Top	Bottom	Top	Bottom
Mouth	-	-	8,0	8,0
Old Weir	6,0	5,0	8,1	8,2
Wooden Bridge	5,8	4,0	9,0	9,0
King George Fort	1,0	0,0	9,0	9,0
High School	3,0	1,0	9,0	9,0

The vertical gradient in summer in the upper estuary was predicted, although not measured by Millard and Scott (1954). The anoxic state of the bottom water at King George Fort (see Centrespread) will obviously limit animal life. However, no vertical gradient exists in winter.

Weil (1974) also measured the diurnal variation in dissolved oxygen in the *Ruppia* weed beds at the old weir in March. Not unexpectedly he found a peak at 14h00-15h00 which coincides with the period of maximum photosynthesis (Table 9).

An analysis of Rietvlei water quality by Strachan (1977) revealed that the central area of the vlei was supersaturated with oxygen during the day in May 1977. A mean value of 15 mg/l oxygen was recorded with a maximum of 20 mg/l oxygen. During the night values dropped to 4 and 5,4 mg/l. These values indicate excessive algal growth and some degree of eutrophication.

Nutrients:

Orthophosphate levels measured in Rietvlei in September and October 1972 varied from zero to 2 mg/l (Heydenrych, 1976). Nitrate-nitrite values ranged between zero and 0,3 mg/l, while Kjeldahl nitrogen was between zero and 190 mg/l.

Marais (1973 in MED3; Figures 6, 7 and 8) suggests that water from the Diep River is not a major source of organic and inorganic nutrient pollution. However, it is polluted by effluent (cattle droppings) from the surrounding dairy farms and Heydenrych (1976) states that nitrogen values within the vlei are relatively high with regard to limiting concentrations for eutrophication.

Du Plessis (1983) made a one-year (1980/81) study of dissolved nutrient loads in the Diep River catchment: sediments were not studied. Atmospheric N and P contributions were found to be significant even in the upper catchment (15 kg/ha/yr of N; 0,6 kg/ha/yr of P) and it is assumed that fumes from a fertilizer factory in Milnerton were responsible. Du Plessis also calculated the following nutrient loadings at the old road bridge below Vissershok: 135 000 kg/yr of N; 16 000 kg/yr of P; flow volume 15 000 m^3. From this an average annual concentration in the Diep River entering the lagoon was calculated: 8,9 mg N/l; 1,0 mg P/l.

Extensive records at the Milnerton Sewage Works (Mr K Kenmuir, Milnerton Municipality, *in litt.)* show ammonia N values ranging from 0 to 4,5 mg/l in various parts of Rietvlei. Kjeldahl nitrogen values in various parts of the Rietvlei system range from 0 to 21 mg/l. Nitrate values range from 0,4 to 40,00 mg/l. Nitrite values range from 0 to 0,85 mg/l. Orthophosphate values range from 0 to 12,0 mg/l. Although the normal chloride concentration of the treated effluent discharged from the sewage works is *ca.* 250 mg/l, chloride values in the Rietvlei system ranged from 168-16508 mg/l. The latter figure, from the upper reaches of Milnerton Lagoon, is not unexpected as the estuary is tidal. However, chloride values as high as 2947 mg/l have been obtained from Vissershok on the Diep River. These high levels are the consequence of leaching from the saline Malmesbury Formation soils.

It therefore, appears that the two major potential sources of organic and inorganic nutrients are the Diep River and Milnerton Sewage Works, even though Marais (1973 in MED3) suggested that the river was not a serious pollution hazard, although,if plans to build a dam in the upper catchment area materialize sometime in the future, the question of management of Rietvlei by releases would be compounded by the likely effect of impounded sediments and nutrients.

3.2.12 Pollution and Public Health Aspects

(Source of information: Regional Office: Department of Water Affairs, Cape Town).

Sewage, treated to the required relaxation from the General Standard, is discharged into the Diep River.

The operation of the so-called Potsdam sewage works and the conditions of discharge are governed by permit issued to the Municipality by the Department of

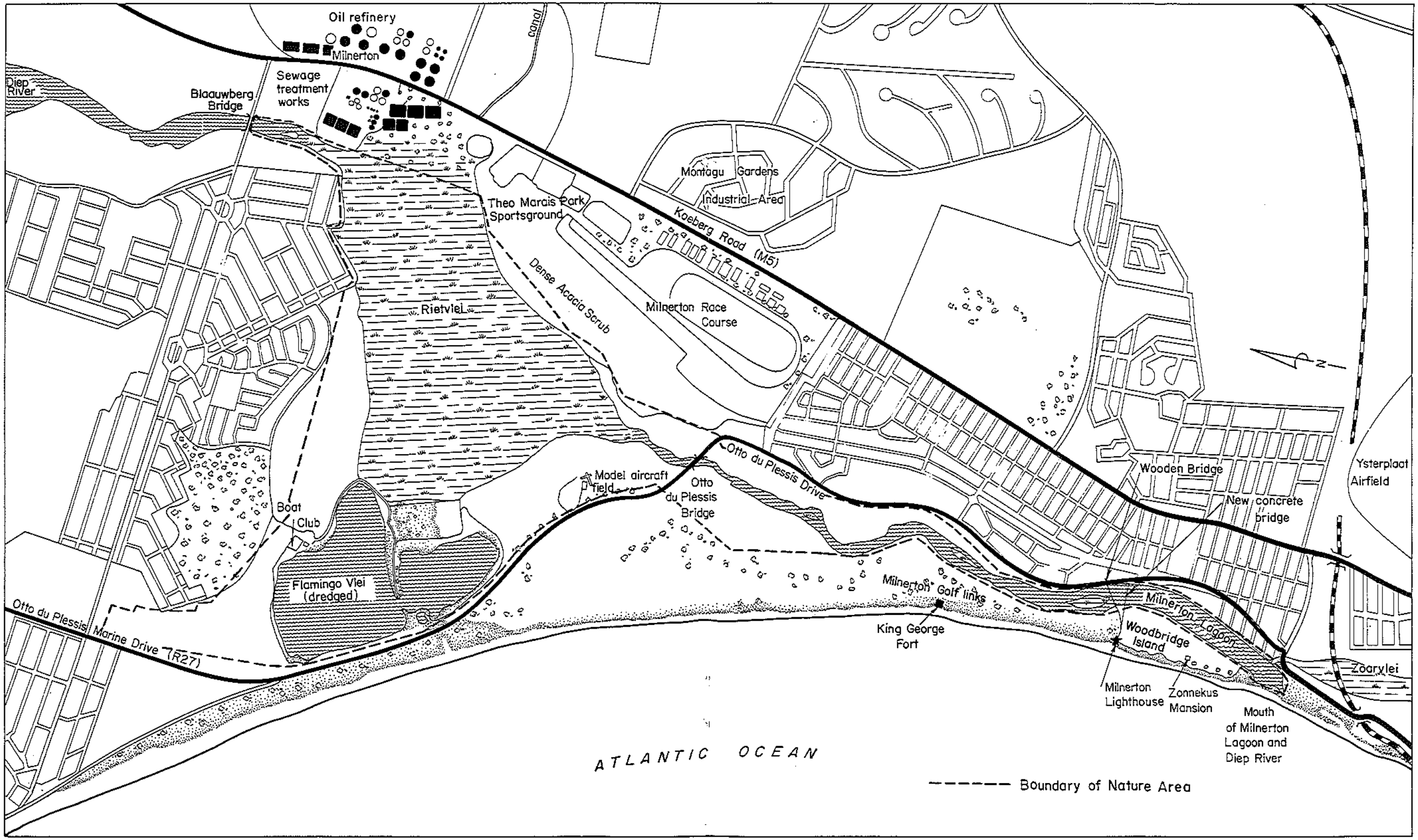
Water Affairs. In terms of this, an average daily dry weather flow of 26 000 m^3 may be disposed of as follows: by means of irrigation on the race course, golf course, sports fields and parks and gardens; by industrial re-use; the balance to be discharged to the Diep River. The municipal authorities are required to keep the discharge to the Diep River to a minimum. The standard of purity required is the General Standard but with a relaxation to allow 1 000 *E. coli* (Type 1) per 1000 ml (except for industrial re-use). A number of permit conditions control public use of the lagoon. It is required for example that ameliorative steps be taken by the Municipality if eutrophic conditions threaten or persist. In addition, the estuary must be regularly opened to the sea. The Department of National Health and Population Development requires continual (bacteriological) monitoring of the water sport area. At present (1987), the following table expresses the percentage of flow disposed of in different ways.

Irrigation of lands and ground *etc.*	16
Industrial re-use	0,0(2)
Discharge to Diep River	<84

The Milnerton Waste Water Treatment Works treats sewage received from the Cape Town City Council, Parow and Goodwood Municipalities and Blouberg Strand (Divisional/Regional Services Council). No separation of domestic and industrial flows takes place. The plant was originally built in 1958 and expanded in 1975 and again in 1987. The latter expansions are designed to bring the works to its full design flow of 23 000 m^3/day. The old works consisted of primary and secondary treatment including primary settling, biological filtration, humus removal and eventually maturation in ponds. There are three primary ponds of 5,5 megalitres each and five secondary ponds of 5,9 megalitres each. To this has been added two primary settlers, two biofilters and two humus tanks. The sludge treatment is the Zimpro one (Anon, 1986) converted from old digesters. About 50 percent of the sludge is treated using a dual digestion process which combines thermophilic aerobic digestion and anaerobic digestion in a two-step system. The process combines the advantages of a certain degree of pasteurisation and low energy requirements with additional unique advantages of process stability and reduced capital costs. The final product can be beneficially utilized in agriculture under controlled conditions without the threat of pollution of surface and underground water and without endangering the health of man and animals through exposure to pathogenic viruses, bacteria and parasites. The Municipality, under contract to the Water Research Commission, is currently investigating a new method of sludge treatment, involving oxygen injection and auto-oxidative conditioning, known as "dual digestion".

Samples of the effluent are analysed regularly for *Escherichia coli* and coliform bacteria counts. Figures (State Pathology Laboratory: first half of 1987) indicate a range in MPN/100 ml of 180 to >2 400 for coliform bacilli and zero to >2 400 for *E. coli,* with a median of about 500. The chemical purity (first half of 1986) was as follows: pH 7,3-8,2; ammonia as N 1,2-8,1 mg/l; COD 50-81 mg/l; chloride as cl 204-249 mg/l; DO supersaturated. For comparison Strachan (1977) presented values for the Diep River and Rietvlei revealing that coliform counts in the system were also >1 800 but *E. coli* counts were nil. Data confirm that coliform counts in the vlei system may be as high as 2 400 while *E. coli* counts are usually low, but may reach 1 800 at times (Mr K Kenmuir, *in litt.).*

Other potential pollution sources include a fertilizer factory and a petroleum refinery, both to the north-east of the vlei. The effluent pipeline from the fertilizer factory crosses the lagoon at the Wooden Bridge and enters the sea offshore to the north of the golf club. The effluent pipeline from the oil refinery passes through Table View residential area and discharges into the sea in deep water. Although the possibility of pipe rupture is remote, pollution



<u>CENTRESPREAD</u> : Rietvlei and the Diep Estuary (Milnerton Lagoon)

problems can arise because of storm water run-off to Rietvlei which could be rich in nutrients and hydrocarbons. This aspect is strictly controlled by both factories.

Air pollution originates from the fertilizer factory and the refinery (MED1). Stack emissions from the factory include phosphate dust, ammonium nitrate and nitrogen dioxide. The extent to which this aerial fall-out reaches Rietvlei is not known but Du Plessis *(loc. cit.)* has shown that the plume effects can be traced in the upper Diep River catchment, driven by prevailing SE winds.

The refinery emits both sulphur dioxide and hydrogen sulphide into the atmosphere (MED1, 1973). Pollution and public health aspects of the Rietvlei/ Milnerton Lagoon area are discussed by HKS (1971), MED1 (1973), MED3 (1973), Strachan (1977) and Stauth (1983).

In a study to assess the effects of polluted water entering Table Bay from the Salt River, Orren *et al.* (1981) concluded that the source of abnormally high nutrient levels on the shore at the mouth of the Diep River was probably the Salt River rather than the Diep River. These nutrients included phosphates, silicates, nitrates and nitrites.

4. BIOTIC CHARACTERISTICS

4.1 Flora

4.1.1 Phytoplankton/Diatoms

Phytoplankton in the Diep/Riet system has not been studied in detail but a number of genera of diatoms have been recorded in the course of zooplankton and other studies. *Skeletonema costatum* and *Coscinodiscus* have been recorded even in muddy fresh water. Sea-water coming in with the tide from Table Bay when the mouth is open is rich in diatoms and genera recorded included *Coscinodiscus, Rhizoselenia, Biddulphia, Thallassiosira* and *Skeletonema* (Grindley, 1957).

4.1.2 Algae

The filamentous alga *Enteromorpha intestinalis* appears along the water's edge in the Diep River in spring and becomes more abundant as summer advances. Towards the seaward side of the vlei algae appear among the other submerged plants, becoming abundant in early summer. They include *Hydrodictyon africanum* and species of *Spirogyra, Rhizoclonium* and *Oedogonium*. The charophyte *Chara stachymorpha* also becomes common in early summer. In the estuary or lagoon area algae such as *Enteromorpha, Cladophora, Ectocarpus* and *Lyngbya* fringe the banks; they form a thick blanket along the margin in the late summer when salinities are high. These algae are absent from the upper part of the estuary where the salinity becomes very high in summer but they can tolerate salinities from 0,8 to 38 parts per thousand (Millard and Scott, 1959).

4.1.3 Aquatic Vegetation

In the backwaters of the Diep River 'wateruintjies' *(Aponogeton* possibly *A. distachyos)* flourish, sometimes accompanied by *Cotula coronopifolia*. In the vlei as the water deepens, an abundance of plants with floating leaves appear. These are chiefly wateruintjies, *Aponogeton* sp.; with them and extending beyond them towards the middle of the shallow vlei are beds of submerged *Ruppia maritima* and *Zannichellia aschersoniana*. Beyond these the central part of the vlei has bare submerged mud banks. In the upper part of the estuary or lagoon there is a thick seasonal growth of *Ruppia maritima,* accompanied in places by *Zannichellia* *aschersoniana.* In late summer when salinities become high these submerged aquatics usually die back; *Ruppia maritima* dies back if the chlorinity rises much above 38 parts per thousand (that is, a salinity of 69 parts per thousand). *Zostera* is entirely absent from the estuary (Day, 1981). This is probably due to the extremely wide salinity range or excessive turbidity of the water (Stephens, 1929; Millard and Scott, 1954).

4.1.4 Semi-aquatic Vegetation

The marginal vegetation of the Diep River is affected by the brackish and temporary nature of the water, and tends to resemble that of Rietvlei rather than that of a fresh-water stream. Clumps of the rush *Juncus kraussii* accompanied by *Cotula coronopifolia*, Arum lilies, *Zantedeschia aethiopica*, the sedges *Scirpus maritimus* and *Cyperus textilis* occur here. The banks of Rietvlei are almost flat and marshy in winter with three broad zones of semi-aquatic vegetation round the vlei. The upper zone is characterized by plants typical of damp, brackish soil and is not very well marked, grading into the surrounding scrub. It includes *Juncus kraussii, Sarcocornia pillansiae, Sarcocornia natalense* and salt marsh grasses such as *Sporobolus virginicus*. *Triglochin elongatum* is also common. The *Sarcocornia* dominates the vlei once the water has disappeared, giving it a reddish colour. The middle zone includes belts of the sedges *Scirpus maritimus* and *S. littoralis* and they can form islands in the vlei itself when water levels drop. In places a thick sward of *Cotula coronopifolia* interspersed with *Triglochin bulbosa* and *Ranunculus trichophyllus* occurs. Towards the end of spring a tiny rush, *Scirpus venustulus*, and other plants such as *Cotula filifolia* become abundant in this zone.

In the estuary or lagoon the upper zone of vegetation covers the tops of the banks, and is only reached by the water during floods or at the highest tides. This zone is carpeted with Chenopodiaceae including *Salicornia meyeriana, Sarcocornia natalense* mixed with *Triglochin bulbosa*. The larger bushy *Sarcocornia pillansiae* interspersed with tufts of *Juncus kraussii* and the salt marsh grass *Sporobolus virginicus* occur on top of the banks. Below the banks the middle zone, uncovered at low water, is a mud-flat including dense beds of *Scirpus maritimus* but also includes some *Triglochin bulbosa* and *Cotula coronopifolia* (Millard and Scott, 1954). *Spartina* is absent (Day, 1981).

In recent years as a result of increased sedimentation from erosion in the catchment of the Diep River and possibly also because of higher nutrient levels resulting from releases of sewage effluent from the Milnerton Sewage Works dense beds of high reeds have developed in the north-eastern part of Rietvlei. These include *Phragmites australis* and *Typha capensis*. Another major change in the semi-aquatic vegetation has been the remarkable spread of the vlei grass *Paspalum vaginatum*. This grass now covers large areas of the mud flats with tussocks to the detriment of wading birds. *Scirpus nodosus* is common on the banks of the lagoon today. *Plantago carnosa* was not reported by Millard and Scott (1954) but appears commonly in the semi-aquatic marginal vegetation of Rietvlei today (J R Grindley, pers. obs.). Referring specifically to this invasion by *Paspalum vaginatum*, Longrigg (1985) in his 1984/85 Bird Count Report said:

> "The remarks made in the 1985 Cape Bird Club Rietvlei report about the environmental degradation of the area, still apply with even more force. The spread of the grass *Paspalum vaginatum* into the vlei and across the mudflats is little short of phenomenal. In spite of letters and promptings from the CBC (Cape Bird Club), nothing is being done by the authorities to remedy the situation. A total inertia seems to be pervading the responsible bodies which makes a mockery of the fanfares in the media two years ago when the proclamation of Riet-

vlei as a Nature Area was hailed as a great step forward for conservation. The last natural wetland of significance in the Peninsula is being allowed to die before our eyes, which is ironical as that year was the 'Year of the Wetland'."

4.1.5 Terrestrial Vegetation

The terrestrial vegetation adjoining the Diep River and Rietvlei has been extensively disturbed by human activities for centuries and is now dominated by alien Acacias over large areas. *Acacia saligna* (Port Jackson wattle) is the dominant species but *Acacia cyclops* (rooikrans) and *Acacia longifolia* (Long-leaf wattle) are also present. Several species of exotic Australian *Eucalyptus* trees are prominent in a number of areas. The undergrowth of the Acacia thickets where it exists is largely ruderal also including grasses such as *Avena barbata* (Mediterranean wild oat) and *Digitaria sanguinalis*, an annual grass common on open sand. *Chenopodium* species appear among the annual herbs. Prickly pear, *Opuntia ficus-indica* is another alien present in some places. However, being a largely sandy area, a wide range of sandveld wild flowers appear in the spring. Thus a considerable number of indigenous species do occur despite its disturbed nature.

The vegetation of the coastal dunes is predominantly indigenous and includes a wide variety of species from primary dune pioneers to the richer, more diverse plant community characteristic of dune slacks and sheltered areas behind the dunes. Only a few species of plants are adapted to the harsh environment of the primary dunes.

The dune pioneers include *Tetragonia fruticosa* (kinkelbossie), *Tetragonia decumbens* (klappiesbrak), *Eragrostis cyperoides* (steekriet), *Trachyandra divaricata* (hotnotskool), *Myrica cordifolia* (wasbessie), *Arctotheca populifolia* (seepampoen), the *Didelta carnosa* (duinegousblom), *Hebenstreitia cordata*, and others.

Areas which have been undisturbed for a substantial period of time are also indicated by the nature of the dune vegetation. Species such as *Sideroxylon inerme* (melkhout), *Euclea racemosa* (kersbos), the *Euphorbia caput-medusa* (vingerpol), *Carpobrotus edulis* (sour figs), *Nylandtia spinosa* (skilpadbessie), and *Pennisetum clandestinum* (Kikuyu grass) grow in the shelter behind the primary dunes.

In addition to those previously mentioned, *Chrysanthemoides monilifera* (bietou), *Metalasia muricata* (blombos), *Ehrharta villosa* (pypgras), *Stenotaphrum secundatum*, (coarse quick), *Antholyza ringens* (rotstert), and others occur. Particularly in the south some of the indigenous dune plants have been replaced by the introduced *Ammophila arenaria* (marram grass). Immediately behind the top of the dunes, thickets of *Metalasia muricata* (blombos), appear with their tops pruned by the salt spray. Behind this dense stands of the alien *Acacia cyclops* (rooikrans) have covered the landscape. Even rooikrans, when growing on the primary dunes is pruned by the salt spray to a low ground covering form with shrivelled ends to the leaves. In some areas behind the dunes *Myoporum serratum* (manitoka) flourishes.

4.2 Fauna

4.2.1 Zooplankton

Diep River

The plankton of the upper reaches of the Diep River is restricted in species but includes Entomostraca, Hydracarina, copepods and Chironomid larvae, Ostracoda, *Cypridopsis* sp., Cladocera, *Moina dubia, Simosa vetuloides* and *S. australiensis*. In spring most Cladocera disappear but *Simosa vetuloides* remains until water finally disappears in December or January.

Rietvlei

The fauna of Rietvlei is similar to that of other temporary brackish vleis of the Cape Flats, consisting of animals that appear, multiply rapidly, and settle down for the winter and spring, disappearing again as the water dries up. The Entomostraca leave resistant stages in the dry mud. There is a greater preponderance of Entomostraca in the vlei than in the upper reaches of the river. Copepods including Diaptomids, Cyclopoids and Harpacticoids are present throughout and the large Diaptomid *Lovenula* sp. is common. Cladocera include *Simosa vetuloides, Echinisca capensis,* Ostracoda species of *Stenocypris* and *Cypridopsis* and Conchostraca *Leptestheria rubidgei*. A group of species important in the wet period appear in June or July, show a rapid increase in numbers, and disappear again in spring. Most of the Cladocera and Ostracoda such as *Daphnia hodgsoni, D. propinqua, Moina brachiata, Megalocypris tuberculata, Isocypris priomena,* and *Pseudocypris testudo* behave in this way. *Macrothrix spinosa* persist until the water disappears.

Milnerton Lagoon (Estuary)

Conditions in the upper channel of the lagoon are extreme and the fauna is poor. A few minute Ostracods, species of *Cypridopsis* and *Stenocypris* and numbers of the Cladoceran *Moina brachiata* appear in autumn. These disappear by September or October and are replaced by other Crustacea including the estuarine amphipod *Afrochiltonia capensis*. Vlei species which appear are *Leptestheria rubidgei, Megalocypris d'Urbani, Isocypris priomena,* Copepods and Hydracarines. Most species begin to disappear from the upper channel towards the end of October when the water commences to dry up and salinities rise and the water become hypersaline.

The lagoon where water is always present shows a wide salinity range and this is reflected by the Cladocera present which include *Daphnia* sp., *Scapholeberis* sp., *Moina dubia* and *M. brachiata* and the Conchostracan *Leptestheria rubidgei*. The estuarine amphipods *Melita zeylanica* and *Afrochiltonia capensis* appear as well as the isopod *Exosphaeroma hylecoetes* and juvenile *Hymenosoma orbiculare* and the shrimp *Palaemon pacificus*. On sand near the mouth the isopod *Euridice longicornis* may be found. The marine isopod *Paridotea ungulata* and the marine amphipod *Exosphaeroma varicolor* appear near the mouth (Millard and Scott, 1954).

Zooplankton sampled in August 1957 in muddy brown fresh water on the surface contained *Cyclops* sp., *Diaptomus* sp. and *Pseudodiaptomus hessei*. On the bottom although the water was less than a metre deep, *Paracalanus parvus* was present. This suggests that there was a subsurface current of sea-water as *P. parvus* is not known from fresh water. A sample taken in the mouth, in green sea-water, with an incoming tide contained seven species common in the neritic marine plankton of Table Bay. These included *Centropages brachiatus, Paracalanus parvus, Paracartia africana, Oithona nana, Oithona similis, Saphirella* sp. and various Harpacticoida. Other zooplankton included the Foraminifera *Rotalia* sp. and *Globigerina* sp. a Siphonophore of the *Dinophyes* type and numerous Polychaete larvae.

Cumacea included *Iphinoe truncata*. Crustacean larvae included nauplii, crab zoaea, cypris larvae of cirripedes and megalopae of *Hymenosoma orbiculare*. Twenty-eight species of zooplankton have been recorded from Milnerton Estuary. Fish eggs, tadpole larvae of sea squirts (Ascidiacea) and among the Thalliacea, *Salpa* sp. were present. The fresh water component included the Cladoceran *Daph* *nia* sp., Ostracoda, the amphipod *Afrochiltonia capensis* and Hydracarines and *Diaptomus capensis*. (Grindley, 1957, 1972).

Weil (1974) found that the small amphipod *Afrochiltonia capensis* had a peculiar summer distribution frequenting low salinity areas together with *Melita zeylanica* but also appearing in hypersaline water. The only isopod represented in the lagoon was *Paridotea ungulata*. Examples of the shrimp *Palaemon pacificus* were recorded only in summer.

4.2.2 Aquatic Invertebrates (excluding insects)

The fauna needs to be considered separately for the different regions of this estuarine system.

Diep River

The Diep River contains Mollusca and Hydracarina, including the aquatic snail, *Tomichia ventricosa*. In spring the aquatic snail *Bulinus tropicus* largely replaces *Tomichia*. Fresh-water crabs *Potamonautes perlatus* are always present.

Rietvlei

In Rietvlei the animals survive the dry months in various ways including by aestivation, and the vlei is soon recolonized when it fills with water once more. The water snails *Tomichia ventricosa* and *Bulinus tropicus* may be extremely numerous.

Du Toit (1982) recorded two species of mollusc not mentioned by Millard and Scott (1954). Both were found near the yacht club, on the northern shore of the dredged area. According to Du Toit, a sandy beach has been created by wave action resulting from the prevailing south-westerly wind. The small burrowing bivalve, *Unio caffer,* was found in the wet sand. *Trachycystus rariplicata,* a small gastropod with a flat, coiled shell, was located among the pond-weed, *Potamogeton* sp.

Milnerton Lagoon (Estuary)

The upper channel of the lagoon contains a few snails (*Tomichia ventricosa* and *Bulinus tropicus*). Vlei animals become established in the estuary whenever conditions are suitable. Very few can stand the high salinities reached here but *Tomichia ventricosa* can aestivate in the lower layers of the mud. A few estuarine forms survive for almost the whole year. The most conspicuous is a Serpulid polychaete *Ficopomatus enigmatica* (formerly *Merciarella enigmatica*) whose colonies form mounds of calcareous tubes along the waterline on any solid object. Several small estuarine species find shelter among the worm tubes and also in the water-weed. These include *Melita zeylanica* which is common in summer and *Afrochiltonia capensis*. The isopod *Exosphaeroma hylecoetes* and the crab *Hymenosoma orbiculare* crawl over the mud.

Only one marine animal, the shrimp *Palaemon pacificus,* occurs in this upper part of the lagoon. A few *Hymenosoma orbiculare* and the isopod *Euridice longicornis* may be found here.

The lower part of the lagoon is deeper and wave action is quite strong when the mouth is open so the substratum changes from mud to sand and the sand prawn *Callianassa kraussi* is abundant. The sand banks are pitted with their holes. The damp muddy sand above the water edge harbours little animal life but a few minute polychaetes *Capitella capitata* and *Prionospio sexoculata* and an occasional oligochaete are found. Living in the same muddy sand are the isopod *Euridice longicornis* and polychaetes such as *Nerine cirratulus* var. *capensis* and *Nephtys capensis* in addition to *Capitella capitata*. *Hymenosoma orbiculare* is ubiquitous on or just below the surface and the minute estuarine snail *Assiminea* sp. can be common.

When the mouth is open, marine gastropods such as *Argobuccinum argus* and *Bullia digitalis* appear in the lower reaches of the lagoon. The fauna of the weed includes the estuarine species *Melita zeylanica, Afrochiltonia capensis,* young Hymenosoma orbiculare, Palaemon pacificus, Paridotea ungulata *and the nudibranch Hermaeina sinusmensalis*. The estuarine amphipod *Exosphaeroma hylecoetes* which is found in the upper parts is replaced near the mouth by the marine species

Exosphaeroma varicolor. The crab *Cyclograpsus punctatus* may appear on exposed stones overgrown with *Enteromorpha*. These stones also support the polychaete *Lumbrinereis tetraura, Helcion* sp., *Balanus algicola* and young *Choromytilus meridionalis*.

Weil (1974) surveyed the Milnerton Lagoon (estuary) area. He found the anthozoan *Anthothoe stimpsoni* as far up as the Wooden Bridge, and also the nemertine *worm Lineus olivaceus*. The nemertine preyed heavily on the *Ficopomatus enigmatica* colonies and in places appeared to be damaging the colonies extensively. Weil (1974) found that the amphipod *Afrochiltonia capensis,* described by Day (1974) as frequenting low salinity areas, was found in the extremely saline 'upper reaches' of the estuary in summer.

Millard (1972) reviewed the previous study of Millard and Scott (1954) and suggested that no great changes had occurred in the fauna or physical conditions since 1954. She pointed out that the estuary harbours a permanent population of invertebrates which is poor in species but rich in numbers. This fauna is very important as food for fish and wading birds. Most of the invertebrates live in the mud and sand of the banks or the bed or among water plants. Day and King (in press) simply refer to Millard and Scott (1954) and classify findings as "a typical but impoverished estuarine fauna". They also say that conditions within Rietvlei seem today to be similar to those described by Millard and Scott.

Currie (1979) stressed that the viability of the area depends upon the adaptation of its fauna to the seasonal flooding of the vlei in winter and its dry condition in summer.

4.2.3 Insects

Diep River and Rietvlei

Soon after the first heavy winter rains, the young stages of many insects appear in the Diep River: Corixids *(Micronecta* sp. juveniles); mayflies such as *Cloeon lacunosum, Centroptilum excisum* and *Austrocloeon africanum;* damsel-flies *(Ischnura* sp.) and Chironomids. A month later imagos of Micronecta are common, including *M. scutellaris, M. piccanin* and *M. gorogaiqua*. The mayfly nymphs, Chironomid larvae and Notonectids *(Anisops aglaia)* and Mosquito larvae *(Culex theileri)* appear. Other insects are Hydrophilid, Hydraenid and Dytiscid beetles and Tipulids *(Trimaera* sp.).

The number of species increases in spring, the dominant forms at that time being Notonectids, Corixids, mosquitoes and mayflies. Additional species then present are *Sigara meridionalis, S. contortuplicata, Plea piccanina, P. Pullula, Austrocaenis capensis* and *Pseudocloeon vinosum*. Damsel flies *(Ischnura senegalensis* and *Trithemis* sp.) and dragonflies *(Anax imperator)* are common and Simuliidae are present. Beetles now include Haliplids and Gyrinids in addition to those already mentioned. A few insects persist until the water finally disappears in December or January, but become less and less common. Shortly before the river dries up they will probably include *Simosa vetuloides* and *Austrocaenis capensis* in addition to those mentioned above.

In Rietvlei itself mosquito and Chironomid larvae occur as well as Hydrophilid and Dytiscid beetle larvae (and later imagos); the Corixid *Micronecta scutellaris;* the Notonectid *Anisops aglaia* certain dragonfly nymphs *(Crocothemis erythraea)*, and the mayfly *Cloeon lacunosum*. *C. lacunosum* is the only species of mayfly found in the vlei.

In summer a species of Staphylinid beetle belonging to the genus *Bledius* appeared on the mudflats. *Bledius* burrows in the exposed flats, with densities reaching 70 burrows per metre square within the dry *Ruppia* beds. Weil (1974) believes that this peak density may be due to the *Ruppia* both preventing compaction and providing aeration of the soil. The beetle, a detritus feeder, was never found at the water's edge or in muddy soil. The ground beetle *Pogonus lamprus* (Carabidae) was also associated with the lagoon. The Chironomid larvae of *Tendipes* were present throughout the entire length of the lagoon. A number of Dipteran larvae belonging to the genus *Eristalus* occur attached to the leaves of *Ruppia*. The water boatman *Sigara sjostedti* also occurred in the *Ruppia* beds as did the Hydrophilid beetle *Berosus spretus* (Millard and Scott, 1954).

Milnerton Lagoon (Estuary)

The estuary channel includes *Sigara meridionalis, Micronecta scutellaris, Cloeon lacunosum*, Hydrophilid and Hydraenid beetles and their larvae and Chironomid larvae. On 1 December 1947 in hypersaline water (chlorinity 40 parts per thousand) a few *Sigara meridionalis* and beetles were collected. Most insects disappear when salinities rise in summer.

Weil (1974) found that the Chironomid larva, *Tendipes* sp., was the only insect species of macrofauna present throughout Rietvlei in summer suggesting a very wide salinity tolerance.

In the region of Milnerton High School, Dipteran larvae of the genus *Eristalsus* were found attached to the leaves of *Ruppia maritima*. These larvae are apparently adapted to conditions of low oxygen tensions in that they possess two spiracles on the end of long tails which can be protruded above the water surface.

4.2.4 Fish

(Terminology follows Smith and Heemstra, 1986)

The fauna of the Diep River includes some fish but it is not as rich as that of permanent rivers such as the Berg. Fish include a few small specimens of the *punctifer* - form of *Galaxias zebratus* In the vlei the commonest fish is the southern mullet *Liza richardsonii*, which is abundant at most times of the year but shows a seasonal variation in size. Juveniles of the white steenbras *Lithognathus lithognathus* are usually commoner and reach a larger size than the young of the white stumpnose *Rhabdosargus globiceps*. These three marine fish probably enter the estuary as fry and grow there, but do not breed there, returning to the sea before maturity. Shoals of small fry enter the estuary when the mouth is open. Later in the season the fish are all larger, but none with ripe gonads has been taken in the estuary. The flathead mullet, *Mugil cephalus*, is present at times in the lower part of the lagoon, but is always less common than the other mullet. Juveniles of the Cape sole-*Heteromycteris capensis* have been found in the estuary. *Caffrogobius nudiceps* (barehead goby), *Atherina breviceps* (Cape silverside) and *Gilchristella aestuaria* (estuarine round-herring) are small marine species known to occur but *Psammogobius knysnaensis* (Knysna sandgoby) is the only true estuarine species. Three other species have been recorded including *Clinus superciliosus*-(super klipvis), *Pomatomus saltatrix* (elf), and *Rhabdosargus tricuspidens* - now *R. holubi* (Cape stumpnose) (Millard and Scott, 1954).

Talbot (1955) obtained 631 specimens of *Rhabdosargus globiceps* ranging from 29-98 mm in the Milnerton Estuary from April 1950 - June 1951. They appear to feed mainly on filamentous algae and chironomid larvae. The mullet *Liza richardsonii* feeds almost exclusively on attached diatoms.

G F van Wyk (CDNEC, *in litt.*, 1959) recorded that "springers" (mullet) were netted on 18 February 1959 at the farm Swellengift, near Kalbaskraal. Marine fish thus penetrate far up the Diep River. The area upstream of a small bridge over the river on this farm was described as being completely covered with sand, nearly up to the level of the bridge owing to siltation. A stagnant pool contained *Oreochromis mossambicus* (Mozambique tilapia).

Bell (1976) records four species of fish not mentioned by Millard and Scott (1954). *Chelidonichthys capensis* (Cape gurnard), has been reported from both the lower estuary and the dredged area of Rietvlei. *Caffrogobius saldanha* (commafin goby) has been taken in thrownets. A single unconfirmed specimen of the *Ophisurus serpens* (sand snake-eel), has been located in the sand at the mouth, and *Rhinobatos annulatus* (Lesser guitarfish or 'sandshark'), has been caught at the mouth and in the lower part of the estuary. Sylvester (1977) reported no additional species to those that Millard and Scott (1954) had recorded.

4.2.5 Reptiles and Amphibians

No detailed study of the amphibian and reptile fauna of the Rietvlei system has been undertaken. A check list of amphibians and reptiles likely to occur in Rietvlei and its environs has been compiled by A L de Villiers, Cape Department of Nature and Environmental Conservation (CDNEC) *in litt.* (Appendix V).

The common platanna *Xenopus laevis*, is seen fairly frequently in the area while the Cape river frog *Rana fuscigula* appears in quite large numbers under Blaauwberg Road Bridge but the spotted grass frog *Strongylopus grayi* is the most common frog in the area. The sand toad *Bufo angusticeps* has been seen on a few occasions and probably is quite common. Bell (1976) reports that the sand rain frog *Breviceps rosei* has been dug up in gardens.

Amongst the Lacertilia the marbled gecko *Phyllodactylus porphyreus* occurs commonly and the chamaeleon *Bradypodion pumilium* occurs in gardens and on the acacias. *Mabuya capensis*, the three-striped skink, is the commonest reptile in the area while the burrowing lizards *Scelotes bipes* and *Acontias meleagris* have been encountered. The molesnake *Pseudaspis cana*, is probably the most common snake in the area. Other snakes include the Cape slugeater *Duberria lutrix*, the African eggeater *Dasypeltis scabra*, the spotted skaapsteker *Psammophylax rhombeatus*, the sand snakes *Psammophis* spp. and the Cape cobra *Naja nivea*.

The angulate tortoise is common in the area (Bell, 1976 and A L de Villiers, CDNEC, *in litt.*). In addition the Cape terrapin *Pelomedusa subrufa* is likely to occur in Rietvlei.

4.2.6 Birds

The occurrence of large numbers of waterbirds at Rietvlei and other vleis in the vicinity of Cape Town has been of great interest to ornithologists for many years (Summers *et al.*, 1976, 1977). As early as 1938, the late Prof. G J Broekhuysen started research on migratory wading birds on the vleis. Studies were concentrated on Zeekoevlei, Rondevlei, Zandvlei, Rietvlei and the Black River wetlands. Detailed surveys of the birds in the Rietvlei area have been carried out by the Cape Bird Club since 1947 so that fluctuations in bird populations are well documented. Scott (1954) divided the Rietvlei avifauna into two basic groups, namely the birds of the reed beds and those of the mud flats. The birds appear when the vlei is full and by mid winter there is a large and varied population feeding in the vegetation. The birds of the mud flats include large flocks of Palaearctic waders throughout the summer months. Winterbottom (1960) stated that Rietvlei is the largest and most important of all the temporary vleis. During winter and until December the vlei is a major centre for ducks while from the time of their arrival until their departure on migration large flocks of migrant waders are present. Blaker and Winterbottom (1968) suggested that ecological conditions at Rietvlei had altered little since the earlier studies. They recorded 98 species of birds at the vlei and their census data showed that the total waterbird population had increased since the 1950s. The increase was suggested to be related to the deterioration of the other wetlands in the Cape Town area and particularly to the virtual destruction of Zandvlei. These changes are illustrated in Appendix VII.

Rietvlei serves as a major collecting and redistribution centre for duck at the start of the season. Thereafter the population scatters to numerous small marshes throughout the south-west Cape during winter. The 1975/76 report by the late Dr Currie indicates that Rietvlei is the largest and most important haven in the Cape Peninsula area for duck and for migrant and indigenous waders. Comparison of all the bird counts made in 1952 with those in 1982 reveals a marked increase. It is suspected that some of the additions have moved across from the bird sanctuary at Rondevlei. Bird counts for 1982 revealed 83 species and an average of 8 000 birds (D Longrigg, Cape Bird Club, pers. comm.).

The Cape Bird Club recorded the numbers of each species of bird present each month from January 1980 until April 1985. Full details will eventually be published by the Cape Bird Club. The birds present at Rietvlei, Milnerton Lagoon and the Paardeneiland vleis in summer 1975/76 were recorded by Summers, *et al.* (1976). On 8 November 1975 an estimated 5 000 migrant waders were present on the eastern shore. A fairly complete count on 4 December 1971 gave a migrant wader population of about 10 000 birds. South Africa is a contracting party of the 'Ramsar Convention on Wetlands of International Importance, especially as waterfowl habitat.' South Africa therefore has a responsibility to protect migrant waders which are already protected on their breeding grounds in the Northern Hemisphere (Summers, *et al.*, 1976; Cooper and Summers, 1976).

Counts of waders and other birds at the Rietvlei, Milnerton Lagoon and Paardeneilandvlei coastal wetlands in summer 1980 and winter 1981 are presented in in Appendix VI (Underhill and Cooper, 1982).

4.2.7 Mammals

No formal study of the mammal fauna of Rietvlei has been undertaken. A list of those species that occur or are likely to occur is presented in Appendix VIII. The most common mammals are the rodents in particular the Cape dune molerat *Bathyergus suillus*, the Cape molerat *Georychus capensis*, the Cape gerbil *Tatera afra*, the vlei rat *Otomys irroratus* and the striped field mouse *Rhabdomys pumilio*. In addition, industrial and residential development has brought with it those rodents associated with man namely the black and brown rats *Rattus rattus* and *R. norvegicus* and the house mouse *Mus musculus*. The small antelopes, hares and the small carnivores such as the genet and mongooses can be expected to become less common, if not extirpated, as a consequence of development encircling Rietvlei thus denying access to and from the rural areas to the north-east. The effect of isolation is further compounded by the presence of domestic dogs which pursue antelopes and hares. Unless Rietvlei is enclosed by a dog-proof fence such as that at Rondevlei in the Cape Peninsula there is little long-term prospect for most of the mammal species now present.

5. SYNTHESIS AND RECOMMENDATIONS

Present Status of the System

In its present state the Diep River/Rietvlei system can be divided into four clearly definable components:

- the catchment and Diep River down to its lower reaches where it enters the vlei system;
- the shallow areas of Rietvlei;
- the deeper dredged areas of Rietvlei;
- the truly estuarine reaches of the system, including Milnerton Lagoon.

While each of these components has its own management and conservation requirements, these must be considered together if management of the system as a whole is to be achieved. It is interesting also to note that, at the time of early European settlement of the Cape, the Diep River entered the sea through two mouths, one close to the present one and one where the Salt River now has its mouth. The two mouths were at the time linked by a deep channel which separated Paardeneiland from the mainland. Human activity during the past 300 years (including road and rail construction) has, however, led to extensive siltation and infilling of the Paardeneiland areas and the Diep/Rietvlei system now only has one mouth at the southern end of Milnerton Lagoon. Archaeological and geological evidence furthermore indicated that one or more direct channels connected the main body of the vlei with the sea in prehistoric times (see Section 3.2.2). In the present-day configuration of the system this is no longer of any significance. However, the deep prehistoric connecting channels were considered to be highly relevant when, in the 1960s, serious consideration was given to the construction of a fishing harbour and oil tanker berth at Rietvlei (see Section 2.2).

The significance of the Rietvlei system to Milnerton and the greater Cape Metropolitan area lies in the following:

- It is an ecologically functional system of substantial importance to both aquatic and bird life.
- It represents a natural "green belt" for Cape Town and also an aesthetic feature of very great value to this metropolitan area.
- It represents an exceedingly valuable recreational amenity suitable for a wide variety of sport and other recreational pursuits (see Section 3.2.8).
- It is a "biological filter" receiving treated effluents from the Milnerton Sewage Works, industry (mainly a fertilizer factory and a petroleum refinery), as well as storm water run-off from surrounding residential area.

While some of these uses are environmentally deleterious and conflicting in nature, it is nevertheless considered that the natural processes and aesthetic features of the system can be protected through the application of sound management techniques. To achieve this, an Interim Management Committee was established in 1981 and, after proclamation as a Nature Area in 1984, a permanent Management Committee in 1985 under the auspices of the then Department of Environmental Planning and Energy (now the Department of Environment Affairs). The strategy for the conservation of Rietvlei developed by this management committee is presented in Appendix IX.

Present State of Knowledge

As is the case with many "irreplaceable natural assets" in urban areas, real attention had never been focussed on the Rietvlei System as a whole, until 1953 when widespread concern arose about the proposed lagoon road (now the Otto du Plessis Drive), which was to cross the vlei. With the exception of mention of the freshwater aquatic vegetation of the vlei (Stephens, 1929) and a note on a whale buried on the Cape Flats (Gill, 1928) there is, as far as could be ascertained, no published scientific information on Rietvlei before the latter part of the 1950s, when Millard and Scott published their paper dealing specifically with the ecology of this system. The planning of a fishing harbour stimulated a considerable amount of work in the engineering and economic fields in the 1960s, *inter alia* that which revealed a direct former connection between the vlei and the sea. Concern about the effects of long-term erosion of the Milnerton coastline (which was accelerated by the extensions to Cape Town Harbour) has been highlighted by Swart (1986) and Heydorn, Geldenhuys and Swart (1985). Ornithologists have provided a good and continuing record of birds utilizing the system and this has led to greater appreciation of their habitat requirements (see Section 4.2.6). Stauth (1983) has provided a methodology for resource allocation plans affecting South African estuaries and this is highly significant in a system subjected to multiple use, such as Rietvlei.

It is clear that, despite the widespread concern voiced over a long period of time about the deterioration of the natural environment of Rietvlei, a comprehensive study of the system as a whole has not been conducted and this shortcoming manifests itself when it comes to the formulation of effective management plans. It is disturbing that no controlling authority has taken responsibility for initiating and co-ordinating such a study and it is considered vitally important that the present controlling authority, namely, the Cape Department of Nature and Environmental Conservation, should take the initiative in this regard.

Problems: Present and Forseeable

A number of serious problems, both present and forseeable are facing the authorities who are responsible for finding a meaningful balance between the utilization and conservation of this system.

Present problems are mainly concerned with:

(i) controlling, without stifling, the many forms of sport and recreational pursuits using the whole or components of the system;

(ii) encroaching urbanization in the immediate environs of the system, including the fragile dunes separating it from the sea;

(iii) associated with (ii) above the handling of stormwater run-off which tends to gravitate naturally into the system;

(iv) also associated with (iii) above, possible trends in long-term erosion of the Milnerton coastline as related to extensions to the Cape Town Harbour since the turn of the century;

(v) squatting and trampling as a result of increasing influx of unqualified and jobless people into the greater Cape Metropolitan area;

(vi) the disposal of industrial effluents, as already mentioned.

Future problems are likely to include all of those mentioned above. A major additional one is the proposed development of a dam on the Diep River which, even with careful planning, is likely to disrupt the natural cycle of flooding which is vital to the natural processes governing the Rietvlei System. For example, without periodic flushing the disquieting changes in the semi-aquatic and terrestrial vegetation described in Sections 4.1.4 and 4.1.5 respectively, are like to continue and they may even get worse. Associated with such changes are modifications to the range of habitats presently available and this is likely to have far-reaching ecological and aesthetic consequences.

Recommendations

Recommendations for both the conservation and management of the Rietvlei System must be seen in relation to past efforts in this regard. The first significant step towards managing the system with cognisance of the needs of conservation was taken in 1960 when the then Administrator of the Cape, Dr Nico Malan, agreed to the establishment of a Provincial Nature Reserve in the area. However, the joint efforts by the Cape Department of Nature Conservation, the Milnerton Municipality and Graaff's Trust were complicated at the time by various factors, the most serious of which was the plan to establish a fishing harbour at Rietvlei. Later marina and waterside housing proposals further delayed conservation plans. It was only in 1980 that progress was made when Mr Kent Durr, MP for Maitland, proposed that Rietvlei be declared a Nature Area in terms of the Physical Planning Act 88 of 1967. After some time this was followed by a decision in principle that the area be declared a Nature Area and that the then Department of Environmental Planning and Energy should acquire the Rietvlei area for conservation purposes in the eventual form of a Nature Reserve. It was furthermore considered that the Chief Directorate of Nature and Environmental Conservation would be the best controlling body for the proposed Nature Reserve.

The first meeting of an Interim Management Committee for the Rietvlei Nature Area was held on 28 January 1981 under the auspices of the Department of Environmental Planning and Energy. Consideration was immediately given to the determination of possible cadastral boundaries for the Rietvlei Nature Area.

While it would have been desirable to acquire the whole area including the dune areas with natural vegetation between the vlei and the sea, it was recognized that this would not be possible. Milnerton Estates, the land owner, were aware that the land constituted a valuable asset so the company would not be happy about the proposed reserve unless properly compensated. It was agreed that only the low-lying flood plain of the vlei be considered for conservation purposes. The primary area was agreed to be that from the mouth of Milnerton Lagoon to the Blaauwberg Road Bridge or preferably beyond. The recommended boundaries are shown on the Centrespread. The reservation of this land as a Nature Area was gazetted by the Minister of Constitutional Development and Planning on 23 July 1984 in Government Gazette No. 9345. On 30 May 1985 the Minister of Environment Affairs and Tourism appointed a permanent Management Committee for the Rietvlei Nature Area in terms of the Environmental Conservation Act 100 of 1982. The Management Committee immediately set about revising the broad objectives of a management programme and a strategy for the conservation of Rietvlei was accepted on 18 November 1985. This strategy is presented in Appendix IX.

For purposes of the present report all the recommendations contained in Appendix IX can be endorsed. In addition the severe environmental implications of the plans by the Department of Water Affairs to impound the Diep River need to be emphasized and it is suggested that the following clause be added to the strategy:

"While the importance of a State dam on the Diep River is recognized, no such planning should proceed without a thorough assessment of the potential environmental impacts, especially on the Rietvlei System, of such a dam. In particular attention needs to be given to the water releases, both low flow and flood flow, which would be required to maintain the Rietvlei system in a viable ecological state".

It is known that the Department of Water Affairs is deeply aware of its responsibilities towards the downstream environments of dams and the above clause is therefore in keeping with their approach.

There are details in the strategy which may be difficult to implement, e.g. the erection and maintenance of animal-proof fences to exclude domestic pets from the area. Such details need to be attended to by the executive authority, namely, the Chief Directorate of Nature and Environmental Conservation of the Cape Provincial Administration.

All in all the efforts to conserve the Rietvlei system as described above are to be applauded as it can truly be regarded as a "priceless natural asset" for Cape Town and the country as a whole. However, the absence of a comprehensive study which would provide a valid scientific baseline for decision-taking has already been highlighted and this is a matter which must be addressed urgently.

It is hoped that this report will contribute towards the achievement of a meaningful balance between effective utilization and conservation of the Diep River/Rietvlei system.

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Aerial Photographs

System	Date	Job No.	Photo Nos	Scale, 1:	Type	Source
Rietvlei	1938	126 38	11389 11402-05 11441-44 11454,55	25 000	B&W	Trig. Survey
	1944	61/44	761-65 768-70	20 000	B&W	Trig. Survey
	12.05.79	326	1032-34/5	10 000	Col.	Univ. of Natal
	01.04.80	348	55	20 000	B&W	Univ. of Natal
Diep	1938	126 38	11492-93	25 000	B&W.	
	1944	61/44	767,835-36	18 000	B&W.	Trig. Survey
	1980	348	53,54	20 000	B&W.	Univ. of Natal
	1972	898	498 24	30 000	B&W	Trig. Survey
	12.05.79	326	1035-38/5	10 000	Col.	Univ. of Natal
	Feb. 1987	-	238-45	10 000	Col.	ECRU/DEMAST
	Apr. 1988	-	-	10 000	Col.	ECRU/DEMAST

8. 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: orginating 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 the 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.

EDDY: 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.

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 saline 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.

ISOBATH: a line joining points of equal depth of a horizon below the surface.

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 to the shore.

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.

MEIOFAUNA: microscopic or semi-microscopic animals that inhabit sediments but live quite independently of the benthic macrofauna.

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.

OLIGOTROPHIC: poor in nutrients and hence having a paucity of living organisms.

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.

PERIPHYTON: plants and animals adhering to parts of rooted aquatic plants.

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

PHYTOPLANKTON: plant component 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 silica. 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.

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.

WAVE HEIGHT (average energy wave height): an index which reflects the distribution of average incident wave energy at inshore sites along the coast presented as a wave height.

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 component of plankton.

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APPENDIX Ia: Wetland Plant Species (Millard and Scott, 1954; Linder, 1979 and Carser, 1967)

FLOWERING PLANTS

Potomagetonaceae
Ruppia maritima L.
Zannichellia aschersoniana Graeber

Aponogetonaceae
Aponogeton angustifolius Ait.
Aponogeton distachyos L.f.

Scheuchzeriaceae
Triglochin elongatum Bucher.

Gramineae
Paspalum vaginatum Sw.
Polypogon sp.
Sporobolus virginicus Kunth.

Cyperaceae
Cyperus textilis Thunb.
Scirpus maritimus L.
Scirpus nodosus Rottb.
Scirpus venustulus (Koenth) Boeck.

Juncaceae
Juncus kraussii Hochst.

Araceae
Zantedeschia aethiopica Spreng.

Iridaceae
Romulea sp.

Chenopodiaceae
Salicornia meyeriana Moss.
Sarcocornia pillansiae Moss.
Sarcocornia natalense
Salsola sp.

Plumbaginaceae
Limonium sp.

Caryophyllaceae
Spergularia salina Presl.

Ranunculaceae
Ranunculus trichophyllus Chaix.

Scrophulariaceae
Limosella aquatica L.

Restionaceae
Chondropetalum tectorum

Plantaginaceae
Plantago carnosa

Compositae
Cotula coronopifolia L.
Cotula filifolia Thunb.

ALGAE
Cladophora sp.
Ectocarpus sp.
Enteromorpha bulbosa (Suhr.) Kützing
Enteromorpha compressa f. *complanata* Kützing
Enteromorpha intestinalis (L.) Link
Enteromorpha spp.
Hydrodictyon africanum Yamarouchi
Lyngbya sp.
Oedogonium sp.
Rhizoclonium sp.
Spirogyra sp.

CHAROPHYTA
Chara stachymorpha Ganterer

APPENDIX Ib: Terrestrial vegetation (Carser, 1967; Bell, 1975 and Grindley 1985 (pers. obs., 1986); Truran, 1982, Wright, 1982)

Acacia cyclops
Acacia longifolia
Acacia saligna
Agrostis bergiana
Albuca canadensis
Amaryllis belladonna
Ammophila arenaria
Antholyza ringens
Arctotheca calendula
Arctotheca populifolia
Aspalathus hispida
Avena barbata

Babiana tubiflora
Berkheya rigida
Brunsvigia orientalis

Carpobrotus acinaciformis
Carpobrotus edulis
Chondropetalum microcarpum
Chondropetalum tectorum
Chrysanthemoides monilifera
Conicosia communis

APPENDIX Ib: (Cont.

Cotula coronopifolia
Cotula turbinata
Crassula brachyphylla
Cynanchum africanum
Cynodon dactylon

Didelta carnosa
Digitaria sanguinalis
Dimorphotheca pluvialis
Dipogon lignosus
Drosanthemum floribundum

Ehrharta villosa
Erodium moschatum
Eucalyptus spp.
Euclea racemosa
Euphorbia caput-medusa
Exomis microphylla

Ferraria undulata
Fumaria muralis

Geranium molle
Gladiolus carinatus

Hebenstreitia cordata
Helichrysum metalasoides
Helictotrichon hirtulum
Hermannia ciliaris
Homeria aurentiaca
Homeria breyniana
Homeria ochroleuca

Inula graveolens
Ixia polystrachya

Juncus kraussii

Lachenalia sp.
Lactuca capensis
Lasiochloa echinata
Lasiochloa obtusifolia
Leptocarpus impolitus
Lepturus cylindricus
Lessertia capensis
Leucospermum hypophyllocarpodendron
Limonium scabrum
Lobelia alata
Lobelia setacia
Lycium afrum

Manulea tomentosa
Maytenus heterophylla
Metalasia muricata
Microloma sagittatum
Moraea sp.
Myrica cordifolia

Nemesia sp.
Nylandtia spinosa

Opuntia ficus-indica
Orphium frutescens
Oxalis compressa
Oxalis hirta
Oxalis obtusa
Oxalis pes-caprae
Oxalis purpurea

Passerina rigida
Passerina vulgaris
Pelargonium capitatum
Pelargonium myrrhifolium
Penisetum clandestinum
Phacocapros cracca
Phragmites australis
Podalyria sericea
Protasparagus sp.

Raphanus raphanistrum
Rhus mucronata
Rhus sp.
Romulea duthieae
Romulea rosea
Rumex acetosella
Ruschia tecta

Salsola sp.
Salvia africana-lutea
Scirpus maritimus
Sebaea albens
Senecio maritimus
Sideroxylon inerme
Solanum guineense
Solanum sodomaeum
Sparaxis grandiflora
Spergularis media
Spiloxene sp.
Stenotaphrum secundatum

Tetragonia decumbens
Tetragonia fruticosa
Thamnochortus spicigerus
Trachyandra divaricata
Trachyandra hirsutiflora
Triglochin bulbosa
Triglochin elongatum

Wachendorfia paniculata
Willdenowia striata

Zaluzianskya villosa
Zantedeschia aethiopica
Zygophyllum flexuosum
Zygophyllum morgsana

APPENDIX II: Invertebrate fauna of Rietvlei and Diep River (from Millard and Scott, 1954).

Group		Scientific Name
Polyzoa	Moss animal	*Lophopodella capensis*
Mollusca	Water snails	*Tomichia ventricosa*
		Bulinus tropicus
		Succinea sp.
		Trachycystus rariplicata
		Unio caffer
Crustacea		
Conchostraca	Water fleas	*Leptestheria rubidgei*
Cladocera	Water fleas	*Ceriodaphnia dubia*
		Ceriodaphnia sp.
		Daphnia hodgsoni
		Daphnia tenuispina
		Daphnia propinqua
		Daphnia spp.
		Echinisca capensis
		Macrothrix spinosa
		Moina dubia
		Moina brachiata
		Scapholeberis sp.
		Simosa australiensis
		Simosa vetuloides
Ostracoda	Water fleas	*Cypricercus cuneatus*
		Cypricercus episphaena
		Cypridopsis spinifera
		Cypridopsos sp.
		Eucypris capensis
		Eucypris spp.
		Heterocypris capensis
		Isocypris priomena
		Isocypris sp.
		Megalocypris durbani
		Megalocypris tuberculata
		Megalocypris princeps
		Megalocypris hispida
		Paracypretta acanthifera
		Paracypretta sp.
		Pseudocypris testudo
		Stenocypris hodgsoni
		Stenocypris spp.
	Freshwater crab	*Potamonautes perlatus*
	May flies	*Austracaenis capensis*
		Austrocloeon africanum
		Cloeon lacunosum
		Centroptilum excisum
		Pseudocloeon vinosum
	Dragon fly	*Ischnura senegalensis*
		Anax imperator
		Crocothemis erythraea
		Orthetrum sp.
		Trithemis sp.

APPENDIX II: (Cont.)

Group		Scientific Name
	Water bugs	*Anisops aglaia*
		Notonecta lactitans
		Plea piccanina
		Plea pululla
	Water boatmen	*Micronecta* sp.
		Micronecta gorogaiqua
		Micronecta piccanin
		Micronecta scutellaris
		Sigara contortuplicata
		Sigara meridionalis
	Beetles	*Berosus australis*
		Berosus pudens
		Berosus spretus
		Berosus punctulatus
		Berosus sp.
		Helophorus aethiops
		Helochares dilutus
		Hydrochus sp.
		Ochthebius extremus
		Bidessus aethiopicus
		Canthyporus sp.
		Herophydrus obscurus
		Herophydrus oscillator
		Hydaticus capicola
		Laccophilus cyclopsis
		Rhantus peringueyi
		Tyndalhydrus coriaceus
		Cybister tripunctatus
		Haliplus exsecratus
	Midges	*Trimicra* sp.
		Simulium nigritarsis
		Simulium ruficorna
		Stratiomys sp.
		Chironomus sp.
	Mosquito	*Culex theileri*

APPENDIX III: Invertebrate fauna of Milnerton Lagoon. Information from Millard and Scott (1954), Weil (1974), Du Toit (1982) and Day (1974).

Group	Common Name	Species
Anthozoa	Sea anemone	*Anthothoe stimpsoni*
Nemertinea	Ribbon worm	*Lineus olivaceus*
Nematoda	Round worm	*Lophopodella capensis*
Polyzoa	Sea-mats	*Membranipora* sp.
Mollusca	Black mussel	*Choromytilus meridionalis*
	Oyster	*Ostrea* sp.
	Limpet	*Helcion pruinosa*
	Whelk	*Argobuccinum argus*
	Plough shell	*Bullia digitalis*
	Estuarine snail	*Assiminea globulus*
	Estuarine snail	*Assiminea isosceles*
	Nudibranch	*Hermaeina sinusmensalis*
	Estuarine whelk	*Nassarius kraussianus*

APPENDIX III: (Cont.)

Polychaeta	Polychaete worms	*Scolelepis squamata*
		Prionospio sexoculata
		Lumbrinereis tetraura
		Nephtys capensis
		Capitella capitata
		Oridia parvula
		Nerine curviatulus
		Ficopomatus enigmatica
Oligochaeta	Oligochaete worms	Oligochaete indet.
Arthropoda	Barnacle	*Balanus algicola*
	Isopoda	*Euridice longicornis*
		Exosphaeroma hylecoetes
		Exosphaeroma varicolor
		Paridotea ungulata
	Amphipoda	*Afrochiltonia capensis*
		Melita zeylanica
	Shrimp	*Palaemon pacificus*
	Shore crab	*Cyclograpsus punctatus*
	Crown crab	*Hymenosoma orbiculare*
	Sand prawn	*Callianassa kraussi*
Insecta	Midge larvae	*Tendipes* sp.
		Chironomus sp.

APPENDIX IV: Common fish species (Millard and Scott, 1954; Bell, 1976).

Group	Common Name	Scientific Name
Pisces (Fish)	Elf	*Pomatomus saltatrix*
	Barehead goby	*Caffrogobius nudiceps*
	Knysna sandgoby	*Psammogobius knysnaensis*
	Super klipfish	*Clinus superciliosus*
	Southern mullet	*Liza richardsonii*
	Longnose pipe-fish	*Syngnathus acus*
	White stumpnose	*Rhadosargus globiceps*
	Cape silverside	*Atherina breviceps*
	Cape sole	*Heteromycteris capensis*
	Flathead mullet	*Mugil cephalus*
	Estuarine round-herring	*Gilchristella aestuaria*
	White steenbras	*Lithognathus lithognathus*
	Cape gurnard	*Chelidonichthys capensis*
	Commafin goby	*Caffrogobius saldanha*
	Sand snake-eel	*Ophisurus serpens*
	Lesser guitarfish	*Rhinobatos annulatus*
	Cape galaxias	*Galaxias zebratus* (*punctifer* form)
	Cape kurper	*Sandelia capensis*

APPENDIX V: Amphibians and Reptiles likely to occur in the Rietvlei/Milnerton Lagoon area (A L de Villiers, CDNEC, *in litt.*).

Key: T = threatened species listed in the South African Red Data Book. *X. gilli* is also listed in the Red Data Book of the International Union for the Conservation of Nature and Natural Resources.

APPENDIX V: (Cont.)

L = the **only** species still likely to survive in this area in its present disturbed state.

S = Species capable of surviving in suburbia. These are species that can adapt to gardens that contain ponds and/or are well vegetated but not too heavily cultivated. Species falling in this category survive under these conditions in much reduced numbers and snakes especially are often needlessly killed. Angulate tortoises, on the other hand, thrive in sheltered gardens where they can be fed on fruits and vegetables.

AMPHIBIA (frogs and toads)	T	L	S
Xenopus laevis - common platanna		x	x
Bufo angusticeps - sand toad		x	x
Breviceps rosei - sand rain frog			
Tomopterna delalandii - Cape sand frog		x	
Rana fuscigula - Cape river frog			x
Strongylopus grayii - Spotted grass frog		x	x
Cacosternum boettgeri - Common caco		x	
Cacosternum capense - Cape caco	x	x	
Kassina wealii - Rattling kassina			
Hyperolius horstockii - Arum frog	x		
REPTILIA			
(i) Tortoise and terrapin			
Chersina angalata - Angulate tortoise			x
Pelomedusa subrufa - Cape terrapin		x	
(ii) Lizards			
Phyllodactylus porphyreus - Marbled gecko		x	x
Bradypodion pumilum - Cape dwarf chameleon	x	x	x
Bradypodion ventrale occidentale - Namaqua dwarf chameleon	x		
Agama hispida - Spiny agama		x	
Acontias meleagris - Golden sand lizard		x	
Typhlosaurus caecus - Cuvier's blindworm		x	
Scelotes bipes - Silver sand lizard		x	
Mabuya homalocephala - Speckled skink			
Mabuya capensis - Three-striped skink		x	x
Gerrhosaurus flavigularis - Yellow-throated plated lizard			
Tetradactylus seps - Short-legged plated lizard		x	
Meroles knoxii - Ocellated sand lizard		x	
Chamaesaura anguina - Anguine lizard			
(iii) Snakes			
Typhlops lalandei - Delalande's blind snake		x	
Leptotyphlops nigricans - Black worm-snake			
Lycodonomorphus rufulus - Brown water snake		x	x
Lamprophis fuscus - Yellow-bellied house snake			
Lamprophis aurora - Aurora house snake		x	x
Lamprophis inernatus - Olive house snake		x	x
Pseudaspis cana - Mole snake		x	
Duberria lutrix - Slug-eater		x	x
Dasypeltis scabra - Common egg-eater			
Crotaphopeltis hotamboeia - Herald snake		x	x
Amplerhinus multimaculatus - Reed snake			

APPENDIX V: (Cont.)

	T	L	S
Dispholidus typus - Boomslang		x	
Psammophylax rhombeatus - Spotted skaapsteker		x	
Psammophis notostictus - Whip snake		x	
Psammophis leightoni - Leighton's sand snake			
Psammophis crucifer - Cross-marked sand snake		x	
Aspidelaps lubricus - Coral snake		x	
Homoroselaps lacteus - Dwarf garter snake		x	
Hemachatus haemachatus - Rinkals			
Naja nivea - Cape cobra		x	
Bitis cornuta - Many-horned adder			
Bittis arietans - Puff-adder			

APPENDIX VIa: Bird numbers in summer.

Counts of waders and other birds at coastal wetlands: Rietvlei, Milnerton Lagoon and Paardeneilandvlei (19 December 1980). Underhill and Cooper, 1982.

Name	Rietvlei	Milnerton Lagoon (Blind estuary)	Paarden-eilandvlei	Total
Great Crested Grebe	54	0	0	54
Little Grebe	0	0	20	20
White Pelican	9	9	9	9
Whitebreasted Cormorant	160	4	0	164
Reed Cormorant	9	24	1	34
Darter	9	9	9	9
Grey Heron	10	0	0	10
Purple Heron	1	0	0	1
Little Egret	9	4	2	15
Cattle Egret	21	0	2	23
Blackcrowned Night Heron	16	0	0	16
Yellowbilled Stork	1	0	0	1
African Spoonbill	8	0	0	8
Greater Flamingo	217	0	0	217
Lesser Flamingo	145	0	0	145
Egyptian Goose	30	2	0	32
African Shelduck	9	0	0	9
Cape Shoveller	211	0	51	262
Yellowbilled Duck	105	3	2	110
Redbilled Teal	57	3	3	63
Cape Teal	23	12	0	35
Southern Pochard	0	0	3	3
Blackshouldered Kite	5	0	1	6
Steppe Buzzard	1	0	0	1
African Marsh Harrier	1	0	0	1
Purple Gallinule	1	0	0	1
Moorhen	6	0	5	11
Redknobbed Coot	1 177	38	448	1 663
Painted Snipe	1	0	0	1
Black Oystercatcher	20	0	0	20
Turnstone	7	0	0	7
Ringed Plover	207	8	0	215
Whitefronted Plover	12	2	0	14

APPENDIX VIa: (Cont.)

Name	Rietvlei	Milnerton Lagoon (Blind estuary)	Paarden-eilandvlei	Total
Kittlitz's Plover	559	42	1	602
Threebanded Plover	13	3	2	18
Grey Plover	2	0	0	2
Blacksmith Plover	166	61	12	239
Ethiopian Snipe	15	3	0	18
Curlew Sandpiper	5 791	244	236	6 271
Little Stint	2 061	24	32	2 117
Knot	5	0	0	5
Sanderling	0	16	0	16
Ruff	662	5	28	695
Marsh Sandpiper	66	4	1	71
Greenshank	29	5	1	35
Wood Sandpiper	18	0	0	18
Whimbrel	1	0	0	1
Avocet	28	2	0	30
Blackwinged Stilt	38	7	6	51
Water Dikkop	1	2	0	3
Cape Dikkop	2	0	0	2
Kelp Gull	88	34	4	126
Greyheaded Gull	0	1	0	1
Hartlaub's Gull	209	254	12	475
Caspian Tern	15	1	0	16
Common/Arctic Tern	122	17	0	139
Sandwich Tern	123	19	0	142
Whitewinged Black Tern	4	4	7	15
Pied Kingfisher	18	4	1	23
Cape Wagtail	92	16	16	124
Total	12 670	868	897	14 435
Number of species	56	32	25	60

APPENDIX VIb: Bird numbers in winter.

Counts of waders and other birds at coastal wetlands: Rietvlei, Milnerton Lagoon and Paardeneilandvlei (26 July 1981). Underhill and Cooper, 1982.

Name	Rietvlei	Milnerton Lagoon (Blind estuary)	Paarden-eilandvlei	Total
Great Crested Grebe	14	0	0	14
Little Grebe	12	1	14	27
White Pelican	221	11	0	232
Whitebreasted Cormorant	19	8	10	37
Cape Cormorant	20	11	0	31
Reed Cormorant	38	4	31	73
Darter	26	0	5	31
Grey Heron	8	2	2	12
Purple Heron	4	0	0	4
Little Egret	5	5	0	10
Yellowbilled Egret	7	1	3	11
Cattle Egret	2	0	1	3
Blackcrowned Night Heron	1	0	0	1
Sacred Ibis	119	2	0	121
Glossy Ibis	8	0	0	8
African Spoonbill	11	33	0	44
Greater Flamingo	641	0	0	641
Lesser Flamingo	21	20	0	41
Spurwinged Goose	40	0	0	40
Egyptian Goose	83	3	0	86
African Shelduck	4	0	0	4
Cape Shoveller	266	45	16	327
Yellowbilled Duck	213	2	4	219
Redbilled Teal	239	0	0	239
Cape Teal	148	27	0	175
Southern Pochard	95	0	0	95
African Marsh Harrier	2	0	0	2
Purple Gallinule	1	0	1	2
Moorhen	5	0	4	9
Redknobbed Coot	2 946	319	182	3 447
Black Oystercatcher	0	1	0	1
Whitefronted Plover	0	5	0	5
Kittlitz's Plover	0	12	0	12
Threebanded Plover	4	0	1	5
Blacksmith Plover	83	16	2	102
Ethiopian Snipe	7	0	0	7
Greenshank	7	0	0	7
Wood Sandpiper	1	0	0	1
Avocet	43	15	0	58
Blackwinged Stilt	224	26	0	250
Kelp Gull	366	162	9	537
Hartlaub's Gull	1 020	370	88	1 478
Common/Arctic Tern	5	0	0	5
Whitewinged Black Tern	3	0	0	3
Pied Kingfisher	1	1	3	5
Malachite Kingfisher	3	0	0	3
Cape Wagtail	54	5	0	59
Total	7 040	1 108	376	8 5245
Number of species	44	26	17	47

APPENDIX VII: A comparison of the numbers of the more common birds found at Rietvlei, during the period April to March for
(i) 1952-1958 (from Winterbottom, 1960)
(ii) 1981-1982 (Rowlands, 1983)
with asterisk (*) denoting migratory birds.

BIRDS OF THE MUDFLATS

Bird \ Month		Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Little Stint*	i	0	0	0	0	0	62	51	560	485	226	68	10
	ii	183	11	0	2	170	586	1700	840	1700	620	580	260
Ruff*	i	0	0	0	0	51	358	91	700	424	33	1	0
	ii	125	2	0	1	330	400	700	550	650	1250	990	180
Avocet*	i	0	0	3	0	0	59	156	240	34	0	0	0
	ii	160	140	60	65	45	30	90	150	200	40	35	30
Stilt	i	0	264	130	98	47	49	48	97	59	0	1	0
	ii	73	629	500	224	228	33	122	54	26	2	5	6
Greenshank*	i	0	0	0	0	15	24	43	53	38	0	0	0
	ii	1	1	0	7	2	7	6	10	18	9	8	2
Ringed Plover*	i	3	0	0	0	0	0	0	30	110	55	200	43
	ii	21	0	0	0	0	3	23	23	120	94	113	58
Kittlitz's Plover	i	1	12	3	9	8	9	14	15	7	26	19	5
	ii	303	867	243	56	179	90	180	48	118	455	83	5
Blacksmith Plover	i	Only small numbers											
	ii	202	192	166	83	107	60	60	53	120	153	90	52
Curlew Sandpiper	i	0	0	0	4	0	260	140	757	1205	94	0	0
	ii	205	87	14	0	907	2172	2397	2950	2550	1086	719	377

APPENDIX VII: (Cont.)

	Bird \ Month		Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
BIRDS OF THE REEDBEDS	Redknobbed Coot	i	7	1	400	396	640	264	115	82	1	0	6	6
		ii	1388	1513	1276	2946	1026	1488	869	723	566	632	656	544
	Cape Shoveller	i	0	51	117	160	132	89	69	13	75	0	0	0
		ii	150	652	370	266	99	119	67	365	262	224	198	209
	Yellowbilled Duck	i	0	57	350	112	68	86	171	274	300	1	0	0
		ii	853	617	442	213	167	138	109	135	180	180	173	459
	Redbilled Teal	i	0	45	0	4	6	17	32	62	21	1	0	0
		ii	135	89	79	239	250	35	83	27	48	22	6	61
	Cape Teal	i	0	16	24	0	3	14	3	1	0	0	0	0
		ii	74	145	81	148	250	19	17	4	15	0	1	2
	Pochard	i	0	0	0	0	1	5	0	1	0	0	0	0
		ii	0	0	29	95	42	20	8	12	0	18	0	0
	Spoonbill	i		Not seen often										
		ii	3	10	1	9	43	3	10	21	80	36	7	5
	Greater Flamingo	i	1	40	1	0	0	14	48	70	30	1	0	1
		ii	685	817	1248	641	217	475	525	155	102	0	4	50
	Lesser Flamingo	i	9	0	0	0	0	0	5	0	0	0	0	0
		ii	1379	342	166	21	102	46	52	73	15	2	0	120
	Egyptian Goose	i	0	12	8	7	7	5	11	10	0	0	0	0
		ii	240	102	128	83	50	26	38	152	468	186	212	245
	Crested Grebe	i	Found predominantly at Rondevlei											
		ii	4	10	12	14	29	24	33	8	2	4	5	7

APPENDIX VII: (Cont.)

Group	Bird	Month	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
MARINE BIRDS AND SCAVENGERS	Blackbacked Gull	i	8	21	7	8	13	0	3	2	1	2	17	120
		ii	147	82	182	366	76	62	40	140	71	50	283	941
	Hartlaub's Gull	i	0	5	10	22	49	25	11	2	0	0	0	0
		ii	44	45	61	1020	2116	3147	3598	309	224	274	195	105
	Pied Kingfisher	i	0	1	1	1	0	0	0	0	0	0	0	0
		ii	2	7	4	1	3	8	2	9	11	3	4	1
	Reed Cormorant	i	0	0	2	5	2	0	2	2	0	0	1	0
		ii	39	36	58	38	17	7	9	11	11	61	51	78
	Cape Cormorant*	i	Found occasionally at Rondevlei											
		ii	0	0	0	20	0	5	0	0	6	8	4	15
	Darter	i	Found occasionally at Rondevlei											
		ii	12	45	21	26	10	32	3	5		6	6	8
	Grey Heron	i	8	3	5	1	4	6	9	8	34	11	11	1
		ii	17	31	9	8	14	6	8	10	19	16	8	5
	Yellowbilled Egret	i	21	4	3	2	4	6	12	7	15	3	0	0
			3	2	6	7	6	1	0	5	5	6	5	8
INSECT HAWKING BIRDS	Little Egret	i	0	0	0	0	1	2	3	8	10	3	2	1
		ii	8	4	4	5	3	13	22	17	13	17	10	6
	Cape Wagtail	i	10	9	14	5	9	1	5	5	4	6	6	6
		ii	69	77	89	54	45	51	51	30	46	26	36	25
	Sacred Ibis*	i	Only occasionally seen, but not counted											
		ii	11	34	24	119	43	15	0	0	1	6	6	4
	European Swallow*	1	4	7	3	3	2	2	4	4	3	3	2	6
		ii	10	0	0	1	1	0	0	53	138	320	3000	106
BIRDS OF PREY	African Marsh Harrier	i	1	1	2	1	2	3	1	2	4	1	0	0
		ii	0	1	1	2	1	2	1	1	1	2	1	1

APPENDIX VIII: Mammals occurring or likely to occur in the Rietvlei/Milnerton Lagoon area (after Bell, 1976; Stuart *et al.*, 1980 and P H Lloyd and N G Palmer, Cape Department of Nature and Environmental Conservation, *in litt.)*.

Common Name	Scientific Name
Forest shrew	*Mysorex varius*
Giant musk shrew	*Crocidura flavescens*
Cape hare	*Lepus capensis*
Scrub hare	*Lepus saxatilis*
Cape dune molerat	*Bathyergus suillus*
Cape molerat	*Georychus capensis*
Cape gerbil	*Tatera afra*
Vlei rat	*Otomys irroratus*
Bush Karoo rat	*Otomys unisulcatus*
Grey pygmy climbing mouse	*Dendromus melanotis*
House mouse	*Mus musculus*
Black rat	*Rattus rattus*
Brown rat	*Rattus norvegicus*
Striped field mouse	*Rhabdomys pumilio*
Cape grey mongoose	*Herpestes pulverulentus*
Yellow mongoose	*Cynictis penicillata*
Water mongoose	*Atilax paludinosus*
Cape fox	*Vulpes chama*
Egyptian fruit bat	*Rousettus aegyptiacus leachi*
Cape seroline bat	*Eptesicus capensis*
Horseshoe bats	*Rhinolophus* spp.
Duiker	*Sylvicapra grimmia*
Steenbok	*Raphicerus campestris*
Grysbok	*Raphicerus melanotis*
Porcupine	*Hystrix africaeaustralis*
Genets	*Genetta* spp.

APPENDIX IX: Rietvlei: A strategy for conservaiton of a priceless natural asset

The broad objectives of the management programme of this important vlei and its wetlands, now completely surrounded by urban development are:

1. To maintain and restore, where necessary, the essential ecological processes and life-support systems on which the survival of the fauna and flora of this vlei depends.

2. To preserve as far as possible the diversity of fauna and flora occurring within the proclaimed nature area.

3. To encourage the return of those species which were once found here, and have subsequently disappeared due, either directly or indirectly, to human activity and to endeavour to re-introduce other nature species which no longer occur in the area.

4. To maintain the environmental quality of the vlei and its wetlands as habitat for wildlife and as feeding, resting and breeding grounds for both migrant and resident species of birds.

APPENDIX IX: Cont.

5. To develop the nature area with due regard to the objectives listed above and also enhance the aesthetic and recreational values of the vlei to meet the needs of residents and visitors alike and so improve the quality of life.

In order to attain these objectives the following actions will have to be included in the management plan:

1. The consolidation of the nature area by the acquisition of adjoining land to conform as far as possible with natural boundaries or to include natural elements (e.g. springs, swampland etc.).

2. The fencing of the area to exclude domestic animals, principally dogs and cats and to control access by humans.

3. The planned, progressive eradication of alien vegetation both terrestrial and aquatic, bearing in mind the need to retain shelter belts and cover.

4. The progressive planting of indigenous trees and shrubs.

5. The control of the invasion of the grass *Paspalum* over the mudflats and of the reed beds at the upper end of the vlei resulting from the changing regime.

6. The removal of all refuse dumps and litter from the nature area and surroundings.

7. The judicious "landscaping" of all borrow pits, old roads, and other scars of human activity, in such a manner as to retain natural features of the area.

8. The preparation of a landscape plan including the planting of natural vegetation as habitat for birds, shelter and a source of food for birds, or for aesthetic and recreational purposes, such a plan must include the restoration of the diversity of aquatic features required as environment for birds viz. permanent water, mud flats, island, roosting and breeding areas etc.

9. The planning of public access for nature walks, by means of hiking trails parking ramps, or hides.

10. The provision of accommodation for a resident warden and rangers appointed both for management of the reserve and control of the public, as well as an information centre.

11. The reduction of disturbance by regulations relating to the use of aircraft over the reserve, and within the reserve by regulating the activities of visitors e.g. lighting of fires, use of transistor radios, trail bikes, model aircraft, etc.

Although it is envisaged that the reserve will be managed by the Provincial Nature Conservation Department, the formulation of a policy on which management is based is the responsibility of this Committee which is advisory to the Minister of Environment Affairs and Tourism. (now the Minister of Environment Affairs and Water Affairs).

APPENDIX X: Guide to available information

ESTUARY / RIVERMOUTH / LAGOON: DIEP/RIET

Guide to available information			Acocks	Alsopp and Kolbe	Anon	Assessment of Zonnekus Dev	Beaumont	Beaumont	Beaumont	Beaumont and Heydenrych	Beaumont and Rosenthal	Bell	Blaker and Winterbottom	Boycott	Brooke	Bulpin	Burman	Cape of Good Hope Procl	Cape Provin Admin	Carser
YEAR (DATE OF INFORMATION)			1975	1965	1986	1983	1971	1972	1979	1980	1971	1976	1968	1976	1984	1980	1970	1972	1967/8	1967
MANAGE - MENT		Historical															*			
		Conservation/Utilization							*									*		
		Management/Planning																*	*	
		Legislation																*		
		Water																		
BIOTIC	Food webs/Ecosystems																			
	Fauna	Mammals										*			*					
		Birds										*	*							
		Reptiles										*								
		Amphibians										*		*						
		Fish																		
		Molluscs																		
		Crustaceans																		
		Other aquatic invertebrates																		
		Terrestrial invertebrates																		
		Zooplankton																		
	Flora	Terrestrial vegetation	*																	*
		Semi-aquatic vegetation																		*
		Aquatic vegetation																		
		Algae																		
		Phytoplankton																		
	Microbiology																			
ABIOTIC	Chemistry	Pollution			*															
		Eutrophication																		
		General Chemistry																		
	Salinity									*										
	Physics	Circulation and mixing																		
		Hydrology / Flood regime				*	*	*	*	*	*									
		Oceanography				*														
		Climate					*													
	Geology	Sedimentology																		
		Palaeoenvironment																		
		Geology		*																
	Physiography	Morphology				*		*								*				
		Dams/Obstructions																		
		Catchment characteristics																		

Sources of information

APPENDIX X: (Cont)

ESTUARY / RIVERMOUTH / LAGOON: DIEP/RIET

Guide to available information

		Sources of information	Cooper and Summers	Cornell	Cox	Crous	Currie	Day	Day and King	De Swardt	Du Plessis	Du Toit	Duvenage	Dynamics of Diep River Mouth	Effect of a proposed new fishing harbour	Fleishmann	Gill	Götz	Green	Grindley
YEAR (DATE OF INFORMATION)			1976	1970	1971	1979	1979	1974	In Press	1970	1983	1982	1983	1988	1964	1967	1928	1982	1961	1957
MANAGEMENT		Historical																	*	
		Conservation / Utilization																*		
		Management / Planning				*				*						*				
		Legislation																		
		Water				*			*											
BIOTIC		Food webs / Ecosystems																		
	Fauna	Mammals															*			
		Birds	*															*		
		Reptiles																		
		Amphibians																		
		Fish																		
		Molluscs						*												*
		Crustaceans						*												*
		Other aquatic invertebrates						*												
		Terrestrial invertebrates																		
		Zooplankton																		*
	Flora	Terrestrial vegetation																		
		Semi-aquatic vegetation																		
		Aquatic vegetation							*											
		Algae																		
		Phytoplankton																		
		Microbiology																		
ABIOTIC	Chemistry	Pollution									*				*					
		Eutrophication									*									
		General Chemistry		*	*					*										
		Salinity										*								*
	Physics	Circulation and mixing												*						
		Hydrology / Flood regime					*				*		*		*					
		Oceanography																		
		Climate					*													
	Geology	Sedimentology										*								
		Palaeoenvironment																		
		Geology		*	*					*							*			
	Physiography	Morphology	*										*		*					
		Dams/Obstructions																		
		Catchment characteristics																		

APPENDIX X: (Cont)

Guide to available information																				
ESTUARY / RIVERMOUTH / LAGOON	DIEP/RIET	Sources of information	Grindley	Grindley	Grindley	Grindley	Grindley and Cooper	Grindley et al.	Grindley and Heydorn	Grindley et al.	Harris	Harry Fuchs Inv	Heydenrych	Heydorn and Tinley	Heydorn et al.	Hill Kaplan Scott and Partner	Jezewski and Roberts	Kensley	Kensley	Lawless
YEAR (DATE OF INFORMATION)			1972	1980	1983	1985	1979	1976	1979	In Press	1978	1983	1976	1980	1985	1971	1986	1975	1985	1972
MANAGEMENT		Historical																		
MANAGEMENT		Conservation/Utilization		*		*	*	*				*	*	*						
MANAGEMENT		Management/Planning				*	*	*	*			*		*	*	*				
MANAGEMENT		Legislation															*			
MANAGEMENT		Water																		
BIOTIC		Food webs/Ecosystems																		
BIOTIC	Fauna	Mammals																		
BIOTIC	Fauna	Birds		*			*													
BIOTIC	Fauna	Reptiles																		
BIOTIC	Fauna	Amphibians																		
BIOTIC	Fauna	Fish																		
BIOTIC	Fauna	Molluscs																		
BIOTIC	Fauna	Crustaceans																		
BIOTIC	Fauna	Other aquatic invertebrates																		
BIOTIC	Fauna	Terrestrial invertebrates																		
BIOTIC	Fauna	Zooplankton	*																	
BIOTIC	Flora	Terrestrial vegetation			*															
BIOTIC	Flora	Semi-aquatic vegetation																		
BIOTIC	Flora	Aquatic vegetation																		
BIOTIC	Flora	Algae																		
BIOTIC	Flora	Phytoplankton																		
BIOTIC		Microbiology																		
ABIOTIC	Chemistry	Pollution																		
ABIOTIC	Chemistry	Eutrophication																		
ABIOTIC	Chemistry	General Chemistry											*							*
ABIOTIC		Salinity											*			*	*			
ABIOTIC	Physics	Circulation and mixing									*									
ABIOTIC	Physics	Hydrology / Flood regime		*	*				*											
ABIOTIC	Physics	Oceanography						*		*	*									
ABIOTIC	Physics	Climate												*						
ABIOTIC	Geology	Sedimentology								*										
ABIOTIC	Geology	Palaeoenvironment								*								*	*	
ABIOTIC	Geology	Geology								*				*				*	*	*
ABIOTIC	Physiography	Morphology															*			
ABIOTIC	Physiography	Dams/Obstructions																		
ABIOTIC	Physiography	Catchment characteristics												*						

APPENDIX X: (Cont)

ESTUARY / RIVERMOUTH / LAGOON: DIEP/RIET

Guide to available information

Group	Subgroup	Sources of information	Linder	Longrigg	Millard	Millard and Scott	Milnerton Estates Develop	Milnerton Estates Develop	Milnerton Estates Develop	Milnerton Waste Water Treatment	Minutes of First Meeting	Nichols	Niehaus	Noble and Hemens	Oberholzer	Ocean Science and Engineering	Orren et al.	Pike and Saayman	Pitman et al.	Pitman et al.
YEAR (DATE OF INFORMATION)			1979	1985	1972	1954	1973	1973	1973	1984	1981	1977	1967	1978	1977	1965	1981	1966	1981 a	1981 b
MANAGEMENT		Historical																		
		Conservation/Utilization									*				*					
		Management/Planning					*	*	*		*		*		*			*		
		Legislation																		
		Water								*									*	*
BIOTIC		Food webs/Ecosystems																		
	Fauna	Mammals																		
		Birds		*	*	*														
		Reptiles																		
		Amphibians																		
		Fish			*	*														
		Molluscs																		
		Crustaceans																		
		Other aquatic invertebrates			*	*														
		Terrestrial invertebrates																		
		Zooplankton			*	*														
	Flora	Terrestrial vegetation																		
		Semi-aquatic vegetation	*																	
		Aquatic vegetation																		
		Algae																		
		Phytoplankton																		
		Microbiology																		
ABIOTIC	Chemistry	Pollution								*							*			
		Eutrophication										*								
		General Chemistry															*			
		Salinity			*	*														
	Physics	Circulation and mixing												*						
		Hydrology / Flood regime																		
		Oceanography																		
		Climate																		
	Geology	Sedimentology										*				*				
		Palaeoenvironment																		
		Geology														*		*		
	Physiography	Morphology												*		*		*	*	*
		Dams/Obstructions																		
		Catchment characteristics																		

APPENDIX X: (Cont)

ESTUARY / RIVERMOUTH / LAGOON: DIEP/RIET

Guide to available information

		Sources of information	Raven - Hart	Rietvlei Committee	Ripp	River Flow Data	Roberts	Rogers	Rosenthal	Rosenthal	Rosenthal	Rosenthal	Roussouw	Rowlands	Schalke	Scott	Simpson	Smith	Smith & Heemsta	South Africa
		YEAR (DATE OF INFORMATION)	1967	1979	1977	1978	1978	1980	1980	1970	1971a	1971b	1972	1983	1973	1954	1973	1972	1986	1967
MANAGEMENT		Historical	*		*				*											
		Conservation / Utilization		*										*						
		Management / Planning		*						*	*	*	*							
		Legislation																		*
		Water				*														
BIOTIC		Food webs / Ecosystems																		
	Fauna	Mammals																		
		Birds					*							*		*	*			
		Reptiles																		
		Amphibians																		
		Fish																	*	
		Molluscs																		
		Crustaceans																		
		Other aquatic invertebrates																		
		Terrestrial invertebrates																		
		Zooplankton																		
	Flora	Terrestrial vegetation													*					
		Semi-aquatic vegetation																		
		Aquatic vegetation																		
		Algae																		
		Phytoplankton																		
		Microbiology																		
ABIOTIC	Chemistry	Pollution																		
		Eutrophication																		
		General Chemistry																*		
		Salinity																		
	Physics	Circulation and mixing																		
		Hydrology / Flood regime				*				*	*					*				
		Oceanography																		
		Climate				*														
	Geology	Sedimentology						*					*		*					
		Palaeoenvironment						*							*		*			
		Geology						*	*						*		*	*		
	Physiography	Morphology	*		*							*		*						
		Dams/Obstructions																		
		Catchment characteristics																		

APPENDIX X: (Cont)

ESTUARY / RIVERMOUTH / LAGOON: DIEP/RIET

Guide to available information

Category	Group	Item	South Africa	South Africa	South Africa	South African Railways	Stauth	Stephens	Strachan	Stuart et al	Summers et al	Summers et al	Swart	Swart	Sylvester	Table Bay Harbour Dev.	Talbot	Talbot	Talbot	Tankard
YEAR (DATE OF INFORMATION)			1935	1973	1982	1971	1983	1929	1977	1980	1977	1976	1974	1986	1977	1980	1947	1955	1971	1975
MANAGEMENT		Historical																		
MANAGEMENT		Conservation/Utilization			*		*								*					
MANAGEMENT		Management/Planning			*	*	*									*				
MANAGEMENT		Legislation	*																	
MANAGEMENT		Water							*											
BIOTIC		Food webs/Ecosystems					*													
BIOTIC	Fauna	Mammals								*										
BIOTIC	Fauna	Birds									*	*								
BIOTIC	Fauna	Reptiles																		
BIOTIC	Fauna	Amphibians																		
BIOTIC	Fauna	Fish		*											*			*		
BIOTIC	Fauna	Molluscs																		
BIOTIC	Fauna	Crustaceans																		
BIOTIC	Fauna	Other aquatic invertebrates																		
BIOTIC	Fauna	Terrestrial invertebrates																		
BIOTIC	Fauna	Zooplankton																		
BIOTIC	Flora	Terrestrial vegetation																		
BIOTIC	Flora	Semi-aquatic vegetation						*												
BIOTIC	Flora	Aquatic vegetation						*												
BIOTIC	Flora	Algae						*												
BIOTIC	Flora	Phytoplankton																		
BIOTIC		Microbiology																		
ABIOTIC	Chemistry	Pollution																		
ABIOTIC	Chemistry	Eutrophication																		
ABIOTIC	Chemistry	General Chemistry																		
ABIOTIC		Salinity							*											
ABIOTIC	Physics	Circulation and mixing																		
ABIOTIC	Physics	Hydrology / Flood regime					*													
ABIOTIC	Physics	Oceanography														*				
ABIOTIC	Physics	Climate												*			*		*	
ABIOTIC	Geology	Sedimentology				*							*	*						*
ABIOTIC	Geology	Palaeoenvironment																		*
ABIOTIC	Geology	Geology															*			*
ABIOTIC	Physiography	Morphology									*	*	*	*						
ABIOTIC	Physiography	Dams/Obstructions																		
ABIOTIC	Physiography	Catchment characteristics															*		*	

Sources of information

APPENDIX X: (Cont)

ESTUARY / RIVERMOUTH / LAGOON: DIEP/RIET

Group		Sources of information →	Truran	Truswell	Underhill and Cooper	Van der Merwe	Venter	VISKOR	Weil	Winterbottom	Woodborne	Woodborne	Woodbridge Island Develop	Wooley	Wright
		YEAR (DATE OF INFORMATION)	1982	1977	1982	1988	1979	1967	1974	1960	1982	1983	1986	1940	1982
MANAGE-MENT		Historical													
MANAGE-MENT		Conservation/Utilization													*
MANAGE-MENT		Management/Planning						*					*	*	
MANAGE-MENT		Legislation													
MANAGE-MENT		Water													
BIOTIC		Food webs/Ecosystems													
BIOTIC	Fauna	Mammals													
BIOTIC	Fauna	Birds			*					*					
BIOTIC	Fauna	Reptiles													
BIOTIC	Fauna	Amphibians													
BIOTIC	Fauna	Fish													
BIOTIC	Fauna	Molluscs													
BIOTIC	Fauna	Crustaceans													
BIOTIC	Fauna	Other aquatic invertebrates													
BIOTIC	Fauna	Terrestrial invertebrates													
BIOTIC	Fauna	Zooplankton													
BIOTIC	Flora	Terrestrial vegetation	*												*
BIOTIC	Flora	Semi-aquatic vegetation	*												*
BIOTIC	Flora	Aquatic vegetation													
BIOTIC	Flora	Algae													
BIOTIC	Flora	Phytoplankton													
BIOTIC		Microbiology													
ABIOTIC	Chemistry	Pollution													
ABIOTIC	Chemistry	Eutrophication													
ABIOTIC	Chemistry	General Chemistry							*						
ABIOTIC		Salinity							*						
ABIOTIC	Physics	Circulation and mixing													
ABIOTIC	Physics	Hydrology / Flood regime					*								
ABIOTIC	Physics	Oceanography						*			*	*			
ABIOTIC	Physics	Climate													
ABIOTIC	Geology	Sedimentology													
ABIOTIC	Geology	Palaeoenvironment		*											
ABIOTIC	Geology	Geology		*				*			*	*			
ABIOTIC	Physio-graphy	Morphology			*	*	*						*	*	*
ABIOTIC	Physio-graphy	Dams/Obstructions													
ABIOTIC	Physio-graphy	Catchment characteristics													

Guide to available information

NOTES

PLATE I:

The Diep River enters Rietvlei under the Blaauwberg Bridge (foreground). Milnerton Lagoon beyond the Otto du Plessis Bridge provides the outflow to the sea at the mouth on Milnerton Beach. Cape Town and Table Mountain appear in the background beyond Table Bay into which the estuary mouth opens. (Photo: ECRU, 87-11-01).

PLATE II:

Looking west over Rietvlei where dense vegetation of sedges and grasses cover much of the surface during summer. In the foreground are the Milnerton sewage treatment works and the industrial area including the oil refinery and fertilizer factory. (Photo: ECRU, 87-11-01).

PLATE III:

The upper reaches of Milnerton Lagoon near the limit of tidal influence. These reaches support a wide range of salt-tolerant plants including abundant wildflowers in spring. (Photo: J R Grindley, September 1986).

LIST OF REPORTS PUBLISHED BY ECRU TO DATE

Estuaries of the Cape Part I. Synopsis of the Cape Coast. Natural features, dynamics and utilization. A E F Heydorn and K L Tinley. CSIR Research Report 380.

Estuaries of the Cape Part II. Synopses of available information on individual systems.

Report No.	Estuary Name	CSIR Research Report No.
1	*Spoeg	400
2	*Buffels	401
3	*Groen	402
4	*Swartlintjies	403
5	*Holgat	404
6	Bitter	405
7	Gamtoos	406
8	Rooiels	407
9	Uilkraals	408
10	*Kowie	409
11	Hartenbos	410
12	*(Buffels Wes, Elsies, Sir Lowry's Pass) (Steenbras, Buffels Oos)	411
13	*Silvermine	412
14	Sand	413
15	Zeekoe	414
16	Eerste	415
17	Lourens	416
18	*Bot	417
19	*Groot (Wes), Sout	418
20	*Groot Brak	419
21	*Breë	420
22	*Swartvlei	421
23	Swartkops	422
24	Onrus	423
25	Heuningnes	424
26	Olifants	425
27	Wildevoëlvlei	426
28	Riet/Diep	427
29	Houtbaai(in prep.)	428
30	Knysna	429
31	Keurbooms/Bitou and Piesang	430
32	Verlore	431
33	Krom, Seekoei, Kabeljous	432
34	Duiwenhoks, Kafferkuils (in prep.)	433
35	Boknes, Boesmans, Kariega, Kasuka (in prep.)	434
36	Rufane, Riet, Kleinemondes (in prep.)	435
37	Palmiet (in prep.)	436
38	Gourits (in prep.)	437
39	Quko	438
40	Klein (in prep.)	439
41	Groot Berg (in prep.)	440

* Out of print.