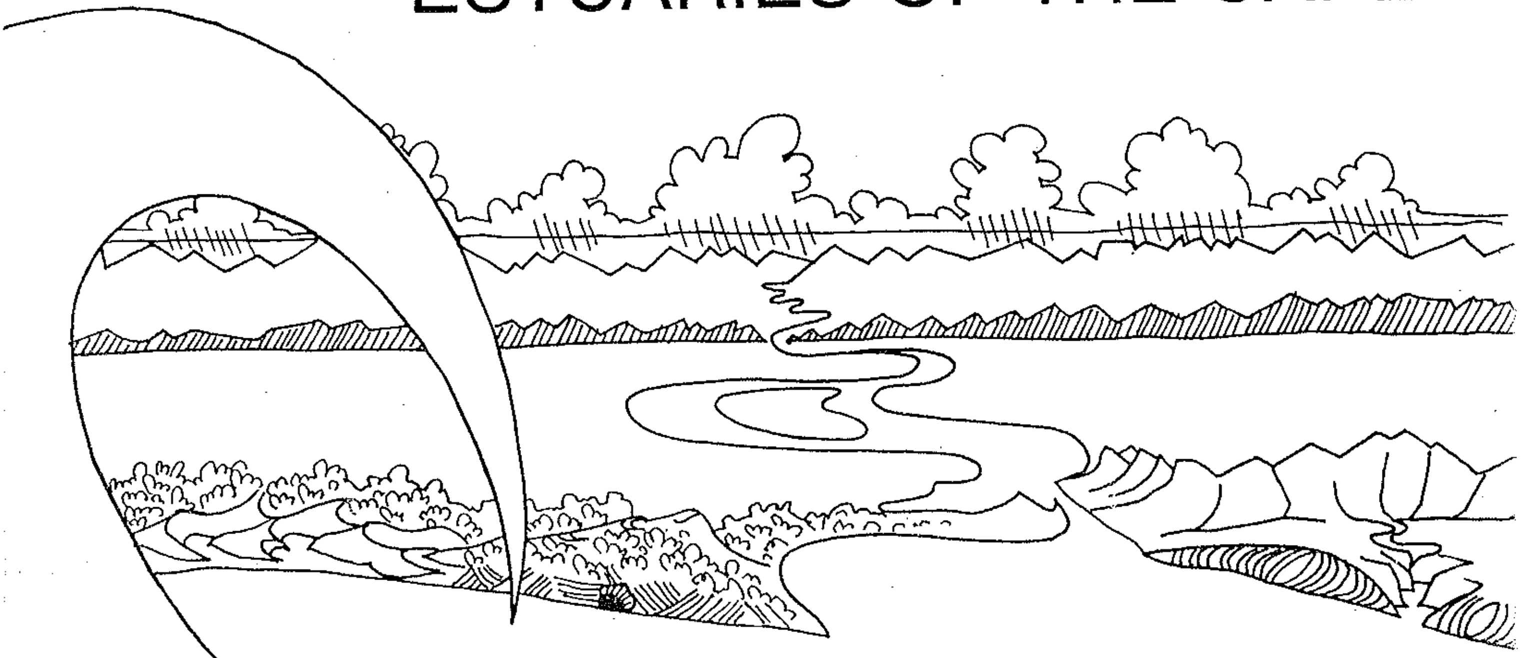
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY
ESTUARINE AND COASTAL RESEARCH UNIT - ECRU

ESTUARIES OF THE CAPE



PART II
SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

REPORT NO. 15

ZEEKOE (CSW 5)

CSIR RESEARCH REPORT 414

Stellenbosch, South Africa
December 1982

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PART II: SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

EDITORS:
A E F HEYDORN, National Research Institute for Oceanology, CSIR, Stellenbosch
J R GRINDLEY, School of Environmental Studies, University of Cape Town

FRONTISPIECE: ZEEKOE CANAL AND COMPONENTS OF THE DRAINAGE STYSTEM — ALT. ± 500 m, NRIO 82-12-20

REPORT NO. 15: ZEEKOE (CSW 5)

(CSW 5) CSIR Estuary Index Number

BY: I B BICKERTON

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December 1982

ZEEKOE

ECRU SURVEYS:	16 September 1980; 25 and 28 May 1982; 7, 21 and 29 June 1982	
SURVEY TEAM:	Mr IB Bickerton	(ECRU - 21 and 29 June 1982)
	Mr TJE Heinecken	(ECRU - 16 September 1980)
	Dr GAW Fromme	(NRIO - 25 and 28 May 1982 and 7 June 1982)
	Dr PD Bartlett	(NRIO - 21 June 1982)
	Mr RI Dick	(Cape Town City Council - 21 June 1982)
	Mr G Boddington	(Cape Town City Council - 29 June 1982)
	Mr P King	(Cape Divisional Council - 29 June 1982)
	Dr BR Davies	(Univ of Cape Town - 29 June 1982)
	Dr P Weisser	(Botanical Research Institute - 16 September 1980)
	Miss R Parsons	(Botanical Research Institute - 16 September 1980)

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PREFACE

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

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

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

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

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

These surveys are, however, not adequate to provide complete understanding of the functioning of estuarine systems under the variable conditions prevalent along the South African coastline. The ECRU therefore liaises closely with Universities and other research institutes and encourages them to carry out longer-term research 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.

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

FP Anderson
DIRECTOR

National Research Institute for Oceanology
CSIR

+CSIR Research Report 380

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ZEEKOE

1. HISTORICAL BACKGROUND

1.1 Synonyms and derivations

de Groot Zeekoe Vlei:	the original name given to the original vlei incorporating Rondevlei and Zeekoevlei by Jan van Riebeeck in 1656 (Burman, 1962).
De Zee Koe Valeyen:	so named when granted to Governor Simon van der Stel in 1699 (Cape Town City Council Press Release of 19 January 1981).
Seekoevlei:	the name as given on the 1:50 000 Sheet 3418 BA Strandfontein.
Zeekoevlei:	the historically correct name as given on the 1:50 000 Sheet 3418 BA Mitchell's Plain and officially adopted by the Cape Town City Council. This name is henceforth used in this report.
Zeekoe:	the name used in this report for the estuary or canal draining Zeekoevlei and Rondevlei.

1.2 Historical Aspects

Although old maps show a natural outlet from Zeekoevlei to the sea, this closed up during the first quarter of the century. Old inhabitants reported that sea and estuarine fish had been common before the original opening closed; these included white steenbras *Lithognathus lithognathus*, flathead mullet *Mugil cephalus* and longfin eel *Anguilla mossambica* (Harrison, 1958).

By 1942, Zeekoevlei and Rondevlei were not directly connected to the sea as can be seen from early aerial photographs. However, a series of marshes stretched from the south-eastern corner of Zeekoevlei and were flooded during high water levels in winter (JR Grindley, pers. comm.).

Yachting on Zeekoevlei started in the 1920s with boats being brought in by oxwagon. Beynon (1971) describes the early days of sailing and the formation of the Zeekoevlei Yacht Club. In those days water levels fluctuated greatly and in summer large marginal areas of the vlei became dry white sandflats. The water was brackish and formed salt crusts where it evaporated on the shore. The water was clear and water weeds were present in the northern areas (late Dr EN Grindley, pers. comm.). With development of the Grassy Park area, increased run-off caused high water levels and consequent flooding of houses adjoining the vlei in the 1940s. The water weed *Potamogeton* increased to such an extent in the clear water, that the Zeekoevlei Yacht Club had to maintain a weed cutter to make yachting possible. In the 1950s increasing concentrations of micro-algae caused the water to become a peasoup green thereby limiting light penetration and restricting *Potamogeton* growth (JR Grindley, pers. comm.).

According to Burman (1962), during the eighteenth century the Cape Flats was plundered of bushes by slaves in search of firewood. Because of this the Cape Flats soon became a vast desert of rolling sand dunes. Photographs in the Cape Town City Engineer's Annual Report (1936) show that in 1935, sand dunes driven by south-easterly winds were encroaching into Zeekoevlei. In 1936, the Cape Town City Council commenced dune reclamation activities in order to stabilize the sand. This was done by bushing and the establishment of marram grass and rooikrans *(Acacia cyclops)*. Sewage effluent from the Wynberg and Lansdowne areas was pumped into the dune area, now occupied by the final maturation ponds of the Cape Flats Sewage Works, to enhance the growth of the introduced vegetation. However, mobile dunes were still encroaching on the south-western corner of the vlei in 1950 (JR Grindley pers. comm.).

In 1942 the Zeekoe Canal was built to prevent flooding along the banks of the vlei in the winter months (Brummer, 1981) and in this way the artificial connection to the sea was created. Then, in 1958 Zeekoevlei and Rondevlei, which were originally connected, were separated and a weir built at the south-eastern corner of Rondevlei. A canal connecting this weir to the Zeekoe Canal was also constructed at this time.

In 1962 the present outlet from the Cape Flats Sewage works into the Zeekoe Canal was constructed and since then the outflow from the oxidation ponds has largely dominated the run-off via the Canal.

2. LOCATION

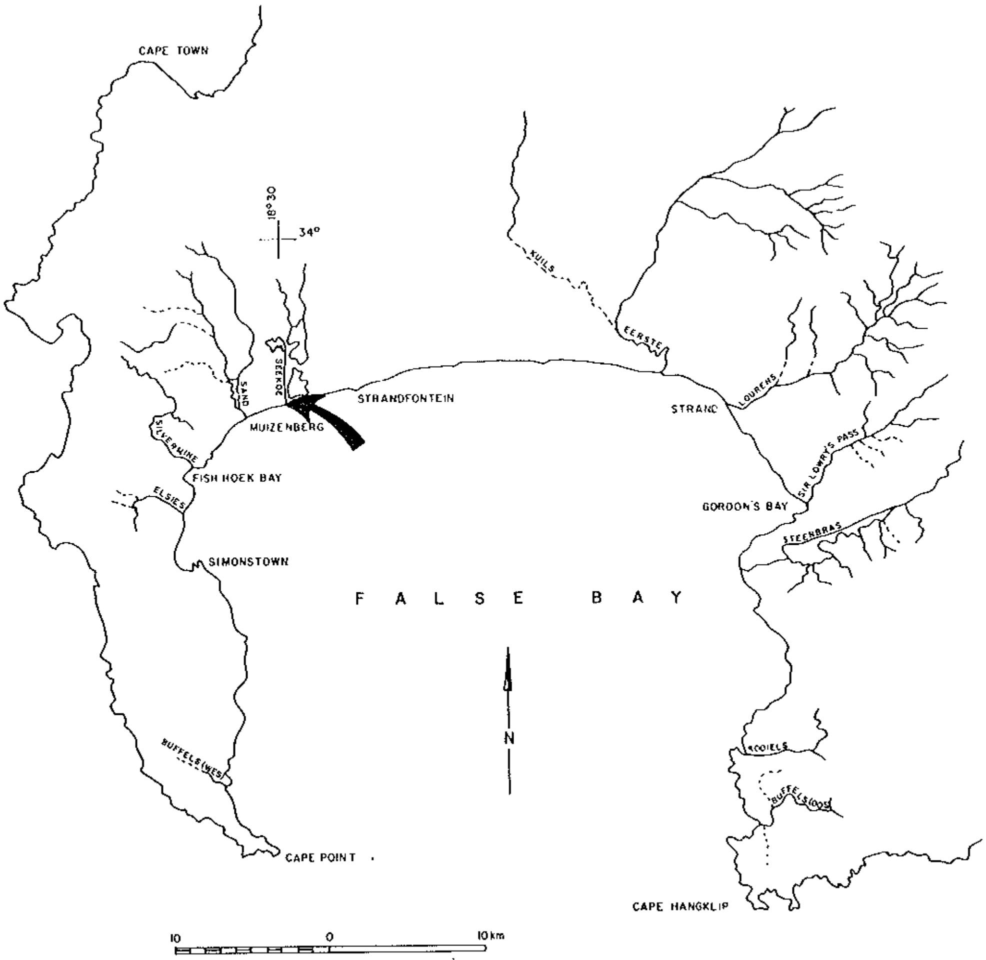
The mouth of Zeekoe is situated at 34°06'S, 18°30'E, about 20 km south of central Cape Town (1:250 000 Topographical Sheet 3318 Cape Town).

2.1 Accessibility

Baden Powell Drive, the coastal road from Muizenberg to Swartklip, crosses the Zeekoe Canal about 150 m from its mouth. Access to the eastern side of Zeekoevlei is via Strandfontein Drive and to the Peninsula and western side, via Victoria Road.

2.2 Local Authorities

Two local authorities have jurisdiction over the Zeekoe drainage system (see Figure 1). The Cape Town City Council controls the following parts of the Zeekoe System: The Zeekoe Estuary and canal up to approximately 2 km from the mouth and the undeveloped area to the west of it; Cape Flats Sewage Works to the east of the canal; the eastern bank of Zeekoevlei up to 1 km to the east of the vlei; the water body of the vlei itself. In the upper catchment, the Cape Town City Council controls Princess Vlei



(which flows into Rondevlei), the upper reaches of the Little Lotus River (which flows into Zeekoevlei) and parts of the Big Lotus River (which also flows into Zeekoevlei).

The Cape Divisional Council controls the following areas: the western bank of Zeekoevlei; Rondevlei; the bulk of the catchment area to the north-west of Zeekoevlei.

3. ABIOTIC CHARACTERISTICS

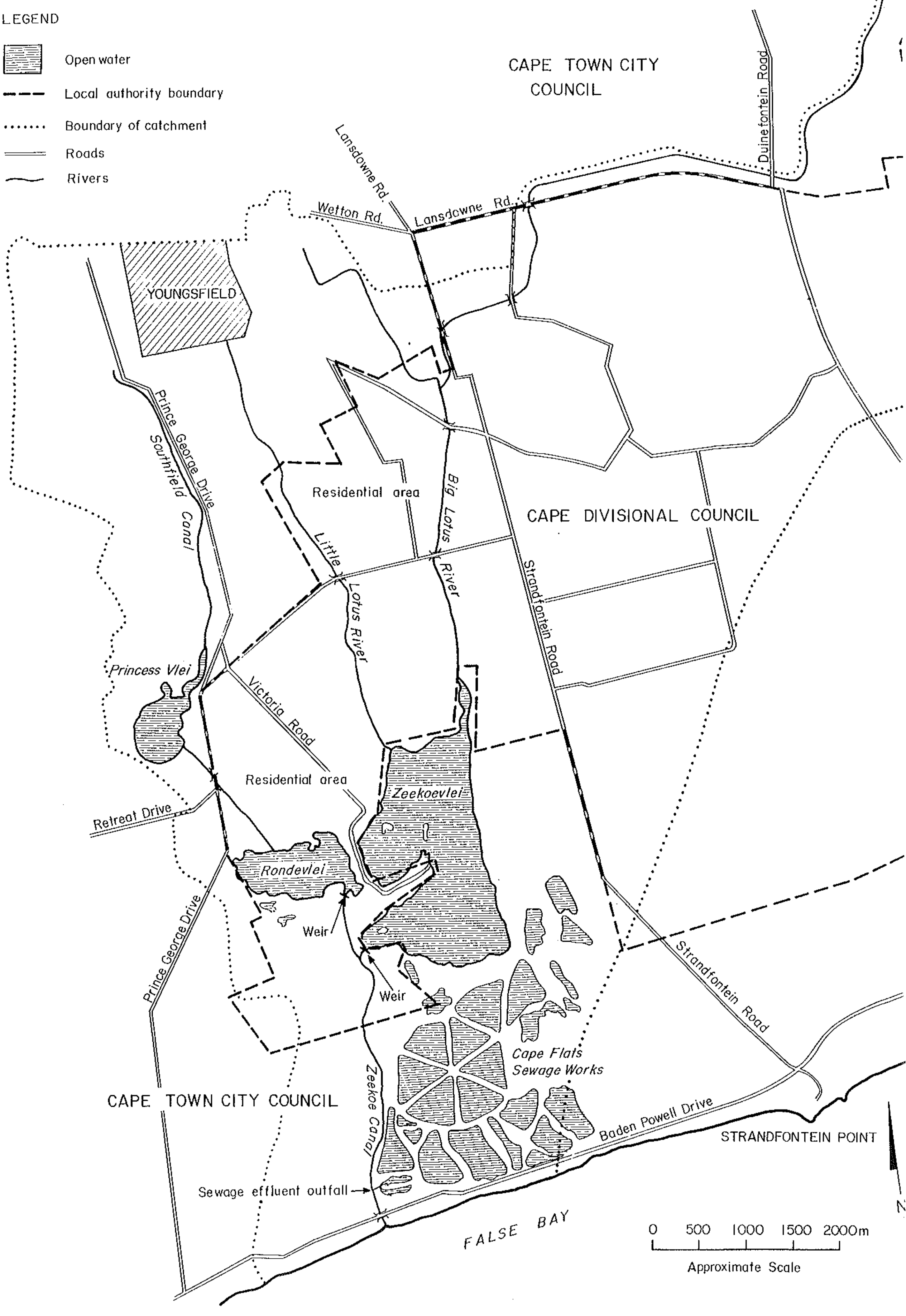
3.1 River Catchment

3.1.1 Catchment Characteristics

Area

The area of Zeekoe catchment has been altered extensively by urbanization, stormwater drainage and the input from the Cape Flats Sewage Works. Also, the eastern boundary is difficult to define as gradients are almost indiscernable. According to the Cape Town City Engineer *(in litt.)* the area of the Zeekoe catchment is 8334 ha as measured on Cape Town City Council Map TPX 8770 (1982).

FIG. I : Major components of the Zeekoe Drainage System



River length

The total drainage length of Zeekoe from the mouth of the Zeekoe Canal to the source of the Big Lotus River at the DF Malan Airport stormwater dam is approximately 18 km (Cape Town City Council Map TPX 8770). The Zeekoe Canal is approximately 3 km in length from its mouth to the Zeekoevlei Weir (1:50 000 Sheet 3418 BA).

Tributaries

The Zeekoe drainage system consists basically of four components (see Frontispiece and Figure 1). These are:

(a) Rondevlei and the run-off from Princess Vlei and the Southfield Canal;

(b) Zeekoevlei and the Big Lotus and Little Lotus rivers;

(c) Sewage effluent from the Cape Flats Sewage Works outfall (see Plate II).

(d) Seepage from the Cape Flats Aquifer.

Geomorphology

The Zeekoe drainage system is situated on the Cape Flats, the topography of which is dominated by sandy soils and dunes. Most of the upper catchment is now characterized by urbanization and the consequent hardening of previously porous surfaces with canalization of the main water courses. The direction of drainage from the upper catchment to the mouth of the Zeekoe Canal is generally from the north-east to the south-west.

There are three major vleis in the catchment of the Zeekoe drainage system (see Figure 1). These are Princess Vlei (area: 36 ha; maximum depth: 3 m) in the north-west and Rondevlei (area: 100 ha; maximum depth: 3,6 m) and Zeekoevlei (area 260 ha; maximum depth 3,6 m) in the south. Originally Rondevlei and Zeekoevlei were connected by a small channel but the two vleis were separated in 1958.

Seaward of Zeekoevlei and Rondevlei the predominant southerly winds have built sand dunes which range from 10 to 35 m in height (Brummer, 1981). There are a large number of dunes in the area south of Rondevlei whereas to the east of Zeekoevlei there are flat pasture lands (Brummer, 1981).

Geology

The following description is based on the comprehensive account of the geology of the Cape Flats on which the Zeekoevlei complex lies, given in Brummer (1981):

The Zeekoevlei complex lies in the south-western corner of the Cape Flats which are a lowland lying between the Cape Peninsula Mountain Range on the west and the Hottentots-Holland Mountain Range to the east. The Cape Flats are Cenozoic deposits indicating that they are younger than 65 million years old. The Cape Peninsula Mountains were once offshore islands with a shallow channel separating them from the mainland. A sandbar or tombola formed and has been enlarged and reinforced by the building up of a sand layer through the recent stabilization of sea level. The Cape Flats are characterized by low sand dunes, sandy soil and a number of vleis.

Geological evidence shows that the recent deposits overlay an early-pleistocene erosion surface of the Cape Peninsula Pluton which consists of granite. The granite outcrops at two places to the north of Zeekoevlei between the Big Lotus and Little Lotus Rivers.

Rainfall and run-off

According to Henzen (1973) and Brummer (1981) the bulk of the catchment area lies between the 600 mm and 800 mm mean annual isohyets. Brummer (1981) gives the annual average rainfall at Strandfontein as 705 mm and the average rainfall to be expected over the lower reaches of the Zeekoe catchment as 550 mm to 750 mm per annum.

As mentioned earlier most of the upper catchment is now characterized by urbanization and the consequent hardening of previously porous surfaces and canalization of the main water courses. As the proportion of impervious surface increases with the development of the catchment, increased run-off will be led into the major water courses via pipes (frequently 500 - 750 mm diameter) (Cape Town City Engineer, *in litt.*). Because of this the existing lined sections of the Big Lotus River are not large enough to handle future flood flows (Fraser, 1980). A solution to this would be to pond the flow and four possible pond sites have been investigated (Fraser, 1980). The Cape Divisional Council is considering this proposal at present (P. King, Cape Divisional Council, pers. comm.). The alternative to this is to rebuild the canal and all its structures (Fraser, 1980). The present flood capacity of the Big Lotus Canal just before it enters Zeekoevlei is 18,83 cumecs and the predicted future flow is 30,94 cumecs (Fraser, 1980). No run-off data are available for the Little Lotus River.

In a report for the Cape Town City Council on the cause of the floods in the Rondevlei catchment on 7 July 1976, Mr K Sheel mentions that the inflow into Rondevlei is partly dependent on the discharge from Princess Vlei. According to him the factors limiting the outflow from Princess Vlei were the three pipes under Prince George Drive.

Because of the Mediterranean rainfall regime, the Big and Little Lotus Rivers flow during winter only and thereby cause fluctuations of as much as 0,8 m in the water level of Zeekoevlei (Brummer, 1981). Subsurface water sources are the Cape Flats aquifer, septic tanks of the residential area and seepage from the oxidation ponds which are 8 m above the level of Zeekoevlei (Brummer, 1981). The present weir at the south-western corner of Zeekoevlei is 5,18 m above mean sea level and overflows from August to October during the highest rainfall months (Brummer, 1981).

Water from the Grassy Park and Retreat residential areas drains by means of a canal into Rondevlei. The weir at Rondevlei is situated in the south-eastern corner of the vlei and is 4,9 m above mean sea level (Brummer, 1981). As with Zeekoevlei, the weir at Rondevlei normally overflows from August to October (see Figure 2). It is therefore apparent that run-off from Rondevlei and Zeekoevlei into the Zeekoe Canal occurs only during the late winter and spring months.

From 1962 to 1980 the effluent flow from the Cape Flats Sewage Works into the Zeekoe Canal increased from an average of 10 Mℓ/day to 64 Mℓ/day (Cape Town City Engineer's Reports (1962 - 1980). Since 1962 the sewage effluent has largely dominated the run-off via the Zeekoe Canal. Although the effluent flow has increased over the years fluctuations due to rainfall input into the oxidation ponds do occur.

TJE Heinecken (ECRU, pers. comm.) recorded a flow rate of 2,5 m/sec above the sewage effluent outfall on 16 September 1980 (weirs overflowing). GAW Fromme (NRIO, pers. comm.) recorded a flow rate of 1,8 m/sec in May 1982.

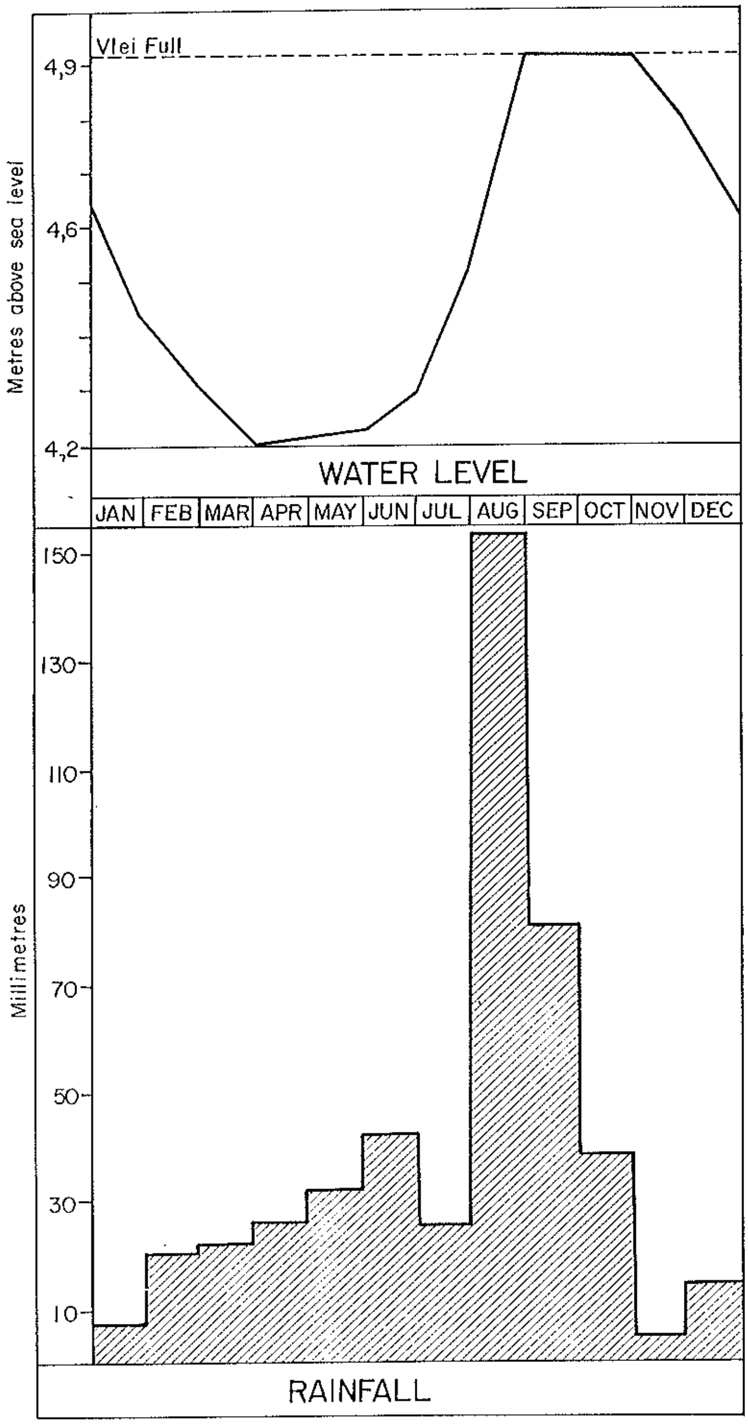
3.1.2 Land Ownership/Uses

DF Malan Airport is situated in the upper reaches of the catchment in the north-east. Much of the eastern side of the catchment is owned by small plot holders who farm their lands for cash crops and vegetables (Cape Town City Engineer, *in litt.*). Part of the area has been proclaimed a silica mining/beneficiation and agricultural area by Government proclamation (Government Gazette 2178 of 68-10-04, GN 1760/68) (Cape Town City Engineer, *in litt.*). Light industry is located along Lansdowne Road, and is expanding south-east of DF Malan Airport (City Engineer, *in litt.*). The rest of the catchment consists largely of residential areas, but also includes Youngsfield Military Base which is situated in the north-western part of the catchment (see Figure 1).

Zeekoevlei and most of its surrounds are used for water-based recreation. Rondevlei has been a bird sanctuary since 1952.

An area of undeveloped land immediately to the south of Rondevlei and west of Zeekoevlei is owned by the Cape Land and Finance Company (Brummer, 1981). The eastern boundary of this area is the canal from Rondevlei and lower down, the Zeekoe Canal. To the south of Zeekoevlei lies the Cape Flats Sewage Works. Most of the land to the west of the Zeekoe Canal is undeveloped and occupied by squatters, a riding school, a youth camp and cemetery.

FIG. 2: Water level and rainfall at Rondevlei during 1978 (From Brummer (1981) - Source: Langley, 1978)



3.1.3 Obstructions

With much of the catchment having been urbanized, there are numerous obstructions to the drainage of water within it. Most of the main water courses have been canalized and are traversed by many bridges.

The major obstructions are as follows (Cape Town City Engineer, *in litt.*):

(a) The holding dam at DF Malan Airport, the run-off from which feeds into the Big Lotus River.

(b) Eleven bridges across the Southfield Canal.

(c) Twenty-four bridges across the Big Lotus River.

(d) Sixteen bridges across the Little Lotus River.

(e) Several hundred stormwater pipes which discharge into the main water courses.

(f) The weir at the south-eastern corner of Rondevlei.

(g) The weir at the south-western corner of Zeekoevlei.

In addition, a flood-control weir is to be installed at the south-eastern outlet from Princess Vlei to Rondevlei in 1984 (Cape Town City Engineer, *in litt.*).

3.1.4 Siltation

Siltation does not appear to be a major problem in the water courses of the Zeekoe Drainage System, but where the rivers enter the vleis, deposition of sediment loads necessitates dredging every few years (e.g. Princess Vlei and Zeekoevlei) (Cape Town City Engineer, *in litt.*).

In Zeekoevlei, the settlement of dead algae and mud has resulted in accumulations of up to 2 m in thickness on the bottom of the vlei (Brummer, 1981). During late 1982 a dredging programme was undertaken in Home Bay to alleviate this problem. However, as Howard-Williams (1976) has pointed out, dredging of only a part of the vlei is likely to prove unsatisfactory due to infilling by material from other parts of the vlei. A larger area of the vlei will therefore probably have to be dredged.

In earlier days up to about 1950, wind-blown sand used to enter Zeekoevlei from the south-east. Artificial stabilization of the dunes to the south-east of Zeekoevlei was commenced by the Cape Town City Council in 1936 (Cape Town City Engineer's Report, 1936). This stemmed the movement of sand into the vlei.

The Cape Town City Council has problems with sediments in stormwater pipes which have to be cleared approximately once every three years (Cape Town City Engineer, *in litt.*).

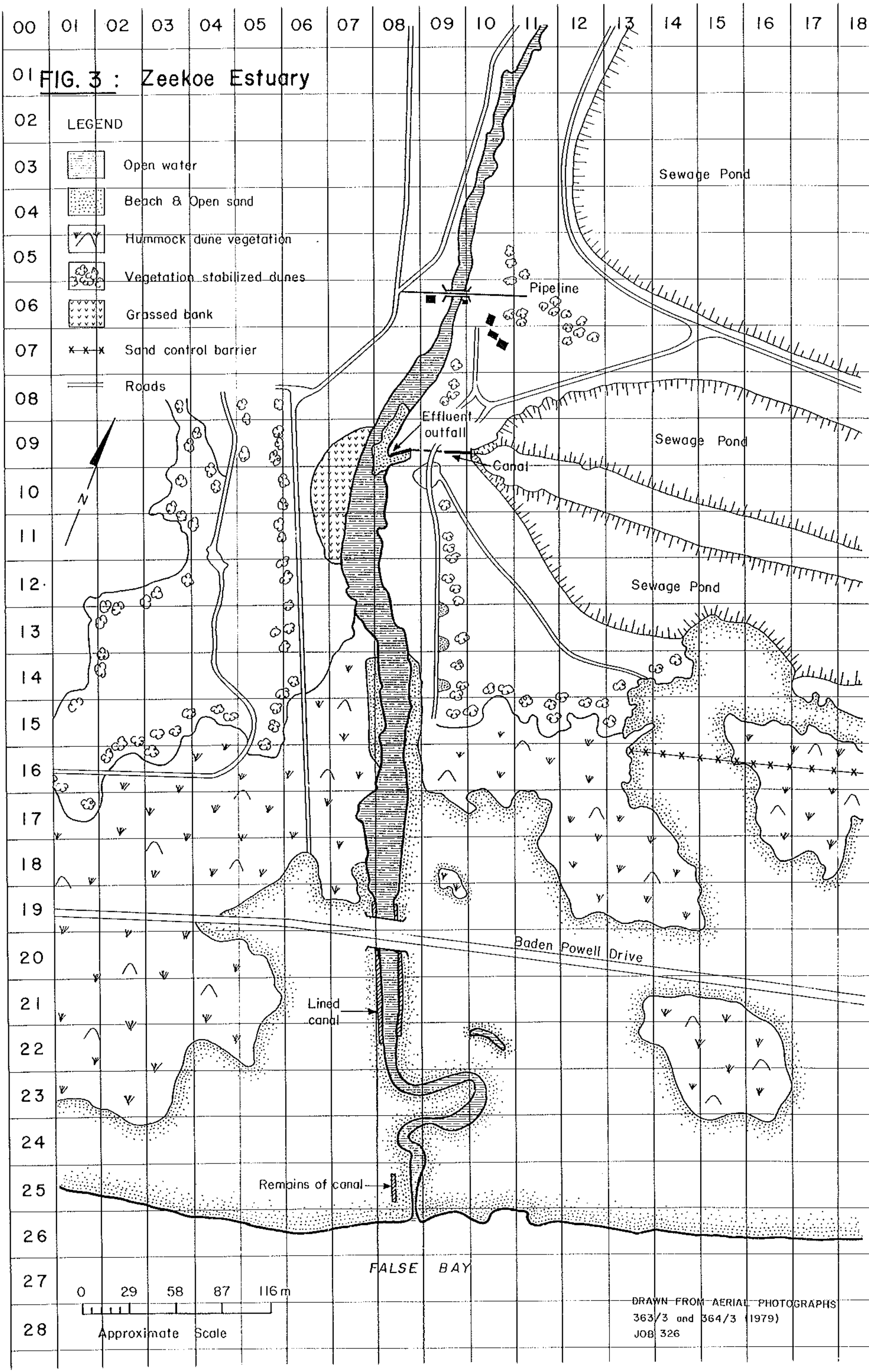


FIG. 3 : Zeekoe Estuary

3.1.5 Abnormal Flow Patterns

In earlier days the areas immediately to the north of Zeekoevlei (e.g. Grassy Park) were prone to flooding. Because of this the Big Lotus and Little Lotus Rivers were canalized in the 1950s (Cape Town City Engineer, *in litt.*). However, there are no available records of flood lines.

According to the report for the Cape Town City Council by K Sheel, a storm on 7 July 1975 caused flooding in the Rondevlei catchment area. He concluded that the main cause of this was blockage of the canal below the Rondevlei weir. In 1977, backflooding occurred at Rondevlei and Princess Vlei (P King, Cape Divisional Council, pers. comm.). Harrison (1962) records heavy flooding in the early 1940s.

3.2 Estuary

3.2.1 Estuary Characteristics

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

Drainage from Zeekoevlei and Rondevlei is concentrated in a narrow canal (see Figure 3, Plates I and III) through the large dunefields of the Cape Flats. The extensive Cape Flats Sewage Works oxidation ponds discharge their effluents into this canal (see Plate II). The mouth of the canal is situated approximately 8 km east of Muizenberg. It emerges onto the beach where it is often dammed up behind a two to three metre high beach bar. This causes the river to spread onto the flat backshore area between the beach bar and the seaward front of the dunes of the hinterland leading to the formation of a shallow longshore orientated lagoon. In this way a similar situation is created as at the mouth of the Eerste River (Grindley, 1982) lying to the east of the Zeekoe.

Because of the high elevation of the backshore above sea level, the lagoon is non-tidal and tends to overtop the beach bar, i.e. across slacks. The outflow-channel over the beach bar usually forms large meanders (see Figures 3 and 4 and Plate I).

At the time of the ECRU surveys in May and June 1982, a lagoon had developed extending approximately 200 m to the east of the eastern point of the canal from the dunes. Because of the high organic loads in the sewage effluent, the lagoon bed was covered with sludge. The Cape Town City Council periodically covers the sludge with a thin layer of sand and also straightens the outlet seaward of the Baden Powell Drive bridge to prevent excessive meandering of the channel. In this manner, the mouth is kept permanently open.

To assist the river in cutting through the beach bar in a straight line from the bridge to the edge of the sea, this section of the canal has been lined with concrete. In spite of this, the river still tends to break out through the sides which has resulted in partial destruction of the concrete walls.

FIG. 4: Mouth of the Zeekoe Canal looking upstream, showing meandering of the channel towards the east. The remains of the eastern concrete berm can be seen in the foreground (ECRU: 80-09-16)

Aerial photography in 1944 showed that before construction of the sewage works and concrete walls, the Zeekoe formed a small lagoon on the eastern and sometimes also western backshore area.

3.2.2 Mouth Dynamics

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

The coastal morphology, inshore oceanography and sedimentology of the Sandvlei and Zeekoe mouths were investigated by the Hydraulics Research Unit of the CSIR from August 1970 to September 1971 in connection with the planning of the Muizenberg Marina Project (CSIR Report ME 1103/1, 1971).

The report states that "in general the onshore profiles displayed a considerable degree of stability". The offshore profiles showed little change between surveys.

For the investigation of littoral dynamics it is necessary to make an assessment of the wave climate on the coast. Wave data covering a 20-year period on deep sea wave direction, height and period (Swart and Serdyn, 1982) and wave refraction diagrams for False Bay were used to compute the total inshore wave energy and the average energy-wave height at the mouth of the Zeekoe.

It was found that the inshore wave energy for the coast at the mouth of the Zeekoe was 10 per cent above the mean energy calculated for the eleven river mouth beaches in False Bay.

The average energy-wave height[+] was 0,98 m. This classifies the Zeekoe beach amongst the False Bay beaches as receiving a medium wave energy.

The stability of the beach at the mouth of the Zeekoe appears to be a result of the flat sea bed in the breaker zone which reduces the incident wave forces at the beach. Notwithstanding this, there is a build up of a high beach bar, which together with sand accumulations caused by sediment discharge from the Zeekoe Canal, tends to block the outlet of the river, so that a backshore lagoon develops.

During the Muizenberg Marina Project sand grain diameters were found to increase whereas the beach slopes decreased from west to east. The grain sizes were in the range of fine to medium. Steeper beach slopes are usually associated with coarser sand grains. The apparent disagreement of these two parameters (beach slopes and sand grain size along the beaches at the mouths of Sandvlei and the Zeekoe) was associated with the coarse sand prevalent at the mouths of both systems and the predominantly east-bound surfzone current which spreads coarse sand from the mouth towards the east.

3.2.3 Land Ownership/Uses

The Zeekoe Canal and adjacent land is controlled by the Cape Town City Council (see Figure 1). The Cape Flats Sewage Works is situated immediately to the east of the canal and the oxidation pond effluent outfall is situated approximately 500 m upstream of the mouth of the canal (see Figure 3 and Plate II). The oxidation ponds attract large numbers of water birds and bird-watchers are able to enter the area if they acquire a permit from the Cape Town City Council. The land lying immediately to the west of the Zeekoe Canal is unused at present and is likely to be developed for housing (Brummer, 1981).

The area east of Zeekoevlei and the sewage settling ponds which is covered mostly by high quality Coastal Strandveld has been demarcated as an Indian housing area by the state (Cape Town City Engineer, *in litt.*). A structure plan for the area is now being prepared by a planning committee.

Brummer (1981) made land use proposals for the Zeekoevlei complex. Amongst these, he proposed nature conservation status for the oxidation ponds of the sewage works and the establishment of a 500 m wide buffer zone on the western side of the Zeekoe Canal.

The beach at the mouth of the Zeekoe Canal is used by fishermen (TJE Heinecken, pers. comm.).

[+]Average energy-wave height: an index which reflects the average incident wave energy at inshore sites along the coast, presented as a wave height.

3.2.4 Obstructions

The Baden Powell Drive roadbridge (see Figures 1 and 4) is situated at the mouth. This road is the main route between Strandfontein and Muizenberg. On the upstream side of the bridge, the bridge embankments are protected from erosion by a creosote pole palisade on the western bank and a concrete embankment on the eastern bank.

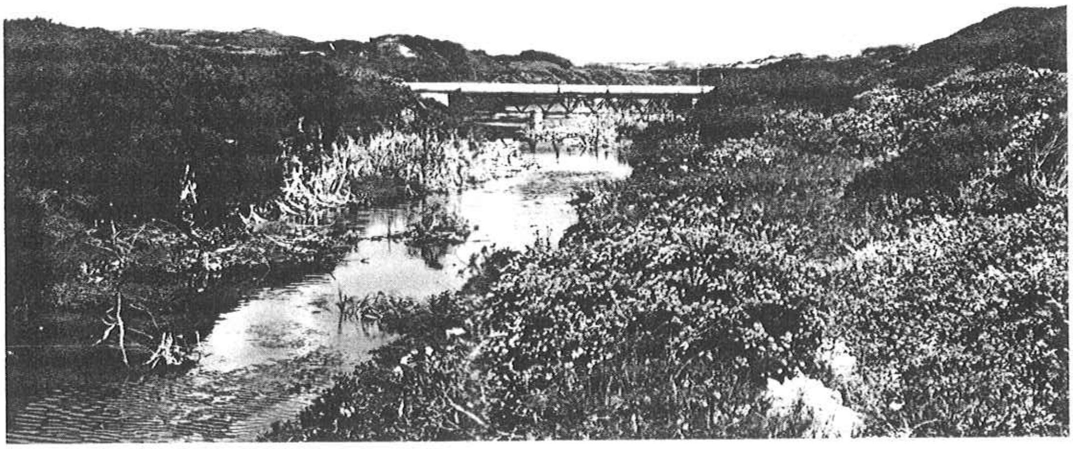


FIG. 5: Muizenberg raw sewage pipeline which crosses the Zeekoe Canal approximately 400 m upstream of the mouth. The photograph was taken looking downstream with the Cape Flats Sewage Works situated to the left of the photo (ECRU 80-09-16).

Approximately 400 m upstream of the road bridge, the Muizenberg raw sewage pipeline crosses the Zeekoe Canal (see Figure 5). This pipeline is supported by pylons.

3.2.5 Physico-chemical Characteristics

Monitoring of the physico-chemical features of the various components of the Zeekoe drainage system has been carried out by the authorities responsible for the respective areas. The Cape Divisional Council from time to time samples the Big Lotus River, Little Lotus River, canals draining into Rondevlei and Rondevlei itself (P King, Cape Divisional Council, pers. comm.). The Cape Town City Council monitors the Little Lotus River, the Big Lotus River, Zeekoevlei and the final pond effluent draining into the Zeekoe Canal near its mouth (Cape Town City Engineer's Reports 1973 - 1981). The lower reaches of the Zeekoe Canal were sampled during the ECRU surveys on 16 September 1980 and 21 June 1982. Harrison (1962) has described the hydrobiology of Zeekoevlei, Rondevlei and Princess Vlei and has given physico-chemical data for Zeekoevlei.

The data for the rivers and canals draining into Zeekoevlei and Rondevlei generally indicate enrichment of the run-off, particularly during dry periods. Chloride and sulphate concentrations are consistently high. Tschortner (1969) discussed the changes that had made Rondevlei unfavourable for birds, including aspects of plant growth, water level and water quality. He considered the effects of weedbeds in Rondevlei on the fertility of the open vlei. He found generally that nutrients were trapped within areas of dense *Potamogeton* growth and also in the mud settling within the weed beds due to lack of turbulence. As long as the barrier effect of the weed lasted, the nutrients were not available to the open vlei.

As numerous chemical data for Zeekoevlei can be found in Harrison (1962) and Cape Town City Engineers reports (1973 - 1981) and also because the vlei is to a large degree isolated from the Zeekoe Canal by the weir, only the salient features of the data are mentioned here.

The concentration of dissolved solids is high with a maximum of 6 262 mg/ℓ having been recorded in the north-eastern parts of the vlei in 1974 (Cape Town City Engineer's Report, 1974). The average for 1981 was 1 538 mg/ℓ (Cape Town City Engineer's Report, 1981).

Chloride concentrations are consistently high with a maximum concentration of 3 070 mg/ℓ having been recorded in 1974 (Cape Town City Engineer's Report, 1974). The mean for 1981 was 561 mg/ℓ (Cape Town City Engineers Report, 1981).

Seasonal and summer diurnal fluctuations of pH in the weed *(Potamogeton pectinatus)* beds which were present in Zeekoevlei in the late 1940s were recorded by Harrison (1962). The seasonal extremes were 7,5 in August and 12,5 in December. The diurnal variation in pH was measured during January 1947 and ranged from 9,3 in the early morning to 12,5 in the late afternoon. These fluctuations are caused by the photosynthetic activity of the *Potamogeton* (Harrison, 1962) and their significance was investigated by Schütte and Elsworth (1954). pH values as high as those recorded are possible only when sodium ions (or those of other alkali metals) predominate (Harrison, 1962).

Since the *Potamogeton* weed beds have almost completely been replaced by suspended algae, light penetration has been reduced, particularly during windy conditions when the vlei takes on a typical greenish colour. The generally lower pH values recorded since elimination of the weed beds are probably due to less photosynthesis resulting from reduced light penetration.

Zeekoevlei is rich in nutrients which enter the water by the following routes, resulting in eutrophication (Brummer, 1981):

(i) Stormwater drains into the two Lotus Rivers; organic material, including dead animals, urine and faeces enter the vlei in this way.

(ii) Seepage of treated effluent from oxidation ponds at the Cape Flats Sewage Works. Curtin *et al.* (1975) estimated that as much as 100 cubic metres per day could move through the sands from the oxidation ponds into Zeekoevlei (Howard - Williams, 1976).

(iii) Seepage from septic tanks of the houses around Zeekoevlei (Brummer 1981).

The lower reaches of the Zeekoe Canal are largely dominated by the effluent outfall from the Cape Flats Sewage Works (see Plate II). Analytical data for samples collected by Dr PD Bartlett (Marine Chemistry Division, NRIO) during the ECRU survey, are shown in Appendix II. At low tide the surface water was fresh at all stations, indicating a strong flow and little sea water penetration. There may, however, be salinity layering in the lower reaches of the canal particularly during high spring tides.

The levels of all nutrients were high. This is to be expected from the type and volume of effluent being carried. The levels were considerably elevated above those for a typical unpolluted estuary (PD Bartlett, pers. comm.). It would seem that the high ammonia levels are responsible for the scarcity of aquatic animal life in the Zeekoe Canal.

In the main flow, dissolved oxygen was approximately fifty percent of saturation. In view of the high organic and nutrient loads in the sewage effluent this is to be expected (PD Bartlett, pers. comm.). At the pipe crossing (Grid Ref 0609) (see Figure 3) the dissolved oxygen level was close to zero. It appears that at high tide, sewage effluent is pushed upstream into this part of the canal where, because of the low flow, it becomes further de-oxygenated.

The pH was the same as that of the effluent from the Cape Flats Sewage Works.

The dissolved organic carbon values were high and reflect the highly organic nature even of secondary-treated sewage effluent (PD Bartlett, pers. comm.).

3.2.6 Pollution

With much of the catchment of the Zeekoe System having been urbanized, various forms of pollution occurred and do occur from time to time. However, pollutants in the catchment and in Zeekoevlei reach the lower reaches of the Zeekoe Canal only when the weir is overtopped, usually only from August to October (Brummer, 1981) or after floods. This also applies at Rondevlei.

The Cape Divisional Council periodically clears the waterways of the Big Lotus River of bank vegetation. Herbicides are initially applied and drag-lines are then used to remove the dead vegetation (P King, pers. comm.).

Sewage

In the Nyanga area (controlled by the Western Cape Administration Board) there have been numerous instances of direct raw sewage contamination of the Nyanga Canal (Big Lotus River) arising from malfunction of the poorly maintained local sewage system (Cape Town City Engineer, *in litt.*).

A sewage pump station approximately 800 m upstream of Princess Vlei has been a potential source of sewage pollution of the Southfield Canal and Princess Vlei. During power failures this station occasionally discharged raw sewage into the Southfield Canal. Following such discharge it has been the practice to apply HTH (a proprietory hypochlorite powder) powder to the affected canal and water area (Cape Town City Engineer, *in litt.*).

The power supplies of almost all the City's sewage pump stations will soon be monitored by an automatic early warning system. This will alert standby staff of station malfunctions and thereby greatly reduce the risk of sewage pollution of important water courses and water bodies (Cape Town City Engineer, *in litt.*).

The contribution of seepage from the oxidation ponds has probably been reduced since 1980 through the upgrading of the Cape Flats Sewage Works by means of an Activated Sludge Treatment Plant. Analytical data for Zeekoevlei collected recently by the Cape Town City Council support this (Cape Town City Engineer, *in litt.*).

The sewage effluent outfall from the Cape Flats Sewage Works (see Plate II) is a major input of treated effluent into False Bay. Before construction of the sewage works and effluent outfall in 1962, raw sewage was pumped into the area now occupied by the oxidation ponds and some subsurface seepage into the surf-zone may have occurred.

From 1962 to 1980 the flow of effluent to the sea via the Zeekoe Canal increased from an average of 10×10^3 m^3 to 64×10^3 m^3 per day (10 Mℓ to 64 Mℓ/day) (Cape Town City Engineer's Reports 1962 - 1980). In 1980, the sewage works was modified by the incorporation of a sludge treatment system which has been designed to produce an effluent complying with the South African General Standards (COD-Chemical Oxygen Demand = 75 mg/ℓ, OA-Oxygen Absorbed = 10 mg/ℓ, suspended solids = 25 mg/ℓ and ammonia as nitrogen = 10 mg/ℓ, Cape Town City Engineer, *in. litt.*).

Annual mean analytical data for the Cape Flats Sewage Works final pond effluent for the period 1962 to 1981 are shown in Appendix I. The following data are extracted from this appendix and data collected during the ECRU survey (Appendix II).

Since 1962 the mean annual COD of the effluent has ranged from 386 mg/ℓ in 1965 to 81 mg/ℓ during 1981. The average levels of suspended solids have ranged from 144 mg/ℓ in 1965 to 26 mg/ℓ in 1967. The average for 1981 was 72 mg/ℓ. The ammonia as nitrogen concentrations were lowest in 1971 (average = 6 mg/ℓ), but have been as high as 40 mg/ℓ, as in 1979. The average for 1981 was 31,4 mg/ℓ. In June 1982, the ammonia concentrations of the final effluent were measured as 19 mg/ℓ (PD Bartlett, pers. comm.) and 22 mg/ℓ (P King, Cape Divisional Council, pers. comm.). It would seem that the high ammonia levels are responsible for the scarcity of aquatic animal life in the Zeekoe Canal. Generally all nutrient levels in the Zeekoe Canal are considerably greater than those found in a typical unpolluted estuary (PD Bartlett, pers. comm.). In June 1982, the phosphate concentration of the effluent was 7,08 mg/ℓ and nitrate as nitrogen 0,33 mg/ℓ.

Data collected by the Marine Pollution Monitoring Group of the NRIO in winter 1975 (Appendix III) and summer 1975/76 (Appendix IV) show that nutrient levels in the sewage effluent are significantly diluted at distances of 600 m to the east and west of the mouth of the canal. OA values decreased with distance from the mouth; at 600 m from the mouth values only slightly higher than normal were obtained (Fricke *et al.*, 1975). Monitoring of the nutrient levels along the coastline to the east and west of the mouth of the Zeekoe Canal by the Cape Town City Council during 1982 (Appendix V) indicated slightly elevated concentrations near the mouth of the canal. However, these values were somewhat lower than those recorded by the Marine Pollution Monitoring Group of the NRIO in 1975 and 1976. This is possibly as a result of the modernization of the Cape Flats Sewage Works in 1980.

There are large numbers of sand mussels mainly *Schizodesma spengleri*, at the mouth of the Zeekoe Canal. This is probably related to the high levels of suspended solids in the sewage effluent. Phytoplankton blooms are often visible as patches of brown water in the surf-zone to the east and west of the mouth of the canal. This may be related to the nutrient input into the surf-zone due to the effluent outfall or possibly due to sub-surface seepage. McLachlan and Lewin (1981) in a study of surf phytoplankton blooms along the South African coast, often observed rich blooms after good rainfall. They suggest that rainfall possibly increases groundwater seepage, thereby flushing more nutrients out of the intertidal interstitial system.

According to Hennig *et al.* (1983), the ratio of harpacticoid copepods to nematodes in unpolluted beaches is approximately one to one. They found that the optimum sand particle diameters for meiofauna in unpolluted sandy beaches (sediment size range 196-337 µm) was 284 µm. The number of both nematodes and harpacticoids decreased in a normal distribution on either side of the optimum. For a median particle size of 414 µm, as calculated for the beach to the west of the Zeekoe mouth in February 1976, the high mean numbers of both harpacticoids (940) and nematodes (648) per 100 cm^3 sample suggest a degree of perturbation. Also the mean number of flatworms (39) per 100 cm^3 sample, is high. In unpolluted beaches the number of flatworms is usually 0 - 3 per 100 cm^3 sample (H Hennig, Marine Biology Division, NRIO, pers. comm.).

Under all conditions of sewage pollution coarser sediments support greater numbers of harpacticoids (H Hennig, pers. comm.). With greater compaction and blockage of the sediments by organic matter in sewage effluent, harpacticoid numbers decrease, whereas nematode numbers do not. In general, the meiofauna data indicate some degree of perturbation by sewage, although the large numbers of harpacticoids suggest that the interstitial beach sediments are well oxygenated (H Hennig, pers. comm.).

No published information is available on trace metal concentrations in the Cape Flats sewage effluent. However, it is unlikely that significant quantities of metals would pass through the sewage works since these would be removed in the activated sludge (PD Bartlett, pers. comm.).

At present the Cape Town City Council is dumping solid waste garbage in the dunes to the east of the Cape Flats Sewage Works and landward of Baden Powell Drive. The practice appears to be to bulldoze trenches behind the primary dunes and then to cover over the deposited garbage with sand when the trenches are full. This could result in pollution of the adjacent beaches by sub-surface seepage, particularly after heavy rain.

3.2.7 Public Health Aspects

Regular monitoring of bacteriological levels (*E. coli*/100 mℓ) in Zeekoevlei is carried out by the Cape Town City Council. Summaries of the data can be found in the Cape Town City Engineer's Reports. Comparison of these data with the European Economic Community (EEC) faecal coliform standard for freshwater bathing waters (*E. coli* counts in 95 percent of the samples must be equal to or lower than 2 000 *E. coli*/100 mℓ - Edington and Edington, 1977) indicates that bacteriological levels in Zeekoevlei do exceed this standard from time to time, particularly at the mouths of the Big and Little Lotus Rivers (Cape Town City Engineer's Reports 1973 - 1981).

Bacteriological data for the final pond effluent of the Cape Flats Sewage Works from 1962 to 1981 are shown in Appendix I. The annual average number of *E. coli*/100 mℓ ranged from a minimum of 67 in 1967 to an occasional maximum of $16{,}6 \times 10^4$ as was recorded by the Cape Town City Council in 1980 (Cape Town City Engineer's Report, 1980). The latter maximum figure was, however, strongly biased by two or three results. As the Zeekoe Canal is accessible to the public (although warning signs do exist), it constitutes a serious public health hazard.

Bacteriological data from the Cape Town City Engineer's Reports (1973 - 1980) for the beaches at Muizenberg Pavilion and Strandfontein Resort (to the west and east of the Seekoe Canal respectively) indicated that most of the samples had counts of *E. coli*/100 mℓ below 200. This figure is well below the EEC faecal coliform standards for seawater bathing waters (counts for 95 percent of samples must be equal to or lower than 5 000 *E. coli*/100 mℓ at temperatures of less than 20^{o}C and 2 000 *E. coli*/100 mℓ at temperatures of greater than 20^{o}C - Edington and Edington, 1977).

4. BIOTIC CHARACTERISTICS

4.1 Flora

4.1.1 Phytoplankton/Diatoms

Phytoplankton blooms commonly occur in the surfzone to the east and west of the mouth of the Zeekoe Canal. These give rise to the unsightly brown patches of discolouration which cause concern to bathers using the beaches as far west as Muizenberg. Although this phenomenon occurs naturally elsewhere on the South African coast (McLachlan and Lewin, 1981) there is some controversy about the extent to which such blooms are caused by nutrients in sewage effluent from the Zeekoe Canal (Cape Times of 6 October 1982).

Grindley and Taylor (1970) in a publication on plankton blooms in False Bay, recorded brown discolourations in the surfzone off Muizenberg beach, particularly during the autumn period in the 1960s. These blooms were found to be caused by a species of *Anaulus*.

A single sample of surfzone bloom at Muizenberg recorded by McLachlan and Lewin (1981) was a mass of almost pure *Anaulus* sp. although no cell counts were done. These authors found that *Anaulus* cells became buoyant, floated to the surface and tended to concentrate as patches over rip currents during the day. With the onset of darkness they started disappearing, probably due to the cells losing buoyancy and sinking.

RA Carter (Marine Biology Division, NRIO, pers. comm.) sampled the phytoplankton blooms in the surfzone at four stations between Strandfontein and Muizenberg on 13, 14 and 19 December 1979. He assessed the species composition and measured chlorophyll *a* concentrations of the samples. Samples from the mouth of the Zeekoe Canal consisted of *Anaulus* sp. (probably *birostratus*) and a flagellate which was dominant. The dominant species in the other samples to the east and west of the mouth of the canal were: *Anaulus* sp. (probably *birostratus*), *Skeletonema costatum*, *Thalassiosira* sp., *Chaetoceros* sp., *Rhizoselenia* sp. and *Nitschia* sp. Generally chlorophyll *a* levels were highest at the mouth of the canal. Blooms are generally visible only during south-easterly winds and it is notable that the wind was blowing from that direction on the above-mentioned sampling days.

Mean values for *Anaulus birostratus* densities (Appendix V) derived from monthly samples collected by the Cape Town City Council from May to October 1982 did not suggest an increase in density at the mouth of the Zeekoe Canal. Those values for sampling stations to the west of the canal were generaly greater than those for stations to the east of it.

4.1.2 Algae

Harrison (1962) reported a very varied algal flora for Zeekoevlei, including *Scenedesmus*, *Cosmarium*, *Closterium*, *Anabaena*, *Oscillatoria*, *Cladophora* and *Rhizoclonium*. Whether this composition has changed since then, is not known.

Dense beds of the weed *Potamogeton* which were a feature of Zeekoevlei for many years, have been replaced by a thick growth of unicellular algae so that the water is now muddy and intensely green (Day and King, In press). These authors go on to state that Stephens (1929) and Harrison (1962) both mentioned a cyclic alternation between *Potamogeton* and algae. However, the algae appear to have become dominant and water free of algae has not been seen for more than twenty years (Day and King, In press).

4.1.3 Aquatic Vegetation

Stephens (1929) stated that Rondevlei (which was more saline than Zeekoevlei) was connected to Zeekoevlei by an overflow channel and had a bottom covering of *Potamogeton exiguus* (now *pectinatus*) whereas Zeekoevlei was clear of this weed. During the early 1920s the water in Zeekoevlei was green with algae (Harrison, 1962; Howard-Williams, 1976 and JR Grindley, pers. comm.). Then during the early 1940s the vlei was well scoured out by floods, the water became clear and *Potamogeton* became established (Harrison 1962, JR Grindley, pers. comm.). By 1946 the growth was so dense that coot were able to build nests on it and yachting was limited to the small area of deeper water (Harrison, 1962). During the late 1940s algal blooms became established in Rondevlei and in the northern basin of Zeekoevlei (Harrison, 1962). In 1951 the Cape Town City Council sprayed parts of Zeekoevlei with a weed killer (Sodium arsenite) which caused the final elimination of *Potamogeton* from the vlei (Cape Town City Engineer's Report, 1951). By 1953 the whole of Zeekoevlei was green with algae and practically clear of weed, a situation which has persisted up to now (Harrison, 1962; Howard-Williams, 1976).

Brummer (1981), however, stated that during the Second World War, aircraft parts were shipped to the Cape and a dried weed, *Potamogeton pectinatus* was used for packing. This packing was dumped into the newly built canal from Youngsfield and duly found its way into Zeekoevlei where conditions were ideal for it to flourish. In view of the fact that *P. pectinatus* is indigenous and had been previously recorded in Rondevlei (Stephens, 1929), this does not seem to be a valid explanation for its invasion of Zeekoevlei.

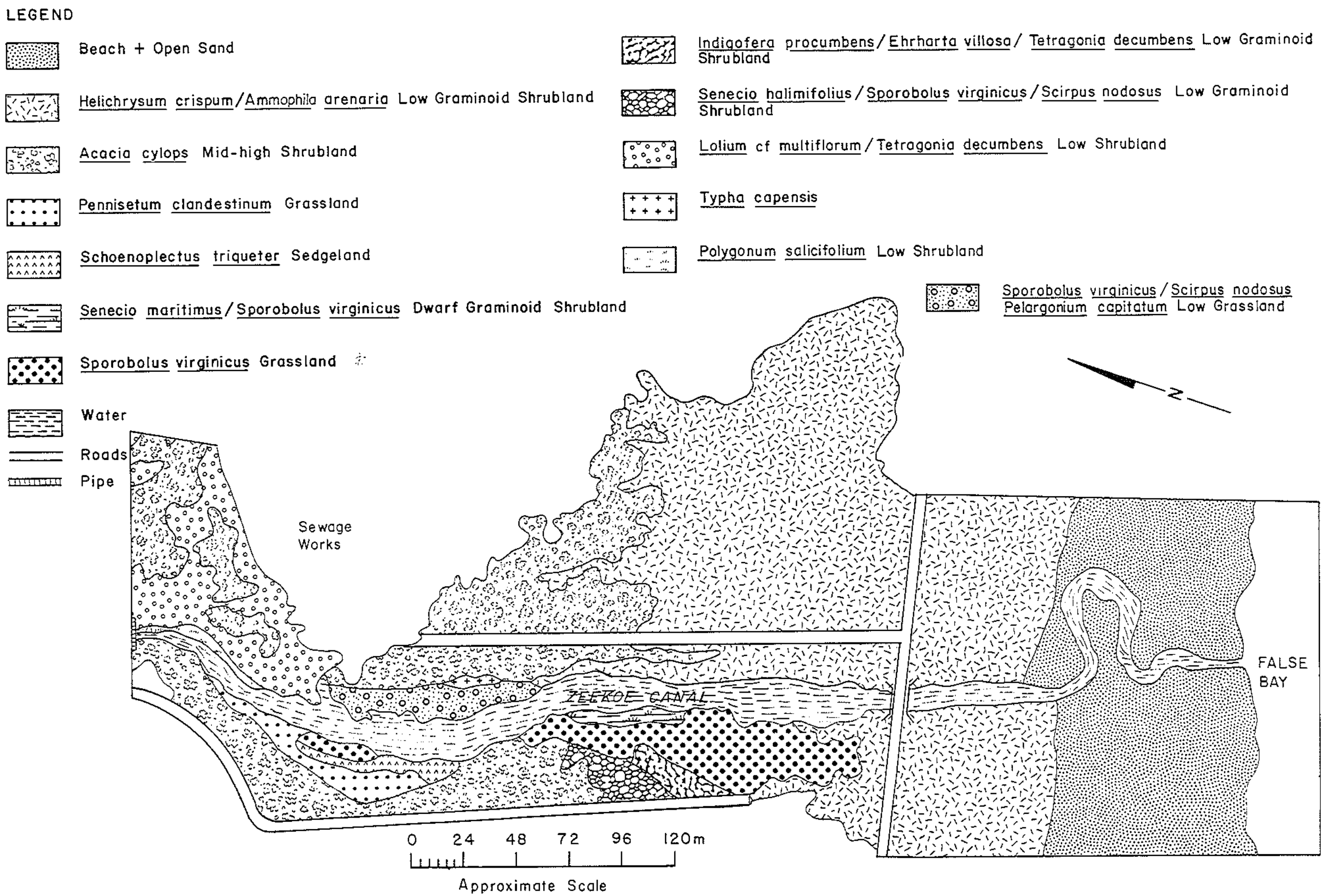
The final decline of *P. pectinatus* and resulting proliferation of algae in Zeekoevlei was due to the following:

(a) Underwater cutting of the weed and the fact that the cut weed was not removed but was left to rot would have provided nutrients for algae (Brummer, 1981).

(b) Spraying of parts of Zeekoevlei with sodium arsenite by the Cape Town City Council killed the weed which sank, causing anaerobic decomposition on the bottom (Brummer, 1981). This was the critical factor.

(c) Turbidity caused by algae limits penetration by light and therefore the growth of the weed.

FIG.6: Vegetation mapping units of the area studied at the Zeekoe Canal



4.1.4 Semi-aquatic Vegetation (Zeekoevlei)

Davies (1983) looked at changes in the shoreline and in the amount of submerged and emergent vegetation around Zeekoevlei by comparison of aerial photographs taken in 1968 and 1980. This indicated that there had been a considerable decrease in the amount of shoreline vegetation (mainly *Phragmites*), particularly on the south-eastern and north-eastern shores. On the south-eastern shore the decrease was due mainly to the greater number of points of access to the water's edge in 1980.

Conversely there had been a general increase in the amount of submerged and emergent vegetation (mainly *Typha*) particularly along the north-eastern shoreline. The reasons for these changes are not clear but they are probably related either directly or indirectly to man's impact on the vlei.

4.1.5 Semi-aquatic and Terrestrial Vegetation (Lower reaches of the Zeekoe Canal only)

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

This area falls into Acock's Veld Type 47, Coastal Macchia (Acocks, 1975).

Twelve main vegetation mapping units were identified. Their structure, species composition and area are shown in Appendix VI and their spatial distribution in Figure 6. The height of the vegetation varies from the 1,5 m of the *Typha capensis* Sedgeland to the 0,2 m of the *Senecio maritimus/Sporobolus virginicus* Dwarf Graminoid Shrubland. The *Sporobolus virginicus* Grassland has the highest cover (100 percent) while the *Schoenoplectus triqueter* Sedgeland has the lowest with a total cover of 30 percent. The *Helichrysum crispum/Ammophila arenaria* Low Graminoid Shrubland has the highest species diversity with a total of 21 species noted. The *Pennisetum clandestinum* Grassland has the lowest species diversity with only one species recorded.

The vegetation mapping units can be consolidated into six main plant formations namely grassland, sedgeland, mid-high shrubland (1,0 - 2,0 m), low shrubland (0,25 - 1,0 m), low graminoid shrubland (0,25 - 1,0 m) and dwarf graminoid shrubland (< 0,25 m). The low graminoid shrubland is the most extensive, covering an area of 3,34 ha of the 8,79 ha studied. This is followed by the mid-high shrubland (1,51 ha), grassland (0,60 ha), low shrubland (0,38 ha), sedgeland (0,33 ha) and dwarf graminoid shrubland (0,03 ha).

The vegetation is very disturbed and most of the natural vegetation has been destroyed and replaced. Rooikrans *(Acacia cyclops)* has invaded large parts of the area. Another factor which is indicative of disturbance is the large grassy element, an element normally not conspicuous in this vegetation type. Most of the other communities consist of pioneer or ruderal species and no further succession towards the naturally occuring mature vegetation can be expected due to the continuing disturbance.

4.2 Fauna

4.2.1 Zooplankton

Harrison (1962) gave a list of the zooplankton species recorded in Zeekoevlei. He also recorded three species of rotifer in the lower reaches of the Zeekoe Canal in December 1949.

During a preliminary survey by the ECRU on 16 September 1980, numerous mosquito larvae were found in a sample collected just upstream of the pipeline crossing the Zeekoe Canal (ECRU Grid Ref. 0609).

A water sample collected from the outfall of the final oxidation pond of the Cape Flats Sewage Works during the ECRU survey on 16 June 1982, contained a large number of Cladocerans.

4.2.2 Aquatic Invertebrates

The most numerous invertebrates present in Zeekoevlei are Ostracoda (Crustacea) and *Chironomus* larvae (Diptera: Chironomidae). Copepoda and Cladocera (Crustacea) are not uncommon and Amphipoda (Crustacea), Belastomatidae and Ephemeroptera nymphs (Insecta) are rarely found (Curtin *et al.*, 1975).

Harrison (1962) differentiated the invertebrate fauna of the *Potamogeton* weed beds of Zeekoevlei into permanent weed bed dwellers and a migrating component. He gave the seasonal occurrence of the various species in the weed beds from winter 1946 to spring 1947. Of particular note was the occurrence of the amphipod *Talorchestia ancheidos* which was commonly regarded as an estuarine species. Its presence suggested that Zeekoevlei is a relict estuarine lake (Harrison, 1962).

No benthic fauna was noted in the Zeekoe Canal during the ECRU surveys (80-09-16 and 82-06-21). Furthermore "D" net sampling on both occasions yielded no aquatic invertebrates. Of particular note was the absence of the burrowing sandprawn *Callianassa kraussi*. This was confirmed by CM Gaigher (CPA Department of Nature and Environmental Conservation, *in litt.*).

On the beach at the mouth of the Zeekoe Canal there are large numbers of sand mussels, mainly *Schizodesma spengleri*.

4.2.3 Fish

Zeekoevlei has been a popular angling venue for many years. According to McVeigh (1979) the following fish species occur in Zeekoevlei:

Carp	*Cyprinus carpio* (introduced)
Mozambique tilapia	*Oreochromis* (previously *Saratherodon*) *mossambicus* (introduced)
Banded tilapia	*Tilapia sparrmanii* (introduced)
Sharptooth catfish	*Clarias gariepinus* (introduced)
Freshwater mullet	*Myxus capensis* (introduced)

The following species were also introduced into the vlei but do not seem to have survived:

Largemouth bass — *Micropterus salmoides*
Redbreast tilapia — *Tilapia rendalli* (previously *melanopleura*)

Using mark-recapture techniques Hamman *et al.* (1977) estimated population sizes and standing stocks for the two most common species *C. carpio* and *O. mossambicus* in Zeekoevlei. The data are shown in Table 1.

Table 1: Population estimates and standing stock for *Cyprinus carpio* and *Oreochromis mossambicus* in Zeekoevlei (after Hamman *et al.*, 1977)

Species	Total Population Estimate	Standing Stock(kg/ha)
C. carpio	226 000	682,87
O. mossambicus	523 000	90,92
Total (both species)	749 000	773,79

The total standing stock figure of 774 kg/ha is particularly high and is 15 times greater than that of Baberspan, Loskop Dam or Doorndraai Dam where similar studies have been carried out. Zeekoevlei's advanced state of eutrophication enables it to support such large stocks of fish (Hamman *et al.*, 1977).

Since the above study was carried out before the introduction of the Sharptooth catfish *Clarias gariepinus* which preys on smaller fish, the numbers and standing stock of e.g. *O. mossambicus* may since have been reduced.

McVeigh (unpublished) has recommended that consideration should be given to the construction of a fish ladder at the outflow weir of Zeekoevlei to allow mullet in the Zeekoe Canal to enter the vlei. He goes on to say that the Zeekoe Canal is well stocked with Mosquito fish *(Gambusia affinis)* (an exotic species imported from North America).

"D" net hauls in the lower reaches of the Zeekoe Canal during the ECRU surveys (80-09-16 and 82-06-21) yielded only one juvenile *Liza richardsoni* and there were no signs of fish activity in the water. The high ammonia levels in the sewage effluent entering the canal are probably responsible for the paucity of fish in its lower reaches. With the stagnant eutrophic conditions that exist in the upper reaches of the canal (see Plate III) when the Zeekoevlei and Rondevlei weirs are not overflowing, it is unlikely that fish would be able to survive there during such periods.

4.2.4 Reptiles and Amphibians

According to the Cape Town City Engineer's Report (1944), the Boomslang, Mole Snake, Night Adder, Puff Adder, Cape Yellow Cobra and Spotted Cobra occurred commonly in the vicinity of Zeekoevlei.

No specimens of reptiles or amphibians were collected during the ECRU surveys. However, a list of species recorded for the area covered by the 1:50 000 Sheet 3418 BA Mitchell's Plain, in which most of the Zeekoe drainage system is situated, was obtained from RC Boycott and AL de Villiers *(in litt.)* of the CPA Department of Nature and Environmental Conservation. The species list, which is incomplete for the area is given in Appendix VII.

Eight species of frogs, seventeen snake species, six lizard species and three species of tortoise have been recorded in the area. Of these, two frog species have been listed in the South African Red Data Book as being rare or threatened. These are the Cape Platanna and Arum Lily Frog (McLachlan, 1978).

4.2.5 Birds

Bird investigations at Rondevlei and Zeekoevlei date back to before the Second World War (Winterbottom, 1960). Cape Bird Club count data for Rondevlei and Zeekoevlei from 1952 to 1958 are reported on by Winterbottom (1960).

Since the establishment of Rondevlei as a bird sanctuary in 1952, regular counts have been carried out there by the sanctuary warden. These data are published in the Annual Reports on the Rondevlei Bird Sanctuary. Blaker and Winterbottom (1968) give count data for the Strandfontein (Cape Flats) Sewage Works.

Wader counts for Princess Vlei, Rondevlei, Zeekoevlei, the Cape Flats Sewage Works and Strandfontein Beach carried out during the summer of 1975/76 have been published by Summers *et al* (1976). Data from more recent (January 1981) counts of all water bird species for Princess Vlei, Rondevlei, Zeekoevlei and the Cape Flats Sewage Works (Underhill and Cooper, in press) are given in Appendix VIII. Winter (July 1981) data for the Cape Flats Sewage Works (Underhill and Cooper, in press) are given in Appendix IX.

The Zeekoe Drainage System supports a diverse and abundant bird fauna as borne out by the count data in Appendix VIII. Of note is the paucity of wader species (1) at Rondevlei. According to Summers *et al.* (1976) the status of Rondevlei as a wader habitat had declined due to the growth of *Paspalum* grass on the mudbanks. There were 32 waterbird species and 750 individuals at Zeekoevlei whilst Rondevlei had 25 species and 1216 individuals. The lower individual count for Zeekoevlei could be due to human disturbance.

The highest waterbird counts in the drainage system have always been recorded at the Cape Flats Sewage Works (800 ha of shallow pans) (see Frontispiece and Figure 1). A total of 22 554 water-associated birds consisting of 56 species was counted on

23 January 1981 (Appendix VIII). Of these 19 species were recognized waders making up a total of 3 203 birds. The waders consisted of 12 migrant species (1911 birds) and 7 resident species (1 292 birds). A comparative winter count carried out on 16 July 1981 revealed a total of 18 652 water-associated birds consisting of 40 species (Appendix IX). Of the total number of individuals 12 000 were Cape Cormorants. The lower number of species in winter was due mainly to the absence of migrant waders.

Clearly the Cape Flats Sewage Works is a very important water bird habitat, particularly during the summer months when many of the natural vleis elsewhere in the South-western Cape, become dry. The birds including Greater and Lesser Flamingo use the area for feeding and Cape Cormorants and other species use the area for roosting. The abundance of birds is probably due to the fact that the area is protected by the Cape Town City Council and that access is restricted to permit holders. There is considerable bird interchange daily between the Cape Flats Sewage Works, Rondevlei and Zeekoevlei (Brummer, 1981).

At present the sewage works oxidation ponds serve only as a standby for the new activated sludge system inaugurated in 1980. As such these ponds should be managed as a waterbird habitat (Curtin 1975, Cooper *et al.* 1976, Brummer 1981).

4.2.6 Mammals

According to the Cape Town City Engineer's Report (1944) the following mammals occurred commonly in the vicinity of Zeekoevlei: Grysbok, Steenbok, Grey mongoose, Musk cat, Porcupine and Striped polecat.

In November 1981 two hippopotami (*Hippopotamus amphibius*) were introduced into Rondevlei in an attempt to check the growth of the grass *Paspalum* over mudflats previously utilized by waders. This is apparently proving to be successful.

Mammal records for the area covered by the 1:50 000 Sheet 3418 BA Strandfontein were obtained from Stuart *et al.* (1980) and Stuart (1981). The checklist is given in Appendix X.

Thirteen mammal species, none of which is listed in South African Red Data Books as being rare or threatened, have been recorded for the area. These exclude the hippopotami at Rondevlei.

With urbanization, the number of mammal species found in the vicinity of Zeekoevlei can be expected to decline.

5. SYNTHESIS

In their original undisturbed state Zeekoevlei and Rondevlei were directly connected and drained to the sea via a swampy area running from the south-eastern corner of Zeekoevlei. The early occurrence of marine fish in Zeekoevlei (see Section 1.2) indicated that there must have been a direct connection to the sea.

Inhabitation and development over the years has resulted in the following major changes to the original system:

(a) Closing up of the original connection to the sea.

(b) Increased run-off into the vleis due to urbanization in the catchment.

(c) Separation of Rondevlei and Zeekoevlei, construction of weirs at their southern extremities and construction of the Zeekoe Canal draining excess water to the sea.

(d) Construction of the Cape Flats Sewage Works and effluent outfall into the Zeekoe Canal.

As a result of development of the Zeekoe Drainage System, the following major environmental problems have arisen:

(a) Flooding along the banks of the Big Lotus River (see Section 3.1.1) and the continual necessity to remove river bank vegetation.

(b) Enrichment of the run-off into Princess vlei, Rondevlei and Zeekoevlei (see Sections 3.2.5 and 3.2.6).

(c) The presence of nutrient-rich sediments of decomposed weed and algae on the floor of Zeekoevlei which has favoured extensive algal growth (see Sections 3.2.5, 4.1.2 and 4.1.3).

(d) Enrichment of the Zeekoe Canal by the Cape Flats Sewage Works effluent outfall (see Sections 3.2.5, 3.2.6 and 4.1.1).

Rectification of the problems associated with the Zeekoe Drainage System is made more complex by the intensive human habitation of the catchment (see Section 3.1) and the problem of divided control (see Section 2.2). Because the main water bodies are close to a city centre, they have great recreational value, an asset which must increase with time. Management of the system must, of necessity, be human orientated, including Rondevlei which has enjoyed sanctuary status for thirty years, but is nevertheless open to the public.

In order to improve environmental conditions in the drainage system a consultant's report needs to be drawn up which would contain an overall management plan encompassing the parts of the catchments and the vleis controlled by both the Cape Town City Council and the Cape Divisional Council. In other words, an overall system orientated management approach needs to be followed.

Management recommendations for Zeekoevlei have been put forward by Curtin *et al.* (1975) and Brummer (1981). In addition Howard-Williams (1976) and Allanson (1977, 1978a and 1978b) have made recommendations and research proposals to the Cape Town City Council regarding the vleis (including Zeekoevlei) under its control. Dr BR Davies of the Zoology Department, University of Cape Town is at present acting as an ecological consultant to the Cape Town City Council for these vleis. He will be dealing with management problems and making detailed recommendations, so this aspect is only briefly covered in this report.

Generally, the following considerations are necessary to resolve the problems associated with the drainage system:

(a) Identification of the various nutrient inputs into the vlei system and rectification where possible. In this respect there is a dearth of fundamental hydrological data (e.g. flow rates) for most of the system. Without volumetric inflow/outflow data, no meaningful assessment of nutrient loadings of the components (in particular Zeekoevlei) can be made. Such assessments are essential if the eutrophication problems associated with virtually the whole system are to be overcome.

(b) The need for close co-operation between the Cape Town City Council and the Cape Divisional Council to improve the quality of run-off.

(c) The need for removal of nutrient-rich algal mud from the bottom of Zeekoevlei, in keeping with the recommendations by Howard-Williams (1976).

(d) Ecological requirements, e.g. the need to establish a favourable balance between algal populations and fish production in Zeekoevlei.

(e) The need to look at present socio-economic problems relating to the use of the vleis due to the diverse forms of housing developments in their vicinity and above all, the need for protection of future requirements to optimize on the recreational/educational potential of the system with its various vleis. The key to this is maintenance of ecological viability.

The importance of the Cape Flats Sewage Works as a perennial coastal habitat for water birds in the South-western Cape has already been mentioned in this report (see Section 4.2.5). Since the oxidation ponds are now essentially redundant, they should now be managed to the full advantage of the birds. The elevation of the sewage works to nature reserve status has already been recommended by Curtin *et al.* (1975), Cooper *et al.* (1976) and Brummer (1981) and this proposal is strongly supported in this report. The Strandfontein (Cape Flats) Sewage Works, although not a natural wetland, has been identified by Cooper *et al.* (1976) as one of the ten major coastal habitats of waders in the South-western Cape. In terms of the "Ramsar Convention on

Wetlands of International Importance, Especially as Waterfowl Habitat", South Africa being a contracting party, should increase its protected wetland habitats. This country has a responsibility to protect migratory waders already protected in their Northern Hemisphere breeding grounds (Cooper *et al.*, 1976).

The above proposals are made not only with a view to conserving an ecologically valuable wetland complex, but also to providing an attractive area for controlled recreational utilization by the public.

The Zeekoe Canal at present constitutes a public health hazard (see Section 3.2.7), particularly where it passes under the Baden Powell Drive bridge and flows across the beach into the sea. The need for an enclosed pipeline to carry this effluent is widely acknowledged and, in spite of substantial financial implications, the construction of such a sea outfall warrants serious further attention. Controversy regarding the effects of the Cape Flats Sewage effluent on phytoplankton blooms in the surfzone also points to the need for further investigation (see Section 4.1.1). The relevance of such a study should be assessed in relation to the wider importance of maintaining the beach area which is of great and rapidly increasing recreational importance, in aesthetically pleasing condition.

The area to the east of the Cape Flats Sewage Works (see Figure 1) is covered mostly by good Coastal Strandveld, and is one of the few remaining substantial stands of this vegetation type on the Cape Flats. Consideration should be given to the conservation of this area, as has been proposed in the Cape Town City Engineer's Department Report No 214 (1982), which suggests that it be incorporated in the proposed False Bay Coastal Park as part of the "Greening of the City" programme. This ambitious and well-founded report which *inter alia* proposes incorporation of Rondevlei, Zeekoevlei, and the Cape Flats Sewage Works and their surrounding areas in the establishment of the False Bay Coastal Park, should be given the strongest possible support.

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7. GLOSSARY OF TERMS USED IN PART II REPORTS

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

epifauna: animal life found on the surface of any substrate such as plants, rocks or even other animals.
epiphyte: a plant living on the surface of another plant without deriving water or nourishment from it.
episodic: sporadic and tending to be extreme.
estuary: a partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with fresh water derived from land drainage (Day 1981).
eutrophication: the process by which a body of water is greatly enriched by the natural or artificial addition of nutrients. This may result in both beneficial (increased productivity) and adverse effects (smothering by dominant plant types).
flocculation (as used in these reports): the settlement or coagulation of river borne silt particles when they come in contact with sea water.
fluvial (deposits): originating from rivers.
food web: a chain of organisms through which energy is transferred. Each "link" in a chain feeds on and obtains energy from the preceding one.
fynbos: literally fine-leaved heath-shrub. Heathlands of the south and south-western Cape of Africa.
geomorphology: the study of land form or topography.
gill net: a vertically placed net left in the water into which fish swim and become enmeshed, usually behind the gills.
habitat: area or natural environment in which the requirements of a specific animal or plant are met.
halophytes: plants which can tolerate salty conditions.
HAT (Highest Astronomical Tide) and LAT (Lowest Astronomical Tide): HAT and LAT are the highest and lowest levels respectively, which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; these levels will not be reached every year. HAT and LAT are not the extreme levels which can be reached, as storm surges may cause considerably higher and lower levels to occur (South African Tide Tables 1980).
hummock (dune): a low rounded hillock or mound of sand.
hydrography: the description, surveying and charting of oceans, seas and coastlines together with the study of water masses (flow, floods, tides etc.).
hydrology: the study of water, including its physical characteristics, distribution and movement.
indigenous: belonging to the locality; not imported.
intertidal: generally the area which is inundated during high tides and exposed during low tides.
isohyets: lines on maps connecting points having equal amounts of rainfall.
isotherms: lines on maps joining places having the same temperature at a particular instant, or having the same average, extremes or ranges of temperature over a certain period.
lagoon: an expanse of sheltered, tranquil water. (Thus Langebaan lagoon is a sheltered arm of the sea with a normal marine salinity; Knysna lagoon is an expanded part of a normal estuary and Hermanus lagoon is a temporarily closed estuary (Day 1981)).
limpid: clear or transparent.
littoral: applied generally to the seashore. Used more specifically it is the zone between high- and low-water marks.
longshore drift: a drift of material along a beach as a result of waves breaking at an angle.

macrophyte: any large plant as opposed to small ones. Aquatic macrophytes may float at the surface or be submerged and/or rooted on the bottom.
marls: crumbly mixture of clay, sand and limestone, usually with shell fragments.
matrix: medium in which a structure is embedded.
meiofauna: microscopic or semi-microscopic animals that inhabit sediments but live quite independently of the macrofauna, or benthos.
metamorphic: changes brought about in rocks within the earth's crust by the agencies of heat, pressure and chemically active substances.
MHWS (Mean High Water Springs) and MLWS (Mean Low Water Springs): the height of MHWS is the average, throughout a year when the average maximum declination of the moon is 23°, of the height of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is greatest. The height of MLWS is the average height obtained by the two successive low waters during the same periods (South African Tide Tables 1980).
morphometry: physical dimensions such as shape, depth, width, length etc.
osmoregulation: the regulation in animals of the osmotic pressure in the body by controlling the amount of water and/or salts in the body.
pathogenic: disease producing.
photosynthesis: the synthesis of carbohydrates in green plants from carbon dioxide and water, using sunlight energy.
phytoplankton: plant components of plankton.
piscivorous: fish eating.
plankton: microscopic animals and plants which float or drift passively in the water.
quartzite: rock composed almost entirely of quartz recemented by silicon. Quartzite is hard, resistant and impermeable.
riparian: adjacent to or living on the banks of rivers, streams or lakes.
rip current: the return flow of water which has been piled up on the shore by waves, especially when they break obliquely across a longshore current.
salinity: the proportion of salts in pure water, in parts per thousand by mass. The mean figure for the sea is 34,5 parts per thousand, written 34,5°/₀₀.
secchi disc: a simple instrument used to measure the transparency of water.
sheet flow: water flowing in thin continuous sheets rather than concentrated into individual channels.
slipface: the sheltered leeward side of a sand-dune, steeper than the windward side.
teleost: modern day bony fishes (as distinct from cartilaginous fishes).
trophic level: a division of a food chain defined by the method of obtaining food either as primary producers, or as primary, secondary or tertiary consumers.
trough: a crescent shaped section of beach between two cusps.
wetlands: areas that are inundated or saturated by surface or ground water frequently enough to support vegetation adapted to life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.
zooplankton: animal components of plankton.

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{ZEEKOE MOUTH} Bl. and Wh. Job No 126 38. Photo No 11793, Trig. Survey Mowbray. 1:250 000, 1938.

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APPENDIX I: Annual mean analytical data values for the Cape Flats Sewage Works final pond effluent for the period 1962 to 1981. Data extracted from Cape Town City Engineer's Reports (1962 - 1981).

Year	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
B.O.D. (mg/ℓ)	-[+]	-	-	-	-	25,0	52,0	30,0	66,0	49,0	56,0	38,0	24,0	25,0	24,0	-[+]	42,0	35,0	21,0	-
C.O.D. (mg/ℓ)	-	-	-	386	239,6	234,0	285,0	281,0	287,0	302,0	284,0	262,0	179,0	206,0	178,0	-	178,0	180,0	160,0	156,0
Settleable solids (mℓ/ℓ)	Nil	-	-	0,2	0,4	<0,1	<0,1	0,1	1,0	0,3	0,1	0,2	0,1	0,1	0,15	-	0,2	0,11	0,34	0,1
Suspended solids (mg/ℓ)	11,0	-	-	144,0	56,0	26,0	100,0	107,0	117,0	107,0	105,0	84,0	52,0	47,0	53,0	-	71,0	63,0	62,0	72,0
Total dissolved solids (mg/ℓ)	654,0	-	-	586,0	673,0	817,0	846,0	896,0	932,0	1042,0	930,0	962,0	828,0	826,0	752,0	-	681,0	710,0	692,0	620,0
Ammonia as N (mg/ℓ)	17,0	-	-	16,5	26,0	18,0	11,0	11,0	7,0	6,0	11,6	9,6	19,0	26,6	23,7	-	17,2	31,1	31,4	2,92
Organic nitrogen as N (mg/ℓ)	12,0	-	-	29,5	10,6	14,0	14,0	10,0	13,0	15,9	16,5	13,9	9,1	9,8	8,5	-	10,8	11,1	10,3	-
Nitrite as N (mg/ℓ)	0,01	-	-	0,6	0,15	0,15	0,58	0,49	0,8	-	-	0,4	0,18	0,13	0,17	-	0,07	0,57	0,06	1,0
Nitrate as N (mg/ℓ)	0,3	-	-	0,34	0,61	0,54	3,0	5,9	9,4	6,1	3,5	2,8	0,91	0,88	1,30	-	0,88	0,14	0,46	
pH	8,1	-	-	7,8	7,9	7,8	7,8	7,6	7,3	8,1	7,7	7,6	7,8	7,7	7,7	-	7,8	7,9	7,9	8,3
Alkalinity as $CaCO_3$ (mg/ℓ)	-	-	-	202,0	292,6	266,0	216,0	206,0	172,0	208,0	224,0	235,0	252,0	239,0	262,0	-	304,0	293,0	277,0	158,0
Chloride as Cl (mg/ℓ)	-	-	-	168,0	196,0	248,0	266,0	278,0	283,0	302,0	281,0	294,0	252,0	178,0	215,0	-	210,0	224,0	196,0	168,0
Sodium as Na (mg/ℓ)	-	-	-	-	-	-	-	-	-	-	-	221,0	186,0	143,0	148,0	-	148,0	135,0	155,0	135,0
Potassium as K (mg/ℓ)	-	-	-	-	-	-	-	-	-	-	-	35,0	30,0	25,0	26,0	-	21,0	21,0	12,0	20,0
Total phosphorus as P (mg/ℓ)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8,9	-	9,2	11,0	10,8	6,3
Phosphate as P (mg/ℓ)	-	-	-	-	-	3,19	3,6	3,9	5,8	7,1	19,5	11,0	8,0	11,2	-	-	-	-	-	-
Sulphate as SO_4 (mg/ℓ)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80,0	-	67,0	63,0	68,0	-
OA (mg/ℓ)	16,5	-	-	44,1	22,0	72,0	27,0	25,0	33,0	33,0	32,1	28,6	22,2	23,0	21,0	-	20,0	23,0	22,0	22,0
Dissolved O_2 (mg/ℓ)	7,0	-	-	3,9	7,8	4,9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Algal weight (mg/ℓ)	-	-	-	0,14	0,07	0,09	0,12	0,10	0,10	-	-	-	-	-	-	-	-	-	-	-
E. coli MPN[++]/100 mℓ	620	10500 50% of samples <50	-	52% of samples <20	1278	67	527	476	3000	1500	3000	4600	5500	54000	11900	-	22000	5170	166000	3090

[+] indicates data not recorded or not obtained from the Cape Town City Council
[++] MPN = Most Probable Number

APPENDIX II: Physico-chemical data collected during the ECRU survey at low spring tides on 82-06-21. See Figure 3 for Grid References.

Position of Sampling site	ECRU Grid. Ref.	Surface Salinity (Parts per thousand)	Phosphate as P (mg/ℓ)	Nitrite as N (mg/ℓ)	Nitrate as N (mg/ℓ)	Ammonia as N (mg/ℓ)	Dissolved O_2 (mg/ℓ)	Temp. (°C)	pH	Dissolved Organic Carbon (mg/ℓ)	Dissolved Inorganic Carbon (mg/ℓ)
At mouth	2208	0	4,76	0,11	0,38	11,01	5,29	13,0	7,6	15,1	21,2
At road bridge	1908	0	6,87	0,09	0,35	15,36	5,20	13,0	7,5	14,9	32,1
Just downstream of outfall	1008	0	6,87	0,09	0,36	17,60	5,94	13,0	7,6	52,6	27,2
Sewage effluent outfall	0908	0	7,08	0,08	0,33	18,69	4,18	12,8	7,6	20,0	27,5
At pipe crossing	0609	0	4,23	0,01	0,004	13,39	0,04	15,2	7,3	17,0	46,9

APPENDIX III: Surfzone surface water sample analytical data collected by the Marine Pollution Monitoring Group of the NRIO on 75-06-13. Samples were taken at 100 m intervals from the mouth of the Zeekoe Canal eastwards. There was a light south-westerly wind blowing at the time.

Distance of sampling station from the mouth eastwards (m)	Salinity (parts per thousand)	Total Phosphorus (mg/ℓ)	Silicate as Si (mg/ℓ)	Nitrite as N (mg/ℓ)	Nitrate as N (mg/ℓ)	OA mg/ℓ	Dissolved oxygen (mg/kg)	Temp. (°C)	pH
0	<3	0,73	4,21	0,02	0,04	35,00	2,97	13,22	8,21
100	13,39	0,55	–	0,01	0,08	34,34	4,39	14,2	7,28
200	24,59	0,54	1,36	0,01	0,02	20,40	7,10	14,8	7,35
300	26,95	0,41	1,16	0,01	0,01	20,40	7,13	14,9	7,39
400	28,48	0,43	0,67	0,01	0,24	22,48	6,77	14,9	7,39
500	31,89	0,25	0,52	0,01	0,03	12,29	5,99	15,0	7,38
600	33,29	0,16	0,38	0,01	0,02	11,28	5,21	15,0	7,42

APPENDIX IV: Surf-zone surface water sample analytical data collected by the Marine Pollution Monitoring Group of the NRIO on 76-02-13. Samples were taken at 100 to 300 m intervals from the mouth of the Zeekoe Canal westwards. There was a moderate south-westerly wind blowing at the time.

Distance of sampling stations from the mouth	Salinity (parts per thousand)	Total phosphorus (mg/ℓ)	Silicate as Si (mg/ℓ)	Nitrite as N (mg/ℓ)	Nitrate as N (mg/ℓ)	OA (mg/ℓ)	Dissolved oxygen (mg/ℓ)	Temperature (°C)	pH
0	1,44	2,54	5,54	0,06	0,07	33,03	2,93	19,0	-
300	34,92	0,04	0,04	0,00	0,02	7,19	4,85	17,5	8,05
400	34,92	0,04	0,02	0,00	0,06	9,24	6,08	18,0	7,90
500	34,92	0,04	0,06	0,00	0,01	7,19	4,99	19,0	7,95
600	34,93	0,05	0,04	0,00	0,02	-	6,40	17,0	-

APPENDIX V: Minimum, mean and maximum values for coastal nutrient survey samples and *Anaulus birostratus* density data collected by the Cape City Council at stations to the west and east of the Zeekoe Canal mouth. Monthly samples were collected from May to October 1982. The distances of the sampling stations to the west or east of the mouth of the canal are given.

	Distance of sampling point to west or east of canal mouth (km)						
	2,4 W	1,6 W	0,5 W	0,6 E	1,2 E	2,6 E	4,8 E
Ammonia as N (filtered) (mg/ℓ)	0,02 0,03 0,04	0,02 0,10 0,28	0,01 0,15 0,53	0,01 0,36 0,86	0,10 0,16 0,23	<0,01 0,07 0,16	0,002 0,03 0,06
Nitrate and Nitrite (filtered) (mg/ℓ)	0,01 0,03 0,07	0,01 0,18 0,61	<0,01 0,05 0,12	0,01 0,07 0,12	<0,01 0,04 0,09	<0,01 0,04 0,09	0,01 0,09 0,24
Total phosphorus as P (mg/ℓ)	0,04 0,18 0,61	0,04 0,14 0,32	0,04 0,17 0,29	0,12 0,28 0,49	0,05 0,13 0,17	0,05 0,14 0,28	0,04 0,12 0,24
Total phosphorus as P (filtered) (mg/ℓ)	0,01 0,03 0,07	<0,01 0,03 0,07	0,01 0,06 0,19	0,01 0,15 0,35	<0,01 0,06 0,16	<0,01 0,04 0,09	0,02 0,04 0,06
Ortho-phosphate as P (filtered) (mg/ℓ)	<0,01 0,01 0,03	<0,01 0,02 0,07	<0,01 0,05 0,18	<0,01 0,11 0,33	<0,01 0,04 0,14	<0,01 0,03 0,08	<0,01 0,02 0,05
Silicate as Si (filtered) (mg/ℓ)	0,04 0,16 0,37	0,06 0,17 0,48	0,12 0,19 0,38	0,01 0,38 0,57	0,07 0,22 0,59	0,05 0,22 0,71	0,11 0,22 0,59
Annalus birostratus count/mℓ	45 5724 33000	<6 4748 24000	90 2992 10000	90 3073 17000	45 673 2000	45 476 1411	<4 51 270

APPENDIX VI: Species composition and physical features of the vegetation mapping units of the area studied at the Zeekoe Estuary.

	+Area (ha)	% of area studied	Cover (%)	Height (m)
Helichrysum crispum/ Ammophila arenaria Low graminoid Shrubland	3,22	36,63	35	0,40
Acacia cyclops Midhigh Shrubland	1,51	17,18	95	1,20
Pennisetum clandestinum Grassland	0,11	1,25	90	0,60
Schoenoplectus triqueter Sedgeland	0,32	3,64	30	0,80
Senecio maritimus/ Sporobolus virginicus Dwarf Gramminoid Shrubland	0,03	0,34	70	0,20
Sporobolus virginicus Grassland	0,33	3,80	100	0,40
Indigophera procumbens/ Ehrharta villosa/Tegragonia decumbens Low Graminoid Shrubland	0,05	0,57	90	0,30
Senecio halimifolius/ Sporobolus virginicus/ Scirpus nodosus Low Gramminoid Shrubland	0,07	0,80	95	0,80
Lolium cf *multiflorum/ Tetragonia decumbens* Low Shrubland	0,36	4,10	80	0,40
Typha capensis Sedgeland	0,01	0,11	70	1,5
Polygonum salicifolium Low Shrubland	0,02	0,23	80	0,40
Sporobolus virgincus/ Scirpus nodosus/Pelargonium capitatum Low Grassland	0,16	1,78	90	0,30
Road	0,34	3,87		
Water	0,78	8,87		
Sand	1,48	16,84		
Total	8,79			

(+Estimated values)

Helichrysum crispum/Ammophila arenaria Low Graminoid Shrubland

Acacia cyclops (r); *Ammophila arenaria* (2); *Arctotheca populifolia* (1); *Cotula coronopifolia* (r); *Crassula glomerata* (r); *Ehrharta villosa* (+); *Ficinia dunensis* (r); *Hebenstretia cordata* (+); *Helichrysum crispum* (2); *Heteroptilis suffruticosa* (r); *Metalasia muricata* (r); *Passerina ericoides* (+); *Pennisetum clandestinum* (+); *Phylica ericoides* (r); *Senecio elegans* (r); *Senecio maritimus* (+); *Silene crassifolium* (+); *Sonchus oleraceus* (r); *Tetragonia decumbens* (2); *Trachyandra divaricata* (r).

Acacia cyclops Mid-high Shrubland

Acacia cyclops (5); *Solanum guineense* (+); *Tetragonia decumbens* (4); *Santedeschia aethiopica* (+).

Pennisetum clandestinum Grassland

Pennisetum clandestinum (5).

Schoenoplectus triqueter Sedgeland

Hycrocotyle cf *verticillata* (r); *Polygonum salicifolium* (r); *Scirpus nodosus* (+); *Schoenoplectus triqueter* (2); *Senecio halimifolius* (+); *Sonchus oleraceus* (r); *Typha capensis* (+); *Urtica urens* (r); *Zantedeschia aethiopica* (r).

Senecio maritimus/Sporobolus virginicus Dwarf Graminoid Shrubland

Acacia cyclops (r); *Arctotheca calendula* (r); *A. populifolia* (r); *Chenopodium murale* (r); *Cotula coronopifolia* (+); *Isolepsis* sp. (Parsons 17)* (r); *Pelargonium capitatum* (r); *Pennisetum clandestinum* (2); *Polyganum* sp. (Parsons 13) (r); *Rorippa nasturtium-aquaticum* (+); *Rumex spathulatus* (r); *Senecio elegans* (1); *Senecio maritimus* (3); *Sonchus oleraceus* (r); *Sporobolus virginicus* (3); *Zantedeschia aethiopica* (r).

Sporobolus virginicus Grassland

Ehrharta villosa (+); *Lolium* cf *multiflorum* (r); *Pennisetum clandestinum* (+); *Sonchus oleraceus* (r); *Sporobolus virginicus* (5); *Zantedeschia aethiopica* (+).

Indigophera procumbens/Ehrharta villosa/Tetragonia decumbens Low Graminoid Shrubland

Carpobrotus acinaciformis (+); *Drosanthenum* sp. (Parsons 21) (r); *Ehrharta villosa* (3); *Helichrysum crispum* (r); *Indigophera procumbens* (3); *Isolepis marginata* (r); *Sonchus oleraceus* (r); *Sporobolus virginicus* (+); *Tetragonia decumbens* (3).

Senecio halimifolius/Sporobolus virginicus/Scirpus nodosus Low Graminoid Shrubland

Ficinia dunensis (r); *Scirpus nodosus* (3); *Senecio halimifolius* (3); *Senecio* sp. (Parsons 23) (+); *Sonchus oleraceus* (+); *Sporobolus virginicus* (3); *Zantedeschia aethiopica* (1).

*Parsons species numbers (e.g. Parsons 17) refer to the legit and specimen number of species not identified at the time of writing.

Lolium cf *multiflorum/Tetragonia decumbens* Low Shrubland

Acacia cyclops (4); *Carpobrotus acinaciformis* (r); *Ehrharta villosa* (1); *Lavatera arborea* (r); *Lolium* cf *multiflorum* (3); *Metalasia muricata* (r); *Sonchus oleraceus* (r); *Tetragonia decumbens* (3); *Zantedeschia aethiopica* (r).

Typha capensis Sedgeland

Polygonum salicifolium (1); *Rumex spathalatus* (+); *Scirpus nodosus* (r); *Senecio halimifolius* (r); *Typha capensis* (4); *Zantedeschia aethiopica* (1).

Polygonum salicifolium Low Shrubland

Polargonium capitatum (1); *Pennisetum clandestinum* (1); *Polygonum salicifolium* (3); *Rorippa nasturtium-aquaticum* (+); *Rumex spathalatus* (+); *Scirpus nodosus* (+); *Typha capensis* (r); *Zantedeschia aethiopica* (1).

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

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

APPENDIX VII: A checklist of amphibians and reptiles recorded for the area covered by the 1:50 000 Topo-cadastral sheet 3418 BA Strandfontein (RC Boycott and AL de Villiers, Cape Department of Nature and Environmental Conservation, *in litt.*). The list is incomplete and more collecting is required in this area. Threatened species listed in the South African Red Data Book are indicated with an asterisk.

Amphibians

Frogs and toads: Recorded from Cape Department of Nature and Environmental Conservation unpublished records

Common name		Scientific name
Common Platanna	-	*Xenopus laevis*
Cape Platanna	-	+*Xenopus gilli*
Sand Toad	-	*Bufo angusticeps*
Leopard Toad	-	*Bufo pardalis*
Sand Rain Frog	-	*Breviceps rosei vansoni*
Cape Sand Frog	-	*Tomopterna delalandii*
Cape Rana	-	*Rana fuscigula*
Spotted Rana	-	*Rana grayii*
Dainty Frog	-	*Cacosternum boettgeri*
Cape Caco	-	*Cacosternum capense*
Long-toed Running Frog	-	*Kassina wealii*
Arum Lily Frog	-	+*Hyperolius horstocki*

Reptiles

Snakes: Records from Boycott (pers. obs.), Broadley (1975), Dyer (pers. obs.), FitzSimons (1962) and Visser (1979).

Common name		Scientific name
Pink Earth Snake	-	*Rhinotyphlops lalandei*
Black Worm Snake	-	*Leptotyphlops nigricans*
Brown Water Snake	-	*Lycodonomorphus rufulus*
Yellow-bellied House Snake	-	*Lamprophis fuscus*
Common Mole Snake	-	*Pseudaspis cana*
Russet Garden Snake	-	*Duberria lutrix*
Common Egg-eating Snake	-	*Dasypeltis scabra*
Herald Snake	-	*Crotaphopeltis hotamboeia*
Cape Many-spotted Snake	-	*Amplorhinus multimaculatus*
Spotted Skaapsteker	-	*Psammophylax rhombeatus*
Whip Snake	-	*Psammophis notostictus*
Leighton's Sand Snake	-	*Psammophis leightoni*
Cross-marked Cross Snake	-	*Psammophis crucifer*
Dwarf Garter Snake	-	*Elaps lacteus*
Cape Cobra	-	*Naja nivea*
Puff Adder	-	*Bitis arietans*
Yellow and black Sea Snake	-	*Pelamis platurus*

Lizards: Records from FitzSimons (1943) and Broadley and Greer (1969)

Common name		Scientific name
Marbled Gecko	-	*Phyllodactylus porphyrens*
Cape Spiny Agama	-	*Agama hispida*
Common Skink	-	*Mabuya capensis*
Golden Sand Lizard	-	*Acontias meleagris*
Ocellated Sand Lizard	-	*Merolis knoxii*
Anguine Lizard	-	*Chamaesaura anguina*

Tortoises: Records from Greig and Burdett (1976) and Cape Department of Nature and Environmental Conservation unpublished records.

Common name		Scientific name
Angulate Tortoise	-	*Chersina angulata*
Padloper or Parrots-beak Tortoise	-	*Homopus areolatus*
Cape Terrapin	-	*Pelomedusa subrufa*

APPENDIX VIII: Summer 1980/81 water bird counts for the various components of the Zeekoe drainage system (after Underhill and Cooper, in press). The names of the components and the dates of the counts are indicated.

Roberts Number	Species	Princess vlei 81-01-23	Rondevlei 81-01-28	Zeekoevlei 81-01-28	Cape Flats Sewage Works 81-01-23	Wetland System 81-01-23
4	Great Crested Grebe	0	11	0	0	11
5	Black-necked Grebe	0	0	0	416	416
6	Dabchick	0	20	22	435	477
42	White Pelican	0	140	84	22	246
47	White-breasted Cormorant	4	14	24	19	61
48	Cape Cormorant	0	0	0	261	261
50	Reed Cormorant	3	9	13	8	33
52	Darter	1	26	10	63	100
54	Grey Heron	1	6	5	4	16
55	Black-headed Heron	0	7	3	8	18
57	Purple Heron	0	1	0	0	1
59	Little Egret	0	0	2	1	3
60	Yellow-billed Egret	0	0	2	0	2
61	Cattle Egret	15	1	0	57	73
69	Night Heron	0	0	0	1	1
83	Glossy Ibis	0	0	5	0	5
85	African Spoonbill	2	1	1	0	4
86	Greater Flamingo	0	0	0	2015	2015
87	Lesser Flamingo	0	0	0	530	530
88	Spur-winged Goose	0	0	0	1	1
89	Egyptian Goose	4	8	0	135	147

APPENDIX VIII: (Cont.)

Roberts Number	Species	Princess Vlei 81-01-23	Rondevlei 81-01-28	Zeekoevlei 81-01-28	Cape Flats Sewage Works 81-01-23	Wetland System 81-01-23
90	South African Shelduck	0	0	0	11	11
94	Cape Shoveller	3	188	17	1404	1612
95	Black Duck	0	0	0	1	1
96	Yellow-billed Duck	4	21	3	26	54
97	Red-billed Teal	5	1	4	25	35
98	Cape Teal	4	4	3	1416	1427
102	Red-eyed Pochard	0	475	19	328	822
103	Maccoa Duck	0	0	0	486	486
167	African Marsh Harrier	0	0	0	1	1
203	Black Crake	0	0	0	1	1
208	Purple Gallinule	0	14	4	2	20
210	Moorhen	1	6	17	91	115
212	Red-knobbed Coot	37	27	38	1214	1316
231	Black Oystercatcher	0	0	0	15	15
233	Ringed Plover	0	0	1	16	17
237	Kittlitz's Sand-plover	0	0	0	1	1
238	Three-banded Sand-plover	0	0	4	13	17
241	Grey Plover	0	0	0	2	2
245	Blacksmith Plover	7	10	39	112	168
250	Ethiopian Snipe	0	0	1	3	4
251	Curlew Sandpiper	38	0	4	750	792
251X	Pectoral Sandpiper	0	0	0	1	1
253	Little Stint	6	0	30	491	527
255	Sanderling	0	0	0	19	19
256	Ruff	0	0	1	579	580
258	Common Sandpiper	0	0	0	3	3
262	Marsh Sandpiper	0	0	0	18	18
263	Greenshank	0	0	0	16	16
264	Wood Sandpiper	0	0	2	15	17
269	Avocet	4	0	0	723	727
270	Black-winged Stilt	4	0	0	423	427
272	Red-necked Phalarope	0	0	0	1	1
275	Cape Dikkop	0	0	0	2	2
287	Kelp Gull	1	5	10	1115	1131
288	Grey-headed Gull	0	0	1	0	1
289	Hartlaub's Gull	71	130	143	1995	2339
291/294	Common/Arctic Tern	0	0	0	1	1
296	Sandwich Tern	0	0	0	249	249
298	Swift Tern	0	0	2	110	112
304	White-winged Black Tern	0	89	236	6832	7157
394	Pied Kingfisher	0	2	0	0	2
686	Cape Wagtail	0	0	0	67	67

APPENDIX VIII: (Cont.)

Summary of Counts.	Princess Vlei 81-01-23	Rondevlei 81-02-28	Zeekoevlei 81-01-28	Cape Flats Sewage Works 81-01-23	Wetland System 81-01-23
Total No of birds	215	1216	750	22554	24735
No. of species	20	25	32	56	63
Wader Numbers					
Migrants	44	0	38	1911	1993
Residents	15	10	44	1292	1361
TOTAL	59	10	82	3203	3354
Wader Species					
Migrants	1	0	5	12	12
Residents	3	1	3	7	7
TOTAL	4	1	8	19	19

APPENDIX IX: Winter 1981 water bird count for the Cape Flats Sewage Works (after Underhill and Cooper, in press.). The count was done on 81-07-16.

Roberts Number	Species	No. counted	Roberts Number	Species	No counted
5	Black-necked Grebe	494	101	Fulvous Whistling Duck	1
6	Dabchick	434	102	Red-eyed Pochard	529
47	White-breasted Cormorant	54	103	Maccoa Duck	392
48	Cape Cormorant	12000	167	African Marsh Harrier	5
50	Reed Cormorant	5	208	Purple Gallinule	2
51	Crowned Cormorant	9	210	Moorhen	136
52	Darter	21	212	Red-knobbed Coot	573
55	Black-headed Heron	2	231	Black Oystercatcher	6
57	Purple Heron	1	237	Kittlitz's Sandplover	20
60	Yellow-billed Egret	1	238	Three-banded Sand-Plover	2
61	Cattle Egret	28	245	Blacksmith Plover	61
81	Sacred Ibis	2	269	Avocet	23
86	Greater Flamingo	767	270	Black-winged Stilt	42
87	Lesser Flamingo	88	287	Kelp Gull	1238
88	Spur-winged Goose	2	288	Grey-headed Gull	2
89	Egyptian Goose	59			

APPENDIX IX: (Cont.)

Roberts Number	Species	No. counted	Roberts Number	Species	No. counted
94	Cape Shoveller	447	289	Hartlaub's Gull	561
96	Yellow-billed Duck	27	298	Swift Tern	2
97	Red-billed Teal	16	304	White-winged Black Tern	104
98	Cape Teal	436	305	Whiskered Tern	1
			686	Cape Wagtail	59

Total No. of birds	18652	Wader species	
Total No. of species	40	Migrants	0
Wader Numbers		Residents	6
Migrants	0	TOTAL	6
Residents	154		
TOTAL	154		

APPENDIX X: A checklist of mammals recorded for the area covered by the 1:50 000 Topocadastral Sheet 3418 BA Strandfontein. Records from Stuart *et al.* (1980, unpublished) and Stuart (1981).

Common name		Scientific name
Cape Fur Seal	-	*Arctocephalus pusillus*
Grey Duiker	-	*Sylvicapra grimmia*
Krebs' Fat Mouse	-	*Steatomys krebsi*
Cape Porcupine	-	*Hystrix africaeaustralis*
Cape Dune Molerat	-	*Bathyergus suillus*
Cape Molerat	-	*Georychus capensis*
Cape Fox	-	*Vulpes chama*
Striped Polecat	-	*Ictonyx striatus*
Common Genet	-	*Genetta genetta*
Large-spotted Genet	-	*Genetta tigrina*
Cape Grey Mongoose	-	*Herpestes pulverulentus*
Cape Wild Cat	-	*Felis lybica*
Caracal	-	*Felis caracal*

APPENDIX XI: Summary of available information.

ESTUARY / RIVERMOUTH / LAGOON: ZEEKOE (Drainage System)

Summary of available information			Acocks	Allanson	Allanson	Allanson	Beynon	Broadley	Broadley & Greer	Brummer	Burman	Cape Town City Engineer	Cape Town City Engineer	Cape Town City Engineer	Cape Town City Engineer	Cooper *et al*	Curtin *et al*	Davies	Davies	Day & King
YEAR (DATE OF INFORMATION)			1975	1977	1978a	1978b	1971	1975	1969	1981	1962	1936	1944	1962-80	1982	1976	1975	1982	1983	1980
BIOTIC		Food Webs																		
	Fauna	Mammals											*							
		Birds								*						*				
		Reptiles & Amphibians						*	*											
		Fish								*										
		Fauna on soft substrates																		
		Fauna on hard substrates																		
		Insects																		
		Other invertebrates																		
		Zooplankton																		
	Flora	Terrestrial	*							*										
		Phytoplankton								*										
		Halophytes																	*	*
ABIOTIC	Other	Historical					*			*	*									
		Utilization								*				*	*		*			
		Conservation								*						*	*	*	*	
		Modelling																		
		Aquaculture																		
		Management		*	*	*				*		*			*		*	*		
		Bacteriology												*						
	Chemistry	Pesticide residues																		
		Metal residues																		
		Eutrophication								*				*	*		*			*
		General chemistry												*						
	Geomorphology	Sediment transport & deposition									*	*			*					
		Paleoenvironment																		
		Geology								*					*					
	Physics	Circulation & mixing																		
		Density variations																		
		Hydrology								*					*		*			
	Physiography	Morphology																		
		Catchment characteristics								*					*					

Sources of information

APPENDIX XI: (Continued)

ESTUARY / RIVERMOUTH / LAGOON: ZEEKOE (Drainage System)

		Sources of Information	Summary of available information	Edington & Edington	Fraser	FitzSimons	FitzSimons	Fricke *et al*	Grindley	Grindley and Taylor	Hamman *et al*	Harrison	Harrison	Hennig *et al*	Henzen	Heydorn & Tinley	Howard-Williams	Mc Lachlan	Mc Lachlan & Lewin	Mc Veigh	Mc Veigh
		YEAR (DATE OF INFORMATION)		1977	1980	1943	1962	1975	1982	1970	1977	1958	1962	1983	1973	1980	1976	1978	1981	-	1979
BIOTIC		Food Webs																			
BIOTIC	Fauna	Mammals																			
BIOTIC	Fauna	Birds																			
BIOTIC	Fauna	Reptiles & Amphibians				*	*											*			
BIOTIC	Fauna	Fish									*	*								*	*
BIOTIC	Fauna	Fauna on soft substrates											*	*							
BIOTIC	Fauna	Fauna on hard substrates																			
BIOTIC	Fauna	Insects											*								
BIOTIC	Fauna	Other invertebrates											*								
BIOTIC	Fauna	Zooplankton											*								
BIOTIC	Flora	Terrestrial																			
BIOTIC	Flora	Phytoplankton								*			*				*		*		
BIOTIC	Flora	Halophytes																			
ABIOTIC	Other	Historical										*									
ABIOTIC	Other	Utilization														*					
ABIOTIC	Other	Conservation																			
ABIOTIC	Other	Modelling																			
ABIOTIC	Other	Aquaculture																			
ABIOTIC	Other	Management									*					*	*			*	*
ABIOTIC		Bacteriology		*																	
ABIOTIC	Chemistry	Pesticide residues																			
ABIOTIC	Chemistry	Metal residues																			
ABIOTIC	Chemistry	Eutrophication															*				
ABIOTIC	Chemistry	General chemistry						*					*				*				
ABIOTIC	Geomorphology	Sediment transport & deposition																			
ABIOTIC	Geomorphology	Paleoenvironment																			
ABIOTIC	Geomorphology	Geology													*						
ABIOTIC	Physics	Circulation & mixing																			
ABIOTIC	Physics	Density variations																			
ABIOTIC	Physics	Hydrology			*										*						
ABIOTIC	Physiography	Morphology							*												
ABIOTIC	Physiography	Catchment characteristics			*										*						

APPENDIX XI: (Continued)

ESTUARY / RIVERMOUTH / LAGOON: ZEEKOE (Drainage System)

Group	Subgroup	Item	Summary of available information	Muizenberg Marina Project	Roberts	Schütte & Elsworth	Sheel	South Africa (Republic) Govern. Notice	Stephens	Stuart	Stuart *et al*	Summers *et al*	Swart & Serdyn	Tschortner	Underhill & Cooper	Valsbaai Strandverbeteringe	Visser	Winterbottom		PD Bartlett (pers. comm.)	RA Carter (pers. comm.)
BIOTIC		Food Webs																			
BIOTIC	Fauna	Mammals								*	*										
BIOTIC	Fauna	Birds			*							*			*			*			
BIOTIC	Fauna	Reptiles & Amphibians															*				
BIOTIC	Fauna	Fish																			
BIOTIC	Fauna	Fauna on soft substrates																			
BIOTIC	Fauna	Fauna on hard substrates																			
BIOTIC	Fauna	Insects																			
BIOTIC	Fauna	Other invertebrates																			
BIOTIC	Fauna	Zooplankton																			
BIOTIC	Flora	Terrestrial																			
BIOTIC	Flora	Phytoplankton				*			*												*
BIOTIC	Flora	Halophytes							*					*							
ABIOTIC	Other	Historical																			
ABIOTIC	Other	Utilization						*													
ABIOTIC	Other	Conservation																			
ABIOTIC	Other	Modelling																			
ABIOTIC	Other	Aquaculture																			
ABIOTIC	Other	Management																			
ABIOTIC		Bacteriology																			
ABIOTIC	Chemistry	Pesticide residues																		*	
ABIOTIC	Chemistry	Metal residues																		*	
ABIOTIC	Chemistry	Eutrophication																		*	
ABIOTIC	Chemistry	General chemistry				*								*						*	
ABIOTIC	Geomorphology	Sediment transport & deposition		*												*					
ABIOTIC	Geomorphology	Paleoenvironment																			
ABIOTIC	Geomorphology	Geology																			
ABIOTIC	Physics	Circulation & mixing		*												*					
ABIOTIC	Physics	Density variations																			
ABIOTIC	Physics	Hydrology		*			*						*			*					
ABIOTIC	Physiography	Morphology																			
ABIOTIC	Physiography	Catchment characteristics																			
YEAR (DATE OF INFORMATION)				1977	1978	1954	1976	1968	1929	1981	1980	1976	1982	1969	-	1980	1979	1960			

Sources of information: see column headings.

APPENDIX XI: (Continued)

ESTUARY / RIVERMOUTH / LAGOON: ZEEKOE (Drainage System)

		Sources of Information	Summary of available information	GAW Fromme (pers. comm.)	JR Grindley (pers. comm.)	Late Dr EN Grindley (pers. comm.)	TJE Heinecken (pers. comm.)	HF-KO Hennig (pers. comm.)	P King (pers. comm.)	JA Lusher (pers. comm.)		RC Boycott & AL de Villiers (*in litt.*)	Cape Town City Engineer (*in litt.*)	CM Gaigher (*in litt.*)	ECRU Survey	ECRU Survey		Maps	S.A. 1: 50 000 Sheet 3418AA	S.A. 1:250 000 Sheet 3318	Cape Town City Engin. 1:50 000
		YEAR (DATE OF INFORMATION)													1980	1982			1975	1977	1982
BIOTIC		Food Webs																			
BIOTIC	Fauna	Mammals																			
BIOTIC	Fauna	Birds																			
BIOTIC	Fauna	Reptiles & Amphibians										*									
BIOTIC	Fauna	Fish														*					
BIOTIC	Fauna	Fauna on soft substrates						*						*							
BIOTIC	Fauna	Fauna on hard substrates																			
BIOTIC	Fauna	Insects																			
BIOTIC	Fauna	Other invertebrates																			
BIOTIC	Fauna	Zooplankton														*					
BIOTIC	Flora	Terrestrial														*					
BIOTIC	Flora	Phytoplankton				*							*								
BIOTIC	Flora	Halophytes				*			*												
ABIOTIC	Other	Historical			*				*				*								
ABIOTIC	Other	Utilization					*		*				*			*			*		
ABIOTIC	Other	Conservation														*					
ABIOTIC	Other	Modelling																			
ABIOTIC	Other	Aquaculture																			
ABIOTIC	Other	Management							*	*			*			*					*
ABIOTIC		Bacteriology											*								
ABIOTIC	Chemistry	Pesticide residues											*								
ABIOTIC	Chemistry	Metal residues											*								
ABIOTIC	Chemistry	Eutrophication							*				*			*					
ABIOTIC	Chemistry	General chemistry							*				*			*					
ABIOTIC	Geomorphology	Sediment transport & deposition											*			*					
ABIOTIC	Geomorphology	Paleoenvironment																			
ABIOTIC	Geomorphology	Geology											*								
ABIOTIC	Physics	Circulation & mixing																			
ABIOTIC	Physics	Density variations																			
ABIOTIC	Physics	Hydrology		*			*		*				*		*	*					
ABIOTIC	Physiography	Morphology														*			*	*	*
ABIOTIC	Physiography	Catchment characteristics							*				*			*			*	*	*

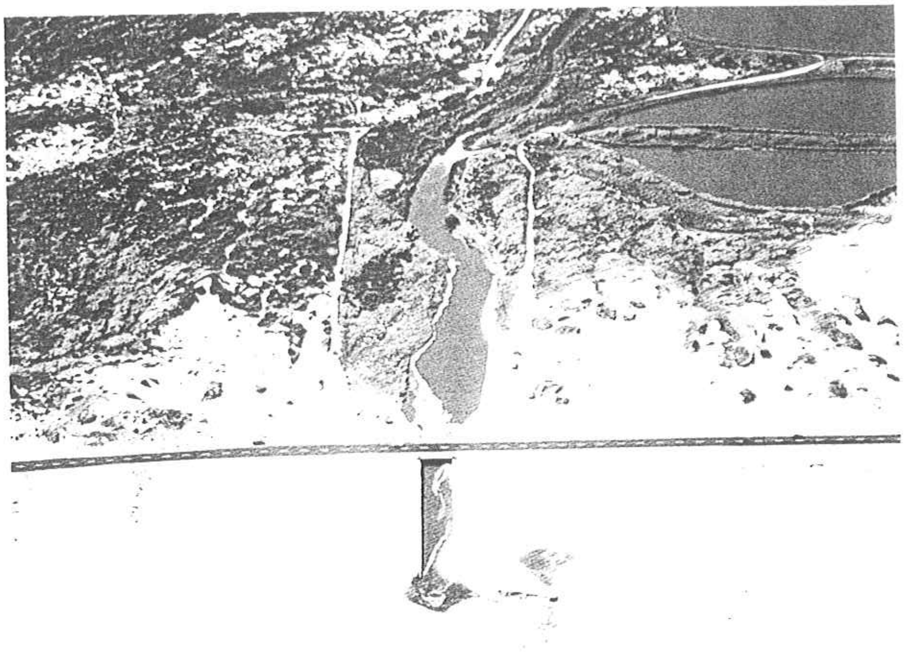

PLATE I:

Infra-red aerial view of the mouth of the Zeekoe Canal. The meandering mouth can be seen in the foreground and the effluent outfall from the Cape Flats Sewage Works oxidation ponds in the background. (Photo C Best, 83-02-27).

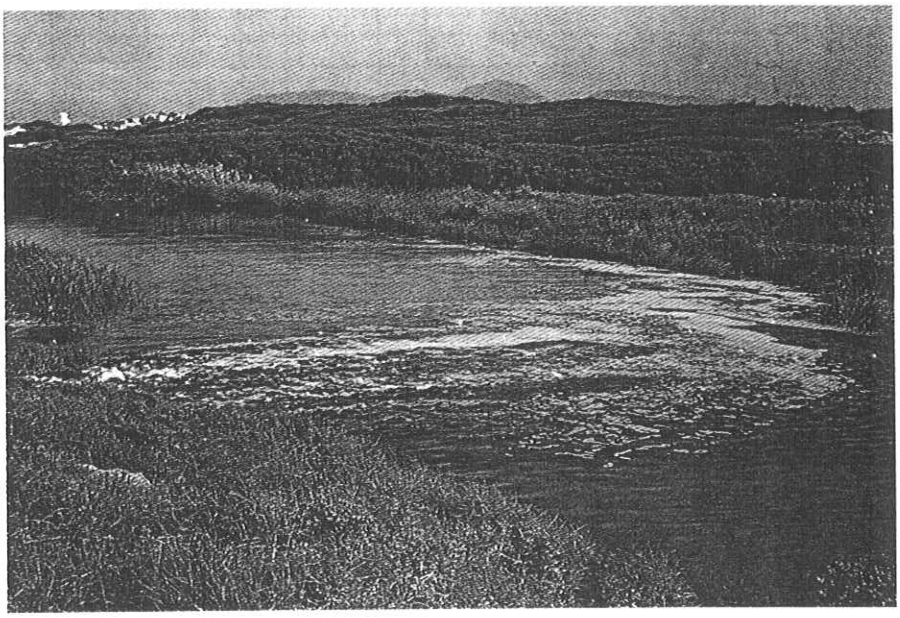

PLATE II:

Cape Flats Sewage Works final pond effluent outfall into the Zeekoe Canal. The effluent is entering from the left, looking downstream (ECRU: 82-06-21).

PLATE III:

Upper reaches of the Zeekoe Canal just downstream of the Zeekoevlei weir, looking downstream. The canal from Rondevlei can be seen joining the Zeekoe Canal on the right of the photo. The stagnant water and eutrophic conditions can be seen. (ECRU: 82-06-21).