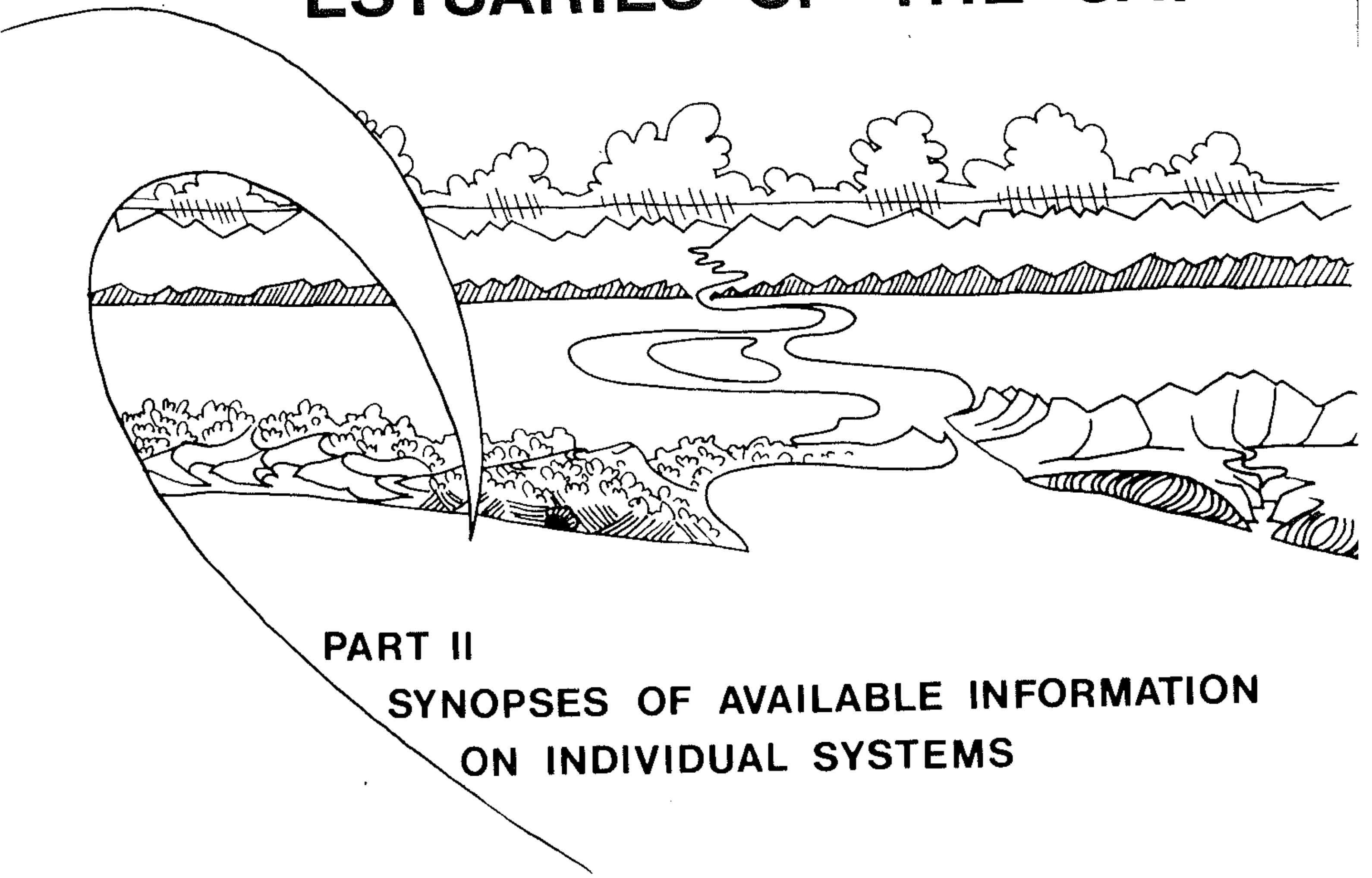
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY
ESTUARINE AND COASTAL RESEARCH UNIT - ECRU

ESTUARIES OF THE CAPE



PART II
SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

REPORT NO. 22
SWARTVLEI (CMS 11)

CSIR RESEARCH REPORT 421

Stellenbosch, South Africa
December 1983

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PART II: SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

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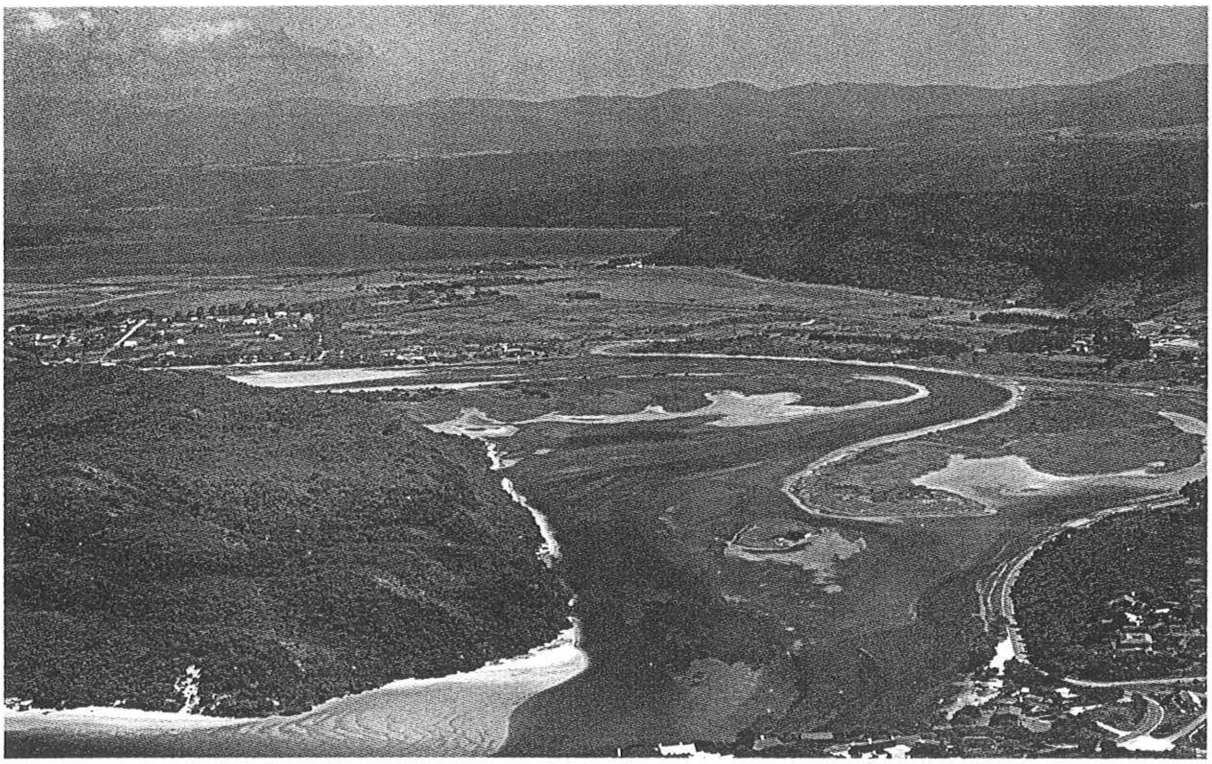

FRONTISPIECE: SWARTVLEI SYSTEM FROM THE AIR (ABOUT 100m) ON 8 FEBRUARY 1983. THE WINDING ESTUARY CAN BE SEEN IN THE FOREGROUND AND LAKE IN THE BACKGROUND (IFWS 83-02-08)

REPORT NO. 22: SWARTVLEI (CMS 11)

(CMS 11 – CSIR Estuary Index Number)

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PREFACE

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

- to contribute information relevant to the development of a cohesive management policy for the South African coastline;

- to compile syntheses of all available knowledge on the 167 estuaries of the Cape between the Kei and the Orange rivers;

- to identify gaps in information, to conduct research to fill these and to stimulate Universities, Museums and other institutions to become involved in this kind of work;

- to contribute to *ad hoc* investigations carried out by NRIO on the impacts of proposed developments in the coastal environment, and especially in estuaries.

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

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

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

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

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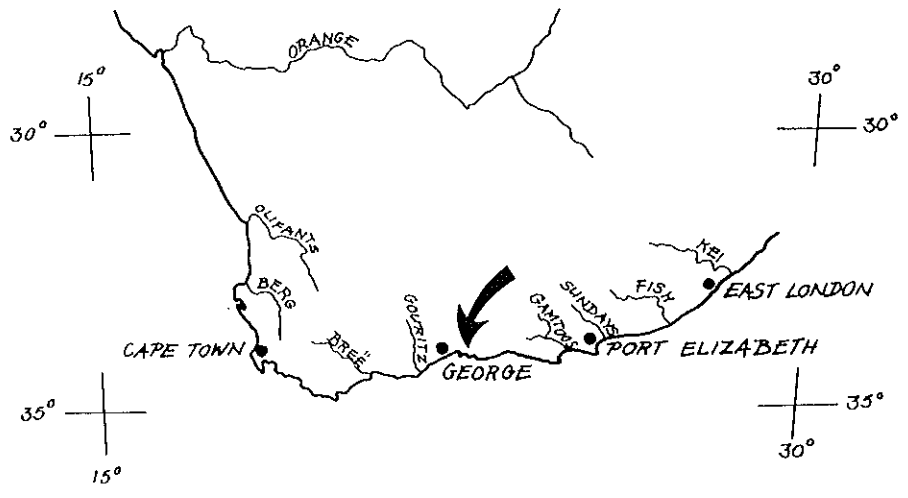
SWARTVLEI

1. REVIEW OF ACTIVITIES

Swartvlei ranks among the most intensively studied of all Cape estuarine systems. The hydrology of the Swartvlei catchment has been investigated by the then Department of Water Affairs, hydrographic surveys have been conducted by the Coastal Engineering and Hydraulics Division of the National Research Institute for Oceanology, geological and geophysical investigations have been made by the University of Cape Town Marine Geoscience Unit and trace metal studies have been carried out by the National Physical Research Laboratory of the Council for Scientific and Industrial Research. The Institute for Freshwater Studies (IFWS) from Rhodes University has conducted a series of detailed research programmes covering the physico-chemical limnology and the biology of organisms both in Swartvlei and the Swartvlei estuary. Zoological studies by the Cape Department of Nature and Environmental Conservation and Port Elizabeth Museum have also contributed to an understanding of the ecology of the area.

Altogether 30 published and 23 unpublished research documents have emanated from the above research groups and organizations, thus enabling scientists to put forward long-term management proposals for the Swartvlei system. It is hoped that this fund of knowledge, built up over the past 10 years, will be of use to those who are responsible for the future planning and management of the system.

2. LOCATION



The Swartvlei system (34°S, 22°46'E) comprises two main sections, the estuary and an upper lake. In this report the term Swartvlei refers to the lake-like portion and the Estuary to the area down-stream of the railway bridge (see Figure 1).

2.1 Accessibility

Both the main coastal road and rail links between George and Knysna traverse the Swartvlei estuary. Distances to the nearest towns are 30 km to George and 28 km to Knysna.

2.2 Local Authorities

The area surrounding Swartvlei falls within the jurisdiction of the Outeniqua Divisional Council but the upper catchments of the Wolwe, Hoëkraal and Karatara Rivers are controlled by the Directorate of Forestry of the Department of Environment Affairs. The eastern banks of the Swartvlei estuary are situated within the Municipality of Sedgefield (see Figure 1).

3. ORIGIN

Martin (1962), Hill (1975) and Birch and Du Plessis (1977) have discussed the origin and history of the Swartvlei system and this brief review draws on their evidence concerning coastal formation in the area.

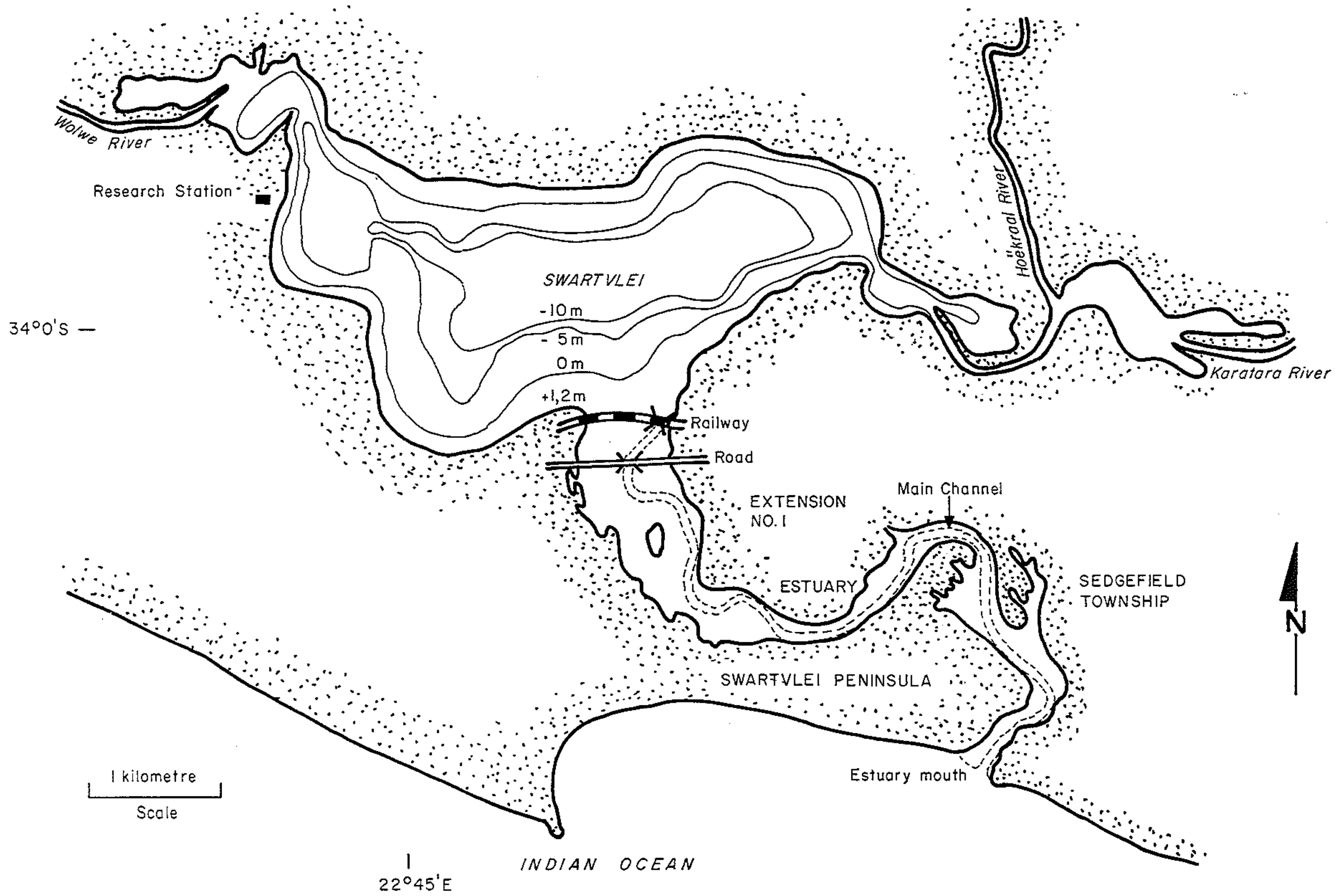
During the last ice age (16 000 - 45 000 years Before Present (BP)) the sea level was 100 - 120 m lower than it is now. With this low sea level, the valley that is now Swartvlei would have been cut down as the rivers flowed out to sea. The basement of the present-day Swartvlei is at least 30 m below the present sea level (Martin, 1962). At the end of the ice age the sea level rose again, drowning the deeply incised river valleys. It is thought that approximately 6 000 years B.P. the sea level was about 2,5 m above the present level. At that stage much of the flat areas surrounding Swartvlei and what is now the town of Sedgefield were formed by dune erosion. The sea then fell back to its present level about 4 000 years B.P. after which time the mouth of the estuary migrated 2 km eastwards to its present position. Birch and Du Plessis (1977) have proposed that the drowned original valley was filled mostly with wind blown sands. This input would have decreased as the dune became vegetated and the amount of sand being blown into Swartvlei estuary at present is minimal as the dunes have all been stabilized by fairly dense vegetation.

The portion of the drowned valley forming what is now Swartvlei was filled in by sands blown from the dunes, and wave cutting around the margins formed a littoral shelf around the deeper central lake portion. Fine sediment from the inflowing rivers (Hill, 1975) and organic matter produced in the lake have accumulated slowly in the central basin of Swartvlei. Attempts have been made to determine the depth of these, which from rough estimates (Birch and Du Plessis, 1977) appear to be between 7 and 13 m depending on what portion of the lake bottom was considered. Howard-Williams and Allanson (1978b) estimated a mean annual sedimentation rate of 2 mm per yr but this is likely to have increased considerably in recent years (see Section 6).

4. GEOLOGY

The geology of Swartvlei and its surroundings has been described by Martin (1962), the Department of Planning (1970) and Birch and Du Plessis (1977). Swartvlei is situated on a system of Quaternary sands which lie along the

FIG. 1: The Swartvlei system showing selected depth contours (O = GMSL*). The estuary channel is defined by dotted lines.
(*Geodetic Mean Sea Level)



coast in an area known as the Wilderness-Knysna embayment. Sand ridges cemented by calcium carbonate form dune rock or aeolianite in this zone (Martin, 1962). Inland from these Quaternary sands is a 200 m-high Tertiary coastal platform through which the rivers flowing into Swartvlei have cut deep valleys. The Outeniqua Mountains, where these rivers originate, are made up of intensely folded Table Mountain Sandstone.

5. CLIMATE

This section deals with meteorological observations recorded at the I.F.W.S. Swartvlei Station between January 1975 and December 1982. The mean annual precipitation of 786 mm is lower than for the Swartvlei catchment where the annual rainfall is between 900 and 1 000 mm per yr (Adamson, 1975). It rains throughout the year with no identifiable wet or dry season. Monthly totals vary erratically from 11 to 244 mm. The mean daily maximum air temperature at Swartvlei is 25°C in summer and 19°C in winter, whilst the mean daily minimum is 15°C in summer and 7°C in winter. The absolute minimum recorded temperature is 2°C and maximum 33°C.

Solar radiation at Swartvlei ranges from 2,25 kJ per m^2 per day in summer to 0,75 kJ m^2 per day in winter (Howard-Williams and Allanson 1978b).

According to Howard-Williams and Allanson (1978b) south-west winds predominate throughout the year. North and north-east (Berg winds) are fairly common in the winter months. In summer the wind usually blows from the south-east. Strong winds are rare in the area with 97 per cent below 30 km per hr.

6. RIVER CATCHMENTS

The total Swartvlei catchment area is 340 km^2 with the Wolwe River system covering 125 km^2, Hoëkraal system 109 km^2 and Karatara system 106 km^2 (see Figure 2). The three catchments contribute about equal amounts of water to Swartvlei, the mean annual run-off from the Wolwe River amounting to 19,8 x 10^6 m^3, the Hoëkraal River 24,8 x 10^6 m^3 and the Karatara River 20,1 x 10^6 m^3. An extra 1 x 10^6 m^3 can be added from minor streams and direct precipitation, resulting in an average total freshwater input of 66 x 10^6 m^3 from the catchment each year (Hidrouliese studie van die Swartvlei estuarium, 1978). Because of the all year round rainfall pattern in the area there is no distinct seasonality in river flow (see Figure 3). Flow is continuous throughout the year with occasional floods causing short-lived peak inflow periods. The Sedgefield Municipality has a water pumping station on the Karatara River and in 1982 1,8 x 10^4 m^3 of water per month were abstracted during the year until the peak holiday season when the volume rose to 4,0 x 10^4 m^3 per month. Thus approximately 2,6 x 10^5 m^3 is abstracted in this way each year.

The Department of Environment Affairs is considering the building of dams on the Wolwe and Karatara river systems which would in turn affect the amount of water flowing into Swartvlei (Dept of Constitutional Development & Planning, 1983).

The upper slopes of the catchment area are covered with fynbos vegetation which gives way to forest lower down (see Figure 4), Although large sections of indigenous forest remain, a considerable proportion of the catchment is under pine and gum plantations. A total of 4 100 ha is classified as agricultural land by the Department of Agricultural Technical Services (1975). Much of this is under pastures with a small percentage being cultivated for intensive vegetable production.

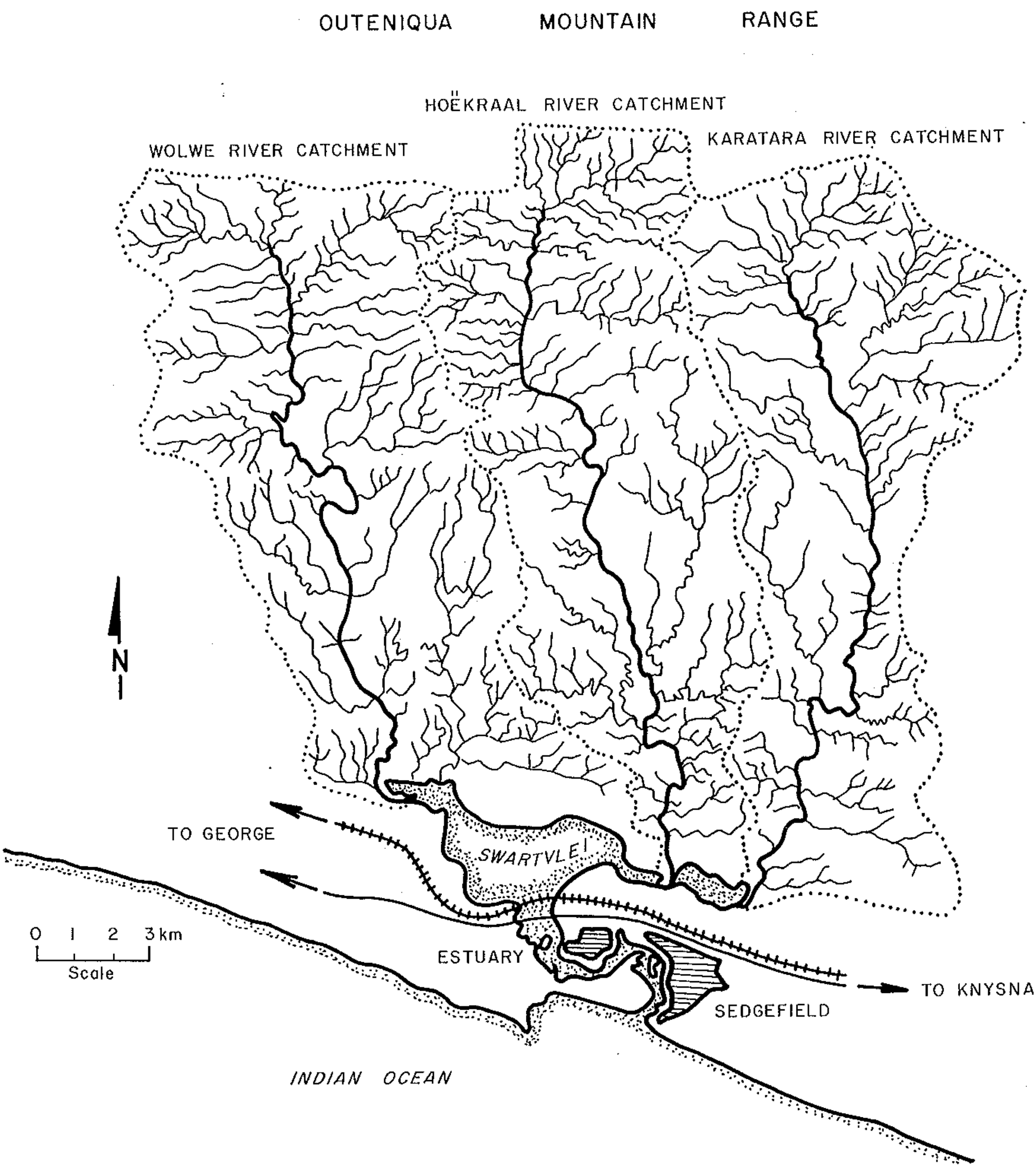


FIG. 2: The Swartvlei system showing the extent of the three catchment areas.

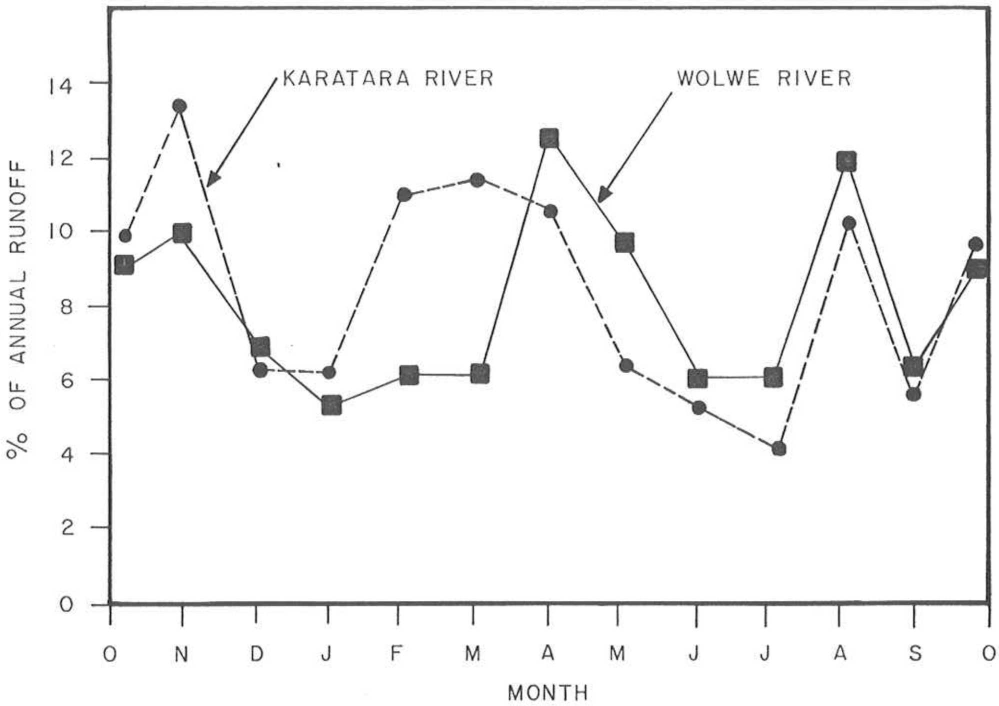


FIG. 3: Flow patterns of two of the inflowing rivers to Swartvlei showing the lack of a seasonal peak. (Data from Adamson, 1975)

The rivers of the Swartvlei catchment are characteristically stained brown by the humic matter from the vegetation in the area. They are low in electrolytes and can be classified as acid (pH 4 - 5). The dissolved organic matter concentration of the Wolwe River is about only half that of the Karatara and Hoëkraal Rivers. According to Howard-Williams and Allanson (1978b) this reflects the geology of the catchment area of the Wolwe River which includes a large area of Cape granite as opposed to the Table Mountain sandstone in the other catchments. However, suspensoid

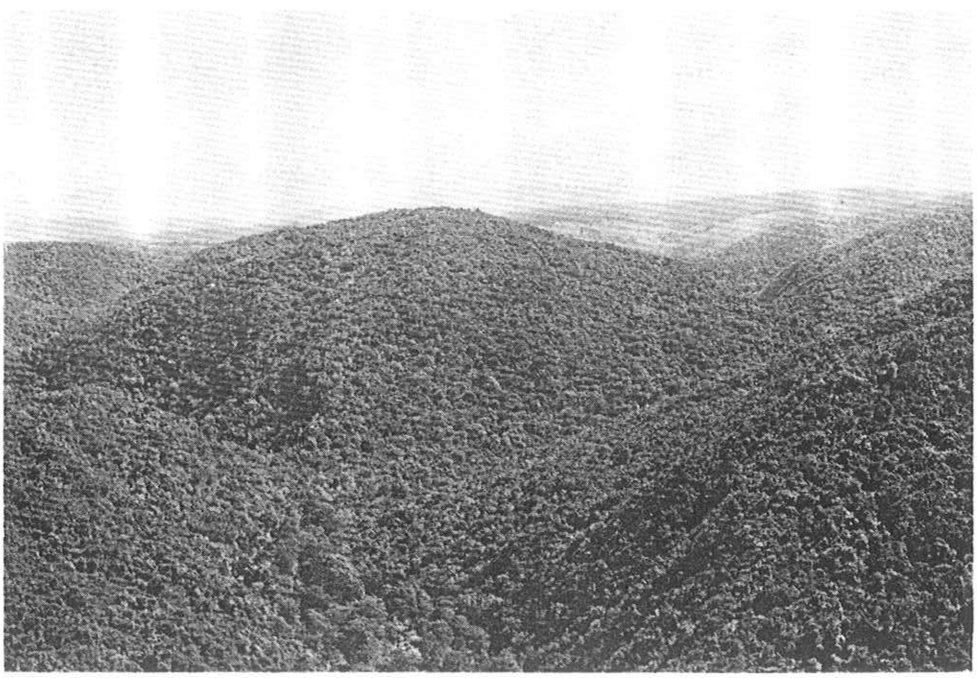


FIG. 4: The Hoëkraal River catchment with indigenous forest in the foreground and pine plantations in the background (IFWS: 83-03-08).

determinations from the Wolwe River indicate that this system is responsible for much of the fine sediment carried into the lake. Although the rivers usually carry a low silt load (< 10 mg per ℓ) this can increase to 250 mg per ℓ during a flood (Howard-Williams and Allanson, 1978b). According to Allanson and Whitfield (1982) there is a significant negative correlation between lake water transparency and total river inflow during the period August 1974 - April 1981. In recent years there has been a marked decrease in transparency of the lake due to high river flow and poor land management (see Figure 5).

FIG. 5: Road construction adjacent to the Wolwe River showing one of the sources of sediment which enter Swartvlei following heavy rain (IFWS: 83-03-08).

Concentrations of nutrients in riverwater flowing into Swartvlei were given by Howard-Williams and Allanson (1978b). Soluble phosphate (PO_4-P) concentrations were 6 μg per ℓ during a 'normal' flow periods and 42 μg per ℓ during floods.

7. SWARTVLEI SYSTEM

(Sections 7.1 to 7.3 were contributed by Dr GAW Fromme of the Sediment Dynamics Division of NRIO).

The Swartvlei system represents the eastern exit of the Wilderness Lakes valley. It is divided into two sections because of important physical and biological differences between the lake and estuary.

7.1 Physical Characteristics

The Swartvlei system is dammed-up behind a Holocene (16 000 BP to present) coastal dune belt, 2 km long and 30 to 75 m high. This is bordered in the west by the conspicuous dune rock formation of Gericke Point, and in the east by similar rock formations east of the present mouth (see Figures 6a-6d).

FIG 6a: Swartvlei Estuary in 1936 (Approx Scale: 1cm=345m).

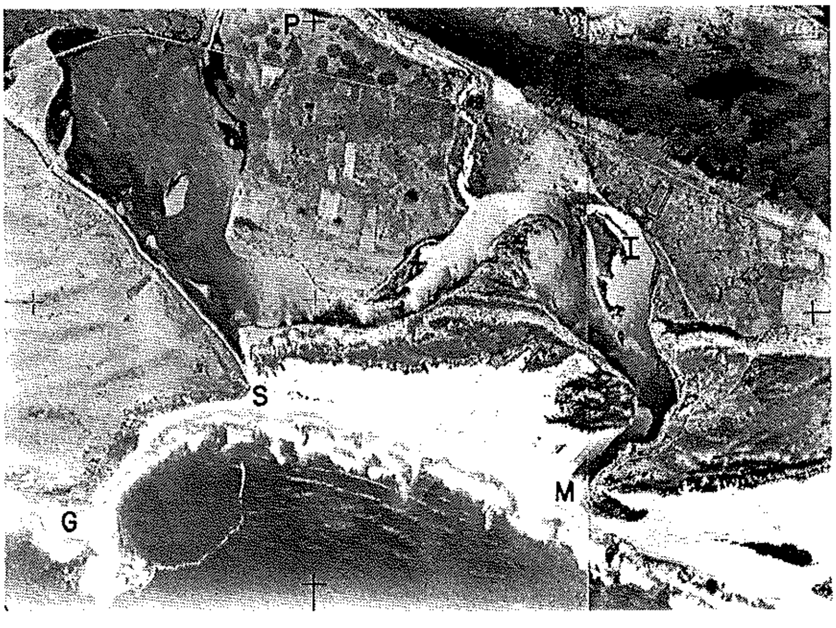


FIG 6b: Swartvlei Estuary in 1942 (Approx Scale: 1cm=500m).

Legend: P - Perdespruit Stream
S - Swartvleistrand
I - The Island.
M - Present mouth
G - Gericke Point

FIG. 6c: Swartvlei Estuary in 1958. (Approx Scale: 1cm=570m).

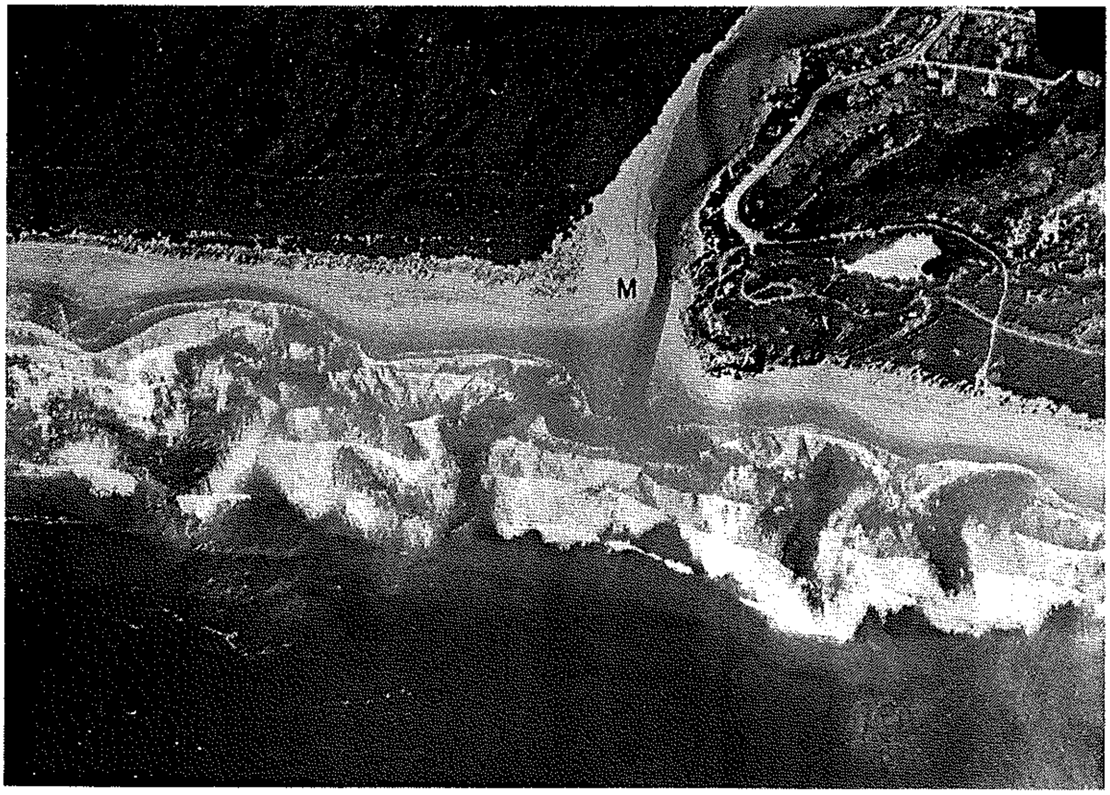


FIG. 6d: Swartvlei Estuary in 1977 (Approx Scale: 1cm=100m).

Legend: P - Perdespruit Stream M - Present mouth
S - Swartvleistrand G - Gericke Point
I - The Island.

The lake (see Figure 7) is 8,8 km^2 in area with a mean depth ($\bar{z}$) of 5,5 m and a maximum depth of 16,7 m. There is a wide littoral shelf which occupies some 3,8 km^2 and slopes gently to a water depth of 2 m, beyond which the lake floor drops steeply to a fairly flat bottom at 12 m. The shelf and slope are comprised mainly of sand whereas the bottom of the basin is filled with soft mud (Hill, 1975). The lake volume at a water level of 0,65 m above MSL is 48 x 10^6 m^3.

FIG. 7: View of Swartvlei from the east towards the north west with the Outeniqua Mountains in the background (IFWS: 83-03-08).

The estuary forms a 7,2 km shallow channel-like link between the lake and the sea. This crosses the low-lying sandy plains of the present-day Sedgefield Extension I. The overall gradient of the channel is very small (1: 14 400) with a maximum depth of 4 m and a water surface area of 2 km^2 (Liptrot, 1978). The sediments of the entire estuary are made up of recently deposited dune sands except in the mouth region where dune rock occurs (see Figure 8).

According to an eleven-year record of mouth conditions the estuary inlet is open about 50 percent of the time. (see Figure 9). The mouth is almost always closed during winter i.e. 97 percent of the time, whereas it is closed only about 30 to 40 percent of the time during the other seasons.

Mouth closures are, however, not associated with seasonal floods because heavy rainfalls can occur in this area at any time of the year. As will be explained in Section 7.2.5 the predominance of mouth closures in winter appears to be caused mainly by the rough south-westerly wave conditions which occur during this season. During the last few decades artificial breachings of the mouth have been carried out at water levels of MSL + 1,5 to 2,25 m to prevent flooding of low-lying developments.

FIG. 8: The Swartvlei estuary mouth showing the presence of dune rock on the near shore which prevents the mouth from migrating further eastwards (IFWS: 83-03-08).

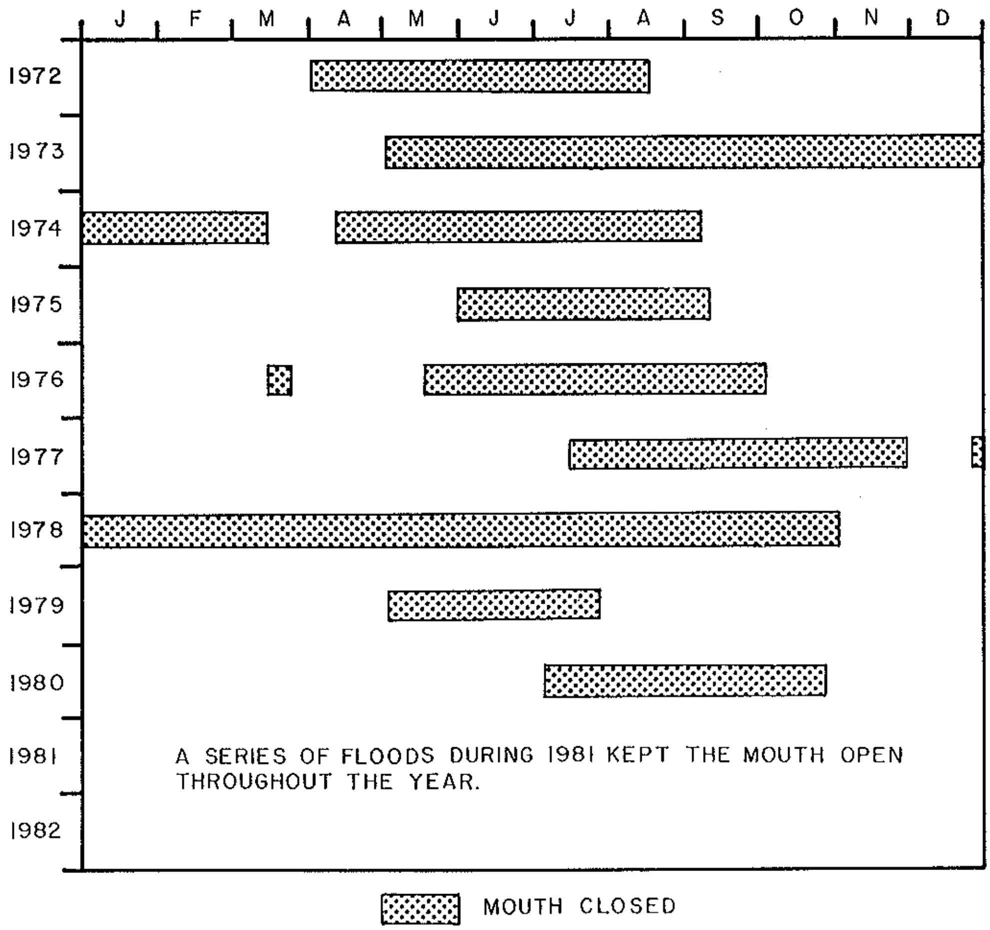


FIG. 9: An eleven-year record of periods when the estuary mouth has been closed (A. Whitfield, pers. comm.).

7.2 Hydraulics of Swartvlei

7.2.1 Tidal exchange

If open, the tidal inlet causes a considerable damping of the sea tide (extreme range 1,98 m). Only 0,5 km upstream of the mouth the tidal range is reduced by one third, while the tidal lag (with outgoing tide) is two hours. At the upper end of the estuary the tidal range is reduced by 90 percent, and upstream of the SAR-Bridge by as much as 99 percent, while the tidal lag between in-and outgoing tides amounts to six and a half hours (Hydrographic Survey of Sedgefield Lagoon, 1975).

There are only two places at which resistance to water flow is high, that is, the narrow estuary mouth and at the railbridge. (see Figures 8 and 10).

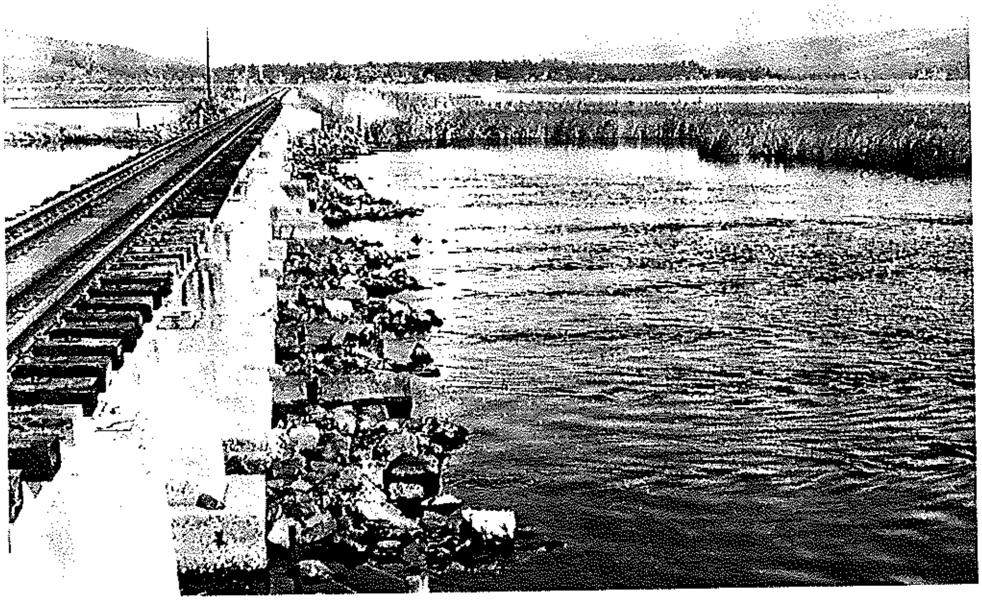


FIG. 10: The upstream side of the railway bridge during a flood tide. Note the boulders at the base of the bridge which reduce tidal exchange between the estuary and lake (IFWS: 83-03-08).

During neap tides there is virtually no inflow from the sea. During spring high tides the upper estuary is filled to a high water level which causes strong outflow during spring low water. Because of the pan-like bathymetry of the upper estuary and the relatively narrow estuary channel this high water level remains while the sea tide is already receding. Even a back-flow to the lake was observed under this condition. (Hydrographic Survey of Sedgefield Lagoon, 1975). In the lake the water level varies by 0,2 m between spring and neap tide, and in the lake and upper estuary the low water level during neap tides is lower than at low water springs (Howard-Williams and Allanson, 1979).

The strong outflow conditions during falling spring tide were confirmed by current measurements in the mouth by Moes in May 1976 (Hidrouliese studie van Swartvlei estuarium, 1978) and during the ECRU - survey on 7 August 1983. During the latter survey outflow velocities of up to 1,67 m/s versus inflow velocities of 0,8 m/s were measured after heavy rainfalls. During the former survey outflow velocities of 1,4 m/s and inflow velocities of 1,2 m/s were recorded. The total evaporation from Swartvlei is 1 127 mm per year which, at the normal lake level of 0,65 m above GMSL, is equivalent to a total volume lost from the lake and estuary combined of 12,1 x 10^6 m^3. Inflow from the catchment is five times this volume, so at present it is unlikely that Swartvlei will ever become hypersaline, this is however, dependent on future water abstraction from the catchment area.

Swartvlei is normally a meromictic lake i.e. a body of water in which vertical mixing is restricted by differences in density. In Swartvlei this is caused by differences in salinity, (see Section 7.5.1) and this has a marked effect on the fate of inflowing river water. River inflows have a low density and during periods when inflow is strong, flood water moves over the top of the lake in a layer 0,2 - 0,5 m thick. If there are no strong winds during this period, surface fresh water will extend across the lake to flow out under the railway bridge and very little mixing with the lake water will occur. However, there is likely to be appreciable mixing caused by wind, during the low inflow periods, especially when the mouth is closed.

7.2.2 Sediments of Swartvlei

Sand samples collected in the estuary during the ECRU survey on 7 and 8 August 1983 during spring low water showed that particle sizes decreased slightly from the mouth to the upper estuary. That is, from 316 micron (E of mouth, along rocks) and 255 micron (W of mouth, sand bank) to 210 micron on the sand bank below the railway bridge.

Along the beaches largest sand grain sizes were found at the estuary mouth, from where they decreased towards the east and the west, that is from 316 and 255 micron at the mouth to 240 micron to the east, and to 223 micron west of the mouth. At Swartvleistrand (see Figure 6c) the sand grain sizes increased again to 290 micron, due to the proximity of the rocks of Gericke Point.

As decreasing sand grain sizes are indicative of the direction of hydraulic sand movement it can be assumed that in the estuary there is a sedimentation process which progresses upstream from the mouth into the estuary. Along the coast, the decreasing sand grain sizes to the west and east of the mouth tend to indicate that the longshore movement of sand takes place in both directions. There is however, a greater decrease in sand grain size to the east and this would indicate a greater movement of sand in this direction. This phenomenon agrees with the predominant east-going longshore drift which was obtained from the wave analyses.

The estuarine and beach sands show a striking similarity in particle size, shape and mineral composition, which indicates that these sediments are of marine origin.

7.2.3 Cartographic evidence on estuary changes

Nine historical and recent maps of the Swartvlei area dating from 1825 to 1975 and sixteen sets of aerial photographs from 1936 to 1981 were studied in order to trace changes in estuary configuration, mouth openings and closures or migration and changes caused by man in the system (see Maps and Aerial photographs listed under References, Section 11).

Significant changes that can be discerned from the maps are a progressive drying-out of the low-lying area between the upper estuary and the

Perdespruit channel (Sedgefield Extension I), (see Figures 6a-6d) and a drying-out in the ancient mouth area at Swartvleistrand. Both processes could be associated with the increasing practice of premature artificial mouth breachings aimed at the prevention of inundation of these wetlands.

The aerial photographs indicate clearly that the dune ridge between Swartvleistrand and the present mouth is a rather "young" sand formation wedged in between the rocks of Gericke Point and the rocks east of the present mouth. These dunes were only recently (between 1942 and 1958) artificially stabilized with alien vegetation (*Acacia* spp.) (compare Figures 6a and 6c).

Furthermore, the aerial photographs show that the present-day Perdespruit channel represents a former "eastern meander", similar to a very much smaller silted-up meander which has now been partially dredged out around an area called "The Island" near the mouth of the estuary. The aerial photographs reveal no significant changes in the estuary itself.

Some typical features which are also visible from the aerial photographs are a condition when the mouth was open with the estuary drained out (see Figure 6a), and a condition with the mouth closed, demonstrating a "drowned estuary" (see Figure 6b).

Most aerial photographs show an almost symmetrical, slightly eastward offset ebb-tidal delta in the surf-zone off the mouth.

7.2.4 Sediment dynamics of the estuary

The sedimentary evolution of the Swartvlei estuary can be seen to have taken place in an *"ancient"* and in a *"recent"* phase.

> *The ancient phase* included inundations and subsequent influxes of marine sediments during the Pleistocene. The coastal valleys had been deeply incised during the long periods of glacio-eustatic sea level regressions between 1,5 millions and 14 000 years ago (Taljaard, 1949; McLachlan, 1977; Truswell, 1977). During the Pleistocene sea level regression of more than 100 m below the present sea level, wind blown sand from the drying-out continental shelf formed a very large dune field. This would also have formed part of the sediment source which later on in-filled the Swartvlei estuary (Martin, 1962; Birch and Du Plessis, 1977).
>
> With a sea level of 2,5 m higher than present, the Swartvlei estuary of about 6 000 years ago was probably an *open inlet,* 2 km wide, between the rocks west of Swartvleistrand and the rocks east of the present mouth. There would have been inter- to supratidal sand banks and shoals, strong tidal dynamics and also rivers flowing more strongly than at present.
>
> It would have been during that period, that the floodplains around the present Swartvlei estuary were deposited in the shallows of the mouth.
>
> Some 4 000 years ago the sea subsided to its present level. This left the sand banks in the ancient wide inlet and parts of the present inner estuary dry. At least two channels had been cut from the deep lake in the background of the old estuary around the sand deposit in the mouth. Part of the floodplain forms the present Sedgefield Extension I.

The main channel migrated from the Swartvleistrand mouth to its present position, where it became fixed between the rocks in the east and the dunes of the peninsula. Traces of the ancient mouth channel at Swartvleistrand can be seen on historical maps and early aerial photographs. The Perdespruit channel was also part of the system of channels which crossed the floodplains between the lake and the coast (see Section 7.2.3).

Recent sedimentation in the estuary has been limited to minor sand movements caused by tidal currents, erosion and during floods. Increasing agricultural and other activities in the catchments of the Karatara, Hoëkraal & Wolwe rivers feeding the lake has increased erosion. The erosional products are deposited in the lake, with only the very fine suspended sediments reaching the estuary. Comparison of historical and recent maps shows the formation of sand spits where these rivers enter the lake as a result of sediment influx from the catchment.

Chunnett (1972) suggested that opportunities for flushing accumulated sediment and decayed material out to sea are reduced because of the *throttling effect* of the railway bridge. Subsequent work by the CSIR showed that this *throttling effect* was in fact restricted to the immediate vicinity of the bridge (Hidrouliese studie van Swartvlei estuarium, 1978) and that the expected (localized) benefits to be gained from enlarging the span of the railway bridge did not warrant the expected expenditure.

7.3 Hydraulics of the coast

Wind and wave conditions are the main factors in coastal hydraulics. Wind recordings from 1976 to 1980 (I Hunter, NRIO pers comm.) and wave clinometer recordings from 1968 to 1972 (Ashby, Harper, Van Schaik, 1973), as well as a 20 year-record of deep sea wave observations collected from 1960 to 1979 by voluntary observing ships (VOS); (Swart and Serdyn, 1982) were analysed. The respective wind and wave roses are given in Figures 11 and 12. Using the VOS data, the median and maximum wave heights for the Sedgefield coast were calculated, these are given in Table 1, while the seasonal variation of wave directions is given in Table 2.

As the VOS observations, are for various technical reasons more reliable than the clinometer readings, the VOS data was used for the calculations of the incidence of wave energy at the coast. The wind roses show a seasonal variability, but the south-westerly winds are dominant throughout the year. There is a strong south-easterly component during spring and summer, while in winter the north-westerly winds are most frequent. Although relatively low in frequency the strongest winds come from the east and south-east. The dune fields around the Swartvlei estuary are mostly protected against the wind by vegetation cover. Human disturbances of the large dune fields east and west of the estuary mouth (see Figures 6a - 6d) could upset the sedimentary balance of the coast by increasing sand supply to the mouth, and cause more frequent mouth closures.

The wave rose in Figure 12 shows a predominance of the south-westerly waves, while Table 1 indicates that the greatest median wave height of 2,75 m also originates from the south-westerly sector. Table 2 indicates a predominance of the *south-easterly* waves in *autumn* and *summer*, and a predominance of the *south-westerly* waves in *winter* and *spring*.

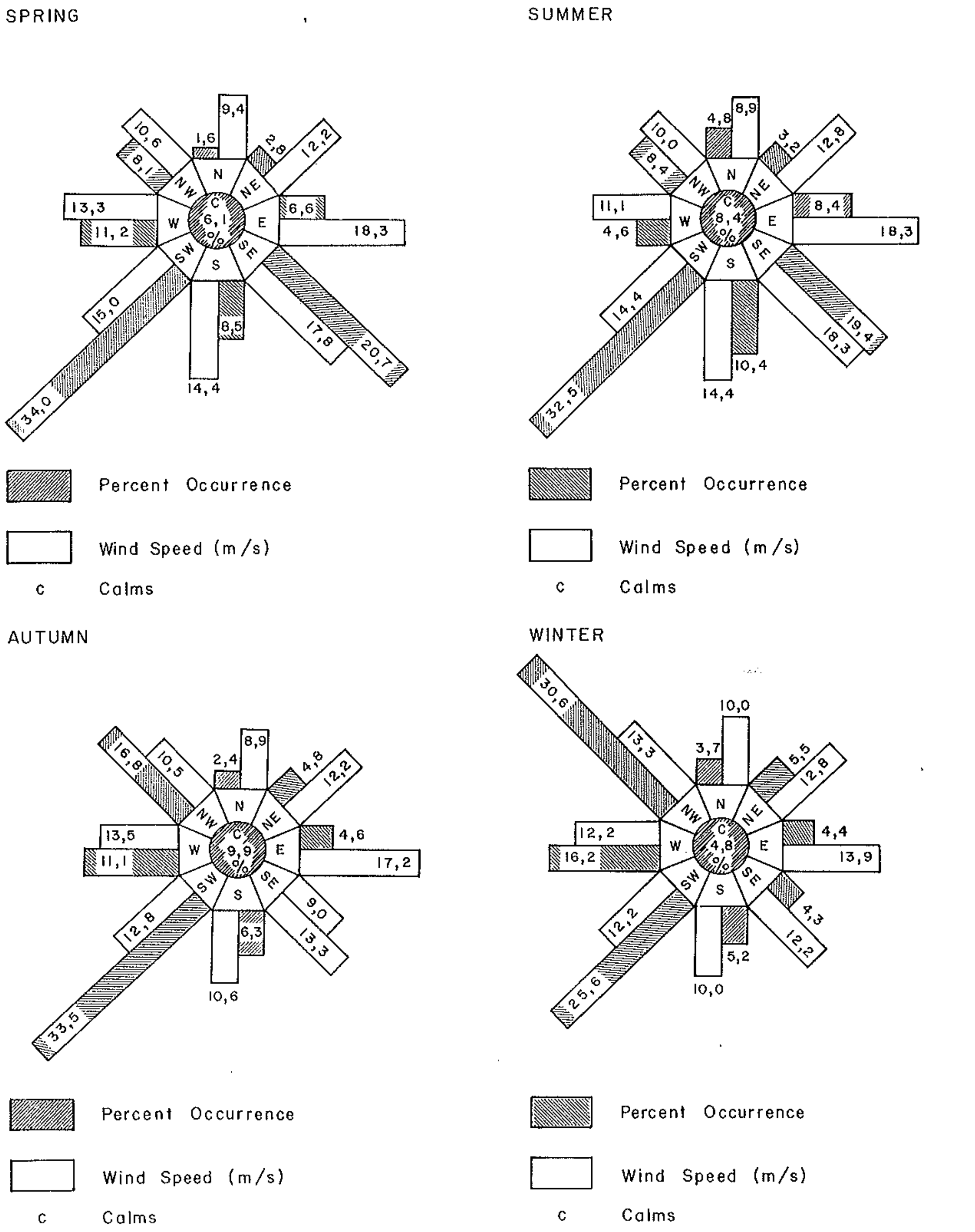


FIG. 11: Wind distribution for Cape St. Blaize (Mossel Bay), 1979-80. (after rough data, Cape St. Blaize, I.T. Hunter, pers. comm.)

TABLE 1: Wave directions, median+ and maximum++ wave heights for Sedgefield (Swartvlei) coast, according to VOS data.

Direction	Degrees	Occurrence (percent)	Wave Height (m)	
			Median	Maximum
E	90	12	2,2	5,6
ESE - SE	120	7	2,25	5,4
SE - SSE	150	6	2,2	5,9
S	180	10	2,25	6,8
SSW - SW	210	26	2,75	6,1
SW - WSW	240	27	2,55	6,7
W	270	12	2,4	7,0
ALL DIRECTIONS		100	2,45	6,0

+ Median wave heights are the expression of a significant mean over a period of 20 years, which is the wave height exceeded for 50 percent of the number of observations (read from an accumulative curve plotted on probability paper).

++ Maximum wave height occurring during the year.

TABLE 2: Seasonal variation of wave directions for Sedgefield (Swartvlei) coast, according to VOS-data.

Direction	Degrees	Occurrence (percent) of total per year			
		Spring	Summer	Autumn	Winter
E	90	3,5	3,4	3,0	1,8
ESE - SE	120	2,0	2,1	2,3	1,3
SE - SSE	150	1,3	1,4	2,0	1,2
S	180	2,1	3,0	3.0	2,2
Σ:E - S	90 - 180	8,9	9,9	10,3	6,5
SSW - SW	210	6,7	7,8	6,0	6,1
SW - WSW	240	7,9	5,1	5,4	8,1
W	270	2,9	1,6	2,4	4,5
Σ:SSW-W	210 - 270	17,5	14,5	13,8	18,7

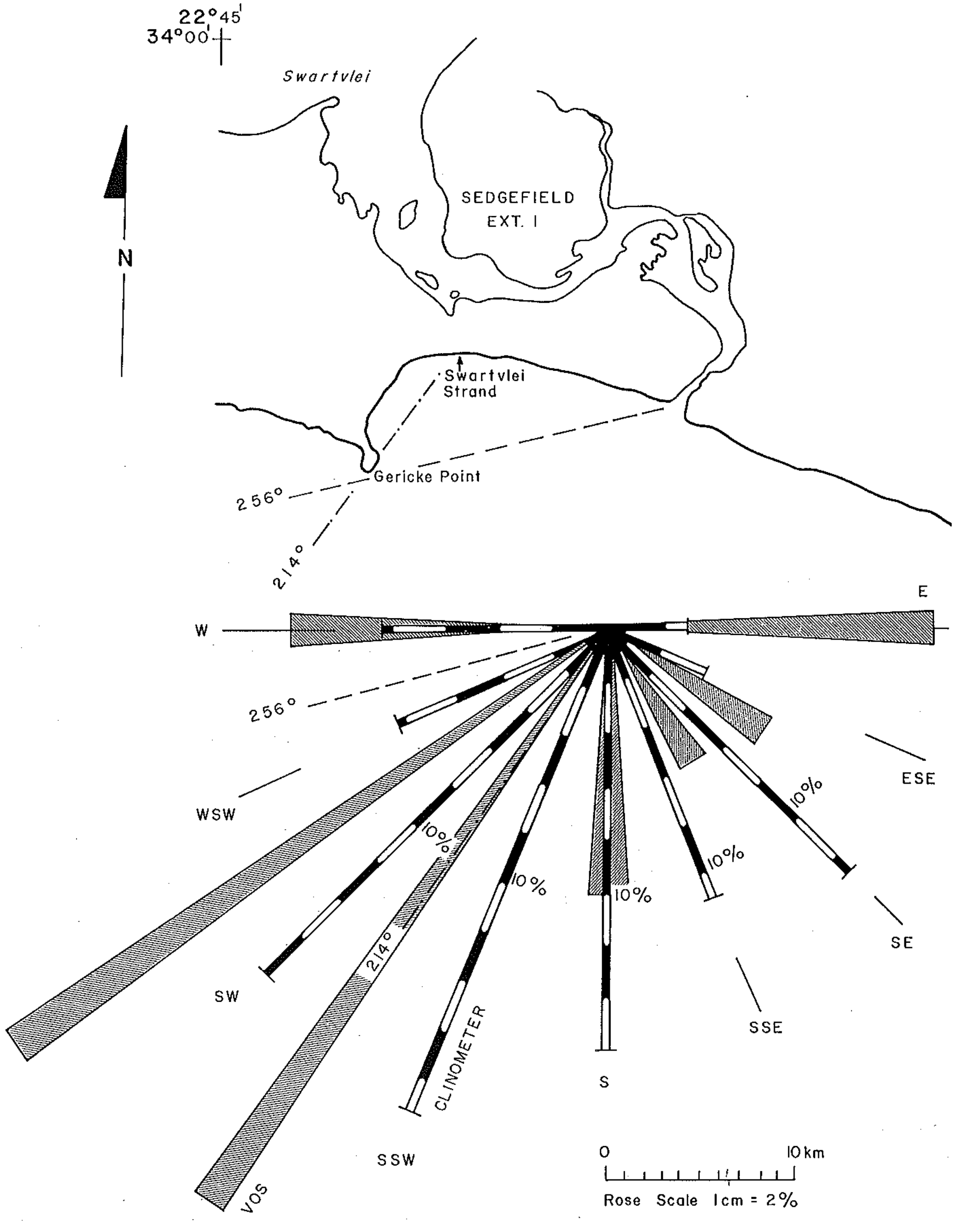


FIG. 12: Wave Rose, Cape St. Blaize
Deep sea waves (Clinometer and VOS)
Percentage distribution (See Table I)

The incidence of wave energy at the coast generates littoral currents which are mainly responsible for the longshore sand movement and which influence the condition of tidal inlets at the coast. As can be seen from Figure 12 the area of the Swartvlei estuary mouth is somewhat sheltered against westerly waves, (west of 256°) but waves originating from south-west to south-east, including the main wave energy from the south-westerly sector (east of 256°), can reach the coastal area surrounding the Swartvlei estuary mouth directly.

Longshore currents and sediment movement depend on the incident wave energy based on the percentages of waves striking the coast at an angle so that water is displaced laterally. The dividing criterion between waves from the south-west or from the south-east is a perpendicular drawn onto the coastline, which coincides with the direction SSW. The sum of the percentage occurrences to either side of the perpendicular were compared. According to this calculation 53 percent of the longshore sediment transport would be east-going and 23 percent would be west-going.

This is supported by the configuration of the ebb-tidal delta off the estuary mouth, which appears on various aerial photographs to be almost symmetrical or off-set slightly eastwards. Another indication of a net east-going longshore sand drift is the increase in width of the beach (visible on the aerial photograph in Figure 6a) and the decrease in slope of the beach (from 5 to 3 degrees) from the west (Swartvleistrand) to the east (estuary mouth). The greater steepness of the slope east of the mouth (4 to 6 degrees) is caused by the proximity of the rocks in this area and has, thus, no bearing on the longshore sand drift direction.

The western part of the Swartvlei coast between Swartvleistrand and Gericke Point is sheltered against deep-sea waves originating west of 214 degrees (see Figure 12). It forms a typical "half-heart" bay and represents, thus, a diffraction area. Because of the anti-clockwise bending of waves around Gericke Point and a damping effect proportional to the increase in the degree of bending, a higher water level is built up in the surf zone near Swartvleistrand, than near Gericke Point. This longshore variation in level inside the surf-zone is called "wave set-up" and this phenomenon results in the generation of a longshore current and sand movement from the outer bay towards Gericke Point. There is thus a *west-bound longshore current* along Swartvleistrand.

The Swartvlei estuary and beaches appear to have two main sources of sand supply. These are:

(a) sand being moved along the coast and around Gericke Point by the predominant east-going longshore drift and

(b) the erosional products from the friable dune-rock which is found all along the coast.

The mechanisms by which this sand is transported along the coast and then deposited on the beaches by onshore wave action in the the Swartvlei estuary are as follows.

(a) A west-going longshore drift which occurs for 23 percent of the time.

(b) A local west-going longshore drift taking place only during extreme westerly wave conditions (i.e. west of approximately 214°). This causes the "wave set-up" condition previously described.

(c) The east-going longshore drift when the offshore direction of wave approach is around 214°. During these conditions the longshore current generated by these waves will move sand along the shore from Gericke Point towards the Swartvlei beaches.

Littoral sand movement tends to close gaps in the shoreline such as an estuary mouth. This can happen only when the longshore sand drift becomes stronger than the forces which keep the inlet open, such as outflow due to river floods or the scouring by tidal currents in the mouth channel.

The majority of mouth closures in Swartvlei, occur in winter which coincides with the predominance of the general south-westerly wave conditions during winter (Table 2) which are responsible for the main longshore sand transport. The closures of Swartvlei estuary mouth can, therefore, be attributed mainly to heavy south-westerly wave conditions.

7.4 Bridges

Mr J Moes of the National Research Institute of Oceanology has developed a mathematical model of the water flow regime in the Swartvlei system (Hidrouliese studie van die Swartvlei estuarium, 1978). With this model it is possible to simulate changes in the water levels and flow rates in the estuary and lake if the bridges were either altered or removed, or if any new bridges were placed across the estuary. In addition Howard-Williams *et al.* (1975) examined the possible biological effects of the present road bridge over the estuary. A summary of the major conclusions from these reports and from data presented in Howard-Williams and Allanson (1978b) and Liptrot and Allanson (1978) is given below.

7.4.1 Railway Bridge

During normal tidal flow and strong outflows from Swartvlei, the railway bridge clearly interferes with the flow of water (see Figure 10). However, the influence of this is confined to the immediate vicinity of the bridge because the main restriction to outflow in the system is the narrow estuary mouth.

Moes's hydrological analysis shows that if the railway bridge were to be removed completely the only result would be a change in lake level of a few millimetres, and it would have no discernible effect on the estuary mouth. As far as influencing the biology of Swartvlei is concerned, the railway bridge has an effect only in the immediate vicinity of the bridge itself. The reed *Scirpus littoralis* is spreading slowly out from the railway embankment near the bridge and organic matter is being deposited in increasing amounts on the western side of the channel upstream of the bridge (see Figure 10). The low dissolved-oxygen concentrations in the channel above the bridge were attributed to the decaying organic detritus (Howard-Williams and Allanson, 1979) and they postulated that the low oxygen values may inhibit migrations of fish into the lake.

The NRIO mathematical model also shows that tidal exchange between the lake and estuary would increase by 40 percent if the bridge were to be removed. While this would have little effect on water level it would assist in the removal of some of the accumulated organic matter from above the bridge.

7.4.2 Road Bridge

The analysis of the hydrological data (Hidrouliese studie van die Swartvlei estuarium, 1978) has shown that the present national road bridge do not affect tidal movement in the estuary and Howard-Williams and Allanson (1979) concluded that the bridge has had no discernible effect on the ecology of the estuary.

7.4.3 Planned Road Bridge

Application of the NRIO mathematical model to the hydraulics of the Swartvlei estuary indicates that the tidal flow will not be affected by the new bridge. As the flooding and draining of the tidal flats are in general at right angles to the main channel, further division of the tidal flats by the new bridge embankment will not seriously influence the ecology of the estuary provided that extreme caution is exercised in preventing soil deposition on the tidal flats during construction of the embankments. It is recommended that large culverts be placed at intervals under the embankment west of the island where tidal flow across the flats is parallel to the main channel. (Howard-Williams and Allanson, 1979).

7.5 Physics and Chemistry

7.5.1 Swartvlei

Details of physical and chemical processes in the lake are given by Howard-Williams and Allanson (1978b) and Allanson and Howard-Williams (in press). The major characteristic of Swartvlei is that it is usually stratified into water layers of different density, caused by vertical variations in salt concentration. Such lakes are known as meromictic lakes. During the tidal phase, when water enters Swartvlei from the upper estuary, the salinity of this water is generally higher than that of the surface waters of the lake. This tidal flow of dense estuarine water, runs down the sandy slope in the vicinity of the rail bridge and accumulates in the Swartvlei basin to form a deep layer some 5 m thick. If a pulse of even higher salinity enters Swartvlei, this layer will be displaced upwards and a new more saline layer will form across the bottom of the lake. The end result is that surface salinities vary between 1 and 12 parts per thousand during periods of stratification with bottom salinities rising to 20 parts per thousand. The amount of wind stress required to break down this layered structure is considerable and as long as the mouth is open, allowing a continual input of estuary water into Swartvlei, this layering persists. The most important aspect of this stratification is the effect it has on the dissolved gases, oxygen (O_2), carbon dioxide (CO_2) and hydrogen sulphide (H_2S). Because stratification prevents wind from mixing the oxygenated surface waters of the lake with those below, decomposition of the abundant organic matter in the bottom sediments rapidly uses up the oxygen and increases the concentration of carbon dioxide. The decomposition of organic matter with proteinaceous sulphur, and the reduction of sulphate under the deoxygenated conditions, result in the accumulation of hydrogen sulphide in these bottom waters. The high carbon dioxide and hydrogen sulphide levels, together with the anaerobic conditions, therefore make the bottom half of Swartvlei a very toxic environment for animal life (Howard-Williams and Allanson, 1979).

The closing of the estuary mouth has a marked effect on the maintenance of stratification because it prevents the inflows of saline water. During the lagoon phase i.e. when the mouth is closed wind mixing of the surface waters gradually disturbs the salinity layering. The longer the mouth is closed the more likely it is that the stratification will break down and oxygenation of the bottom waters will occur (Allanson and Howard-Williams, 1983). The level to which the water rises in the lake has little influence on mixing since it is the length of time for which the mouth is closed, coupled with wind stress, which is important.

Stratification has important consequences for the concentration of plant nutrients in the water column. Soluble reactive phosphate (SRP) concentration is very low in Swartvlei and is often present in undetectable quantities (1 µg per ℓ SRP). This nutrient ion was thought by Robarts (1973) to limit algal growth in the lake. Total dissolved phosphorus (TDP) values range from 10 to 20 µg per ℓ and total phosphorus (TP) up to 30 µg per ℓ. According to Howard-Williams (1977) the SRP, TDP and TP concentrations in stratified bottom waters all exceed 100 µg per ℓ but are unavailable for plant growth. Howard-Williams and Allanson (1978b) and more recently Silberbauer (1982) determined that phosphate is released from the bottom sediments of Swartvlei and maintained in solution, provided the water remains anaerobic. Oxygenation causes the soluble phosphate to precipitate out so that it is then lost to the sediments. Values for Ammonia nitrogen and Nitrate ammonia obtained by Robarts (1973) were very variable with no distinct patterns except that the concentration of Ammonia nitrogen was higher in deoxygenated conditions and that of Nitrate ammonia higher in oxygenated surface waters.

Swartvlei is thus rich in nutrients such as phosphorus during a stratified meromictic condition but these are not directly available to the plants.

7.5.2 The Estuary

Details of physical and chemical processes which occur in the estuary are described by Liptrot and Allanson (1978). Typical salinity profiles of the three tidal regimes (neap, mean and spring tides) show that:

(a) Salinity decreases from the mouth to the rail bridge and from spring to neap tides. Transgression of seawater, with a salinity of 35 parts per thousand, into Swartvlei occurs infrequently and is usually associated with spring tides and abnormally low barometric pressures.

(b) Vertical mixing of the water column is greatest during spring tides. During neap tides the salinity of the surface waters draining through the estuary varies from 10 to 19 parts per thousand which results in slight salinity stratification in the deeper portions of the estuary. As more sea water enters the estuary towards spring tide, this stratification is broken down.

(c) During a tidal cycle, a substantial volume of water is actually retained in the estuary, which means that over a period of several tides the water in the middle section of the estuary will be moved back and forth with the sea water front acting as a piston. The effect of this is that water in the lower reaches is replaced by seawater every tide, while in the upper reaches, estuary and lake water are continually exchanged.

(d) Minimum salinities occur when the rivers are flooding and the mouth is open.

(e) After the mouth has closed salinities in the estuary gradually fall as the estuary becomes diluted with low-salinity (8 to 12 parts per thousand) water from Swartvlei. Wind-induced mixing breaks down vertical stratification during this period.

Dissolved-oxygen values vary mainly in response to biological activity. Horizontal variations depend on the distribution of the aquatic plants in the estuary, higher oxygen values being associated with the presence of aquatic plants. Generally, the dissolved-oxygen concentrations are higher nearer the mouth than further up the estuary. An analysis of the values in the estuary during the tidal phase and the lagoon phase showed that the closing of the mouth has no effect on the mean dissolved-oxygen values in the channel areas. However, deoxygenation does occur in localised areas towards the end of the lagoon phase. These areas are at the sides of the channel where large mats of the floating alga *Enteromorpha* start to rot, and in the deeper portions of the estuary. Rotting *Enteromorpha* is also responsible for a marked rise in total carbon dioxide, bicarbonates and carbonates in the water at the end of winter during the lagoon phase.

Temperature variations in the estuary follow a seasonal pattern with the temperature ranging between 10°C in winter to 29°C in summer. Closure of the mouth has no effect on water temperatures, but during summer when the mouth is open, the waters near the mouth are generally 1°C cooler than further up the estuary.

The rivers flowing into the Swartvlei system are stained dark brown (see Plate I) by dissolved organic matter leached from the vegetation of the catchment area. This humic matter (60 to 80 mg per ℓ) precipitates out in the estuary at salinities above 17,5 parts per thousand provided the pH value is above 8,0. Such conditions are almost always present during the tidal phase, and this humic precipitate probably represents a significant import of organic matter into the estuary.

Of the minor ions, nitrate and phosphate, most work has been done on the latter. Surface nitrate values were studied in 1976 by Coetzee (1979) who found values ranging from not detectable to 21 µg per ℓ $|NO_2 + NO_3|$-N. Howard-Williams and Allanson (1979) recorded values of NO_3-N ranging from 3 to 70 µg per ℓ. NH_4 - N is low (Robarts, 1973) ranging from not detectable to 4 µg per ℓ.
Total dissolved phosphorus remains fairly constant in the main channel of the estuary at about 24 µg per ℓ, except at times during the early lagoon phase when isolated foci of deoxygenated saline water occur at the deeper points. Over these points dissolved phosphorus can rise to 260 µg per ℓ. The main source of phosphorus for the estuary is the sea. During the tidal phase there is a net import and accumulation of phosphorus in the estuary, whereas during the lagoon phase phosphorus is cycled between water plants and sediments. The strong outflow phase immediately after opening of the mouth is characterised by an extensive net outflow of phosphorus, mostly in particulate form.

Trace metal concentrations in the waters and sediments of the estuary are thought to be low, but the concentrations of the major cations Na^+, K^+, Ca^{2+} and Mg^{2+} are all much higher than those in Swartvlei (Watling, 1977).

7.6 Biology

7.6.1 Swartvlei

The structure of the biological community in the open water of Swartvlei was first studied by Robarts (1973) who examined phytoplankton, bacterial numbers and with Grindley and Wooldridge (1973) also made some zooplankton counts. More recently Coetzee (1981) carried out an extensive analysis of the zooplankton of Swartvlei and found two zooplankton communities in the lake during daytime. The aerobic community was dominated by the copepod *Acartia natalensis, Pseudodiaptomus hessei, Musculus virgiliae,* veligers and calanoid copepod nauplii. A community dominated by cyclopoid copepods (mainly *Halicyclops* species), cyclopoid nauplii and polychaete larvae and juveniles was found to occur in water of very low oxygen and in some instances in water where the level of dissolved oxygen had fallen to zero. In how far this represents a real division of the plankton community or, as suggested by Coetzee (1981) was the result of sampling technique is uncertain.

Grindley (1981) showed that *Acartia natalensis* was the dominant species over the deep deoxygenated areas while *Pseudodiaptomus hessei* was the dominant species in the marginal area. In these shallow marginal areas there was no deoxygenated zone. *Pseudodiaptomus* normally migrates to the bottom during the day so they avoided the areas over deep water. The lowest plankton biomass was recorded over the deep water in the area dominated by *Acartia natalensis.*

Robarts (1976a) found three major categories of phytoplankton in Swartvlei viz. diatoms, dinoflagellates and flagellates. The dominant organism was the centric diatom *Coscinodiscus lineatus,* a species common in estuarine and marine habitats in South Africa. A list of common diatoms in Swartvlei is given in Robarts (1973). These primary producers were mostly nano-planktonic (60 µm in diameter) and population density never exceeded $3{,}5 \times 10^5$ cells per ℓ.

Chlorophyllous flagellates and dinoflagellates generally formed a relatively minor part of the plankton, but occasional short-lived blooms of flagellates and dinoflagellates occurred during periods when diatom numbers were low (Robarts, 1973).

Chlorophyll-a determinations in Swartvlei during 1976 (Coetzee, 1979) and in 1977 - 78 (Howard-Williams and Allanson, 1981a) support the initial observations of Robarts (1973) that phytoplankton populations are low. The waters of Swartvlei can be classified as oligotrophic, and Robarts (1976a) concluded that the rates of primary production in the pelagic zone were the lowest recorded for an African water body.

In contrast, the Swartvlei littoral has for many years been characterised by extensive beds of submerged aquatic plants (see Figure 13) which produce up to 2 500 g per m^2 of dry matter per year, and which have been intensively studied by Howard-Williams (1978; 1981), Howard-Williams and Allanson (1978; 1981a; 1981b), Howard-Williams and Davies (1979) and Howard-Williams and Liptrot (1980). This submerged vegetation occurs in fairly distinct zones except in the vicinity of the railway bridge where, due to higher salinities *Ruppia cirrhosa* predominates. *Potamogeton* *pectinatus* grows to a water depth of approximately 2 m while Charophyta are found in the shallower water behind the *Potamogeton* beds. Emergent vegetation grows along the edge of the vlei and consists predominantly of *Scirpus littoralis* and *Phragmites australis*. Other emergent sedges and rushes include *Typha capensis* and *Scirpus maritimus*. A structural analysis of the vegetation in the Swartvlei area is given in Appendix I.

The main types of aquatic plants, the areas they occupy and the amounts of organic matter they produce in a year are given in Table 3. It is immediately clear that by far the largest amount of food for the ecosystem is produced by the aquatic macrophytes, which together with their associated epiphytic algae are responsible for 86 percent of the primary production of the lake.

Associated with the littoral plants is a large invertebrate population dominated by five species; the bivalve *Musculus virgiliae*, the isopod *Exosphaeroma hylecoetes* and amphipods *Corophium triaenonyx*, *Grandidierella lignorum* and *Melita zeylanica*. Other taxa of importance include the tanaid *Apseudes digitalis*, the isopod *Cyathura estuaria*, the crab *Hymenosoma orbiculare*, Chironomidae and Ostracoda (Davies, 1982).

The distribution of *M. virgiliae* in the Swartvlei littoral varies according to the surface area of plant available for attachment. With increasing distance away from the shoreline the numbers of *M. virgiliae* increase from approximately 1×10^3 individuals per m^2 in the *Scirpus/Phragmites* belt to 1×10^4 individuals per m^2 in the *Chara/Lamprothamnium* zone and 1×10^6 individuals per m^2 in the outer *Potamogeton* zone (Davies, 1982).

The rich littoral invertebrate community attract many of the 33 fish species shown in Appendix II, to the area, and are indirectly responsible for the abundance of the popular angling species such as the leervis *Lichia amia* which consumes fishes associated with the plant beds. The mullet species do not feed on invertebrates but instead utilize the detritus from decaying plants. The fish community is normally dominated by two species, the Cape moony *Monodactylus falciformis* and Cape stumpnose *Rhabdosargus holubi*, the former feeding on invertebrates associated with the macrophyte beds and the latter on both invertebrates and growing plants (Whitfield, 1982).

The freshwater fish and certain estuarine species in the upper reaches of Swartvlei and in the rivers feeding the vlei are also given in Appendix II.

The distribution of aquatic macrophytes in Swartvlei is limited by light penetration to water shallower than 3 m. This is of special significance since the area in which the plants are concentrated is also the area where human recreational activities are most intensive and where interference with primary production is most likely to occur.

For instance, the Peripheral *Phragmites* reed beds, although very narrow, account in food production terms alone for 12 percent of that of the lake total (Table 3) and yet these are the first elements to be removed when a holiday resort is being established. Howard-Williams and Allanson (1979) have described how a 10 percent clearing of submerged plants in Swartvlei will cause a striking drop of 20 percent in the total food production of the lake. If there was a massive excess of food production over consumption this would not be serious. However, the ratio of food production to consumption in Swartvlei is approximately 1:1 and Howard-Williams and Allanson (1979) postulated that any loss in primary production would result in a corresponding reduction in the number of consumer organisms in the lake. An assessment of the interacting factors in the lake and its littoral has been given by Allanson (1981).

TABLE 3: The various types of primary producers, the areas they occupy and the amounts of organic matter they produce annually in Swartvlei (from Howard-Williams and Allanson, 1979).

Producer	Zone	Amount produced $kg \times 10^3$ per annum (dry wt)	% of total
Planktonic algae	Pelagic	344	14
Macrophytes:	Littoral		
Potamogeton		1 310	52
Chara		344	14
Phragmites		303	12
Periphyton:	Littoral		
Large algae e.g. *Cladophora*		90	4
Small attached algae e.g. *Cocconeis*		98	4
TOTAL		2 489	100

A decrease in water transparency in 1979 and 1981 due to river floods, and high salinities during 1980 following a drought period, resulted in a die-back of submerged plants in the Swartvlei littoral. Total primary productivity declined by approximately 60 percent between December 1975 and December 1980 because of the reduction in *Potamogeton* and Charophyta standing stocks (Taylor, 1983). Associated with the senescence of the above plants was a 74 percent drop in invertebrate biomass (Davies, 1982), a 69 percent decline in littoral fish populations (Whitfield, 1983) and a 58 percent drop in the number of Red-knobbed Coot (Palmer, pers. comm.). The above sequence of events substantiates the hypothesis of Howard-Williams and Allanson (1979). Therefore, while the value of the shallow peripheral areas for human activity is recognised, it cannot be too strongly stressed that wholesale removal of reeds and submerged aquatic vegetation will seriously endanger the ecology of the system.

Boshoff and Palmer (pers. comm.) are in the final year of a four year study of the species diversity, seasonality and habitat preferences of the birds of the Wilderness lakes, including Swartvlei. Altogether 57 species have been recorded at Swartvlei (Appendix IV) of which 5 species have been listed in the South African Red Data Book as species requiring conservation (Siegfried *et al.*, 1976). The numbers of birds on the lake range from 100 to 5 000 with an average of approximately 1 000 (Palmer, pers. comm.).

A checklist of amphibians and reptiles from the Swartvlei area is given in Appendix III and mammals in Appendix V.

The terrestrial vegetation around the Swartvlei system (see Figures 13 and 14) consists mainly of an *Ehrharta*-dominated foredune vegetation, through *Rhus* dominated dune scrub to thorny riverine scrub. There are also numerous patches of fynbos on the dunes and further inland. Most of the vegetation in this area has been severely disturbed by grazing, trampling (recreation), injudicious development and invasion by numerous *Acacia* and *Pinus* species. Some control of this type of disturbance should be practised, especially in the more sensitive marsh, dune and riverine areas (O'Callaghan, pers. comm.).

7.6.2 The Estuary

The most striking feature of the estuary is the presence of extensive tracts of two seagrasses, *Zostera capensis* and *Ruppia cirrhosa*, which occur in both mixed beds and pure stands (see Figure 14). The zone between high spring tide water level and low neap tide water level is a zone of tidal sand flats, with little or no submerged macrophyte vegetation (see Plate II). In slight depressions *Ruppia* is fairly dense but on the main sand flats the growth of this plant is very sparse, with only small individual leaves occurring above the sand surfaces. These develop rapidly when the estuary mouth is closed and the sand flats are continuously inundated for long periods. During the past two years (1981/82) the estuary has been permanently open (see Figure 9) and this has resulted in a reduction in the size of the area covered by *Ruppia*.

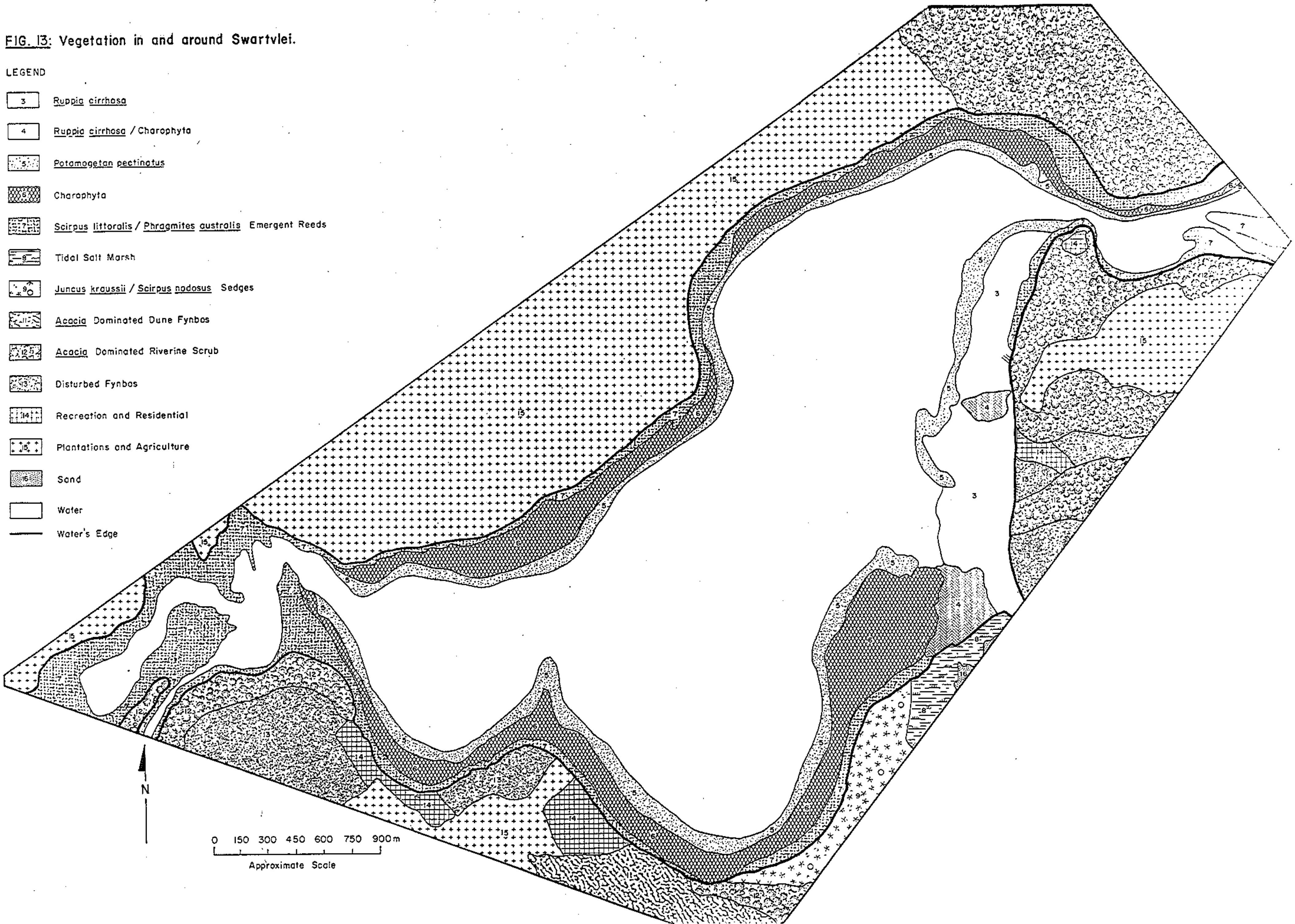
In that part of the estuary which is permanently submerged, dense macrophyte beds occur. *Ruppia* occurs to a depth of 0,4 m below low-water neap tide level, where *Zostera* replaces the *Ruppia* (Howard-Williams and Liptrot, 1980). *Zostera* is especially prevalent on the sides of the estuary channels. The bottom of the main channel is normally bare of macrophytes but where the channel broadens dense *Zostera* beds may occur. Apart from the distinct vertical zonation, there is a horizontal zonation of species with *Zostera* predominating nearer the sea and *Ruppia* predominating upstream (Howard-Williams and Liptrot, 1980).

The macrophytes, particularly *Zostera*, support a large epiphytic algal population. The principal genera include *Enteromorpha*, *Lyngbya*, *Cladophora*, *Percursaria*, *Cocconeis*, *Ectocarpus*, *Polysiphonia*, *Chondria* and *Hypnea* (Howard-Williams and Liptrot, 1980). The biomass of periphyton[+] in the Swartvlei estuary is large, usually about 25 percent of the supporting leaf, although it occasionally exceeds the mass of the supporting leaf. This is particularly true of the green algae *Enteromorpha* which occurs initially as an attached epiphyte but which may form dense mats of entangled filaments over the *Zostera* beds in winter. These extensive growths then rot during the summer often causing sulphide odours and unpleasant conditions in the recreational areas of the estuary.

The marginal salt marshes of the estuary occupy about 65 ha and are flooded at high spring tide and during periods when the mouth is closed. These marshes are made up of the salt marsh plants *Sarcocornia natalensis* and *Salicornia meyerana*, amongst a dense sward of the grasses *Paspalum vaginatum* and *Sporobolus virginicus*. In heavily grazed areas the latter two species are severely depleted. *Juncus kraussi* occurs in clumps throughout the salt marsh (Howard-Williams and Liptrot, 1980).

[+]Periphyton - The plants adhering to parts of rooted aquatic plants.

FIG. 13: Vegetation in and around Swartvlei.



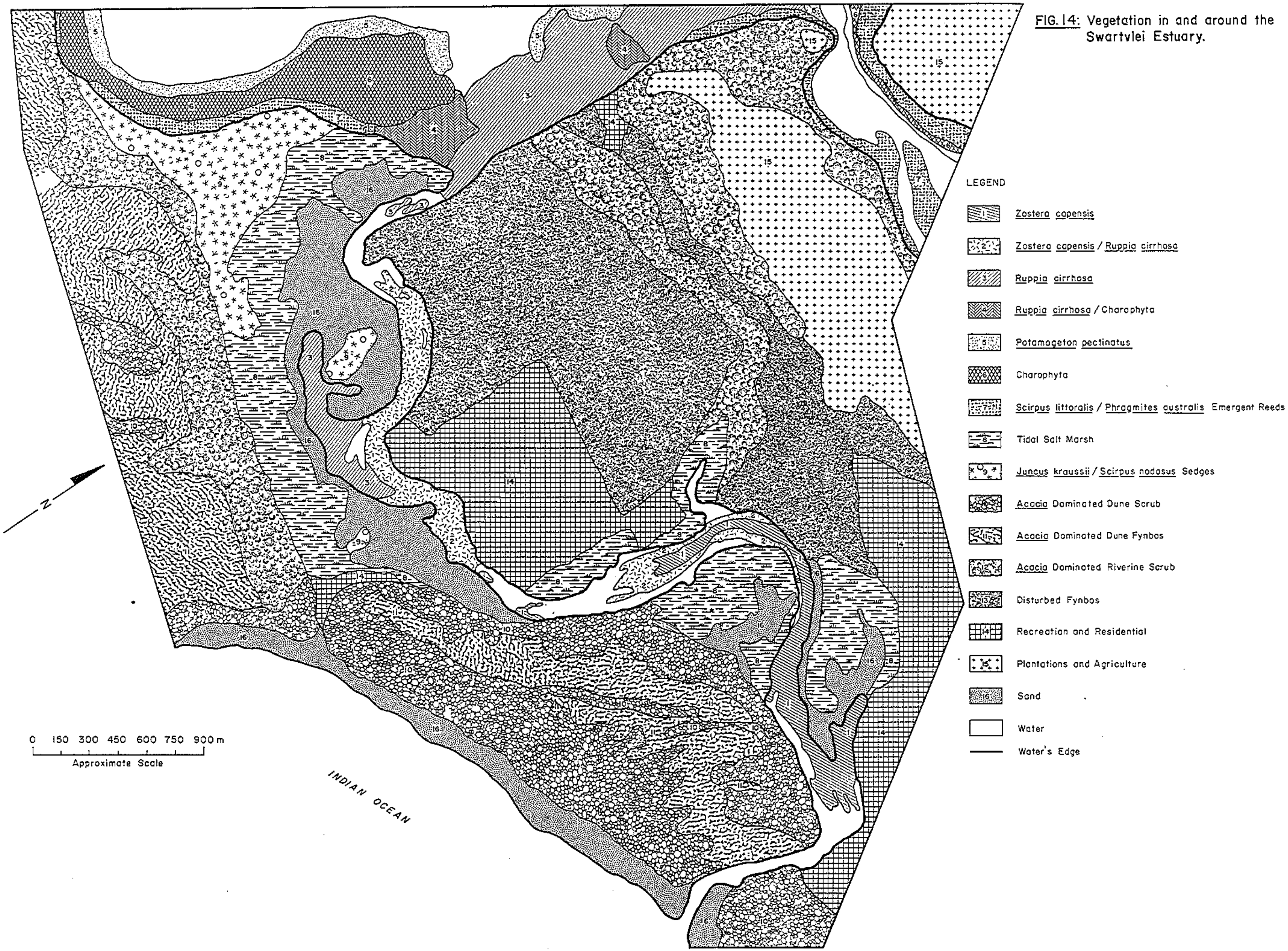


FIG. 14: Vegetation in and around the Swartvlei Estuary.

The Swartvlei estuary has been studied from the production viewpoint in a different way from that in the lake. Details are presented in Liptrot and Allanson (1978). The first point of interest arising from the above study is that the productivity of the estuary follows the same gradient as that of the nutrients i.e. the productivity decreases from the lower seaward region towards the rail bridge. The gross community production at the bridge end of the estuary was only half that lower down.

The second point of interest in the above study on organic production and consumption was that the closure of the estuary mouth did not affect primary production.

The most significant finding of Liptrot and Allanson (1978) was that the rate of utilization of organic material by the biological community was greater than its production rate. This deficit is made larger by the fact that a net export of *Zostera* leaves occurs during the tidal phase. Thus, in order to maintain the consumer productivity of the estuary, significant amounts of organic matter must enter the system from outside. Liptrot and Allanson (1978) postulated that organic matter in the form of humic material from the rivers is precipitated out in the estuary because of elevated pH levels, and the utilization of this material by the community may account for part of the deficit. They concluded that the consumer population of the estuary is probably dependent to a substantial degree on the humic materials derived from the partial decay of plants in the catchments.

There are large populations of invertebrates in the estuary, both in the sediments (e.g. Sand prawns: *Callianassa kraussi*) and among submerged macrophytes (e.g. Sand shrimps: *Palaemon pacificus*). A detailed investigati of the invertebrates and fishes of the Swartvlei estuary commenced in January 1983 as part of the SANCOR National Programme.

During January 1976, Coetzee and Palmer of the Cape Department of Nature and Environmental Conservation carried out a survey of bait organisms in Swartvlei and the Swartvlei Estuary. Only the sand prawn *(Callianassa kraussi)* was found in Swartvlei proper, while the mud prawn *(Upogebia africana)*, pencil bait *(Solen capensis)* and the sand prawn were all found in the estuary, i.e. seaward of the railway bridge.

Sand prawns were distributed throughout the estuarine area, but mud prawns were confined to an area near the mouth where a muddy substrate occurs in association with the *Zostera* beds. At the time of the survey it appeared as if the mud prawn was the most heavily exploited of the three main bait organisms.

Pencil bait is restricted to a small area near the mouth which is almost always underwater (Coetzee and Palmer, 1976).

The removal of bait at Swartvlei is subject to the provisions of the Provincial Proclamation No. 357 of 1972.

This restricts an individual to a total of 70 prawns (either mud or sand prawn) per day and 20 pencil bait. Also, in terms of the ordinance, bait removed at Swartvlei may be used only in Swartvlei and not in other inland waters or along the coast (Cape of Good Hope Prov. Proc. 357 of 1972).

Kok (1981) monitored the changes in the patterns of recruitment of juvenile fishes into the Swartvlei Estuary between July 1978 and December 1980. He found a strong summer recruitment for most fish species, with the mullet *Liza richardsoni* and *Liza dumerili* showing protracted immigration. Kok (1981) also recorded a lag in the recruitment of juvenile steenbras *Lithognathus lithognathus* and stumpnose *Rhabdosargus holubi* into the Swartvlei Estuary when the mouth opened after a prolonged closed period. He concluded that the timing and the period for which the estuary is open to the sea is crucial to juvenile fish recruitment. A checklist of the fish species found in the Estuary is given in Appendix II.

Coetzee (1982a; 1982b) investigated the diet of three fish species from the Swartvlei Estuary namely, estuarine round-herring *Gilchristella aestuarius*, Cape silverside *Hepsetia breviceps* and leervis *Lichia amia*. The leervis is an important angling species and feeds mainly on the estuarine round-herring and sand shrimp *Palaemon pacificus* (Coetzee, 1982b).

Altogether 61 bird species have been recorded at the Swartvlei Estuary (see Appendix IV); three of these have been listed in the South African Red Data Book as species requiring conservation (Siegfried *et al.*, 1976). The number of birds on the estuary range between 700 to 3 200 with a mean of approximately 1 400 (Palmer, pers. comm.). The Swartvlei Estuary is particularly important to Palaearctic migrants which make extensive use of the tidal flats for foraging and roosting.

8. MANAGEMENT CONSIDERATIONS AND RECOMMENDATIONS

The Swartvlei System is situated in an area which has been described by a number of authors as one of unique scenic beauty and as such is one of South Africa's most important outdoor recreational areas (Barry, 1968; Muller, 1970, Gasson, 1970; Dept. of Planning; 1970, Manley, 1972 and the Cape Provincial Administration, 1973).

Much of the planning work previously carried out in the region has been used by a statutory guide plan committee appointed in May 1977 by the Minister of the former Department of Planning and the Environment to produce the "Knysna-Wilderness-Plettenberg Bay Guide Plan" (hereafter referred to only as "the Guide Plan") which was finally approved and published by the Department of Constitutional Development and Planning in April 1983.

The Guide Plan certainly agrees with the views of the above authors, as is shown by the following quotation from its Introduction:

> "This area is extremely popular because of its recreational assets and unique scenic beauty. To tourism and holiday-makers from all over the Republic as well as from abroad, this area features high on the list of priorities because of its singular combination of recreational assets such as mountains, lagoons, indigenous vegetation, beaches, a pleasant climate and the possibility of partaking in a variety of outdoor recreational activities. The occurrence of unique natural phenomena and rare indigenous vegetation makes it an important conservation area, seen from a national point of view.
>
> The above factors, together with a growth in the population, higher incomes, more leisure time and bigger family mobility, place great pressure on this area, so many more people being able today to travel

in their leisure time. To enable the public to reach this area more quickly and in great comfort, a new freeway has been planned through the area that will link Cape Town with Port Elizabeth. At the same time, significant implications for land use arise from the need for residential and recreational facilities to serve not only the tourists but also the growing local population. In order to meet this growing demand for land for residential and recreational purposes, it is essential to draw up an overall land-use plan ensuring that physical development in the area does not take place at the expense of the environment. A balance will have to be struck, in other words, between development on the one hand and the conservation and protection of ecologically sensitive environmental elements on the other hand. Such is the overall object of this guide plan."

According to the National Physical Development Plan (Department of Planning and Environment, 1975) agriculture, forestry and recreation are the main elements which link the region together. Certain limitations exist with respect to the development of agriculture and forestry but the tourist industry is one which can expand considerably.

Development in the area has been slow and one of the reasons for this has been attributed to poor communications. The harbour at Knysna, the main reason for the establishment of the town, ceased to exist after 1928 when a single branch line from George established a rail link with Cape Town. It was only in the late 1940s that the present National road was built. This served to open up the region somewhat and the primitive holiday camping areas which existed at places like Swartvlei and Sedgefield became more accessible.

The township of Sedgefield was in fact established only in 1928 with 930 erven; this was later extended by the addition of Extension No. 1 with a further 429 erven (Cape Prov. Admin., 1973).

Figures from the Cape Coastal Survey (Cape Prov. Admin., 1973) show that at the time of the survey (1962/63), Sedgefield had a permanent population of only 79 people but that the influx during the peak period of the December/January holidays was 4 642 persons. At that time there were two motels at Sedgefield and 10 Caravan Park/Holiday Resort establishments situated in Sedgefield and around the perimeter of Swartvlei proper.

The latest figures given by the Guide Plan (Department of Constitutional Development and Planning, 1983) indicate that Sedgefield has a total permanent population (White, Coloured and Black) of 1 061 and it is estimated that this will increase to 1 775 persons by the year 2000.

Furthermore, according to the Guide Plan, there are at present approximately 1 550 residential erven for Whites in Sedgefield, of which about 420 had been developed. It is estimated from building plans approved up to date that about 1 100 houses will be needed by the year 2000 and with 1 500 erven available at the moment this demand could be met with an oversupply of approximately 35 percent. It is also recommended by the Guide Plan that should any extensions to Sedgefield be necessary in the future, that these must take place towards the east, adjacent to the National road and contiguous to the existing township.

Notwithstanding the above, a township development is envisaged on the "Swartvlei Peninsula", a tongue of land situated between the sea and the Swartvlei Estuary (see Figure 1 and Grindley, 1983). This development was approved of in principle prior to the commencement of the guide plan action, and it seems that this approval cannot now be withdrawn. Nevertheless, very specific recommendations regarding this development have been put forward by the Guide Plan Committee. These are as follows:

"At least 50 percent of the area of the projected township must be used for recreational purposes, provided that the total area of the town is not to exceed that of the holiday resort already approved by the Administrator on the site. No residential units in the recreational area are to be alienated individually.

The development of the township should be nature-orientated with as little disturbance of the natural environment as possible. The design and architecture of the development must harmonise with the environment. Public access, open spaces and parking facilities must be given along lake-shores and the coast.

No buildings with a height of more than eight (8) metres may be erected on waterfront properties.

The recreational developments along the coast and at the estuary must provide for a buffer strip of at least five (5) metres above HWM.

In the case of the most northerly dune both the top and the northern slope must be protected in their entirety, and no development is to take place in this area. This is to ensure that the destabilization of the dry northern slopes of these extremely sensitive vegetated dunes and the creation of paths with sand slumping into the estuary, does not take place (see Figure 15).

The layout of the projected township must be vetted by an eminent landscape architect.

The projected township is not to be developed until such time as all of the peninsula has been brought under the control of the Lake Areas Development Board. (Dept. of Constitutional Development and Planning, 1983). The National Parks Board officially took over the functions of the Lake Areas Development Board on the 1st of April 1983 (Press release by the Minister of Constitutional Development and Planning, 21 July 1983)."

There is also the possibility that in the future thought may be given to providing services and direct access between Sedgefield and the proposed "Swartvlei Peninsula" development by constructing a bridge across the lower part of the Estuary. Any such plans should be viewed with the greatest circumspection.

In spite of the stipulations mentioned above and the recommendations made in the Guide Plan to honour a previous commitment to the Outeniqua (then George) Divisional Council, there remain very serious reservations against the scheme. The development does not comply with basic modern-day

FIG. 15: The central section of the estuary with the Swartvlei peninsula in the middle of the picture. Note the steepness of the vegetated dunes and their proximity to the estuary channel. A low, inadequate causeway in the road crossing the Perdespruit where it joins the Swartvlei estuary can be seen in the centre right of the photograph. (IFWS: 83-03-08).

FIG. 16: View of the Swartvlei peninsula from the east towards the west showing how the sand dunes have been stabilized by vegetation (IFWS: 83-03-08).

principles of coastal zone management such as avoidance of development of as yet undisturbed areas if nearby proclaimed residential areas have not yet been fully utilized; avoidance of private development on, or in the vicinity of, dune areas vulnerable to destabilization; development in prime ecological areas which may stimulate development in other such areas because of this precedent; and reservation of coastal sites for exclusive holiday type of development in the interests of a relatively small number of well-to-do people, while pressures for public utilization are growing rapidly along the whole coast.

Bearing all the above in mind, there is a far more acceptable form of utilization of the "Swartvlei Peninsula". With the National Parks Board (NPB) taking over control of the Wilderness/Swartvlei region, comes public demand for augmenting the kind of well-controlled amenity such as has been developed by the National Parks Board at the Storms River Mouth, Tsitsikamma. The Swartvlei Peninsula would present an ideal location for such a development. In the hands of the NPB there is no doubt that the development would be in empathy with this dune environment. It would furthermore give access to this area to a far greater cross-section of South Africa's general public than would the exclusive private ownership development envisaged at present. Control over the vulnerable dune areas would be far easier and a smaller area would be affected. Control could take the form of a valuable public education exercise, augmenting that already in operation in the rocky coast environment at Tsitsikamma. Such a development would do far more to promote tourism in this region than would private property ownership on the peninsula. Finally, an attempt could be made through negotiation between the Department of Environment Affairs, the Outeniqua Divisional Council and the National Parks Board, to overcome the embarrassment flowing from the need to honour a previous commitment in the knowledge that it would conflict with modern coastal zone management requirements.

Although it is understood that permission has been granted in principle to the Outeniqua Divisional Council to proceed with private property development on the Swartvlei Peninsula it is strongly recommended that the whole matter be urgently reviewed in the light of the comments made above.

As has been mentioned in the Guide Plan, the improved communications and an ever-increasing population are likely to place tremendous pressures on the environment and in particular the lakes, lagoons and estuaries of this region. Swartvlei is the largest, and from a recreational point of view the most important, of the series of lakes which makes up what is known as the Wilderness Lakes system. The CPA Coastal Survey (1973) has pointed out that the water bodies are the magnets for most of the recreational activities and the inaccessibility of shorelines, especially lake shores, to the general public is one of the major problems facing the authorities. The importance of activity zoning is stressed as is the determination of usage capacity to counteract over-utilization so as to ensure that the particular quality of each type of recreation experience is maintained. According to the Provincial Proclamation No 357 of 1972, Swartvlei has been zoned for specific activities. These areas are demarcated by numbered beacons which are situated on the lake shores. The activities permitted in the various zones are listed in the Proclamation. (Cape of Good Hope Prov. Proc, 1972).

A National Plan for Outdoor Recreation is currently being prepared which contains a South African site inventory. This inventory evaluates the recreational potential of sites based on the variety and quality of the recreational experiences that can be enjoyed at a particular site (Dept. of Constitutional Development and Planning, 1983). This inventory should be used in planning the recreational facilities at Swartvlei which should be considered in conjunction with the other lakes of the Wilderness System and not planned in isolation.

The following is an overall summary of the main recommendations made by the Department of Planning's report on the Knysna-Wilderness Lakes Complex (1970), the CPA, Cape Coastal Survey of 1973 and the Knysna-Wilderness-Plettenberg Bay Guide Plan (1983) as they pertain in particular to Swartvlei and the Swartvlei Estuary:

(a) A central controlling body should be appointed to exercise control over and to manage Swartvlei and its estuary. This recommendation is now in the process of being implemented in that Swartvlei and its surroundings are shortly to be incorporated with the proclaimed Wilderness Lakes Area which was taken over by the National Parks Board on the 1st of April 1983. (Dr GA Robinson, National Parks Board, pers. comm.).

(b) The authorities should acquire more shoreline around Swartvlei for general recreation. In particular, areas in Sedgefield Extension I adjacent to the estuary and alongside the south western shores of Swartvlei adjacent to the railway line should be considered.

(c) A strip of land along the northern shores of Swartvlei, the upper eastern extremities of the vlei and the salt marshes south of the national road should all be strictly protected (see Figure 17).

(d) Recreational developments in zoned nature or recreation areas (see Figure 17) should be geared more towards low intensity nature-orientated public facilities such as caravan parks or chalet type holiday resorts which are built in harmony with the environment. If additional township development is considered necessary this must consist of extensions to the existing township of Sedgefield. Any private recreational developments along the coast or shoreline of Swartvlei must allow a five (5) metre buffer strip above HWM. This is to protect sensitive dune areas along the coast and give the public access to the beach and lake shores.

(e) If or when the proposed national freeway is built across Swartvlei (see Figure 17) it must have a single span across the main flow channel and where fill is used, culverts must be placed across minor flow channels running parallel to the main channel. Particular care must be taken during any road or bridge construction across the Estuary to ensure that no pollution or silting-up of channels occurs. The construction should be of such a design so as to cause the minimum of ecological and visual disturbance.

(f) The artificial opening of Swartvlei mouth should be carried out only by the controlling body referred to in (a) above. Under normal circumstances this should take place only once the vlei has reached a level of +2 m above mean sea level (MSL). Under high risk conditions

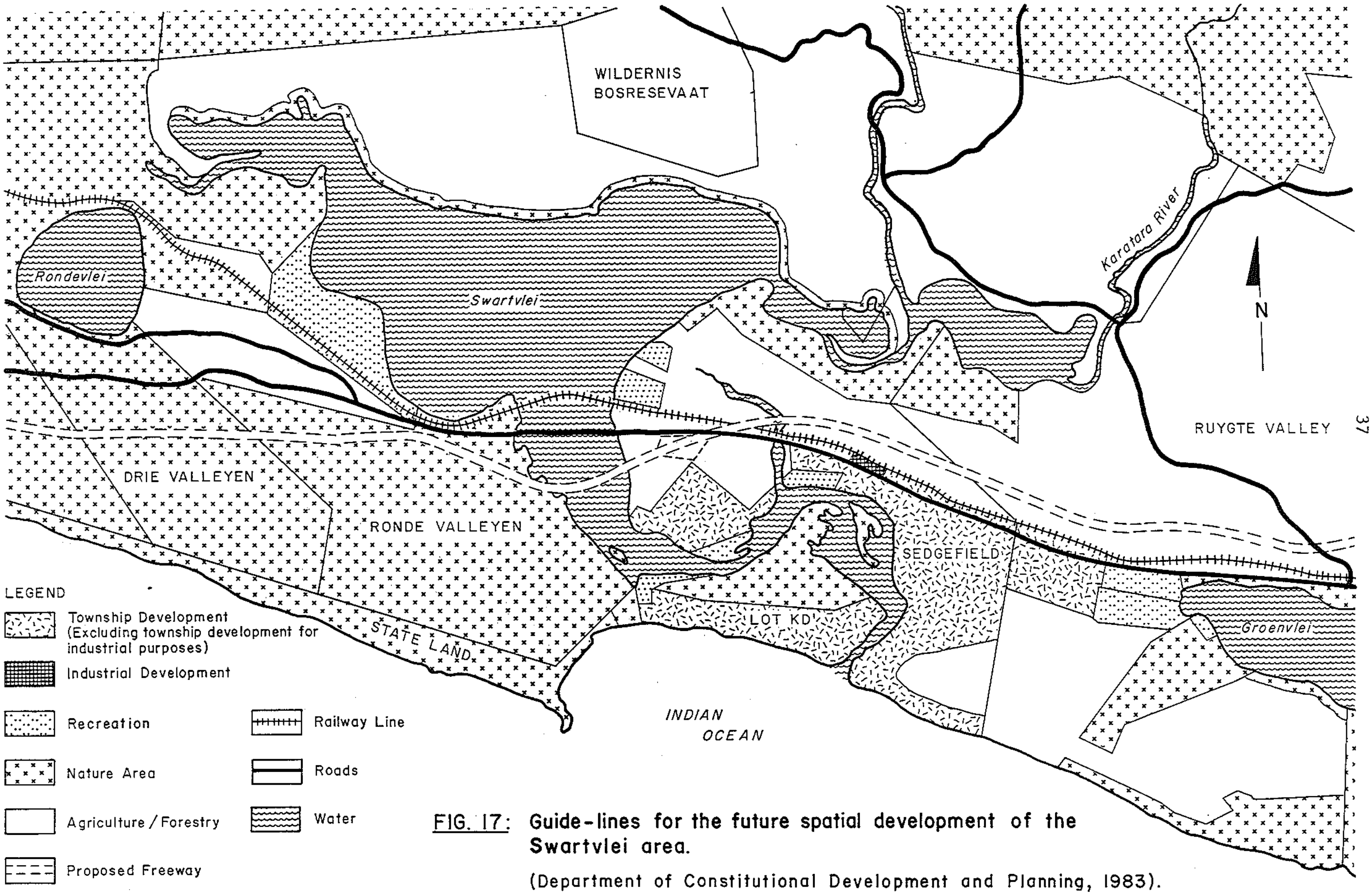


FIG. 17: **Guide-lines for the future spatial development of the Swartvlei area.**

(Department of Constitutional Development and Planning, 1983).

i.e. when the lake level is already high and when there are continuous heavy rains and a rising lake level, consideration can be given to opening the mouth before the +2 m level is reached.

(g) The effect of a reduction of inflow of fresh water into Swartvlei must be taken into account when the building of dams on the rivers feeding Swartvlei or increasing the amount of water extraction for the planned residential developments at Sedgefield, are considered.

(h) The present system of sewage disposal, namely, septic tanks with soak-aways, works efficiently in the sandy substrate around Swartvlei. However, with the tremendous amount of development that is taking place in Sedgefield at present this situation is unlikely to continue and it is strongly recommended that the local authorities seriously consider adopting the use of either conservancy tanks or a fully reticulated sewerage system as soon as possible. Sewage enrichment problems are already being experienced in the Wilderness area (Mr GA Visser, Lake Areas Development Board, pers. comm.). It would be unwise of the Sedgefield Municipality and the Outeniqua Divisional Council to wait until they start having problems before doing anything about it. It is further suggested that a series of monitoring spikes be placed some distance landward of the lake shores in order to check the sub-surface flow into Swartvlei and the Estuary for typical sewage derived nutrients.

(i) The development of a township and recreational facilities on the "Swartvlei Peninsula" has a number of far-reaching implications in so far as the Swartvlei Estuary and Sedgefield are concerned. In view of the present adequate supply of erven in Sedgefield and the previously mentioned Guide Plan recommendations that further extensions to Sedgefield should be contiguous to the existing township and in an easterly direction, the need to develop the "Swartvlei Peninsula" at all, is seriously questioned (see previous comment regarding the proposed "Swartvlei peninsula" development).

The abovementioned recommendations are supported by the various planning authorities. There are, however, certain additional recommendations to be made which are based on the ecological studies carried out on Swartvlei by the Institute of Freshwater Studies. These are as follows:

Swartvlei Catchment

There is an urgent need to assess the erosion characteristics of the catchments of the Wolwe, Hoëkraal and Karatara rivers under existing patterns of agricultural practice and afforestation. The montane catchments are particularly sensitive to the impact of man, and the increasing afforestation of the seaward slopes of the Outeniqua Mountains may be reducing the fynbos cover and with it the water absorption capacity of the headwater catchments. As a consequence, run-off during heavy rain is rapid and the headwater stream beds become eroded with a concomitant increase in suspensoids in what should be clear humate-stained water. The immediate effect upon Swartvlei is to reduce the transparency of its water and, depending upon the duration and timing of the inflow, this could seriously limit the penetration of light energy to the plants of the lake. If the waters of Swartvlei remain turbid for long periods, as occurred during 1981, Aquatic plant growth is inhibited and the community dies.

It is recommended that funds be made available for a sampling programme to measure suspended loads in:

(a) The mountain streams.

(b) The streams and rivers draining the Tertiary uplands (see Section 4, Geology).

(c) The short streams draining the upland scarp and the agricultural land adjoining the northern, northwestern and northeastern shores of Swartvlei.

Swartvlei

(a) Water levels in the lake frequently exceed +2 m MSL prior to the opening of the estuary. Therefore, future development of property at levels below +3 m should not be allowed under any circumstances, and the +5 m contour is recommended as the lower limit for future development.

(b) Cutting of the reeds and other vegetation along the margins of the lake should be strictly prohibited since these plants stabilize the banks and contribute primary food products to the aquatic ecosystem.

(c) Removal of underwater plants should be discouraged. Where unavoidable, the practice should be limited to access corridors opposite established holiday resorts on the southeastern and western shores of Swartvlei.

The Estuary

(a) The CSIR report, (Hidrouliese Studie van die Swartvlei Estuarium, 1978) recommended 2 m above GMSL as the minimum level for opening the mouth of the estuary. This minimal level is acceptable from the biological viewpoint since it will allow the build-up of a sufficient head of water to remove accumulated organic matter from the estuary. However, the time of opening will depend on when the water level reaches +2 m. (MSL). From an analysis of the biological data it seems that only one factor is likely to be influenced in the long run by the time of opening of the mouth and that is the utilization of the estuary by juvenile fish. Kok (1981) has shown that maximum recruitment of fishes into southern Cape estuaries occurs during spring and summer. Therefore, as angling can be regarded as one of the most important recreational pastimes in Swartvlei and the Swartvlei estuary it is recommended that the optimum period for opening the mouth is sometime between October and December, provided that the 2 m water level is attained.

(b) Liptrot and Allanson (1978) and Howard-Williams and Allanson (1978b) have shown that the estuarine sediments and submerged plant community are able to absorb the present input of nutrients from septic tanks. However, the buffering action of these components of the estuarine ecosystem are likely to be affected if developments are permitted too close to the estuary and/or on property less than 5 m above MSL. Inundation of low-lying developments during flooding would carry the additional risk of water contamination and therefore endanger the health of people utilizing the estuary. An additional reason for using the +5 m contour as a baseline for development is that public pressure to open the mouth prematurely will increase if properties are developed on low-lying areas which may then be at risk with rapidly rising water levels during times of flood.

(c) In accordance with the previous recommendation regarding activity zoning within Swartvlei, power boating and water-skiing should be confined to the main part of Swartvlei since this activity is dangerous to people swimming and canoeing in the narrow estuary. It also disturbs the more passive recreational activities such as fishing and bird watching normally carried out in the lower estuarine area.

(d) The harvesting of bait organisms in the estuary should be strictly controlled.

(e) Modification of the shoreline of the estuary (e.g. dredging inlets for boat moorings, etc.) should first be approved by qualified authorities who are able to comment on the physical and biological effects of such developments.

(f) Removal of underwater plants should be limited to access corridors opposite existing slipways. Destruction of submerged *Zostera* beds to improve boating in the estuary should not be permitted at all.

The recent upsurge in the property market has had its effect on Sedgefield and the land around the perimeters of Swartvlei. The relatively new innovations of mobile homes and time-sharing schemes together with an availability of funds and an easing of the fuel restrictions have led to an unpredecented increase in development in Sedgefield and around Swartvlei. Local residents are of the opinion that the tourist and holiday industry is poised for rapid expansion along the entire "Garden Route".

The publication of the Guide Plan by the Department of Constitutional Development and Planning (1983) together with the involvement of the National Parks Board as a central controlling authority for the Lakes Area and the wealth of basic ecological knowledge available from the research organizations involved in the Lakes Area, makes it possible for the authorities to strike a balance between development and the conservation and protection of the ecologically sensitive environmental elements encountered at Swartvlei and in the surrounding area.

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GLOSSARY OF TERMS USED IN PART II REPORTS

ABIOTIC: non-living (characteristics).

AEOLIAN (deposits): materials transported and laid down on the earth's surface by wind.

ALIEN: plants or animals introduced from one environment to another, where they had not occurred previously.

ALLUVIUM: unconsolidated fragmental material laid down by a river or stream as a cone or fan, in its bed, on its floodplain and in lakes or estuaries, usually comprised of silt, sand or gravel.

ANAEROBIC: lacking or devoid of oxygen.

ANOXIC: the condition of not having enough oxygen.

AQUATIC: growing or living in or upon water.

ARCUATE: curved symmetrically like a bow.

BARCHANOID (dune): crescent-shaped and moving forward continually, the horns of the crescent pointing downwind.

BATHYMETRY: measurement of depth of a water body.

BENTHIC: bottom-living.

BERM: a natural or artificially constructed narrow terrace, shelf or ledge of sediment.

BIMODAL: having two peaks.

BIOGENIC: orginating from living organisms.

BIOMASS: a quantitative estimation of the total weight of living material found in a particular area or volume.

BIOME: major ecological regions (life zones) identified by the type of vegetation in a landscape.

BIOTIC: living (characteristics).

BREACHING: making a gap or breaking through (a sandbar).

CALCAREOUS: containing an appreciable proportion of calcium carbonate.

CALCRETE: a sedimentary deposit derived from coarse fragments of other rocks cemented by calcium carbonate.

CHART DATUM: this is the datum of soundings on the latest edition of the largest scale navigational chart of the area. It is -0,900 m relative to the land levelling datum which is commonly called Mean Sea Level by most land surveyors.

COLIFORMS: members of a particularly large, widespread group of bacteria normally present in the gastro-intestinal tract.

COMMUNITY: a well defined assemblage of plants and/or animals clearly distinguishable from other such assemblages.

CONGLOMERATE: a rock composed of rounded, waterworn pebbles 'cemented' in a matrix of calcium carbonate, silica or iron oxide.

CUSP: a sand spit or beach ridge usually at right angles to the beach formed by sets of constructive waves.

"D" NET: a small net attached to a "D" shaped frame riding on skids and pulled along the bottom of the estuary, used for sampling animals on or near the bottom.

DETRITUS: organic debris from decomposing plants and animals.

DIATOMS: a class of algae with distinct pigments and siliceous cell walls. They are important components of phytoplankton.

DYNAMIC: relating to ongoing and natural change.

ECOLOGY: the study of the structure and functions of ecosystems, particularly the dynamic co-evolutionary relationships of organisms, communities and habitats.

ECOSYSTEM: an interacting and interdependent natural system of organisms, biotic communities and their habitats.

EDDY: a movement of a fluid substance, particularly air or water, within a larger body of that substance.

ENDEMIC: confined to and evolved under the unique conditions of a particular region or site and found nowhere else in the world.

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

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

EPISODIC: sporadic and tending to be extreme.

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

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

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

FLUVIAL (deposits): originating from rivers.

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

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

GEOMORPHOLOGY: the study of land form or topography.

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

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

HALOPHYTES: plants which can tolerate saline conditions.

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

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

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

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

INDIGENOUS: belonging to the locality; not imported.

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

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

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

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

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

LIMPID: clear or transparent.

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

LONGSHORE DRIFT: a drift of material along a beach as a result of waves breaking at an angle to the shore.

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

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

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

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

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

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

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

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

PATHOGENIC: disease producing.

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

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

PHYTOPLANKTON: plant component of plankton.

PISCIVOROUS: fish eating.

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

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

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

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

SALINITY: the proportion of salts in pure water, in parts per thousand by mass. The mean figure for the sea is 34,5 parts per thousand.

SECCHI DISC: a simple instrument used to measure the transparency of water.

SHEET FLOW: water flowing in thin continuous sheets rather than concentrated into individual channels.

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

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

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

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

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

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

ZOOPLANKTON: animal component of plankton.

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APPENDIX I: Physical features and species of the vegetation mapping units from the Swartvlei system (M. O'Callaghan, pers. comm.).

Mapping Unit	Area (ha)	% Area	Total Cover (m)	Average Height (m)
Zostera capensis	22,89	0,78		
Zostera capensis/ *Ruppia cirrhosa*	35,47	1,20		
Ruppia cirrhosa	69,69	2,36		
Ruppia cirrhosa/ Charophyta	13,13	0,45		
Potamogeton pectinatus	78,21	2,66		
Charophyta	122,41	4,16		
Scirpus littoralis/ *Phragmites australis*	114,03	3,87	90	2,00
Tidal Salt Marsh	135,57	4,60	80	0,15
Juncus kraussii/*Scirpus nodosus*	53,03	1,80	80	0,60
Acacia dominated Dune Scrub	185,63	6,30	70	2,00
Acacia dominated Dune Fynbos	187,29	6,36	80	1,80
Acacia dominated Riverine Scrub	308,30	10,46	100	3,00
Disturbed Fynbos	284,19	9,46	100	1,20
Recreation and Residential	170,45	5,78		
Plantations and Agriculture	402,03	13,64		
Sand	133,36	4,53		
Water	630,91	21,41		
TOTAL	2 946,59			

APPENDIX I: (Cont.)

Intertidal and Floodplain Areas

Conyza scabrida (+); *Cotula coronopifolia* (r); *Eriocephalis* cf *capitellatus* (+); *Juncus kraussii* (3); *Paspalum vaginatum* (3); *Pennisetum clandestinum* (r); *Scirpus littoralis* (r); *S. nodosus* (1); *Stenotaphrum secundatum* (r); *Sarcocornia natalensis* (2); *Salicornia meyerana* (1); *Triglochin striata* (1).

Foredune and *Acacia* dominated Dune Scrub

Acacia cyclops (5); *A. saligna* (1); *Arctotheca populifolia* (1); *Asparagus aethiopicus* (1); *Carpobrotus edulis* (+); *Colpoon compressum* (+); *Cussonia thyrsiflora* (+); *Ehrharta villosa* (2); *Euclea racemosa* (+); *Grewia occidentalis* (+); *Knowltonia capensis* (+); *Metalasia muricata* (1); *Olea exasperata* (r); *Rhus crenata* (+); *R. laevigata* (1); *R. lucida* (1); *Sideroxylon inerme* (+); *Solanum quadrangulare* (1); *Tetragonia decumbens* (1); *T. fruticosa* (+).

Acacia Dominated Dune Fynbos

Acacia cyclops (especially to the south)(5); *Agathosma capensis* (+); *Astephanus marginatus* (+); *Carpobrotus edulis* (+); *Cassine aethiopica* (1); *Disparago kraussii* (+); *Erica fourcadei* (+); *Ficinia lateralis* (+); *Helichrysum crispum* (1); *Knowltonia capensis* (1); *Metalasia muricata* (2); *Muraltia alapecinoides* (2); *Olea exasperata* (1); *Passerina* sp. (1); *Pelargonium betulinum* (+); *Phylica pinea* (+); *Pterocelastrus tricuspidatus* (+); *Restio eleocharis* (1); *Rhus laevigata* (+); *Struthiola argentea* (+); *Thesium* sp. (1).

Acacia Dominated Riverine Scrub

Acacia cyclops (5); *A. karroo* (+); *Aloe ferox* (+); *Azima tetracantha* (1); *Capparis sepiaria* (+); *Carissa bispinosa* (+); *Cassine aethiopica* (+); *Diospyros dichrophylla* (+); *Ehrharta delicatula* (1); *Hypoestis aristata* (+); *Maytenus heterophylla* (1); *Putterlickia pyracantha* (+); *Rhus longispina* (+); *R. lucida* (2); *Rhoicissus digitata* (1); *Schotia afra* (1); *Scolopia zeyheri* (+); *Sideroxylon inerme* (+); *Solanum rigens* (+); *Sporobolus virginicus* (1); *Themeda triandra* (+).

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

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

APPENDIX II: A checklist of fish species from the Swartvlei system. Estuary data from H. Kok (pers. comm.), MN Bruton and P Skelton *(in litt.)*.

Scientific name	Common name	Swartvlei	Swartvlei Estuary
Argyrosomus hololepidotus	Kob	+	+
Amblyrhynchotes honckenii	Evileyed blaasop		+
Anguilla mossambica	Longfin eel	+	
Arothron hispidus	Whitespotted blaasop		+
Arothron immaculatus	Blackedged blaasop		+
Barbus afer	Eastern Cape redfin	+ (Freshwater sp.)	
Boopsoidea inornata	Fransmadam		+
Caffrogobius multifasciatus	Prison goby	+	+
Caffrogobius natalensis	Baldy		+
Caffrogobius nudiceps	Barehead goby	+	+
Caranx sexfasciatus	Bigeye kingfish		+
Chaetodon marleyi	Doublesash butterfly fish		+
Clinus superciliosus	Super klipfish	+	+
Diplodus cervinus	Zebra		+
Diplodus sargus	Blacktail		+
Elops machnata	Tenpounder	+	+
Engraulis capensis	Cape anchovy		+
Etrumeus teres	Redeye round-herring	+	+
Gambusia affinis	Mosquitoe fish	+ (Freshwater sp.)	
Gilchristella aestuarius	Estuarine round-herring	+	+
Glossogobius giurus	Tank goby	+	
Hemiramphus far	Spotted halfbeak		+
Hepsetia breviceps	Cape silverside	+	+
Hyteromycteris capensis	Cape sole		+
Hippocampus capensis	Knysna seahorse		+
Hyporhampus capensis	Knysna halfbeak	+	+
Iso natalensis	Iso		+
Lactoria cornuta	Longhorn cowfish		+
Lichia amia	Leervis	+	+
Lithognathus lithognathus	White steenbras	+	+
Lithognathus mormyrus	Sand steenbras		+
Liza dumerili	Groovy mullet	+	+
Liza macrolepis	Largescale mullet		+
Liza richardsoni	Southern mullet	+	+
Liza tricuspidens	Striped mullet	+	+
Monodactylus falciformis	Cape moony	+	+
Mugil cephalus	Flathead mullet	+	+
Myliobatus aquila	Eagleray		+
Myxus capensis	Freshwater mullet	+	+
Omobranchus woodi	Kappie blenny		+
Oreochromis mossambicus	Mocambique tilapia	+ (Freshwater sp.)	
Pagellus natalensis	Red tjor-tjor		+
Platycephalus indicus	Bartail flathead		+
Pomadasys commersonni	Spotted grunter	+	+
Pomadasys olivaceum	Piggy	+	+
Pomatomus saltatrix	Elf	+	+
Psammogobius knysnaensis	Knysna sandgoby	+	+
Redigobius dewaali	Checked goby	+	+
Rhabdosargus globiceps	White stumpnose		+
Rhabdosargus holubi	Cape stumpnose	+	+
Rhabdosargus sarba	Natal stumpnose		+
Sandelia capensis	Cape kurper	+ (Freshwater sp.)	

APPENDIX II: (Cont.)

Scientific name	Common name	Swartvlei	Swartvlei Estuary
Sardinops ocellata	South African pilchard		+
Sarpa salpa	Strepie		+
Scombrops dubius	Gnomefish		+
Solea bleekeri	Blackhand sole	+	+
Sparodon durbanensis	Musselcracker		+
Spondyliosoma emarginatum	Steentjie		+
Syngnathus acus	Longnose cowfish	+	+
Tachysurus feliceps	Sea catfish	+	+
Tilapia sparrmanii	Vlei kurper	+ (Freshwater sp.)	
Trachurus capensis	Maasbanker		+
Torpedo fuscomaculata	Blackspotted electric ray		+
Valamugil buchanani	Bluetail mullet		+
Valamugil seheli	Bluespot mullet		+
Total number of species		33	58

APPENDIX III: A checklist of amphibians and reptiles from the Swartvlei system and adjacent areas (G Palmer, pers. comm.).

Amphibians

Plain rain frog	-	*Breviceps fuscus*
Common toad	-	*Bufo regularis*
Arum frog	-	*Hyperolius horstocki*
Spotted rana	-	*Rana grayi*
Long-toad frog	-	*Rana fasciata*
Common rana	-	*Rana fuscigula*
Platanna	-	*Xenopus laevis*
Rattling kassina	-	*Kassina weallii*

Reptiles

Brown water snake	-	*Lycdonomorphus rufulus*
Olive house snake	-	*Lamprophis inornatus*
Cape wolf snake	-	*Lycophidion capense*
Green water snake	-	*Philothamnus hoplogaster*
Russet garden snake	-	*Duberria lutrix*
Common egg-eater	-	*Dasypeltis scabra*
Herald snake	-	*Crotaphopeltis hotamboeia*
Boomslang	-	*Dispholidus typus*
Rhombic skaapsteker	-	*Psammophylax rhombeatus*
Cross-marked grass snake	-	*Psammophis crucifer*
Southern dwarf garter snake	-	*Homoroselaps lacteus*
Cape cobra	-	*Naja nivea*
Common night adder	-	*Causus rhombeatus*
Puffadder	-	*Bitis arietans*
Striped skink	-	*Mabuya capensis*
Speckled skink	-	*Mabuya homalocephala*
Sand lizard	-	*Eremias lineocelata*

APPENDIX III: (Cont.)

Anguine lizard	-	*Chamaesaura anguina*
Amber acontias	-	*Acontias meleagris*
Black zonure	-	*Cordylus cordylus*
Gecko	-	*Pachydactylus geitjie*
Angulate tortoise	-	*Chersine angulata*
Padlopertjie	-	*Homopus areolatus*
Cape terrapin	-	*Pelomedusa subrufa*
Loggerhead turtle	-	*Coretta coretta*

APPENDIX IV: A checklist of aquatic birds from the Swartvlei system (G Palmer and A Boshoff, pers. comm.).

Roberts number	Common name	Scientific name	Swartvlei	Swartvlei estuary
4	Great Crested Grebe	*Podiceps cristatus*	+	+
5	Black-necked Grebe	*Podiceps nigricollis*	+	+
6	Dabchick	*Tachybaptus ruficollis*	+	+
47	White-breasted Cormorant	*Phalacrocorax carbo*	+	+
48	Cape Cormorant	*Phalacrocorax capensis*	+	+
50	Reed Cormorant	*Phalacrocorax africanus*	+	+
52	Darter	*Anhinga rufa*	+	+
54	Grey Heron	*Ardea cinerea*	+	+
57	Purple Heron	*Ardea purpurea*	+	+
59	Little Egret	*Egretta garzetta*	+	+
60	Yellow-billed Egret	*Egretta intermedia*		+
61	Cattle Egret	*Bubulcus ibis*	+	+
62	Squacco Heron	*Ardeola ralloides*		+
64	Black Egret	*Egretta ardesiaca*	+	
67	Little Bittern	*Ixobrychus minutus*	+	
69	Night Heron	*Nycticorax nycticorax*	+	
72	Hamerkop	*Scopus umbretta*	+	
79	Black Stork	*Ciconia nigra*	+	
81	Sacred Ibis	*Threskiornis aethiopicus*	+	+
84	Hadeda	*Hagedashia hagedash*	+	+
85	African Spoonbill	*Platalea alba*	+	+
86	Greater Flamingo	*Phoenicopterus ruber*	+	+
88	Spur-winged Goose	*Plectropterus gambensis*	+	
89	Egyptian Goose	*Alopochen aegyptiacus*	+	+
90	South African Shelduck	*Tadorna cana*		+
94	Cape Shoveler	*Anas smithii*	+	+
96	Yellow-billed Duck	*Anas undulata*	+	+
97	Red-billed Teal	*Anas erythrorhyncha*	+	+
98	Cape Teal	*Anas capensis*	+	+
102	Red-eyed Pochard	*Netta erythrophthalma*	+	+
149	Fish Eagle	*Haliaeetus vocifer*	+	+
167	African Marsh Harrier	*Circus ranivorus*	+	+
172	Osprey	*Pandion haliaetus*	+	+
203	Black Crake	*Limnocorax flavirostris*	+	

APPENDIX IV: (Cont.)

Roberts number	Common name	Scientific name	Swartvlei	Swartvlei estuary
208	Purple Gallinule	*Porphyrio porphyrio*	+	+
210	Moorhen	*Gallinula chloropus*	+	+
212	Red-knobbed Coot	*Fulica cristata*	+	+
231	Black Oyster-catcher	*Haematopus moquini*		+
232	Turnstone	*Arenaria interpres*		+
233	Ringed Plover	*Charadrius hiaticula*		+
235	White-fonted Sandplover	*Charadrius marginatus*		+
237	Kittlitz's Sandplover	*Charadrius pecuarius*	+	+
238	Three-banded Sandplover	*Charadrius tricollaris*	+	+
241	Grey Plover	*Pluvialis squatarola*		+
245	Blacksmith Plover	*Hoplopterus armatus*	+	+
250	Ethiopian Snipe	*Gallinago nigripennis*	+	
251	Curlew Sandpiper	*Calidris ferruginea*	+	+
253	Little Stint	*Calidris minuta*	+	+
255	Sanderling	*Calidris alba*		+
256	Ruff	*Philomachus pugnax*	+	+
257	Terek Sandpiper	*Xenus cinereus*		+
258	Common Sandpiper	*Tringa hypoleucos*	+	+
262	Marsh Sandpiper	*Tringa stagnatilis*	+	+
263	Greenshank	*Tringa nebularia*	+	+
264	Wood Sandpiper	*Tringa glareola*	+	+
267	Curlew	*Numenius arquata*		+
268	Whimbrel	*Numenius phaeopus*		+
269	Avocet	*Recurvirostra avosetta*	+	+
270	Stilt	*Himantopus himantopus*	+	+
274	Water Dikkop	*Burhinus vermiculatus*	+	
275	Dikkop	*Buuhinus capensis*	+	+
287	Southern Black-backed Gull	*Larus dominicanus*	+	+
290	Caspian Tern	*Hydroprogne caspia*	+	+
291	Common Tern	*Sterna hirundo*	+	+
298	Swift Tern	*Sterna bergii*		+
304	White-winged Black Tern	*Chliodonias leucoptera*	+	+
394	Pied Kingfisher	*Ceryle rudis*	+	+
395	Giant Kingfisher	*Megaceryle maxima*	+	+
396	Half-collared Kingfisher	*Alcedo semitorquata*	+	+
397	Malachite Kingfisher	*Corythornis cristata*	+	+
Total number of species			57	61

APPENDIX V: A checklist of mammals from areas adjacent to the Swartvlei system (G Palmer, pers. comm.).

Common name		Scientific name
Forest shrew	-	*Myosorex varius*
Dwarf shrew	-	*Suncus etruscus*
Red musk shrew	-	*Crocidura flavescens*
Duthie's golden mole	-	*Chlorotalpa duthiae*
Cape horseshoe bat	-	*Rhinolophus capensis*
Cape serotine	-	*Eptesicus capensis*
Vervet monkey	-	*Cercopithecus pygerythrus*
Striped polecat	-	*Ictonyx striatus*
White-naped weasel	-	*Poecilogale albinucha*
Honey badger	-	*Mellivora capensis*
Clawless otter	-	*Aonyx capensis*
Large-spotted genet	-	*Genetta tigrina*
Egyptian mongoose	-	*Herpestes ichneumon*
Cape grey mongoose	-	*Herpestes pulverulentus*
Water mongoose	-	*Atilax paludinosus*
Caracal	-	*Felis caracal*
Leopard	-	*Panthera pardus*
Bushpig	-	*Potamochoerus porcus*
Grysbok	-	*Raphicerus melanotis*
Bontebok	-	*Damaliscus dorcas*
Bushbuck	-	*Tragelaphus scriptus*
Scrub hare	-	*Lepus saxatilis*
Cape dune mole-rat	-	*Bathyergus suillus*
Common mole-rat	-	*Cryptomys hottentotus*
Cape porcupine	-	*Hystrix africaeaustralis*
Striped mouse	-	*Rhabdomys pumilio*
Pygmy mouse	-	*Mus minutoides*
Chestnut climbing mouse	-	*Dendromus mesomelas*
Vlei rat	-	*Otomys irroratus*

APPENDIX VI: Guide to available information

ESTUARY / RIVERMOUTH / LAGOON: SWARTVLEI (Estuary/Lagoon)

		Sources of information	Adamson	Allanson	Allanson	Allanson & Boltt	Allanson & Whitfield	Allanson & Howard-Williams	Ashby, Harper and van Schaik	Barry	Birch & du Plessis	Blackbeard	Cape of Good Hope Proc.	Chunnett	Cape Provincial Admin.	Coetzee	Coetzee	Coetzee	Coetzee	Coetzee & Palmer
		YEAR (DATE OF INFORMATION)	1975	1976	1981	1973	1982	1983	1973	1968	1977	1978	1972	1972	1973	1979	1981	1982a	1982b	1976
		Guide to available information																		
MANAGEMENT		Historical													*					
MANAGEMENT		Conservation / Utilization			*		*			*			*		*					
MANAGEMENT		Management / Planning				*	*			*	*			*	*					*
MANAGEMENT		Legislation											*							
MANAGEMENT		Water																		
BIOTIC		Food webs / Ecosystems																		
BIOTIC	Fauna	Mammals																		
BIOTIC	Fauna	Birds																		*
BIOTIC	Fauna	Reptiles																		
BIOTIC	Fauna	Amphibians																		
BIOTIC	Fauna	Fish			*													*	*	
BIOTIC	Fauna	Molluscs			*															
BIOTIC	Fauna	Crustaceans			*															
BIOTIC	Fauna	Other aquatic invertebrates			*															
BIOTIC	Fauna	Terrestrial invertebrates																		
BIOTIC	Fauna	Zooplankton			*											*	*			
BIOTIC	Flora	Terrestrial vegetation																		
BIOTIC	Flora	Semi-aquatic vegetation			*	*														
BIOTIC	Flora	Aquatic vegetation			*	*														
BIOTIC	Flora	Algae																		
BIOTIC	Flora	Phytoplankton			*											*				
BIOTIC		Microbiology																		
ABIOTIC	Chemistry	Pollution																		
ABIOTIC	Chemistry	Eutrophication																		
ABIOTIC	Chemistry	General Chemistry						*				*								
ABIOTIC		Salinity			*											*				
ABIOTIC	Physics	Circulation and mixing		*	*				*											
ABIOTIC	Physics	Hydrology / Flood regime	*	*	*		*					*		*		*				
ABIOTIC	Physics	Oceanography																		
ABIOTIC	Physics	Climate																		
ABIOTIC	Geology	Sedimentology							*		*			*						
ABIOTIC	Geology	Palaeoenvironment									*									
ABIOTIC	Geology	Geology									*									
ABIOTIC	Physiography	Morphology			*						*									
ABIOTIC	Physiography	Dams/Obstructions																		
ABIOTIC	Physiography	Catchment characteristics					*													

APPENDIX VI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: SWARTVLEI (Estuary/Lagoon)

Guide to available information

			Sources of information	Davies	Davies	Fairall	Gasson	Grindley	Grindley	Grindley & Woolridge	Hidrouliese Studie	Hill	Howard-Williams	Howard-Williams	Howard-Williams	Howard-Williams	Howard-Williams & Allanson	Howard-Williams & Allanson	Howard-Williams & Allanson	Howard-Williams & Allanson	Howard-Williams & Allanson
			YEAR (DATE OF INFORMATION)	1979	1982	1981	1970	1981	1983	1973	1978	1975	1977	1978	1979	1981	1978a	1978b	1979	1981a	1981b
MANAGEMENT		Historical																			
MANAGEMENT		Conservation/Utilization					*		*										*	*	
MANAGEMENT		Management/Planning					*		*		*				*		*	*	*		
MANAGEMENT		Legislation																			
MANAGEMENT		Water																			
BIOTIC	Food webs/Ecosystems																				
BIOTIC	Fauna	Mammals																			
BIOTIC	Fauna	Birds				*															
BIOTIC	Fauna	Reptiles																			
BIOTIC	Fauna	Amphibians																			
BIOTIC	Fauna	Fish		*	*																
BIOTIC	Fauna	Molluscs		*	*																
BIOTIC	Fauna	Crustaceans		*	*																
BIOTIC	Fauna	Other aquatic invertebrates																			
BIOTIC	Fauna	Terrestrial invertebrates																			
BIOTIC	Fauna	Zooplankton						*		*											
BIOTIC	Flora	Terrestrial vegetation							*												
BIOTIC	Flora	Semi-aquatic vegetation																			
BIOTIC	Flora	Aquatic vegetation												*	*	*		*	*	*	*
BIOTIC	Flora	Algae																*			
BIOTIC	Flora	Phytoplankton						*										*		*	
BIOTIC	Microbiology																				
ABIOTIC	Chemistry	Pollution																*			
ABIOTIC	Chemistry	Eutrophication											*			*		*	*		
ABIOTIC	Chemistry	General Chemistry											*			*		*	*		*
ABIOTIC	Salinity																	*			
ABIOTIC	Physics	Circulation and mixing																*			
ABIOTIC	Physics	Hydrology / Flood regime																*	*		
ABIOTIC	Physics	Oceanography																			
ABIOTIC	Physics	Climate																			
ABIOTIC	Geology	Sedimentology							*									*	*		
ABIOTIC	Geology	Palaeoenvironment										*						*			
ABIOTIC	Geology	Geology							*												
ABIOTIC	Physiography	Morphology									*	*						*			
ABIOTIC	Physiography	Dams/Obstructions																*			
ABIOTIC	Physiography	Catchment characteristics																*			

APPENDIX VI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: SWARTVLEI (Estuary/Lagoon)

Guide to available information		Howard-Williams & Davies	Howard-Williams & Liptrot	Howard-Williams *et al*	Hydrographic Survey	Kok	Liptrot	Liptrot	Liptrot & Allanson	Manley	Martin	McLachlan	Moss	Robarts	Robarts	Robarts	Robarts	Robarts & Allanson	Selkirk
YEAR (DATE OF INFORMATION)		1979	1980	1975	1975	1981	1977	1978	1978	1972	1962	1977	1976	1973	1976a	1976b	1979	1977	1978
MANAGEMENT	Historical									*									
MANAGEMENT	Conservation/Utilization									*									
MANAGEMENT	Management/Planning			*		*				*			*						
MANAGEMENT	Legislation									*									
MANAGEMENT	Water									*									
BIOTIC	Food webs/Ecosystems																		
BIOTIC – Fauna	Mammals																		
BIOTIC – Fauna	Birds			*															
BIOTIC – Fauna	Reptiles																		
BIOTIC – Fauna	Amphibians																		
BIOTIC – Fauna	Fish					*													*
BIOTIC – Fauna	Molluscs																		
BIOTIC – Fauna	Crustaceans																		
BIOTIC – Fauna	Other aquatic invertebrates																		
BIOTIC – Fauna	Terrestrial invertebrates																		
BIOTIC – Fauna	Zooplankton													*					
BIOTIC – Flora	Terrestrial vegetation																		
BIOTIC – Flora	Semi-aquatic vegetation																		
BIOTIC – Flora	Aquatic vegetation	*	*	*			*	*	*										
BIOTIC – Flora	Algae																		
BIOTIC – Flora	Phytoplankton													*	*	*	*		
BIOTIC	Microbiology													*		*	*		
ABIOTIC – Chemistry	Pollution																		
ABIOTIC – Chemistry	Eutrophication																		
ABIOTIC – Chemistry	General Chemistry	*		*			*	*	*					*				*	
ABIOTIC	Salinity						*	*	*					*				*	
ABIOTIC – Physics	Circulation and mixing			*			*	*	*									*	
ABIOTIC – Physics	Hydrology / Flood regime			*			*	*	*				*						
ABIOTIC – Physics	Oceanography																		
ABIOTIC – Physics	Climate																		
ABIOTIC – Geology	Sedimentology										*	*							
ABIOTIC – Geology	Palaeoenvironment										*	*							
ABIOTIC – Geology	Geology										*	*							
ABIOTIC – Physiography	Morphology				*						*								
ABIOTIC – Physiography	Dams/Obstructions																		
ABIOTIC – Physiography	Catchment characteristics																		

Sources of information: see column headings.

APPENDIX VI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: SWARTVLEI (Estuary/Lagoon)

Guide to available information

Group	Subgroup	Sources of information	Selkirk	Siegfried, Frost, Cooper and Kemp	Silberbauer	S.A. - Dept. of Planning	S.A. - Dept. of Planning & the Environment	S.A. - Dept. of Agric. Tech. Services	S.A. - Dept. of Cons. Dev. and Planning	Swart and Serdyn	Taljaard	Taylor	Truswell	Watling	Whitfield	Whitfield	Wilson & Barnes	A.F. Boshoff (pers. comm.)	J. Jooris (pers. comm.)	H.M. Kok (pers. comm.)
MANAGE-MENT		Historical							*		*		*							
		Conservation/Utilization				*		*	*											
		Management/Planning				*	*	*	*											
		Legislation																		
		Water																		
BIOTIC		Food webs/Ecosystems																		
	Fauna	Mammals																		
		Birds		*														*		
		Reptiles																		
		Amphibians																		
		Fish	*												*	*	*			*
		Molluscs																		
		Crustaceans															*			
		Other aquatic invertebrates																		
		Terrestrial invertebrates																		
		Zooplankton																		
	Flora	Terrestrial vegetation																		
		Semi-aquatic vegetation																		
		Aquatic vegetation							*			*			*	*	*			
		Algae										*			*	*	*			
		Phytoplankton										*								
		Microbiology																		
ABIOTIC	Chemistry	Pollution												*						
		Eutrophication																		
		General Chemistry			*															
		Salinity			*															
	Physics	Circulation and mixing			*															
		Hydrology / Flood regime								*									*	
		Oceanography								*										
		Climate																		
	Geology	Sedimentology						*		*	*		*							
		Palaeoenvironment																		
		Geology									*		*							
	Physio-graphy	Morphology																		
		Dams/Obstructions																		
		Catchment characteristics									*		*							
YEAR (DATE OF INFORMATION)			1979	1976	1982	1970	1975	1975	1983	1982	1949	1983	1977	1977	1982	1983	1976	1983	1978	1982

APPENDIX VI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: SWARTVLEI (Estuary/Lagoon)

Guide to available information

Sources of information	N.G. Palmer (pers. comm.)	M. O'Callaghan (pers. comm.)		Maps	SA 1:250 000 Topo. Sheet 3322	SA 1:250 000 Geological Survey 3322	SA 1:50 000 Sheet 3322 DC/DD, 3422 BA/BB	SA 1:10 000 Orthomaps 3322 DC/DD, 3422 BA/BB	SA 1:50 000 Sheet 3322 DD	SA 1:50 000 Sheet 3422 BB	SA 1:150 000 South Coast	Swartvlei Estuary 1:50 000	Swartvlei 1:5 000	Swartvlei System 1:10 000
YEAR (DATE OF INFORMATION)	1983	1983			1968	1979	1965	1973	1975	1975	1975	1975	1976	1976
MANAGEMENT – Historical														
MANAGEMENT – Conservation/Utilization														
MANAGEMENT – Management/Planning														
MANAGEMENT – Legislation														
MANAGEMENT – Water														
BIOTIC – Food webs/Ecosystems														
BIOTIC – Fauna – Mammals														
BIOTIC – Fauna – Birds	*													
BIOTIC – Fauna – Reptiles	*													
BIOTIC – Fauna – Amphibians	*													
BIOTIC – Fauna – Fish														
BIOTIC – Fauna – Molluscs														
BIOTIC – Fauna – Crustaceans														
BIOTIC – Fauna – Other aquatic invertebrates														
BIOTIC – Fauna – Terrestrial invertebrates														
BIOTIC – Fauna – Zooplankton														
BIOTIC – Flora – Terrestrial vegetation														
BIOTIC – Flora – Semi-aquatic vegetation		*												
BIOTIC – Flora – Aquatic vegetation		*												
BIOTIC – Flora – Algae		*												
BIOTIC – Flora – Phytoplankton														
BIOTIC – Microbiology														
ABIOTIC – Chemistry – Pollution														
ABIOTIC – Chemistry – Eutrophication														
ABIOTIC – Chemistry – General Chemistry														
ABIOTIC – Salinity														
ABIOTIC – Physics – Circulation and mixing														
ABIOTIC – Physics – Hydrology / Flood regime					*		*	*			*			
ABIOTIC – Physics – Oceanography														
ABIOTIC – Physics – Climate														
ABIOTIC – Geology – Sedimentology														
ABIOTIC – Geology – Palaeoenvironment														
ABIOTIC – Geology – Geology						*								
ABIOTIC – Physiography – Morphology					*		*	*	*	*	*	*	*	*
ABIOTIC – Physiography – Dams/Obstructions														
ABIOTIC – Physiography – Catchment characteristics														

PLATE I:

Lower reaches of the Karatara River immediately prior to entering Swartvlei. The floating mat of the water weed *Salvinia molesta* and dark humic stained waters are clearly visible (IFWS: 83-03-02).

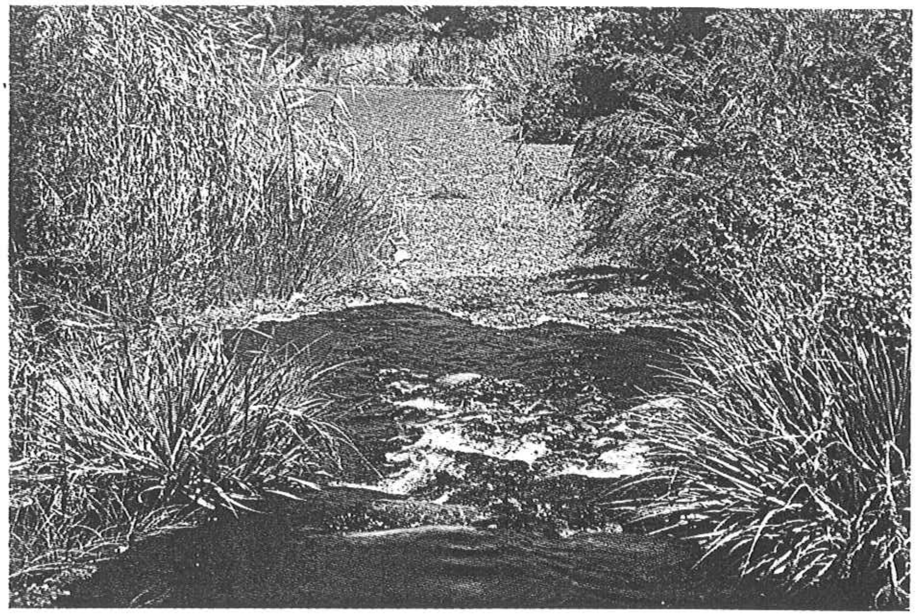

PLATE II:

Road and rail bridges crossing the upper estuary. Note the extensive tidal flats in the foreground and the lake in the background (IFWS: 83-03-02).

PLATE III:

Mechanical digging of a trench through the Swartvlei estuary sandbar in order to artificially open the mouth in October 1980 (AK Whitfield: 80-10-29).