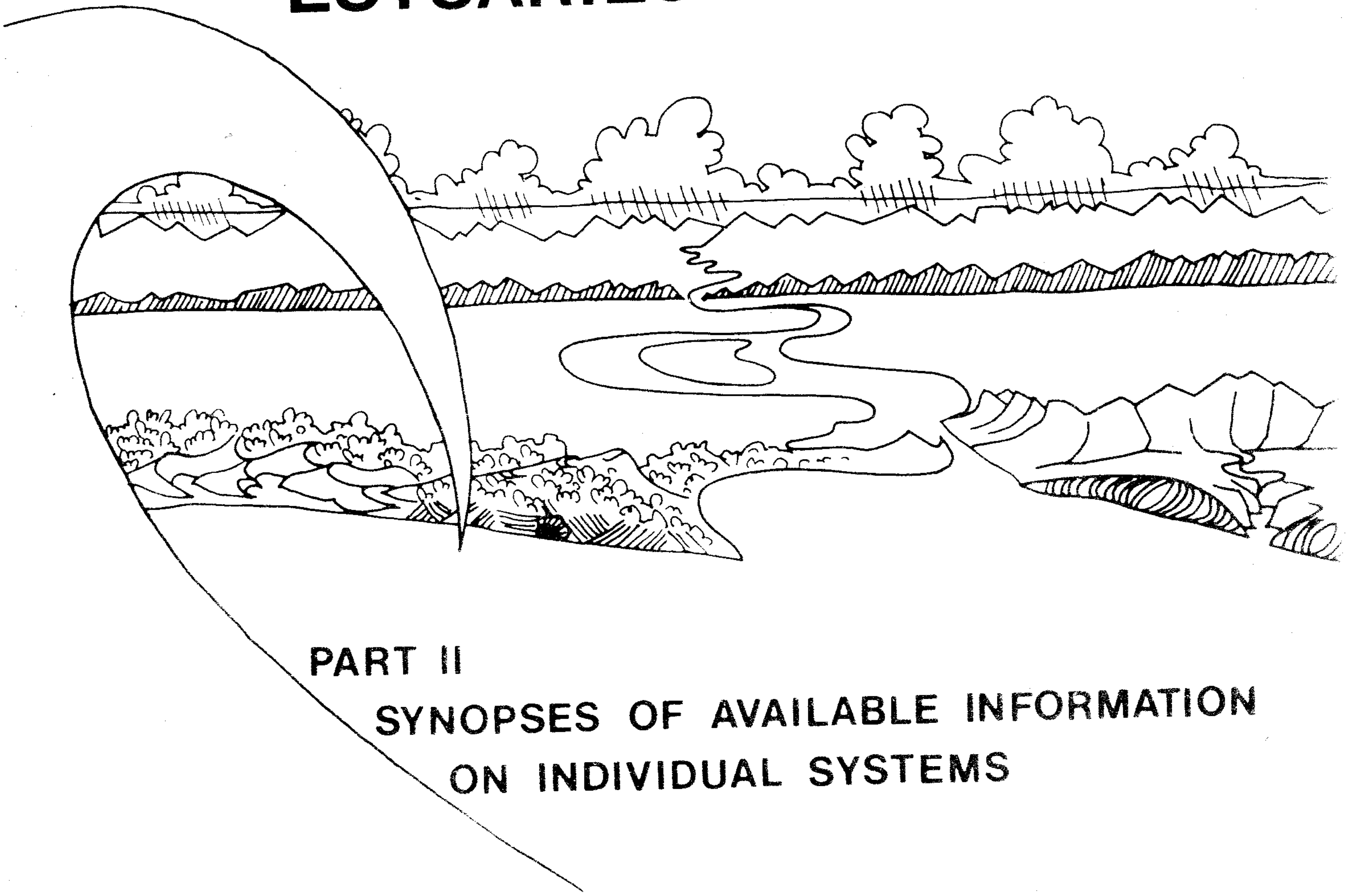
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY
ESTUARINE AND COASTAL RESEARCH UNIT - ECRU

ESTUARIES OF THE CAPE



PART II
SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

REPORT NO. 31

KEURBOOMS/BITOU SYSTEM (CMS 19)
PIESANG (CMS 18)

CSIR RESEARCH REPORT 430

Stellenbosch, South Africa
October 1984

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PART II: SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

EDITORS:
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FRONTISPIECE: KEURBOOMS ESTUARY – ALT. 450m, ECRU 79-10-16

REPORT NO. 31: KEURBOOMS/BITOU SYSTEM (CMS 19) PIESANG (CMS 18)

(CMS 18,19 – CSIR Estuary Index Numbers)

BY: I R DUVENAGE
P D MORANT

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KEURBOOMS AND PIESANG

ECRU SURVEY: 5-9 March 1984

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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 "Estuaries of the Cape, Part I - Synopsis of the Cape Coast. Natural Features, Dynamics and Utilization" (by Heydorn and Tinley, CSIR Research Report 380). 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 "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 J R 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.

F P ANDERSON
CHIEF DIRECTOR

National Research Institute for Oceanology, CSIR

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KEURBOOMS/BITOU AND PIESANG

1. HISTORICAL BACKGROUND

1.1 Synonyms and Derivations

QUEUR BOOM	the name given to the river by Le Vaillant during his travels in 1782 (Storrar, 1982). The name originates from the pioneer tree, *Virgilia divaricata* ,commonly known as the keurboom, which occurs on the fringes of the forests and is very impressive when in flower. Keur means "choice" or "pick" so that the common name means "pick of the trees" (Palmer and Pitman, 1972).
KEURBOOMS	1:50 000 Sheet 3423 AB Plettenbergbaai.
WITTE DRIFT	the name used by Le Vaillant when referring to the present Bitou River (Storrar, 1982).
BITO	Le Roi Le Riche and Hey, 1947.
BITOU	the name commonly used today in publications (Day, 1981; Storrar, 1982) and as indicated on the 1:10 000 Orthomap sheet 3423 AB4 Keurboomsrivier.
BIETOU	the name given on the 1:50 000 Sheet 3423 AB Plettenbergbaai. This is the Afrikaans name for the small bushy tree, *Chrysanthemoides monilifera,* which commonly occurs along the South African coast.
PIESANG	1:50 000 Sheet 3423 AB, Plettenbergbaai.

1.2 Historical Aspects

A very readable and absorbing account of the history of the Plettenberg Bay area can be found in Patricia Storrar's book "Portrait of Plettenberg Bay". Some of the aspects relevant to this report are mentioned here.

The recorded history of Plettenberg Bay dates back almost 500 years to the 15th century when the early Portuguese explorers first called there. It was in 1488 that Bartholomew Dias gave the bay the name "Bahia das Alagoas", or more literally "Bay of Lagoons", in all probability referring to the extensive Keurbooms/ Bitou system. Some 90 years later in 1576, Manuel da Mesquita da Perestrello aptly renamed the bay "Bahia Formosa", the Bay Beautiful.

In 1630 the Bahia Formosa acquired its first Portuguese inhabitants due to a most unfortunate episode - the wrecking of the *San Gonzales*. During early August, while the ship was anchored in the bay, a south-westerly gale shattered it and all 133 men on board perished. However, prior to this, about 100 men had already landed at Bahia Formosa. After spending some time in the area, they managed to construct two vessels and eventually succeeded in returning to Portugal.

In 1778 the then Governor of the Cape, Baron Joachim van Plettenberg visited the bay and named it after himself, giving it the name which is still in use today. It was thereafter that the development of urban settlements was initiated. However, according to the Knysna-Wilderness-Plettenberg Bay Guide Plan, drawn up by the Department of Constitutional Development and Planning in 1983 (referred to in this report as the 'Guide Plan'), the bay continued to be known as Formosa until 1935 when it was declared a local area.

In the 19th century the Plettenberg Bay area was penetrated by pioneers in search of timber and potential farmland. The "Great Fire" of 1869 which swept through the region is thought to have had a significant long-term impact on the vegetation of the river catchments. Much of the development at Plettenberg Bay up to the turn of the century was centred around harbour functions but later on these activities declined.

In 1860 a primitive pontoon was installed to enable travellers to cross the Keurbooms River. Prior to this a ferry boat had been used. The sometimes unreliable pontoon was replaced by a new pontoon in 1881.

Between 1910 and 1920 a whaling station was established on Beacon Island and whaling operations were carried out by a Norwegian whaling company. When these operations were closed down after a series of setbacks, Plettenberg Bay no longer functioned as a harbour.

In September 1927 a new low-level bridge across the Keurbooms River was opened by the Administrator of the Cape. This bridge was swept away during the floods of 1931. The remains of this bridge still partially block the riverbed just downstream of the existing roadbridge.

By 1920 the popularity of Plettenberg Bay and its environs as holiday resorts had shown a marked rise and the necessity to build new roads became apparent. It was not, however, until the 1940s that Plettenberg Bay really developed as a seaside resort.

1.3 Archaeology

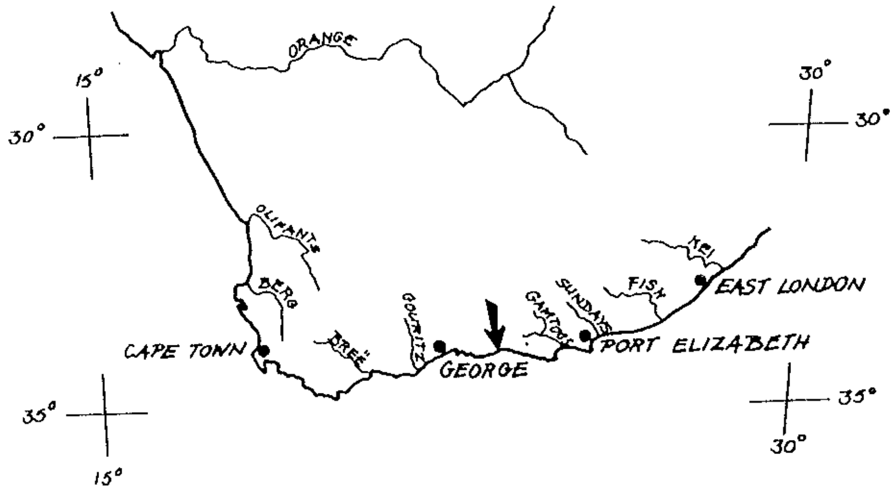
Archaeological sites along the Southern Cape coast have yielded more sub-fossil human remains than any other part of the Republic. Some of these sites have yielded artifacts which have been dated at 30 000 years B.C. (Clark, 1959). Important sites have been excavated at Matjies River and on the Robberg Peninsula and undoubtedly many more undiscovered sites abound along this coast with its numerous caves and plentiful supplies of freshwater (Cape Provincial Administration, 1973). The only documented archaeological site in the vicinity of the Keurbooms River estuary is on Hangklip where there were a number of stone artefacts on the surface (W J Van Ryssen, South African Museum Archaeological Data Recording Centre, Cape Town, *in litt.*).

In 1980 the site on which the survivors of the wreck of the *San Gonzales* set up their camp more than three and a half centuries ago, was discovered. They apparently lived in the Bahia Formosa, in the corner where the Robberg Peninsula joins the mainland, 22 years before Van Riebeeck founded the settlement at the Cape.

2. LOCATION

The mouth of the Keurbooms River is situated at 34° 02'S; 23° 23'E. A major tributary, the Bitou River, joins the Keurbooms River 1,5 km from its mouth. The extensive catchment of the Bitou River, which lies to the west of that of the Keurbooms River, is considered separately in some sections of this report.

The mouth of the Piesang River is situated at 34° 04'S; 23° 22'E (1:50 000 Sheet 3423 AB Plettenbergbaai).



2.1 Accessibility

The National Road (N2) crosses the Bitou and Keurbooms rivers five km and six km north-east of Plettenberg Bay respectively. The Keurbooms Estuary mouth is inaccessible by vehicle while the main road from Plettenberg Bay runs along the western side of the estuary before it joins the National Road. Another road branches off the National Road approximately six km north-east of Plettenberg Bay town and runs along the northern bank of the Bitou River towards Wittedrift. The road which runs through Plettenberg Bay town crosses the Piesang River twice before it rejoins the National Road. This road also provides access to Robberg (Figure 1).

2.2 Local Authorities

The uppermost section of the Keurbooms River catchment falls under the jurisdiction of the Klein Karoo - Langkloof Divisional Council while the rest of the catchment, as well as the Bitou and Piesang catchments, is situated within the area administered by the Outeniqua Divisional Council.

The six State Forests covering part of the three catchments are controlled by the Forestry Branch of the Department of Environment Affairs. The Keurbooms River Nature Reserve, Robberg Nature Reserve and both sand spits at the mouth of the Keurbooms River estuary are managed by the Provincial Administration of the Cape of Good Hope (Department of Nature and Environmental Conservation).

The lower part of the Piesang River Estuary and the lower south-western part of the Keurbooms River Estuary are situated within the boundaries of the Plettenberg Bay Municipality.

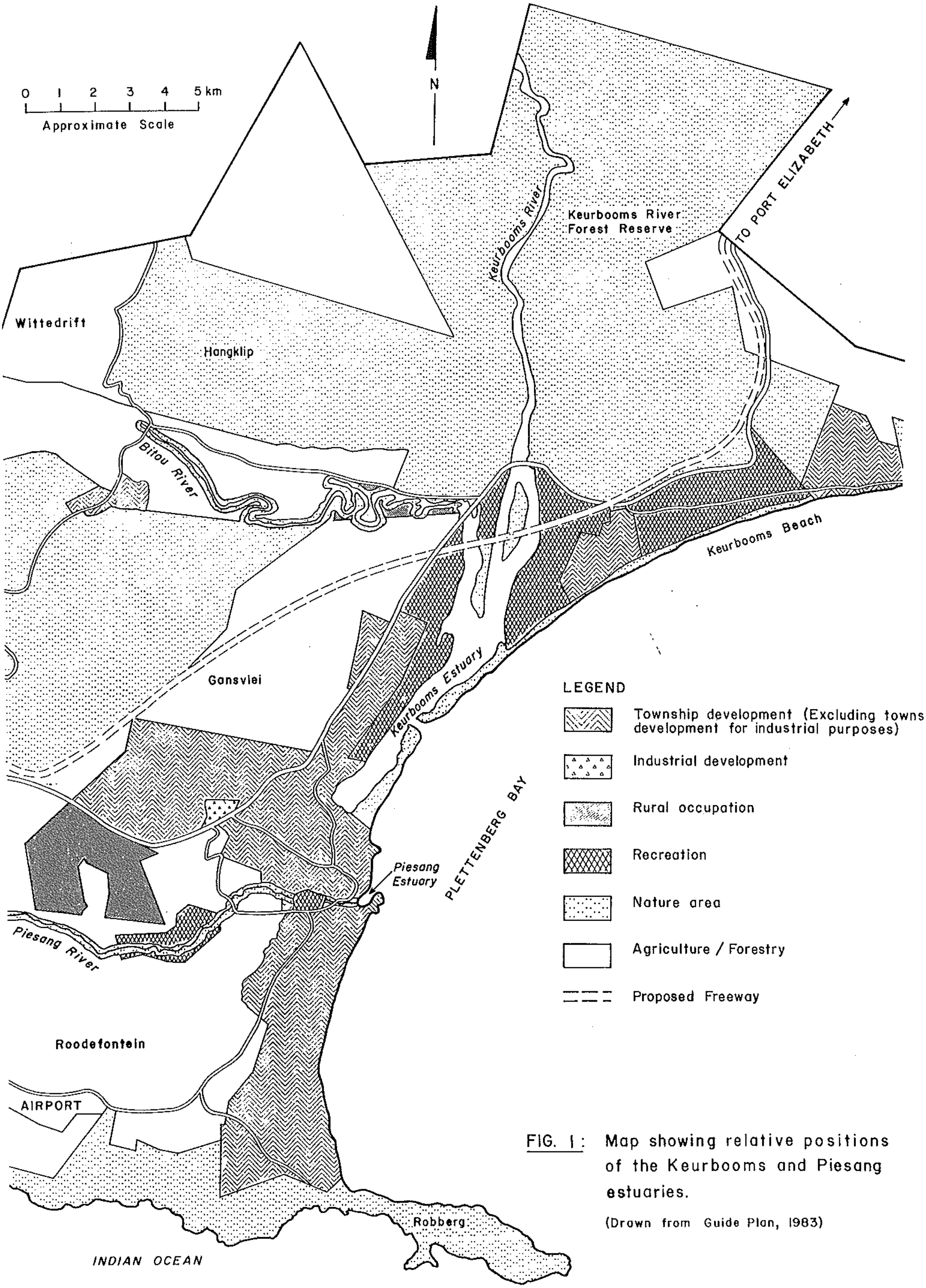


FIG. 1: Map showing relative positions of the Keurbooms and Piesang estuaries.

(Drawn from Guide Plan, 1983)

3. ABIOTIC CHARACTERISTICS

3.1 River Catchment

3.1.1 Catchment Characteristics

KEURBOOMS/BITOU

Area

The area of the combined Keurbooms and Bitou catchments is given as 1 085 km^2 by Midgley and Pitman (1969), while Heydorn and Tinley (1980) give the area as 1 188 km^2. Reddering (1981) estimated the Keurbooms and Bitou catchments to be 859 km^2 and 237 km^2 respectively, thus giving a combined area of 1 096 km^2.

River length

The total length of the Keurbooms River, from the mouth of the estuary to its source at Spitskop in the Outeniqua Mountains is 70 km. Its major tributary, the Palmiet River, is approximately 35 km long. The length of the Bitou River from its point of confluence with the Keurbooms River to its source at Buffelsnek is 23 km (1:250 000 Topographical Sheet 3322 Oudtshoorn).

Tributaries

Tributaries draining into the Keurbooms River include the Hartbees, Duiwelsgat, Palmiet, Klein, Diep, Witels, Kwaai, Peters, Bos and Kykoerie rivers. The Palmiet River has a number of smaller tributaries draining parts of the Langkloof and Tsitsikamma Mountains and joins the Keurbooms River approximately 15 km from the estuary mouth.

A few streams contribute to the lower Bitou River while the Kleineiland, Petrus Brand and Rondebos rivers flow into its upper reaches.

PIESANG

Area

The catchment area of the Piesang River is estimated to be 35 km^2 (1:50 000 Sheets 3423 AB Plettenbergbaai and 3423 AA Knysna). Grindley (1980) gives the area as approximately 40 km^2.

River length

The length of the relatively short Piesang River is approximately 17 km (1:50 000 Sheets 3423 AB Plettenbergbaai and 3423 AA Knysna) while Grindley (1980) estimates it to be approximately 12 km.

Tributaries

According to Grindley (1980) several tributaries drain the hills to the west of Plettenberg Bay extending as far as the Harkerville forest area.

General geology

One of the major features of the region is the Jurassic, west-east trending Cape Fold Belt and in particular the southern orographic line which includes the Outeniqua, Langkloof and Tsitsikamma Mountains. On the seaward side of this mountain range the inland plateau becomes a lake system valley, reaching the sea through the Keurbooms Estuary. This valley is flanked by a coastal plateau which includes the aeolian sand dunes occurring between Robberg and Keurboomstrand.

Following lowering of the sea-level, the rivers have incised deep gorges or valley plains giving the landscape its typical undulating nature. The river mouths have all subsequently been drowned and then partly filled in (King, 1963). The coastline in Formosa Bay was shaped into a crenulate bay by waves diffracted around Robberg during the Flandrian transgression (Bremner, 1983). This peninsula is a resistant fault block which consists of orthoquartzite of the Table Mountain Group and silicified conglomerates of the Robberg Formation which is equivalent to the Enon Formation (Reddering, 1981).

Characteristic of the Tsitsikamma area is the well-defined wavecut platform formed during a period of high sea level in the Tertiary when the seashore lay along the Tsitsikamma Mountains. Rising of the land exposed the wave terrace and the rivers which were rejuvenated, steadily cut deeply into the landscape, following the retreating sea (Toerien, 1976).

Apart from the presence of swelling clays in certain areas, large areas are covered by a sandy soil and driftsand. Soil descriptions are given in the Guide Plan, 1983.

KEURBOOMS

The following descriptions are partly based on an interpretation of the 1:250 000 Geological Sheet 3322 Oudtshoorn.

The Keurbooms Estuary is part of a drowned river valley formed during the Pleistocene and earlier marine regressions. The geological "basement" is overlain by poorly consolidated Cretaceous sediment. This fills a halfgraben formed during the Gondwanide fracturing episode. Local depressions were scoured into these deposits by wave and fluvial action during previous eustatic sea level variations (Reddering, 1981). The Keurbooms Estuary is underlain by Tertiary to Quaternary marine and estuarine terrace gravel and partly calcareous sand. To the north of these deposits, Cretaceous to Tertiary deposits of conglomerate, sandstone, siltstone and clay are found in the vicinity of the roadbridge.

Directly upstream from the bridge the river runs through a narrow strip of shale and siltstone of the Gydo Formation of the Bokkeveld Group. This strip also occurs along the beach between Keurboomstrand and the Keurbooms Estuary mouth while a second strip occurs westwards from Keurboomstrand and forms the edge of the plateau (Guide Plan, 1983).

Moving upstream the drainage basin is composed successively of feldspathic sandstone of the Baviaanskloof Formation, whitish-weathering quartz sandstone and profusely cross-bedded subordinate shale of the Kouga Formation as well as brownish-weathering sandstone and shale of the Tchando Formation.

According to Reddering (1981) the drainage basin is predominantly underlain by orthoquartzite of the Table Mountain Group. This weathers to acid, well-drained soil. Field observations show the sediment yield to be small. Fluvial sand forms only a small part of the estuarine sediment input.

BITOU

The drainage basin is underlain by semi-consolidated immature sandstone, conglomerate and shale of Cretaceous age (Reddering, 1981). The lower reaches of the

Bitou River are underlain by Tertiary to Quaternary marine and estuarine terrace gravel and partly calcareous sand. The Enon Formation (Cretaceous) consists mainly of round pebbles of quartzite occurring in the matrix of silt and sand. The Enon Formation grades vertically and laterally into the Kirkwood Formation and as the soil derived from the Kirkwood Formation is very unstable, landslides and unstable banks are a feature of the Bitou River valley. This area is surrounded by Cretaceous to Tertiary conglomerate, sandstone, siltstone and clay.

Moving upstream the drainage basin is composed successively of feldspathic sandstone of the Baviaanskloof Formation and shale and siltstone of the Gydo Formation of the Bokkeveld Group. The bed of the upper reaches of the river is composed of whitish-weathering sandstone and brownish-weathering sandstone of the Kouga and Tchando Formations respectively.

PIESANG

The mouth region of the Piesang Estuary is underlain by whitish-weathering quartz sandstone of the Peninsula Formation (Table Mountain Group). The rest of the lower catchment area consists of a marine and estuarine terrace gravel strip surrounded by an area of conglomerate, sandstone, silt and clay. The middle reaches of the river runs through quartz sandstone of the Peninsula Formation while the upper catchment area is composed of fixed dunes and dune rock.

The clay horizons of the Kirkwood Formation (Cretaceous) are prominent in the Piesang River valley. Drilling in this valley has shown that these clays are more than 80 metres thick. The soil derived from this Formation is very unstable and active swelling clays are commonplace in the Piesang River valley. The Beacon Island Estate seems to have been developed on a river terrace consisting of sand, silt, and well-rounded, loosely stacked pebbles covered with a fertile sandy silt (Guide Plan, 1983).

Climate

The Keurbooms, Bitou and Piesang catchments fall into climatic region A (Schulze, 1965) which receives rain almost equally in all seasons with peaks in autumn and spring. Rainfall in the Outeniqua and Tsitsikamma Mountains may exceed 1 100 mm per year and on average 8 to 12 rain days per month may be expected. The rain is mainly cyclonic and orographic while thunderstorms are comparatively rare (Schulze, 1965).

According to Heydorn and Tinley (1981) an annual rainfall of 1 120 mm was recorded at Witelsbos on the coastal platform above the Tsitsikamma coast with the catchments lying on the boundary between the bimodal all seasons rainfall regions. Tyson (1971) also recorded this bimodal rainfall pattern at George with peaks in March and September while this was also observed in the Knysna region (Guide Plan, 1983). According to average monthly rainfall data received from the Keurbooms State Forest, peaks occur in March and November with a third and highest peak in January (Directorate of Forestry, *in litt.)*. This could be due to the State Forest lying between two rainfall regions with a further topographic influence caused by the presence of the Langkloof Mountains.

Hail occurs infrequently. The Outeniqua Mountains are occasionally snowcapped in winter and spring. Frost is practically unknown and the heat of summer is tempered by cool sea breezes. Winds blowing along the coast can at times, especially in spring, be unpleasantly strong, whilst in the interior, mainly in late summer, temperatures occasionally rise above 38°C during hot "berg winds". The average occurrence of berg winds is one to three per month (Schulze, 1965).

Run-off and Flow Records

Noble and Hemens (1978) estimated the mean annual run-off for the Keurbooms and Bitou catchments to be 160 x 10^6 m^3 while Midgley and Pitman (1969) recorded values of 127 x 10^6 m^3 and 32 x 10^6 m^3 for the Keurbooms and Bitou rivers respectively. According to Reddering (1981), the mean annual discharge into the Keurbooms River exceeds 72,9 x 10^6 m^3. This is not always the actual value because flood discharge exceeds the capacity of the measuring station.

According to river flow data obtained from the Division of Hydrology, (Department of Water Affairs, *in litt.)*, the mean annual run-off of the Keurbooms River system over the ten-year period, 1960/61 to 1969/70, was calculated to be 64 x 10^6 m^3, measured at the gauging station at Newlands 15 km upstream from the mouth (Department of Water Affairs Station No. K6M02, River flow data (1978)). A value of 71 x 10^6 m^3 was calculated over the period October 1970 to June 1981 at the same station (Figure 2). The variation in mean monthly run-off over the period October 1970 to June 1981 is depicted in Figure 3. Although this station is relatively close to the mouth and below the confluence of the major tributaries, the values are much lower than those estimated by Midgley and Pitman (1969). The values were calculated from different data sources (rainfall versus gauging plate measurements) but this discrepancy is probably due to the discharge regularly exceeding the table limit and thus the capacity of the measuring station.

The influence of sewage effluent from the Gansvlei stream entering the Bitou is insignificant in relation to the natural flow. However, it is highly probable that the plantations affect the run-off, particularly during dry years.

According to a survey carried out by NRIO in 1975 (Keurbooms- en Bitourivierbrûe) the flow in the Keurbooms River is below 0,30 m/s, even at springtide, due to the high friction coefficient of the river.

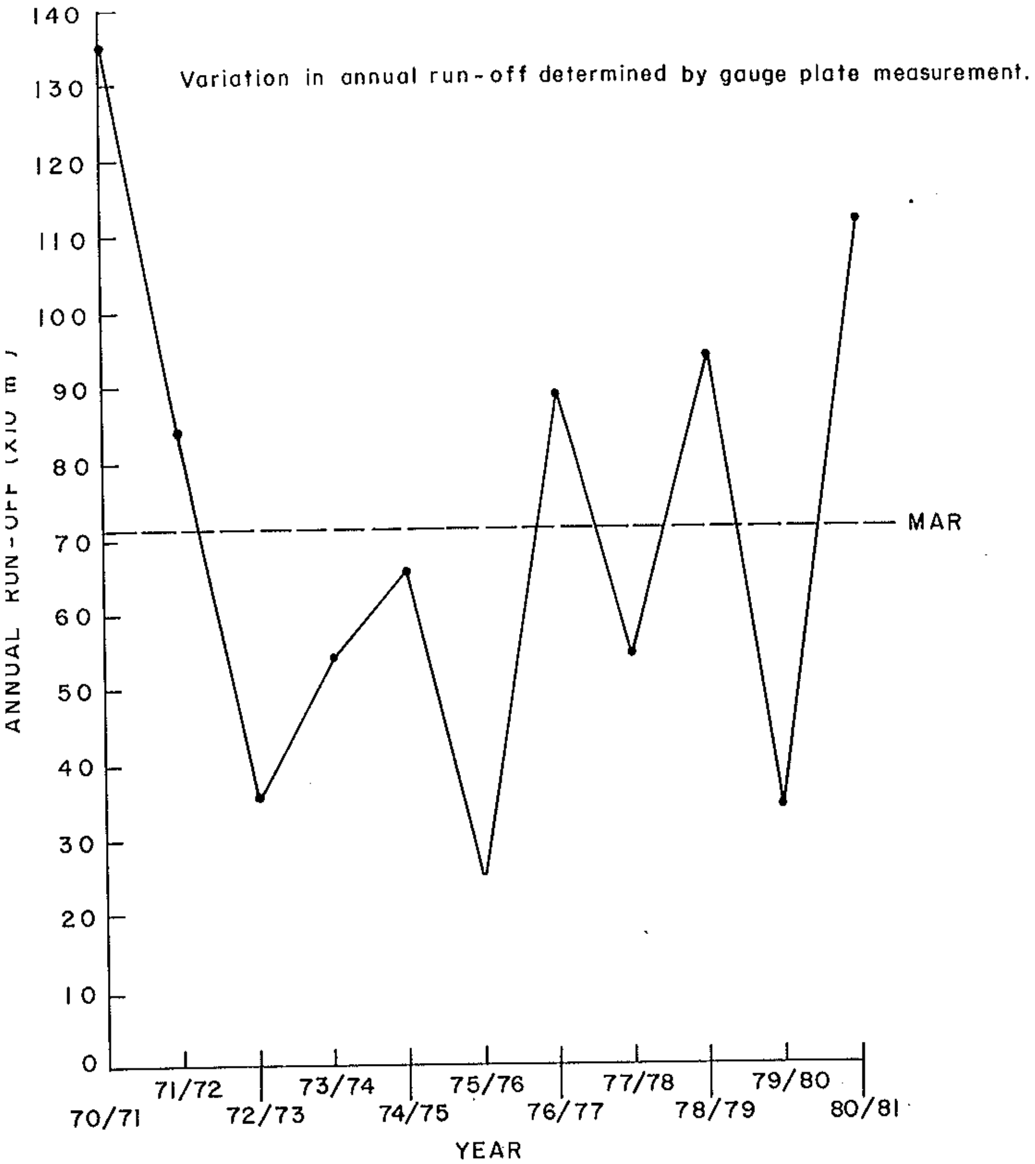
3.1.2 Land Ownership/Uses

KEURBOOMS

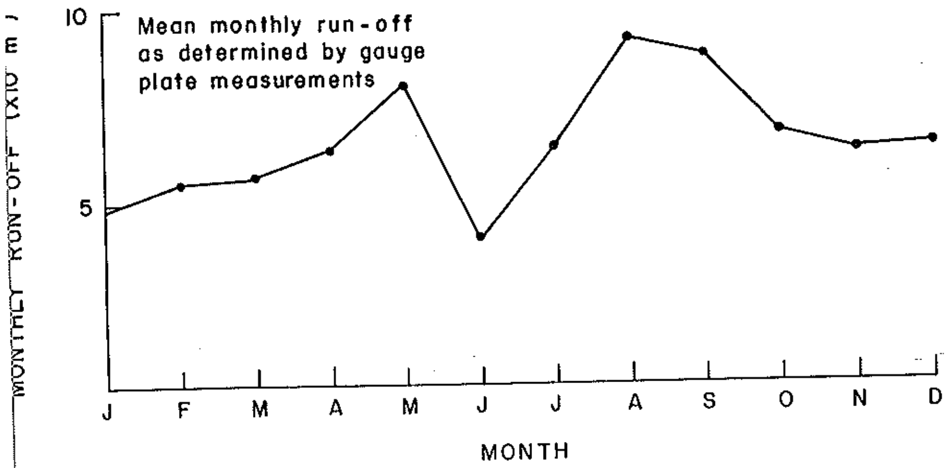
The major part of the river catchment is made up of privately owned farms. The privately owned mountain catchment areas along the upper reaches of the river mostly consist of natural vegetation utilized for cattle and goat farming. The vegetation includes Mesic and Dry Mountain Fynbos with large areas of Wet Mountain Fynbos occurring along the middle reaches of the river. Another feature of this area is cultivated land and orchards on the river banks, while privately-owned indigenous forests occur lower down on the southern side.

The Klein Palmiet River runs through the Klein Palmiet River Forest Reserve before it flows into the Palmiet River. In addition to this area, the entire catchment area south of this confluence up to the Keurbooms River bridge, falls under State Control. This includes the Keurbooms River State Forest, consisting of indigenous forests and plantations, owned by the Directorate of Forestry.

The Keurbooms River Nature Reserve, covering an area of 128,5 ha, under the control of the Cape Provincial Department of Nature and Environmental Conservation (CDNEC), includes the lower reaches of the river and the steep banks covered with indigenous forests. The reserve extends for approximately 6 km



IG. 2 : Variation in annual run-off in the Keurbooms River at Newlands for the period October 1970 to June 1981.



IG. 3 : Mean monthly run-off in the Keurbooms River at Newlands over the period October 1970 to June 1981.

upstream from the National Road (N2) bridge. Most of the reserve lies on the western bank of the Keurbooms River, the narrow eastern portion consists of the steep forested slope running down from the coastal plateau to the river bank. Features of this reserve, established in 1967, are hiking trails, camping sites and holiday accommodation. Angling is permitted in the reserve as is the collection of bait organisms. These activities are subject to the relevant Provincial Ordinances which govern the quantitites of bait organisms which may be taken and the methods by which they can be collected. Similarly, the regulations govern the minimum sizes of angling fish which may be caught. Boating within the reserve is controlled: a speed limit of 10 km/h applies throughout the reserve. However, speeds in excess of 10 km/h and waterskiing are permitted between 10h00 and 16h00 on the 2,5 km-long reach above the N2 bridge. In addition, the CDNEC controls the Keurbooms Estuary below the N2 bridge where a 10 km/h speed limit is also enforced.

BITOU

The upper reaches of the Bitou River and its tributaries run through the Buffelsnek, Krantzbosch and Kafferskop State Forests, consisting mainly of indigenous forests, owned and managed by the Directorate of Forestry.

The rest of the catchment area is made up of privately-owned farms which include indigenous forests and cultivated lands. Small areas of Mesic and Wet Mountain Fynbos, as well as indigenous Forest communities, form part of the natural vegetation of this area.

The Uplands represent the best agricultural area in the region. It has good rainfall, good soil and permanent water supplies. The farms are comparatively big; wheat, dairy products and vegetables are produced and small stock is kept. Second in importance is the Hillview area with 3 500 ha of arable land. Here there are numerous smallholdings used for mixed farming, while dairy produce is the main enterprise on larger units. In the Wittedrift area with an average agricultural potential, the majority of units have been subdivided into such small parcels of land that they cannot be worked economically (Guide Plan, 1983).

PIESANG

The uppermost section of the Piesang River catchment lies within the Harkerville State Forest, consisting mostly of indigenous forests with a small plantation on the eastern side. The upper reaches of the river run through areas of privately-owned plantations and natural vegetation which includes Mesic Mountain Fynbos. According to the Guide Plan (1983) the area in the vicinity of Jackals Kraal as well as both banks along the length of the river, are a nature area.

The middle reaches of the river also run through part of the Hillview area. Rural occupation occurs at Ladywood while the only licensed airport in the Guide Plan area, is on the farm Roodefontein. In this region the river runs through wetland vegetation and the Country Club golf course above the western road bridge.

Below this road bridge the narrow river is lined by the reed, *Phragmites*, surrounded by farmland and township developments. A caravan park is situated on the southern bank above the Otto du Plessis bridge while the building of chalets is envisaged on the northern bank.

3.1.3 Obstructions and Impoundments

KEURBOOMS/BITOU

Although Ninham Shand and Partners (1967) indicated positions for three possible dam sites in the Keurbooms River there are no State-constructed dams in the three catchments. The nature of the area is such that the establishment of a regional water supply scheme is not feasible at this stage. Investigations have shown that possible irrigation schemes would generally be costly because fairly high dam walls would be needed to provide the necessary storage capacity and to lift water from the deep gorges. At this stage the Plettenberg Bay Municipality has a pump station in the Keurbooms River from where water is drawn and piped over a distance of some 20 km (Guide Plan, 1983).

The road bridge at Wittedrift over the Bitou River as well as the old causeway on its seaward side, act as obstructions to water flow and effectively form the upper limit of tidal exchange in this river (Keurbooms- en Bitourivierbrûe, NRIO, 1975).

PIESANG

A road bridge crosses the Piesang River below the Country Club golf course but this does not appear to impede or obstruct the normal flow of the river. According to Grindley (1980), several smaller bridges cross the river and its tributaries beyond the tidal reaches of the estuary.

3.1.4 Siltation

KEURBOOMS/BITOU

According to a memorandum by the agricultural extension officer at George *(in litt.,* 4/7/75) the silt load in the Bitou and Keurbooms Rivers is minimal while Reddering *(in litt.)* states that silting in the Keurbooms River is not apparent and in the Bitou River it is restricted to the immediate vicinity of the bridge. An earlier report by NRIO confirms that the siltation is at its highest near the bridge (Keurbooms- en Bitourivierbrûe, NRIO, 1975).

Siltation due to erosion in the catchment is minimal and although large areas of the catchment are agricultural land, soil erosion does not appear to have caused serious problems. This could be due to the occurrence of good vegetation coverage and hard substrate.

PIESANG

According to Grindley (1980) siltation of the upper parts of the Piesang Estuary does not appear to be serious.

3.2 Estuary

3.2.1 Estuary Characteristics

KEURBOOMS/BITOU

This summary is partly based on a detailed report by the Sediment Dynamics Division of NRIO (G A W Fromme, in prep.).

The combined estuary of the Keurbooms and Bitou Rivers lies on the sandy, micro-tidal coast of Formosa Bay. The estuary is partially contained behind a barrier dune and a permanent tidal inlet connects it to the sea. The constricted inlet reduces the spring tidal range from 1,6 m on the seaward side of the barrier to 1,0 m in the estuary (Reddering, 1981). The Keurbooms/Bitou Estuary can be divided into three main components (Figure 1).

(i) The Keurbooms Estuary which extends for 7 km from its confluence with the Bitou to the head near Whiskey Creek;

(ii) The Bitou Estuary which is 6,7 km long from its head at Wittedrift to the confluence with the Keurbooms;

(iii) The lagoon 3,5 km in length. At the time of writing the mouth lies approximately 1,5 km north-east from Lookout Rocks.

Geomorphologically and geologically, both rivers consist of an upper and lower section. The upper section is cut into the elevated coastal terraces of the hinterland, in contrast to the lower section, where the estuary spreads onto the coastal plains. After the two estuaries have combined into one, they form the actual back-barrier estuary against the recent barrier dune ridge. This ridge forms the core of the two long and massive sand spits which meet at the permanently open estuary mouth. The mouth is approximately 200 m wide during high spring tide and attains depths of 4,5 m below mean sea level at the ebb-dominated north-easterly section. According to Reddering (1981), the depth at the flood-dominated south-westerly section is 2,5 m below mean sea level. This makes the estuary mouth an effective permanent tidal inlet and forms a highly dynamic zone which influences the hydraulics of the entire lower estuary (Figure 4). The surface area of the combined Keurbooms and Bitou Estuaries is 2,7 km^2.

Sediment accumulation which is undesirable both in environmental and recreational terms is taking place in the flood tide dominated Keurbooms Estuary. The flood tide domination is a result of tidal resonance which causes a net marine sediment movement into these estuaries. Flood dominated sediment movement is also aided by wave entrainment of sand at the inlet during flood tides. As a result of lack of wave action in the estuary, wave entrainment of sand does not take place during ebb tides. The higher velocities of the incoming flood-tidal current versus the longer duration of the outgoing ebb-tidal current counteract each other. The action of the waves during high tide is, however, the decisive factor in the flood-tide domination of the sedimentary system. Marine sediment entering the estuary is deposited on flood tidal deltas (Reddering and Esterhuysen, 1983).

As has already been stated, deposition in the estuary of sediments originating in the catchments is not of much significance. According to the map by Rooseboom and Coetzee (1975) the sediment yield of the Keurbooms/Bitou catchment is 150 to 200 tons per km^2 annually, which is comparatively low. With a catchment area of 1096 km^2 this amounts to about 200 000 tons or 100 000 m^3 per year. An undefined part of this volume is, however, retained in the upper stretches of the river or washed out to sea as suspended load. Comparison of aerial photographs suggests that there has been no significant increase in terrestrial sand deposition in the estuary during the past four decades. However, siltation and the transformation of the south-western blind arm of the estuary into a muddy lagoon seems to be in progress.

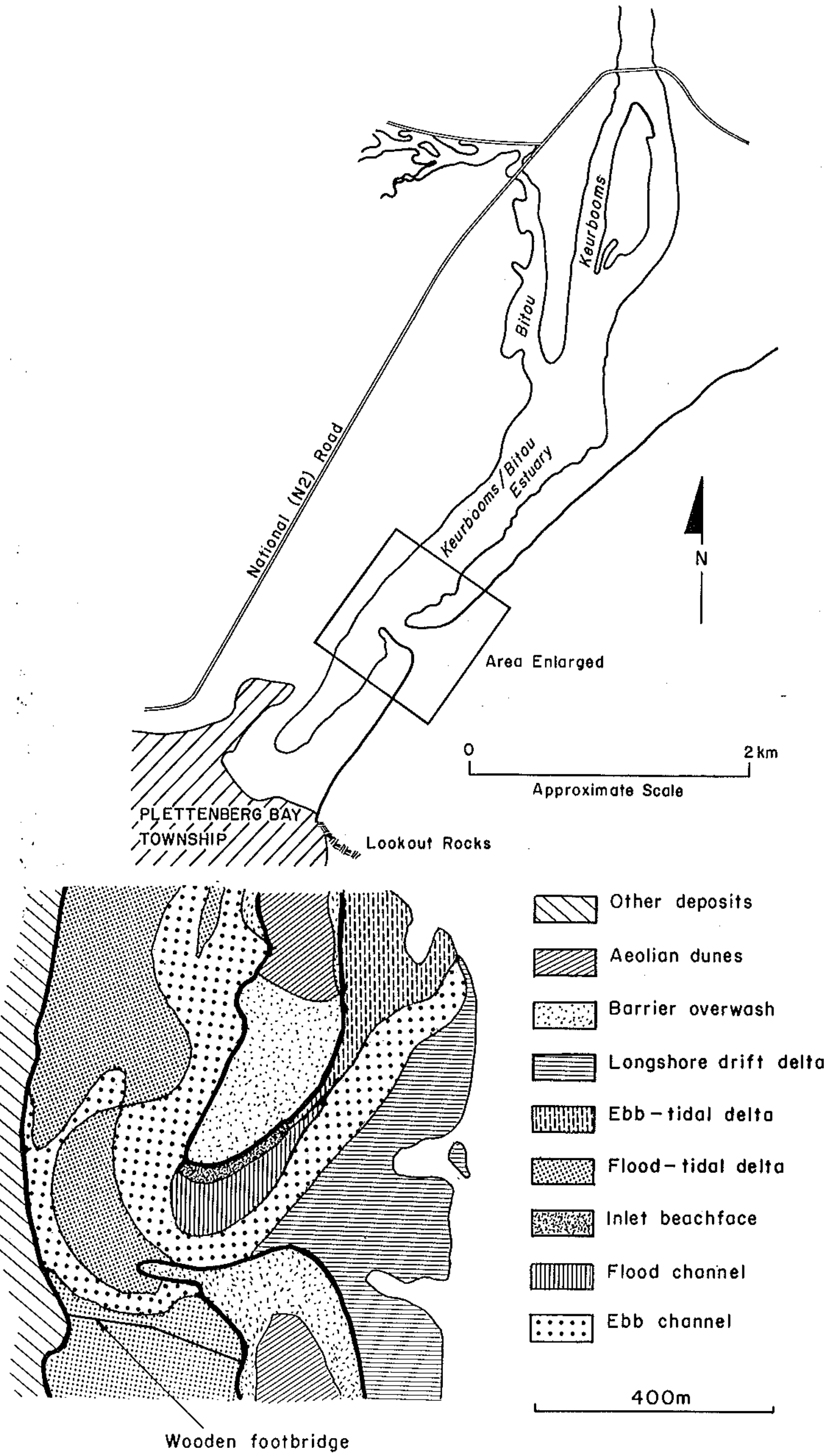


FIG. 4: Subenvironments of deposition in the inlet area of the Keurbooms Estuary

A record of inlet migrations obtained from a set of 14 aerial photographs was compiled by Fromme (1985). The photographs from 1936 to 1942 show the mouth still in the north-easterly position as it was reportedly in 1915. All the other 12 mouth positions discernable on the aerial photographs were in the centre region of the back-barrier estuary, that is, where the mouth is at present (Table 1 and Figure 6).

TABLE 1: KEURBOOMS ESTUARY MOUTH MIGRATIONS ACCORDING TO AERIAL PHOTOGRAPHS 1936 TO 1980

Day	Month	Year	Mouth position in metres SW of reference point (Fig. 6, point NE)	Mouth movement metres to		Orientation of mouth channel towards			No. in Fig. 6
				SW	NE	SW	SE(x)	NE	
		1936	400	-	-			x	1
		1942	500	100			x		2
		1961	1 500	1 000				x	3
3	10	1967	1 940	440				x	4
19	12	1968	1 840		100			x	5
30	4	1970	1 840	0	0		x		6
23	5	1972	1 720		120		x		7
23	9	1972	2 120	400				x	8
4	10	1973	2 120	0	0			x	9
30	5	1974	2 200	80				x	10
5	4	1980	1 980		220		x		11
8	4	1977	2 000	20		x			12
21	4	1979	2 150	150				x	13
	12	1980	1 920		230			x	14
						1	4	9	

(x) Orientation of mouth towards SE = straight out to sea

Note: Mouth positions refer to position of upper channel (where the mouth channel emerges from the estuary).

Although a record with such large time gaps as the one presented cannot be accepted as statistically fully reliable, it gives an indication that the tidal inlet of the estuary fluctuated most of the time around the centre of the back-barrier estuary, i.e. approximately 2 km north-east of Lookout Rocks. However, in 1867 and 1890 the mouth migrated to the extreme southwest adjacent to Lookout Rocks (Fromme, 1985).

In summary, it seems that the position of the Keurbooms mouth goes through very long-term (decades) cycles, which consist of the following elements:

- the estuary breaches the spit at its north-eastern extremity during a major flood;

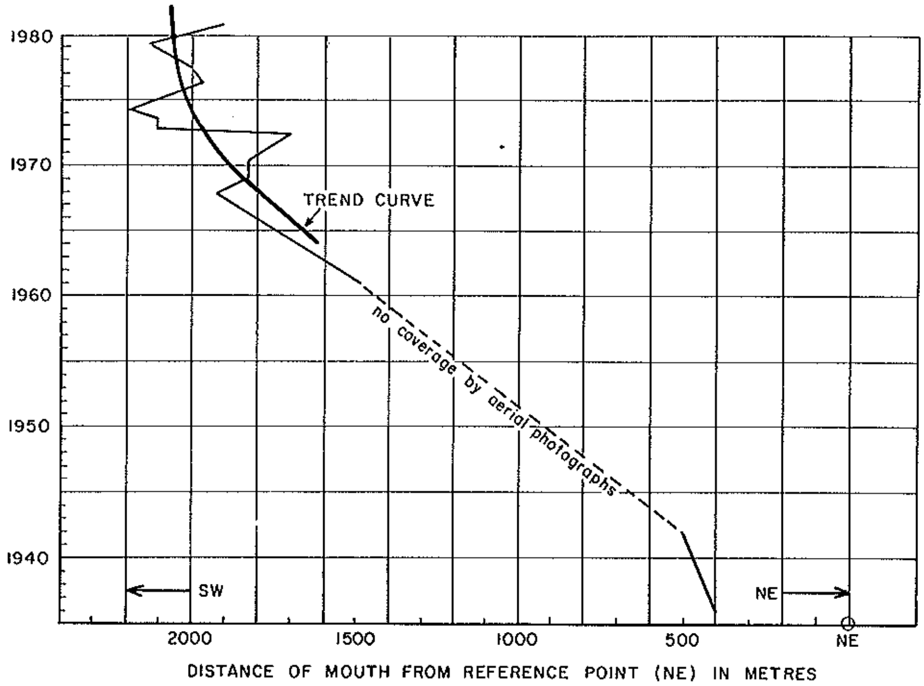
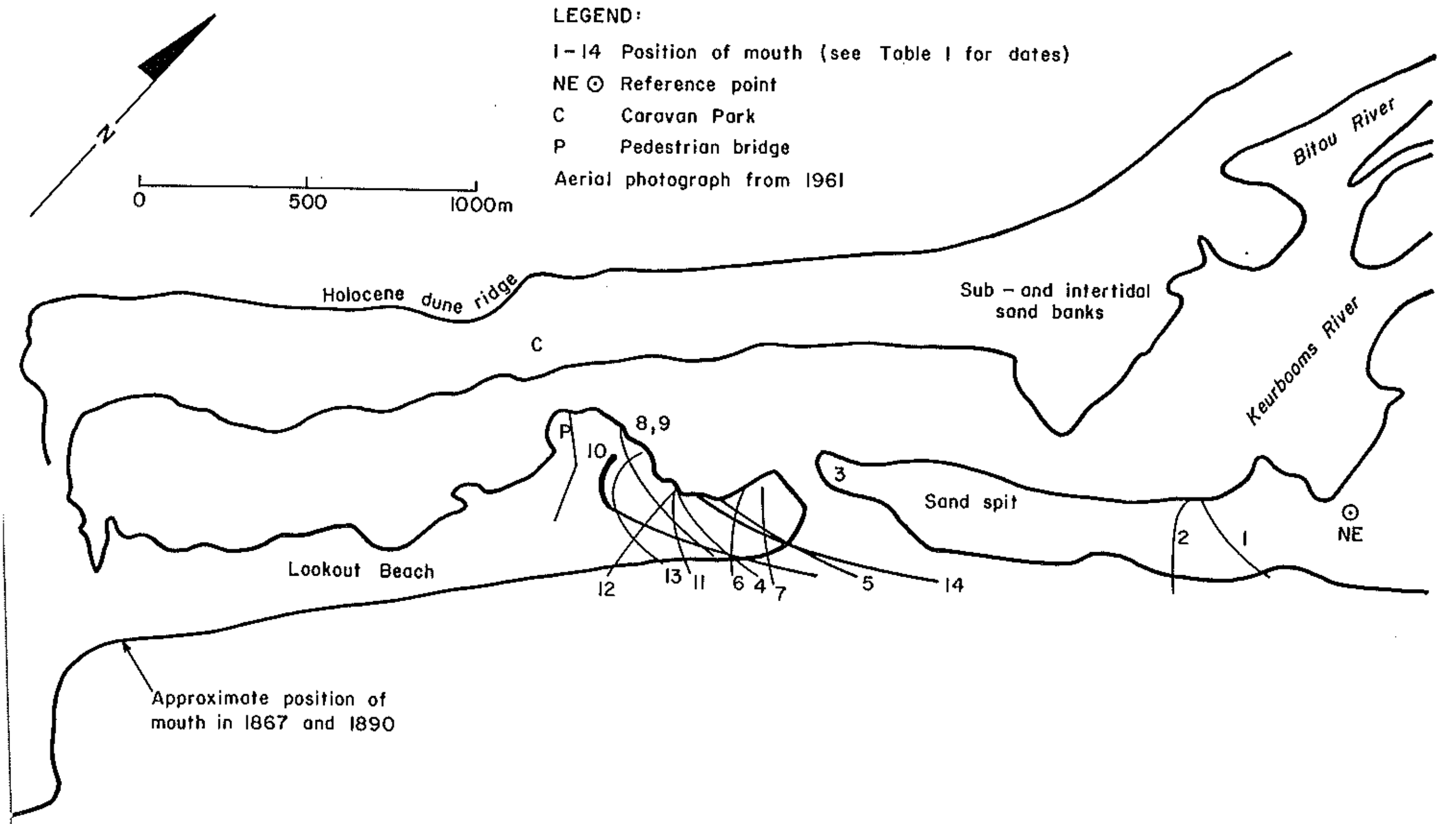


FIG. 5: Diagram of lateral mouth migrations of the Keurbooms Estuary (1936 to 1980)



IG. 6: Lateral mouth migrations in the Keurbooms Estuary from 1936 to 1980

- subsequent to the breaching the mouth gradually moves south-westwards thereby acting as an offset tidal inlet. The migration rate reduces gradually as the mouth moves south-westwards due to the more vegetated and pronounced nature of the coastal dune ridge at its south-western extremity;
- temporary reversals in the direction of migration can take place depending upon the wave climate;
- eventually a major flood breaches the spit in the north-east again, thereby restarting the cycle.

It should be kept in mind that the mouth migrated up to Lookout Rocks in the last century. The possible recurrence of this event will depend upon the flood regime.

A south-westward migration of the estuary mouth is indicated by a best-fit trend curve drawn in Figure 5. This curve seems, however, to flatten out towards 1980. Recent observations in March, June and September 1984 indicate that the mouth seems to be stationary in a central position, or is even moving towards the north-east. It appears that the inlet migrations as observed in the near past (from 1970 onwards) and at present could be ascribed to short-term fluctuations which do not give proof of a distinct long term south-west moving trend (see Synthesis).

PIESANG

The Piesang Estuary stretches for approximately two kilometres from its mouth at Beacon Island to the upper road bridge below the Plettenberg Bay Golf course. The river leaves the narrow valley at the Otto du Plessis Bridge, and enters an open basin, 200 by 600 m in extent, where a small lagoon is dammed up behind the sand bars adjoining Beacon Island. A shallow channel, 0,5 to 0,75 m deep and usually less than 20 m wide, scours its way out to sea along the rocks at the landward side of Beacon Island. This channel is opened mainly by outflow from the estuary, which then acts as a tidal inlet. However, due to the shallowness of the channel the tidal exchange with the estuary is very weak. During dry periods, mainly in summer, the channel closes.

To the north-east of the estuary mouth, a massive sand bar (80 by 100 m wide), blocks the lower estuary basin and is fused with Central Beach, that is, the beach between Beacon Island and Lookout Rocks (Figure 10). The sand bar is frequently breached by river floods but it is sometimes also breached artificially to allow the estuary to flush and prevent flooding of the Caravan Park upstream of the Otto du Plessis Bridge. Inside this bar a sand bank, 400 m long and 100 m wide has formed, part of which is now supratidal. This is the result of the ingress of marine sediment when the mouth is open but is also caused by wash-over across the northern sand bar. To the south of the lower estuary basin another sand bar connects Beacon Island to Robberg Beach. There are no recordings of breaching of this sand bar but frequent wash-over occurred before the sand bar was consolidated by the construction of the access road and parking area for the Beacon Island Hotel. This consolidation is beneficial to the estuary by preventing the influx of marine sand by wash-over from the south.

3.2.2 Land Ownership/Uses

The permitted land use in the environs of the Keurbooms/Bitou and Piesang rivers and estuaries is presented in the Guide Plan (Figure 1).

KEURBOOMS/BITOU

Above the National Road (N2) bridge the banks of the Bitou River are zoned as nature area. Similarly, the Keurbooms River, above the N2 bridge, lies within the Keurbooms Nature Reserve which provides protection to the upper estuary and a large tract of coastal forest. The Anath Peninsula (Figure 10, Grid ref. 0513-1113) lies between the Keurbooms and Bitou estuaries: the northern half is zoned for recreation whereas the southern portion is zoned as nature area. The two parts are separated by a road reserve intended for the major re-alignment of the N2 freeway. In view of the upgrading of the existing alignment of the N2, the proposed re-alignment may be unnecessary in which case the road reserve should be de-proclaimed and added to the nature area. The island in the Keurbooms Estuary and the sandspits on either side of the estuary mouth are zoned as nature areas. The island should be formally incorporated into the Keurbooms Nature Reserve to ensure its retention as a completely natural feature. The remainder of the shores of the estuary are zoned for recreation with the exception of a small portion of the south-western end of the blind lagoon which is included in Plettenberg Bay township. To date small-scale development has taken place within the area zoned for recreation. These developments include a caravan park and a number of private dwellings. However, considerable additional developments are being planned in the areas zoned for recreation, including a major time-share resort development on the northern end of the Anath Peninsula. As the Guide Plan does not define the term "recreation", it is open to a wide range of interpretation. This is an unfortunate situation since many so-called recreational developments differ little physically from townships. The main difference would be that in recreational developments in the true sense, a series of occupiers (that is, the general public) can stay for short periods whereas in a township a house is usually occupied continuously or reserved for holiday use by a single family. Such time-share developments therefore violate the spirit and intent of the zoning of a piece of land for recreation. Recreational areas should be retained for camping, picnicking and sports fields with the minimum of fixed structures associated with them. It is clear that, unless decisive action is taken, there is a real danger that the Keurbooms/Bitou Estuary will be surrounded by semi-urban developments and thus destroy the atmosphere and character which attracts so many holiday-makers to the Plettenberg Bay region. In Plettenberg Bay itself this has already happened to a large extent and holiday-makers complain that overcrowding makes conditions intolerable during peak holiday periods.

PIESANG

The Piesang River and its immediate banks lie within a strip zoned as nature area. The only exception is in the vicinity of the caravan park upstream of the Otto du Plessis bridge where both banks are zoned for recreation. The north bank opposite the caravan park is to be developed as an exclusive group of holiday chalets (Mr A Solomon, private developer, Plettenberg Bay, pers. comm.). Little use is made of the Piesang River except as a source of fresh water mainly to irrigate the golf course and for some small-scale pleasure boating. The backwash water from the municipal filtration plant is discharged into the river opposite the upstream end of the caravan park.

3.2.3 Abnormal Flow Patterns

KEURBOOMS/BITOU

The river flow, calculated from gauging plate measurements represents a minimum value because flood discharge regularly exceeds the capacity of the measuring station (Figure 2). Therefore this method is accurate for measuring river flow during times of low flow while rainfall data should be used for determining flow during times of flood.

The Keurbooms River came down in a very heavy flood in 1915 and a new inlet was breached at the northern end of the barrier island (Reddering, 1981). It appears that the Keurbooms River is subject to floods of substantial magnitude. During May 1981 the entire floor of the Diep River valley, a minor tributary of the Bitou River, was flooded. According to a resident this happened frequently in winter (The Argus, 81-06-01).

PIESANG

The caravan park manager maintains that serious floods have taken place in recent years resulting in flooding of the caravan park south of the Piesang River (Grindley, 1980). The holiday housing scheme, Beau Rivage, situated on the outer bend of the river and only a few metres above normal flow levels, could be prone to inundation during floods (Figure 7).

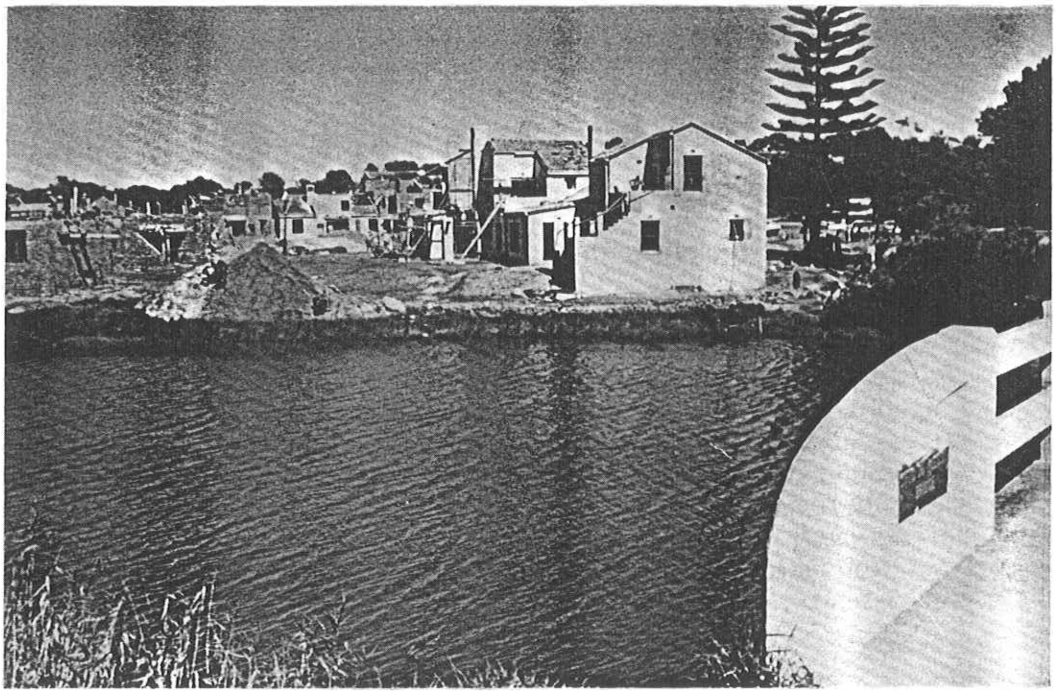


FIG. 7: A low-lying holiday scheme under construction on the floodplain of the Piesang River.

3.2.4 Obstructions

KEURBOOMS

The National Road (N2) crosses the Keurbooms River six km northeast of Plettenberg Bay and this bridge is being widened as part of the upgrading of the existing N2. The obstruction caused by the existing road bridge and embankment covers approximately 45 percent of the river width. The amount of rubble from the remains of an old causeway downstream from this bridge is estimated to be 4 400 m^3 (Keurbooms- en Bitourivierbrûe, 1975). Through this only a narrow channel less than 10 metres wide, is navigable. Environmental changes are apparent above the bridge due to restriction of flow and the vegetation, burrowing fauna, fish and birds are thus limited to the upper reaches (Day, unpubl.).

According to J D van Wyk *(in litt.)* the CPA Roads Department have removed as much of the old causeway as possible while removal of the remainder of the structure was likely to be a costly undertaking. It was felt that the improved flow to be gained by such an operation would not warrant the expense.

BITOU

The Bitou River is crossed by a bridge at the foot of the hill to carry the National Road and directly upstream of this single span bridge, which is being widened, is the remains of an older bridge. This bridge was washed away by floods in about 1940 but part of the earth embankment and the concrete piers remain, restricting the flow and forcing tidal waters to make an abrupt bend (Day, unpublished). This bend is due to the presence of the National Road bridge, the eastern embankment of which closed off the main channel of the river, diverting the flow through a secondary channel (Figure 8).

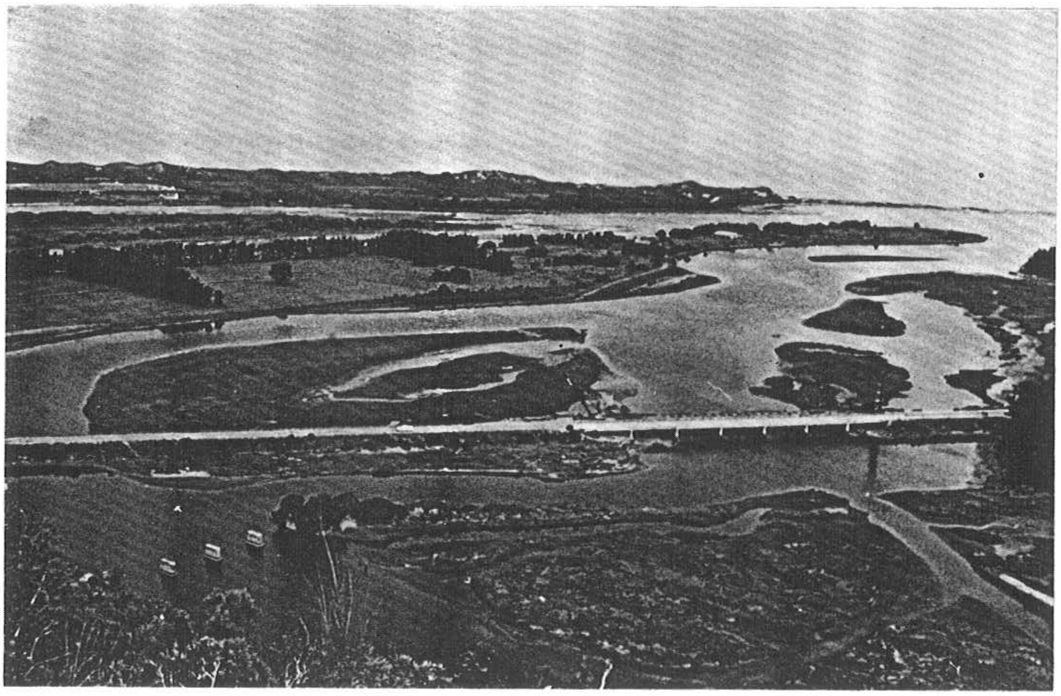


FIG. 8: Downstream view of the bend in the Bitou River. Note the obstruction of the original channel by the road embankment and the diversion of the estuary through an artificial channel under the bridge.

PIESANG

The Otto du Plessis bridge was built in 1961, replacing an earlier bridge, to carry the main road to Beacon Island and the western part of Plettenberg Bay. This bridge is approximately 30 metres long and consists of three spans with two columns in the estuary. Short stub embankments project minimally into the estuary (Grindley, 1980).

A concrete footbridge 45 metres long links the Beacon Island Hotel to Central Beach. It is supported on two columns in the estuary. Occasionally the width of the mouth is greater than the length of the footbridge thus preventing pedestrians from crossing.

3.2.5 Physico-chemical Characteristics

KEURBOOMS/BITOU

pH

Le Roi Le Riche and Hey (1947) recorded pH values of 5,4 in the Bitou River and 5,1 in both the upper and lower reaches of the Keurbooms River. Measurements by the Department of Water Affairs from October 1967 to July 1982 at Newlands in the Keurbooms River, approximately 15 km from the mouth, vary between 4,1 and 8,7. Similar measurements made at Peters River, a tributary of the Keurbooms, 55 km from the mouth, range from 3,9 to 8,7. The relatively low average pH value is probably due to humic acid leached out of decaying vegetation. The elevated maximum pH values may be caused by high photosynthetic activity as both minimum and both maximum values were recorded in the early morning and late afternoon respectively.

During a survey by the School of Environmental Studies, (University of Cape Town) in September 1981, values between 6,8 and 7,4 were obtained. The pH is higher in the estuary than in the river and there is a slight increase towards the mouth in the estuary itself (Table 2, Figure 9). This increase could be due to a higher primary production implying an increase in photosynthetic activity but is mainly caused by the presence of seawater, with its relatively high pH.

Temperature

Day (1981) recorded a seasonal temperature range of 12°C to 28°C between the mouth and bridges and earlier measurements by Le Roi Le Riche and Hey (1947) fall within these limits.

During a survey by Day in January 1973, values from 23°C to 28,2°C were obtained. As expected, the temperature increased towards the head of the estuary while higher values were recorded at low-tide than at high-tide (Table 3). Above the bridges the shallower Bitou is warmer than the deep Keurbooms. The bottom water of the Keurbooms is cooler than the surface which forms a separate layer extending down to the confluence (Day, unpubl.). Similar horizontal and vertical gradients occurred during early March 1984, while temperatures varied between 16,5°C and 24,0°C before the start of the autumn rains (Table 4, ECRU survey, 5-9 March 1984).

Temperatures recorded in July 1974 during a survey by the University of Cape Town (UCT) ranged from 11,8°C to 16°C. Temperatures increased towards the head of the estuary and the highest values were recorded during low-tide (Table 3). A horizontal temperature gradient towards the estuary head still occurred, despite reportedly good winter rainfall (Day, 1974, unpubl.).

Temperatures from 12°C to 19°C were obtained in September 1981 during a UCT survey (Table 2). The temperature decrease towards the head of the estuary is probably due to the cooling effect caused by the inflowing freshwater during spring. According to Tyson (1971), winter is the driest season in this rainfall region and this would explain the temperature gradient pattern recorded in July

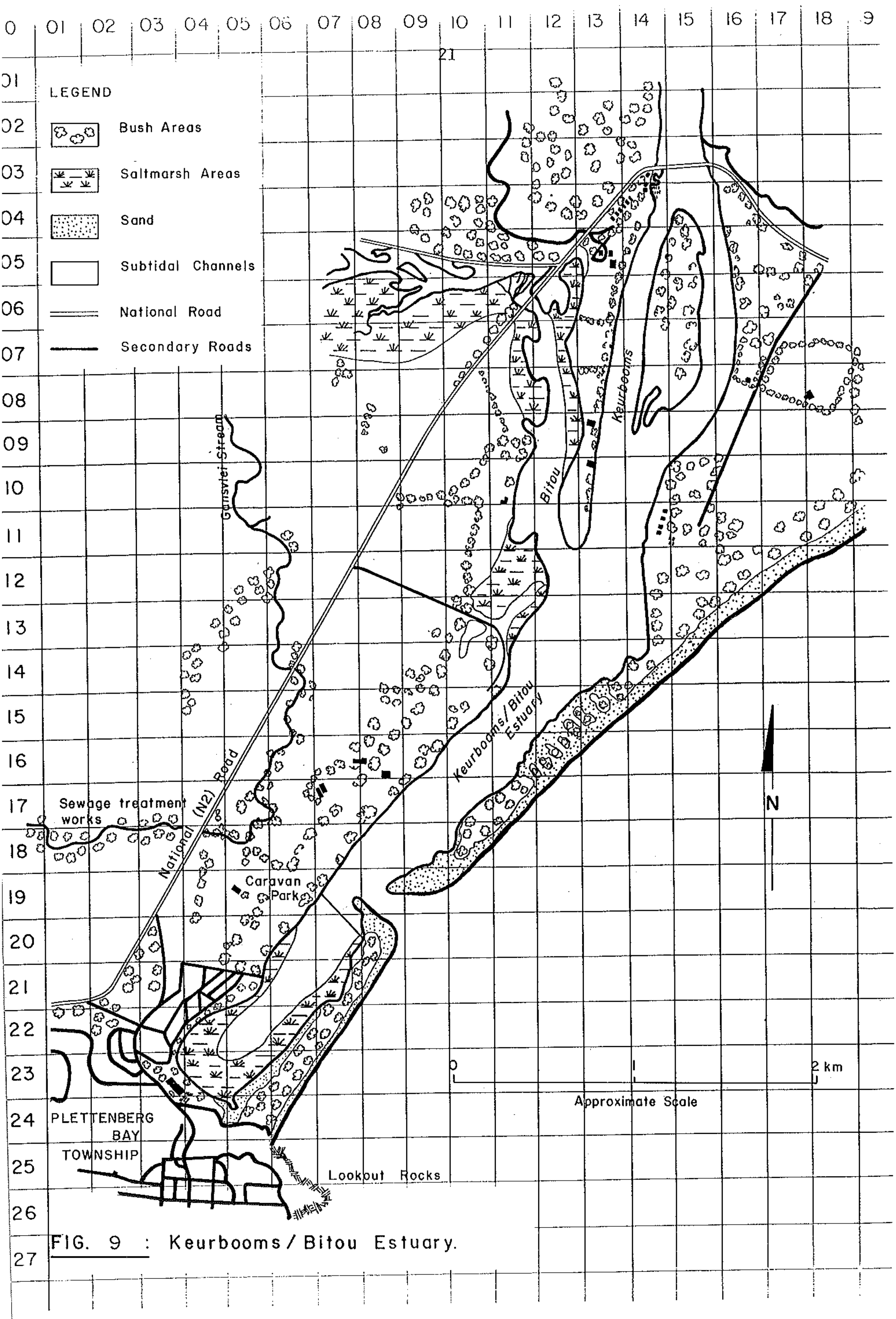


FIG. 9 : Keurbooms / Bitou Estuary.

1974, especially if viewed in combination with the low cloud coverage in winter months mentioned by Barry (1968). A low temperature range was recorded in the mouth region in July 1974, which might have been caused by local upwelling conditions.

Transparency

Le Roi le Riche and Hey (1947) recorded Secchi disc readings of 1,4 m and 1,5 m for the upper and lower reaches of the Keurboom River respectively, while they obtained a value of 1,7 m for the Bitou River. Day (1973, unpubl.) recorded Secchi disc readings of more than a metre in the estuary and this was also found during the ECRU survey (Table 4).

Salinity

The salinity between the bridges and the mouth varies from 13 to 30 parts per thousand, depending on the rainfall (Day, 1981). During a survey by Day in January 1973 relatively high values from 25,0 to 35,4 parts per thousand were measured due to the increase in evaporation during the summer months (Table 3). Furthermore, the drought and low river flow at the time, also contributed to these values. The Bitou is markedly more saline than the Keurbooms River. At low tide there is a vertical salinity gradient extending from the confluence up the Keurbooms but at high tide the vertical gradient is restricted to the upper part of the Keurbooms and there is no vertical gradient at the confluence (Day, 1973, unpublished).

Values ranged from 14 to 34 parts per thousand in March 1984 with the highest value obtained in the shallow blind end of the lagoon subjected to virtually no freshwater inflow (Table 4). The vertical salinity gradients that occurred were similar to those recorded in January 1973. Salinities between 6 and 34 parts per thousand were recorded in July 1974 by UCT (Table 3). The salinity decrease recorded from summer to winter is partly caused by a decrease in evaporation but is mainly due to the increase of freshwater inflow.

During a survey by UCT in September 1981 much lower salinities ranging between 0,3 and 28 parts per thousand were recorded (Table 2). This is probably due to the higher rainfall and the resulting increase in freshwater inflow during spring. The diurnal variation caused by tidal action is evident (Table 3). Salinity studies by the Port Elizabeth Museum showed that the shallow sill at the Keurbooms bridge holds back a dense mass of saline water below the surface.

Dissolved Oxygen

Le Roi Le Riche and Hey (1947) recorded oxygen values of 7,0, 6,6 and 6,0 mg/l for the Bitou and upper and lower reaches of the Keurbooms River respectively.

Values obtained during a survey by UCT in September 1981 vary between 1,0 and 10,4 mg/l (Table 2). The highest and lowest dissolved oxygen values measured were partly due to the effect of temperature and salinity on oxygen solubility in seawater as these values correspond with the minimum and maximum temperature and salinity measurements respectively. Furthermore, the maximum value recorded could be caused by the photosynthesizing activity of *Zostera* surrounding the sampling station.

ECRU recorded dissolved oxygen (DO) values ranging from 4,5 to 8,5 mg/l during a survey in March 1981 (Table 4). The highest values were recorded in the mouth region and are probably due to aeration caused by the high energy in the surf zone while the low value at the Keurbooms bridge is a result of the relatively warm dense mass of saline water held back by the shallow sill under the bridge. The low values recorded at the blind end of the lagoon could be due to the high salinity and presence of decaying weed.

Nutrients

The Division of Hydrology (Dept of Water Affairs) recorded combined values for nitrite and nitrate at Peters River, approximately 55 km from the mouth. Values during the period June 1971 to May 1983 ranged from 0 to 0,35 mg/l. Similar measurements at Newlands, 15 km from the mouth, varied between 0 to 0,48 mg/l between October 1967 and July 1982. Maximum ammonia values of 0,41 and 0,71 mg/l were recorded at the two stations respectively.

During a survey by UCT in September 1981, nitrate values varied between 3,5 and 4,5 mg/l in the estuary itself (Table 2). Decomposition of organic detritus and oxidation of the resulting ammonia, as well as the flocculation process could be partly responsible for this increase in nitrate in the estuary.

Inorganic orthophosphate values between 0 and 0,16 mg/l were recorded by the Division of Hydrology at Peters River and Newlands in the Keurbooms River, while a high maximum value of 0,9 mg/l was recorded in the estuary in September 1981 during a survey by UCT (Table 2). This was probably caused by the sewage effluent from the Gansvlei stream. The treated effluent reaches the Bitou River by means of this stream.

Pollution

Trace metals

The concentrations of copper, zinc, iron, manganese, cobalt, nickel and mercury found in surface water samples are considered to be average for Eastern Cape rivers. Lead and cadmium values are elevated but show no obvious trend and thus no source can be identified. Cadmium levels are, on average, ten times higher than those determined for any of the Eastern Cape rivers studies so far. It is probable that the cadmium is of geochemical origin as there is significant input from the upstream sections of the river, but no obvious man-made source of pollution was apparent in this area (Watling and Watling, 1980).

The sediments in the Bitou River have elevated trace metal levels when compared with the concentrations found in sediments collected in the Keurbooms River in equivalent positions in the estuarine sequence. Metal levels are high in the estuarine area associated with the town of Plettenberg Bay and in the area adjacent to the Angling Club (Watling and Watling, 1980).

An analysis of metal levels in the tissue of the brown mussel *Perna perna* taken from near the estuary mouth, revealed no significantly elevated concentrations (Watling and Watling, 1979).

Sewage

The sewage from the Plettenberg Bay municipal area is led to pump stations in the low-lying areas and is pumped through about 14 stations to the sewage treatment works (Figure 9, Grid. Ref. 1702). The works consist of a five-pond system followed by biological filtration, humus settling and chlorination of the final effluent.

According to a survey by the National Institute for Water Research (NIWR) in October 1981, the Gansvlei stream above the sewage outfall has a COD of 82 mg/l which increases to 98 mg/l because of the sewage works discharge. This implies that even in the absence of the sewage outfall the COD will be higher than the general standard limit of 75 mg/l.

A survey by UCT in September 1981 indicated that although some organic wastes are reaching the stream from the sewage works the water is suitable for all uses except for human consumption. This restriction is necessary because of the high level of occurrence of faecal coliforms. However, it must be recognized that even in the absence of the sewage outfall, it is probable that an unacceptably high coliform count would occur. This is due to the human habitation without proper sanitary facilities upstream of the works as well as the direct contamination of the stream by humans and animals. The Gansvlei stream flows through a wetland consisting of areas of reed and open shallow pools, ensuring that this stream is well-oxygenated and that nutrient levels (nitrogen and phosphorus) have been lowered biologically before entering the Bitou Estuary. In other words the Gansvlei wetlands are serving their natural and useful function of trapping waste products before they get into the estuary (UCT survey, 1981).

Bad odours at certain pump stations could be eliminated by aeration, while the use of aluminium sulphate will cause flocculation of algae and suspended solids (Drews and Van Vuuren, 1981). Many of the recommendations made by NIWR have not been adopted, as a regional sewage scheme is being investigated at present (J Squier, Outeniqua Divisional Council, pers. comm.).

Public Health Aspects

The most important health aspect of any recreational water in which swimming occurs, is the presence of faecal coliforms, particularly *Escherichia coli*. However, no official South African standards for the bacteriological quality of recreational waters exist. Water quality criteria providing guidelines on the limits which must not be exceeded for certain water uses, drawn up by the Marine Pollution Committee of SANCOR, (Lusher, 1984), are listed below:

Microbiological Criteria

Beneficial use: Direct contact recreation (e.g. swimming, diving, windsurfing)

	Maximum acceptable count
Faecal coliforms per 100 ml	100 (50%)
	400 (90%)
	2 000 (99%)

Beneficial use: Collection of filter feeders for food use.

	Maximum acceptable count
Faecal coliforms per 100 ml	15 (50%)
	45 (90%)

(The percentages following the maximum acceptable count are the percentage of samples that must comply with the given count for the specified purposes.)

No data are available on the bacteriological quality of the Keurbooms and Bitou rivers but tests by the South African Bureau of Standards and the Department of Health were carried out at various stations in the Gansvlei stream. The maximum acceptable count mentioned above refers to feacal coliforms whereas only the total coliform and *Escherichia coli* counts for the Gansvlei stream are available. Even the *E. coli* counts do not comply with the above criteria; therefore the faecal coliform count could be much higher than the maximum acceptable count.

According to Livingston (1982) the total coliform count provides only a non-specific indication of waterborne terrigenous pollution and is no indication of faecal pollution caused by sewage contamination. Furthermore the method of using coliforms as microbial indicators to determine the suitability for using seawater for specific purposes is questionable. The incidence of pathogenic organisms in water of low or zero coliform and *E. coli* counts, has been reported by Evison and Tosti (1980). Thus the uncertain correlation between the coliform index and the population of pathogenic micro-organisms is a major limitation to the use of this method (Beekman, 1983). A method, similar to the scheme developed by Livingston (1982), which is based on the sum of a number of factors determining microbial pollution in the marine environment, could partially solve this problem.

PIESANG

pH

The School of Environmental Studies, UCT, recorded a pH of 7,6 in the Piesang lagoon (Table 2, Fig. 10) while G F van Wyk (Department of Nature and Environmental Conservation, *in litt.),* obtained a value of 7,4 in October 1958.

Temperature

Grindley recorded values from 21,8°C to 22,6°C on 17 December 1968 and 16°C to 16,5°C on 29 May 1969 at three stations in the Piesang Estuary (Grindley, 1980, unpublished). Although no horizontal temperature gradient existed, the smallest seasonal variation occurred in the middle reaches of the estuary as expected.

In September 1981 UCT obtained lower values, from 13°C to 15°C, due to the cooling effect of the higher freshwater inflow during the spring rains (Table 2). Values ranged from 20,3°C to 23,7°C in March 1984 with the increase towards the head of the estuary. Thermal stratification was insignificant in the lower reaches due to the shallowness of the estuary and mixing caused by winds and tidal action (Table 4, ECRU survey).

Transparency

Water transparency (Secchi disc reading) varied from 0,8 m near the mouth to more than a metre at the head of the estuary in March 1984 (Table 4, ECRU survey).

Salinity

Grindley (1980) recorded a salinity gradient ranging from 31 parts per thousand at the head of the estuary to 35 parts per thousand at the mouth in December 1968 and from 27 to 32 parts per thousand in May 1969. The higher values in summer are probably due to increased evaporation. Values ranged from 7 to 35

TABLE 2: PHYSICO-CHEMICAL DATA FOR THE ESTUARIES, MARSHES AND WETLANDS OF THE KEURBOOMS, BITOU AND PIESANG SYSTEMS. (SCHOOL OF ENVIRONMENTAL STUDIES, UCT, 1981). SEE FIGURES 9 AND 10 FOR GRID REFERENCES

ECRU Grid Ref.	Position	Date	Tide	Temp (°C)	pH	Oxygen (mg/l)	Saturation %	Salinity °/oo	Phosphate-P (mg/l)	Nitrate-N (mg/l)
Figure 9	Wittedrift bridge	8.9.81	2h before HW	14.0	6.8	-	-	0.5	0.10	3.5
-	Mallard farm	8.9.81	1h before HW	17.0	-	8.0	82	4.2	0.90	4.0
-	Rietvlei bridge	11.9.81	-	15.0	-	7.6	78	1.3	-	-
0512	Above Bitou Bridge	8.9.81	HW	16.0	7.0	-	-	1.8	0.15	4.5
0513	Below Bitou Bridge	8.9.81	HW	19.0	-	-	-	4.2	-	-
0215	Keurbooms Bridge	10.9.81	1h before HW	14.0	7.4	8.8	84	0.5	0.00	4.0
0414	Below Angling Club	11.9.81	1h before HW	16.0	-	7.8	98	1.1	-	-
0312	W. bank saltmarsh	9.9.81	2h before HW	19.0	-	6.4	95	19.6	-	-
1114	Lagoon Resort	11.9.81	LW	12.0	7.1	10.4	97	0.3	0.00	4.5
1608	W. bank lagoon	9.9.81	HW	19.5	-	6.1	82	13.3	-	-
2006	Caravan Park	9.9.81	1h after LW	19.0	-	1.0	11	28.0	-	-
2107	South Sandspit	11.9.81	1h after LW	17.5	-	-	-	24.5	-	-
2303	W. end lagoon	11.9.81	1h after LW	17.5	-	-	-	21.0	-	-
1016	East Swamp	11.9.81	-	13.0	6.9	3.2	30	0.3	-	-
-	Whiskey Creek	8.9.81	-	14.0	-	-	-	0.0	0.00	4.0
Figure 10	Country Club bridge	8.9.81	-	14.0	7.4	11.6	110	0.5	0.24	3.5
-	Piesang Causeway	10.9.81	LW	15.0	-	-	-	1.1	-	-
-	Below Causeway	10.9.81	LW	13.5	-	10.4	100	1.5	-	-
Stn 1	Beacon footbridge	8.9.81	2h after LW	13.5	-	8.3	100	35.0	-	-
Stn 2	Piesang lagoon	8.9.81	1h before HW	13.5	-	-	-	23.1	0.20	3.5
-	Robberg Swamp	11.9.81	-	15.0	-	9.1	85	1.2	-	-
-	Sea opposite lagoon	11.9.81	-	14.0	-	-	-	35.0	-	-
Stn 2	Piesang lagoon	8.9.81	3h after HW	15.0	7.6	-	-	2.0	-	-

TABLE 3: PHYSICO-CHEMICAL DATA FOR THE KEURBOOMS ESTUARY. DAY *(UNPUBLISHED)*. SEE FIGURE 9 FOR GRID REFERENCES

Station description	Sea	Footbridge at mouth	Confluence	Bitou bridge	1km above B. bridge	Keurb. bridge	0,5km above Keurb. bridge	2km above B. bridge
ECRU Grid Ref.	-	1907	1113	0612	0508	0315	0115	-
January 1973 Temperature (°C)	-							-
Low tide: Surface	-	24,80	26,50	26,80	28,20	27,20	26,80	
Bottom	-	-	25,00	-	-	24,90	24,80	-
High tide: Surface	-	23,50	23,30	27,00	27,20	27,90	26,00	-
Bottom	-	-	23,00	-	-	26,00	24,00	-
Salinities (°/oo)								
Low tide: Surface	-	33,22	28,64	30,77	32,34	24,98	25,68	-
Bottom	-	-	33,72	-	-	31,58	29,79	-
High tide: Surface	-	35,44	35,35	32,21	29,56	28,96	27,66	-
Bottom	-	-	35,35	-	-	31,27	29,85	-
July 1974 Temperatures (°C)								
Low tide: Surface	12,30	-	13,60	14,35	14,40	13,20	14,50	-
Bottom	-	-	-	-	-	13,50	-	-
High tide: Surface	-	16,00	13,00	14,00	14,00	11,80	13,30	13,60
Bottom	-	-						-
Salinities (°/oo)								
Low tide: Surface	27,50	-	24,30	12,15	7,00	14,00	13,00	6,00
Bottom	-	-	-	-	-	-	-	-
High tide: Surface	-	34,00	26,00	20,00	14,00	25,80	14,00	-
Bottom	-	-	-	-	-	-	-	-

TABLE 4: PHYSICO-CHEMICAL DATA FOR PIESANG AND KEURBOOMS ESTUARIES (ECRU). SEE FIGURES 9 AND 10 FOR GRID REFERENCES

ECRU Grid Ref.	System and date		(m)	(mg/l) DO		Salinity ($^{o}/_{oo}$)		Temperature (^{o}C)						Transparency
										T (24hrs) B				
		Time	Depth	S	B	S	B	S	B	Max	Min	Max	Min	(m)
Figure 9 Keurbooms/Bitou														
0511	7.3.84	12h55	2,20	6,10	5,30	22	24	22,0	21,9	23,0	20,0	24,0	22,0	1,70
1213	7.3.84	14h40	1,30	6,10	5,80	24	24	21,4	21,2	21,5	16,5	22,0	17,5	1,30+
0315	7.3.84	16h05	2,00	5,30	4,50	14	25	23,1	21,9	23,0	19,0	21,5	17,5	2,00+
1412	9.3.84	11h05	1,35	6,45	7,44	26	32	20,1	17,8	22,5	17,5	22,0	17,0	1,35+
1709	9.3.84	10h20	1,60	7,98	8,50	32	33	17,9	17,7	21,0	16,5	20,0	17,0	1,60+
2106	9.3.84	09h15	1,30	5,60	5,60	34	34	18,0	17,7	-	-	-	-	1,30+
Figure 10 Piesang														
Stn 3	6.3.84	11h40	1,00	6,20	6,10	33	33	20,3	20,4	21,0	17,0	21,0	17,0	1,00+
Stn 4	6.3.84	11h10	1,20	4,80	6,50	32	35	21,0	18,9	22,0	18,0	21,0	18,0	0,90
Stn 5	6.3.84	10h20	1,10	3,60	5,50	7	34	23,7	22,0	24,0	24,0	22,0	22,0	0,80

S = Top
B = Bottom

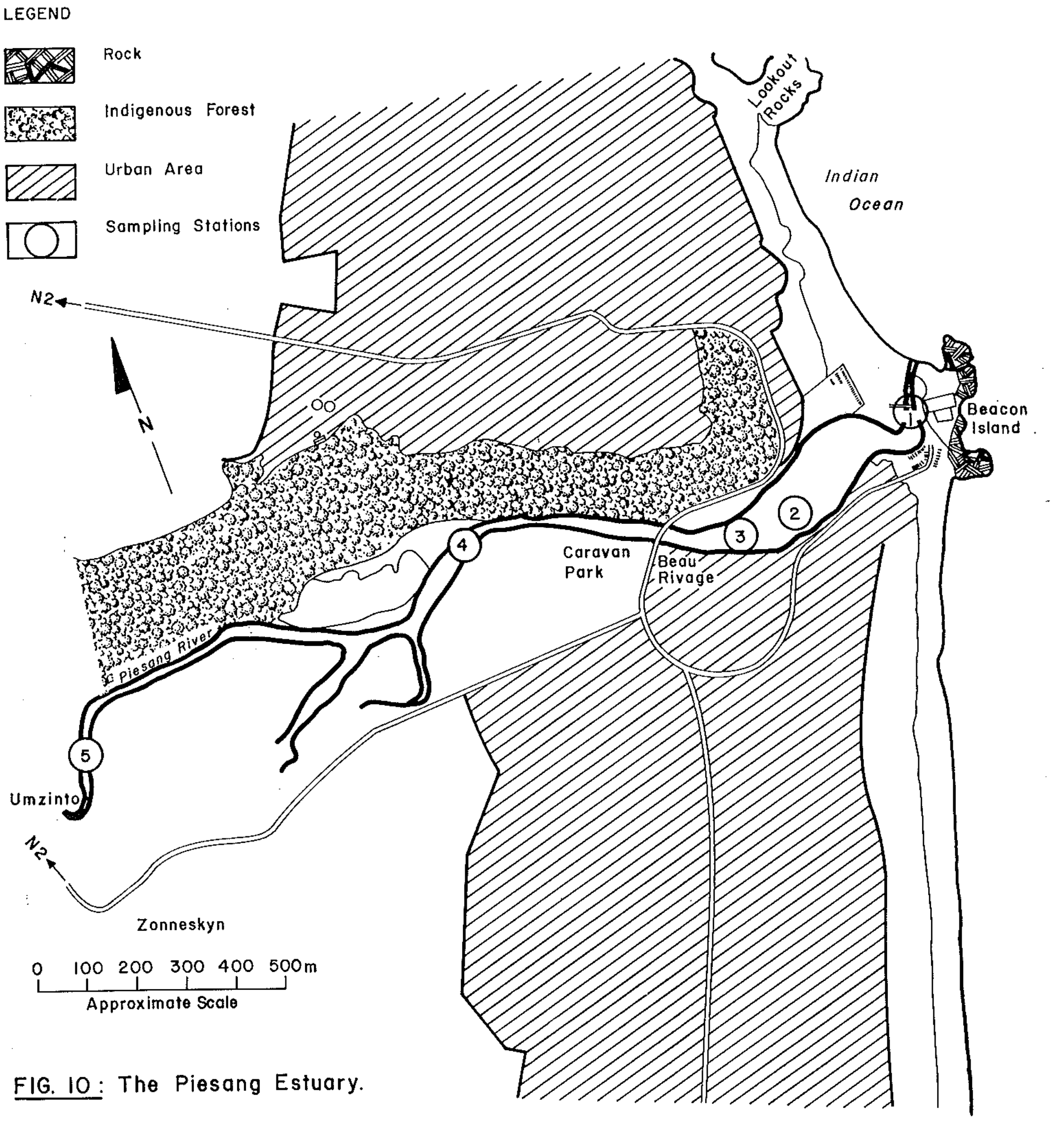


FIG. 10 : The Piesang Estuary.

parts per thousand in March 1984 and penetration of a salt water wedge was detected approximately 2,5 km from the mouth (Table 4, ECRU survey). Values varied between 0,5 and 35 parts per thousand in September 1981 (Table 2, School of Environmental Studies, UCT).

Dissolved Oxygen

During September 1981 the UCT survey team recorded oxygen values from 8,3 to 11,6 mg/l (Table 2). No stratification occurred near the mouth due to mixing, while values decreased towards the head of the estuary (Table 4, ECRU survey). Stratification in the lower and upper reaches of the estuary is probably caused by the presence of photosynthesizing plants and the absence of mixing.

Nutrients

During a survey by UCT in September 1981, nitrate values varied between 3,5 and 4 mg/l while inorganic orthophosphate values ranged from 0,20 to 0,24 mg/l (Table 2).

Pollution and Public Health Aspects

Trace metals

No data are available.

Sewage

Accidental discharge of sewage into the Piesang lagoon occurred on 23 April 1979 which led to the mouth being opened with a bulldozer (Grindley, 1980, unpublished). Mainly as a result of relatively "old" sewage arriving at pump stations near the river, where it is mixed with "fresh" sewage from the Beacon Island Hotel, an anaerobic condition develops which forms hydrogen sulphide in the process. This gas is the main contributor towards the offensive odours and concrete corrosion at the pump stations (Drews and Van Vuuren, 1981).

Evidence of the river being used for general waste disposal, especially during the holiday season, was found in the estuary (ECRU survey, 1984).

4. BIOTIC CHARACTERISTICS

4.1 Flora

(This section was contributed by Mr M O'Callaghan of the Botanical Research Institute

KEURBOOMS/BITOU

4.1.1 Phytoplankton/Diatoms

No data are available.

4.1.2 Algae

No data are available.

4.1.3 Aquatic Vegetation

Beds of *Zostera capensis* (eel grass) were found throughout the lagoon, growing intertidally and below the mean low water mark. At the blind south-west end of the lagoon, these plants become relatively tall and dense and *Halophila ovalis* is also present. The *Zostera* beds in the other parts of the lagoon do not seem to be as well-developed due to trampling, stronger currents and silt deposition.

4.1.4 Semi-aquatic Vegetation

The saltmarshes of this system are very variable, primarily according to microtopography, substrate and salinity regime.

The general marsh can be described in the following way: at mid water mark, patches of *Spartina capensis* (strandkweek) and *Sarcocornia decumbens* (brakbos) are found. Below high water mark, *Salicornia uniflora, Triglochin bulbosa* and *T. striata* are found together with *S. decumbens*. At high water mark, *Poeciolepis ficoidea, Cotula coronopifolia* (gansgras) and *Limonium scabrum* (sea lavender) dominate with *Chenolea diffusa* (soutbos), *Sarcocornia pillansiae* and *Sporobolus virginicus* (quick grass) at the higher levels. Any of the above species may become locally dominant to give a patchy effect. *Juncellus laevigatus* and *Sueda caespitosa* were also found at the southern part of the lagoon while the marshes along the Bitou River consist mainly of *C. coronopifolia, T. striata, Sarcocornia perennis* and *P. ficoidea,* followed by *Juncus kraussii, Disphyma crassifolium* and *C. diffusa* .

The saltmarshes around this lagoon, although well-developed, are not extensive. The limited size of these marshes are due mainly to natural phenomena; however, in some areas, the marshes are subject to human disturbances, especially near recreation areas. Higher in the Bitou River, the floodplain has been all but destroyed by agricultural practices and attempts should be made to maintain some natural vegetation as a fringe to the river.

4.1.5 Terrestrial Vegetation

The terrestrial vegetation of this area can be grouped into five types. The spatial distribution of these types are shown in Figures 11a and 11b while Appendix I lists some of the species and physical features of each type.

(a) Primary dune scrub
This vegetation type is found primarily along the eastern spit with small patches on the northern shore of the lagoon. The hummock dunes have a sparse covering of *Arctotheca populifolia* (sea pumpkin), *Agropyton distichum* (sea wheat), *Ammophila arenaria* (marram grass) and *Tetragonia decumbens* (klappiesbrak). On the primary dunes, the creeping sand binders *Ipomea pes-caprae* (goat's foot) and *Scaevola thunbergii* (seeplakkie) are common.

(b) Secondary dune scrub
The secondary dunes are covered by a scrub consisting of *Passerina vulgaris* (gouna), *Metalasia muricata* (blombos), *Cliffortia ilicifolia,* (doringtee), *Myrica cordifolia* and smaller herbs and grasses, e.g. *Ehrharta villosa* (pypgras), *Stenotaphrum secundatum* (buffalo grass) and *Ficinia lateralis*.

Artificial stabilization has taken place in some areas, especially near the gull colony on the north-eastern spit. This is done largely by planting *Ammophila arenaria*. However, this grass is relatively short-lived and it is recommended that efforts be made to re-establish the scrub species; the easiest method would be by sowing seeds.

(c) Hind dune scrub
Although this vegetation type might have many species in common with the above, it is generally found in more protected areas, is far denser and can reach a

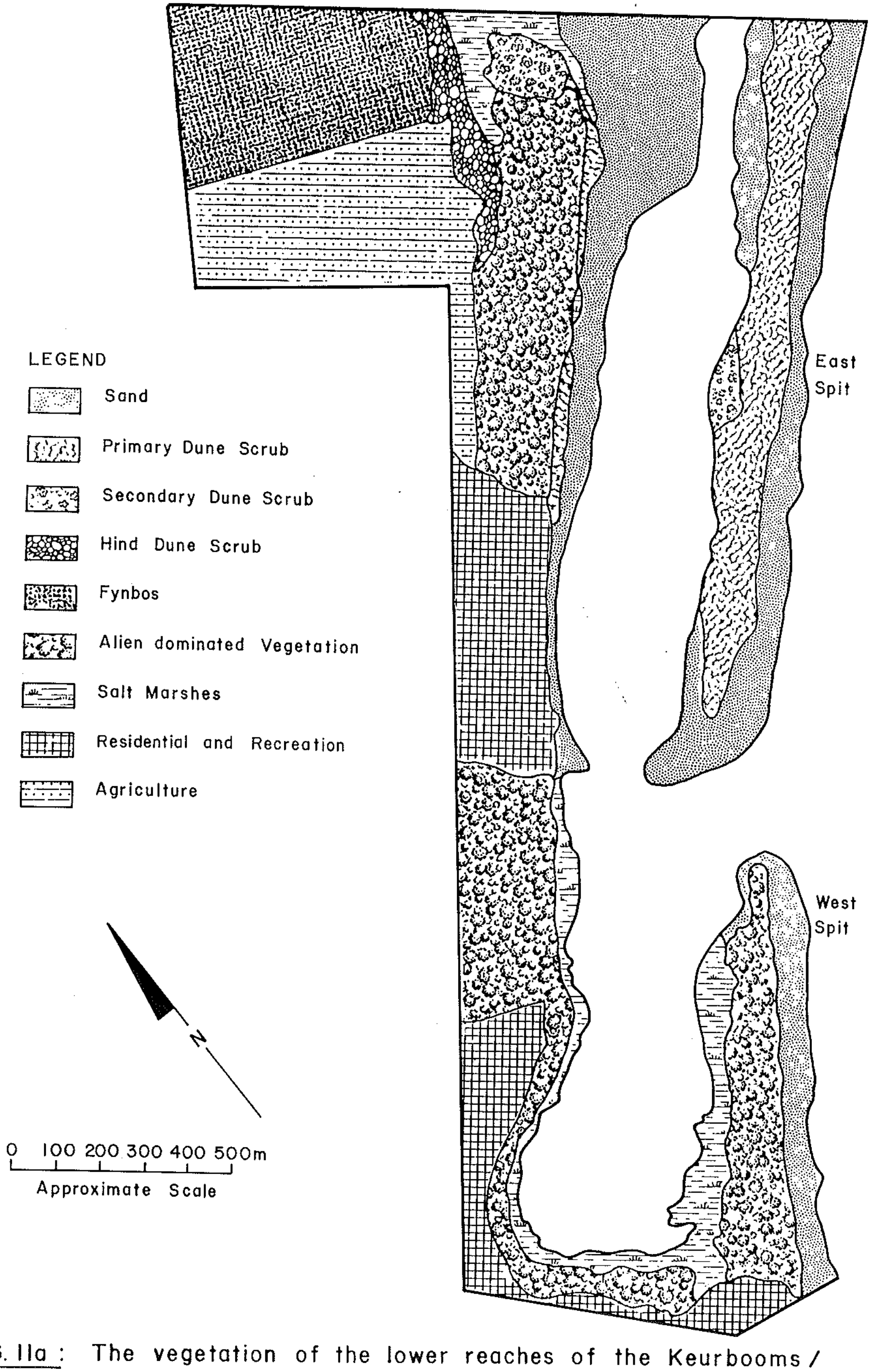


FIG. 11a : The vegetation of the lower reaches of the Keurbooms / Bitou Estuary.

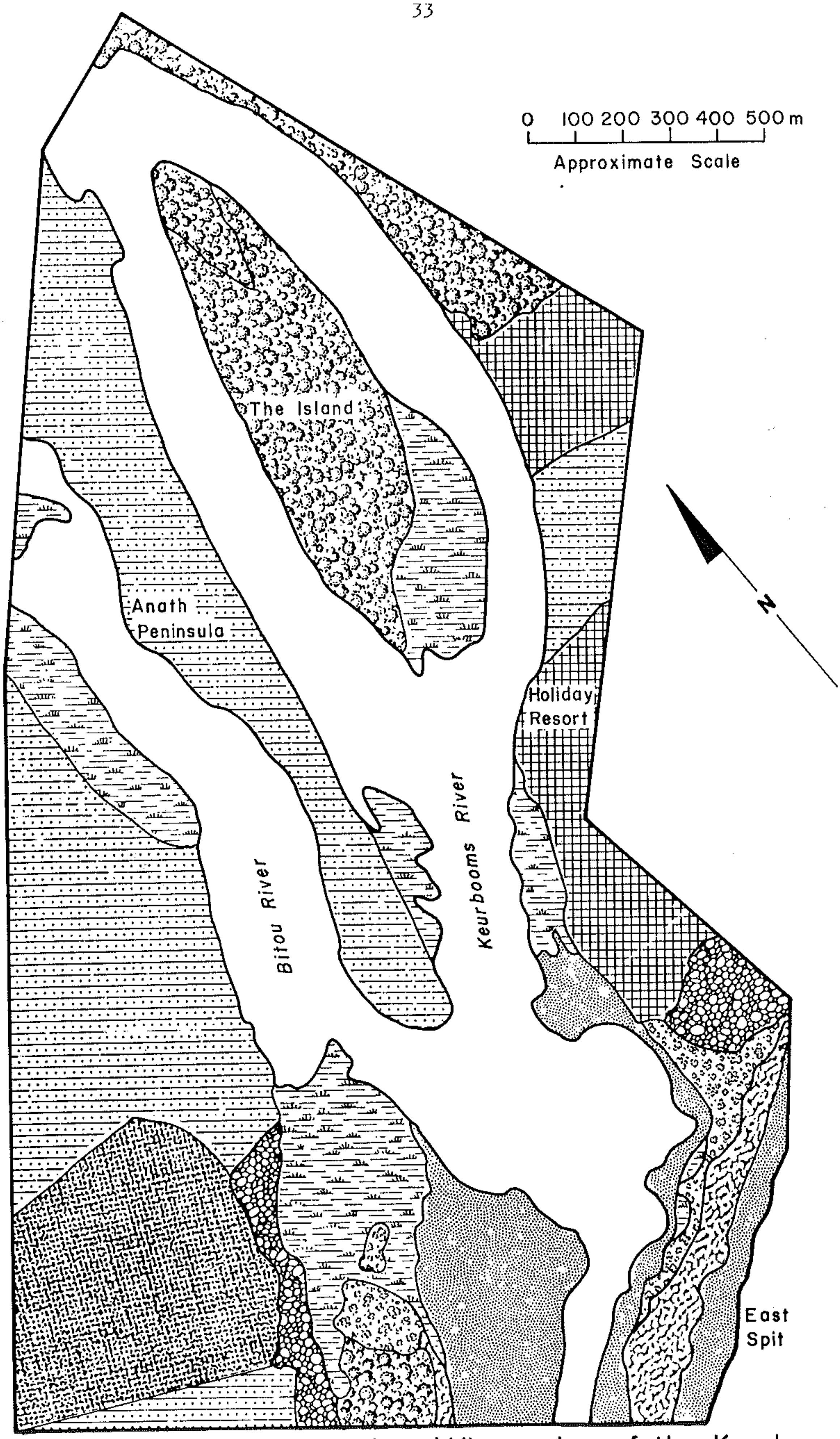


FIG. 11b: The vegetation of the middle reaches of the Keurbooms/ Bitou Estuary.

height of up to 3 m. The most common species are *Rhus glauca* (taaibos), *R. crenata, Chrysanthemoides monilifera* (bitoubessie). *Sideroxylon inerme* (milkwood) and *Buddleia saligna* (basteroelien) might also be present.

(d) Fynbos
The areas north-west and east of the lagoon are largely used for farming. However, many remnants, and in some areas, relatively large patches of fynbos are still to be found, although these are somewhat depauperate. Species such as *Erica peltata, Anthospermum aethiopicum* (cattail) and *Thamnochortus glaber* dominate. Although proteoids are not present, this vegetation is typical of coastal fynbos in the area.

(e) Alien dominated vegetation
Much of the area around this lagoon is dominated by aliens. *Acacia cyclops* (rooikrans) is most prominent and is found with remnants of a thorny riparian scrub forest near the blind end of the lagoon and with remnants of fynbos to the north-west of the lagoon. *A. saligna* (Port Jackson) and *A. mearnsii* (black wattle) are also conspicuous, the latter especially along the lower reaches of the Keurbooms River. These aliens destroy much of the natural vegetation and these areas become less resilient to natural perturbations such as flooding, dune slumping or blow-out erosion. It is recommended that aliens be gradually removed from these areas and the natural vegetation allowed to become re-established.

PIESANG

4.1.1 Phytoplankton/Diatoms

According to J Grindley (unpublished) *Noctiluca miliaris* is found in the estuary.

4.1.2 Algae

No data are available.

4.1.3 Aquatic Vegetation

No data are available.

4.1.4 Semi-aquatic Vegetation

The semi-aquatic vegetation adjacent to this river consists mainly of reed swamps *(Phragmites australis)* with small saltmarshes composed of *Triglochin* spp. (arrowgrass), *Juncus kraussii* (rushes) and *Paspalum vaginatum*. Much of this vegetation has been restricted or destroyed by:

(1) reclaiming and/or stabilizing the banks using rock and stone
(2) farming practices too close to the river
(3) recreation, residential and/or industrial development.

All of these effectively reduce the productivity of the system as well as increasing the probability of a natural disturbance that might have serious effects.

4.1.5 Terrestrial Vegetation

As can be seen from Figure 12, much of the area around this river has been developed for residential, recreational or agricultural use. As such, only two

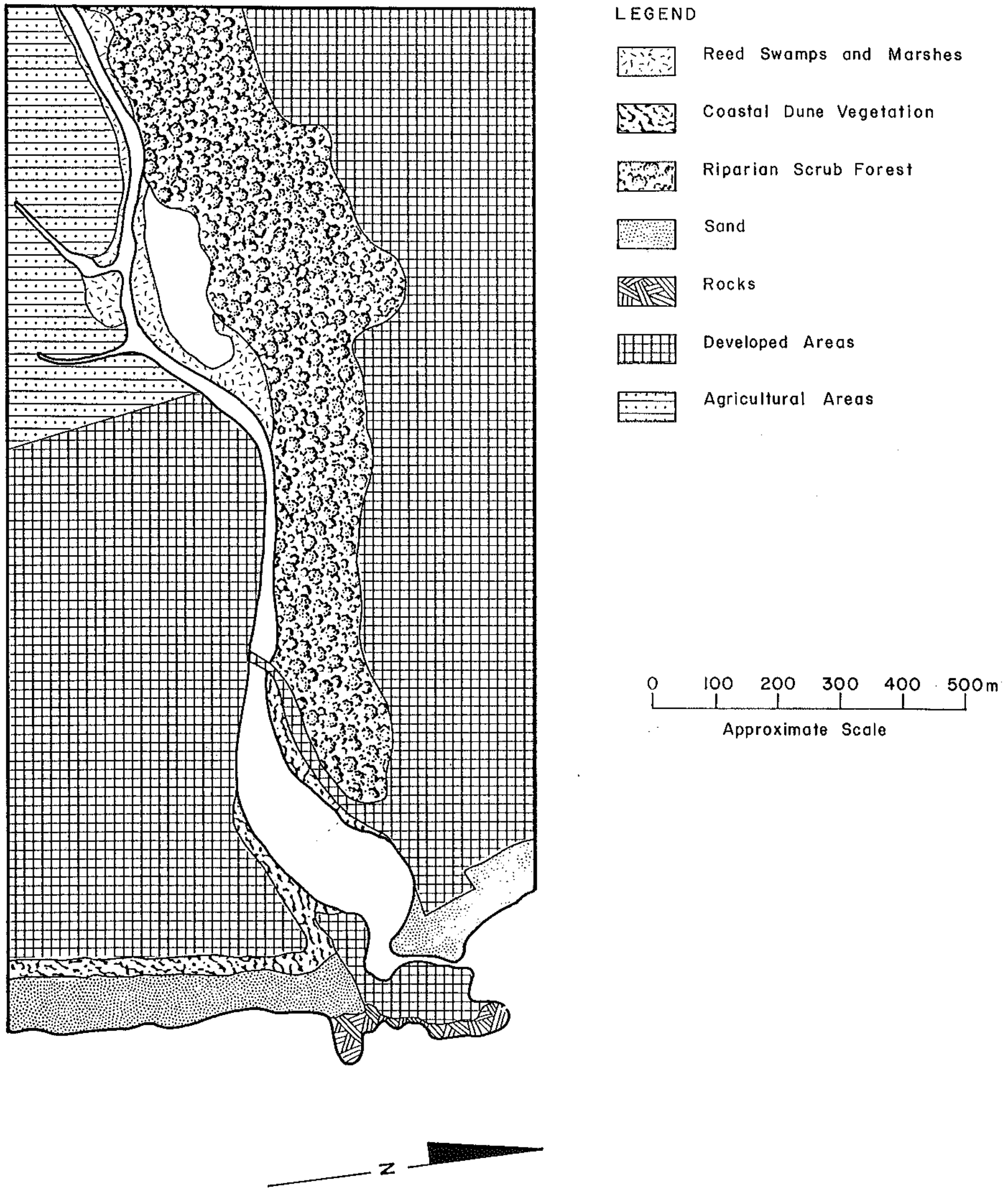


FIG. 12 : Vegetation of the Piesang River.

terrestrial vegetation types are worth mentioning, namely, the dune vegetation and the riparian forest. Appendix II lists some of the species and physical features of each type.

The coastal dune vegetation is only found as a thin strip south of the river with a small patch on the north bank of the river. A distinct zonation is noticed with sparse pioneer vegetation nearer the sea *(Ammophila arenaria, Tetragonia decumbens, Arctotheca populifolia)*. As one proceeds up the primary dune, shrub species such as *Metalasia muricata* (blombos) and *Rhus* spp. (taaibos) dominate while a dense scrub with *Sideroxylon inerme*, (milkwood) *Cussonia thyrsiflora* (kiepersol), *Chrysanthemoides monilifera*, and *Buddleia saligna* (basteroelien) is found on the hind dunes. Much of this scrub has been cleared, leaving bare sand which can erode and has involved the destruction of many protected milkwood trees.

The riparian forest is found on the steep south-facing slopes north of the river. Much of this area is undisturbed but roads and tracks have caused much damage at the forest margins. This vegetation has a typical forest structure with trees such as *Cassine aethiopica* (Cape cherry), *Rapanea melanophloeos* (Cape beech), *Scutia myrtina* (wag-'n-bietjie) and others, often taller than 10 m. Many climbers are also present while smaller shrubs and herbs are to be found in the understorey. Nearer the sea, this forest becomes shorter and approaches the dune scrub as described above. However, much of this has been destroyed by housing and aliens such as *Acacia cyclops* (rooikrans) and *Albizia lophantha* (stink bean) are also present.

4.2 Fauna

4.2.1 Zooplankton

KEURBOOMS/BITOU

According to J Grindley the zooplankton, at the time of his sampling programme in June 1969, was rich with a dry biomass of 2,9 to 108 mg/m^3. Catches with a 36 cm plankton net showed *Pseudodiaptomus hessei* as the dominant copepod and it is particularly abundant in the reduced salinity water above Keurbooms bridge. Grindley *(in litt.)* recorded 39 taxa present in the Keurbooms Estuary in June 1969 (see Appendix III).

A variety of other copepods, amphipods, isopods, shrimps, mysids as well as the larvae of resident fishes and invertebrates are common in night plankton samples. The mysid *Gastrosaccus brevifissura* is common and, as mysids are known to avoid small nets, it may form the bulk of the planktonic biomass as in some other estuaries (Day, 1981).

PIESANG

Grindley (unpublished) recorded 23 taxa present in the Piesang Estuary (see Appendix III).

4.2.2 Aquatic Invertebrates

KEURBOOMS/BITOU

Fauna on Hard Substrata

There are no extensive rocky areas within the system and an invertebrate fauna typically associated with rocks is scarce. The Bitou bridge piers and rubble in the channel underneath are lightly covered with barnacles *(Balanus amphitrite)* and limpets *(Siphonaria oculus)* (Day, unpublished).

Fauna on Soft Substrata

The largest proportion of the invertebrate fauna is either benthic, living on or in the bottom sediments, or is associated with the aquatic vegetation. The Keurbooms River estuary has been subjected to a number of surveys investigating the distribution of its invertebrate fauna. Biologists from the University of Cape Town, Zoology Department, covered this aspect of the system in January 1973 as well as in January and July 1974. Appendix IV lists the taxa recorded.

The benthic fauna is well-developed from the mouth to the bridges with *Callianassa kraussi* in sandy areas, *Arenicola loveni* and *Solen capensis* in muddy sand, and *Upogebia africana* abundant in sandy mud. *Assiminea globulus, Sesarma catenata, Cleistostoma edwardsii* and *Nassarius kraussianus* are abundant while *Scylla serrata* is common in the saltmarsh vegetation and *Zostera* beds. Above the Bitou bridge only *C. kraussi* and *S. catenata* are common and the benthic fauna above the Keurbooms bridge is very poor (Day, 1981).

According to Day the distribution of the benthic fauna is limited due to the presence of the bridges and remains of old bridges in both rivers. These structures as well as the high earth embankments of the existing bridges prevent any flow except through the main channel and also produce an area of "dead" water where silt rapidly accumulates and restricts tidal flow even more (Day, unpublished). During a survey in 1975 by NRIO (Keurbooms- en Bitourivierbrûe) it was determined that the low flow in the river is caused by the high friction coefficient of the river itself, while J D van Wyk (CPA, Department of Nature Conservation, *in litt.)* states that "the ecology of the system has adapted to the present situation and that removal of the causeway would not be worth the expense." More quantitative data are needed before any recommendations can be made concerning the removal of the rubble and its influence on the system. However, the present widening of the bridges should be done according to the scientific advice obtained, so as to ensure that the natural systems remain relatively undisturbed. The position of the proposed freeway, any dam construction or even proposed developments on the river banks, could have a major influence on the distribution of the benthic fauna and should only be carried out after other alternatives have been investigated.

Bait organisms in the estuary have been investigated by C Gaigher *(in litt.)* with additional investigations by Day (unpublished). Supplementary information is also available from the ECRU survey (Appendix IV). Gaigher recorded the distribution and abundance of *C. kraussi* and *Upogebia africana* in the estuary during October 1979. His results are shown in Table 5.

TABLE 5: Densities of *Callianassa kraussi* and *Upogebia africana* in the Keurbooms Estuary in October 1979. See Figure 9 for grid references.

ECRU Grid ref. (Figure 9)	Sediment description	Mean no. of burrow openings/m² *C. kraussi*	*U. africana*
2105	mud-sand		256
2008	sand/silt	36	
0416	sand	220	
0715	mud/sand	140	
0814	mud		400
0714	sand	360	
0913	hard sand	60	
1014	sand	176	
0915	silty sand		192
1211	loose sand	224	
0713	silty sand		336
0813	soft mud		480
1012	silty sand		344

The highest density of *U. africana* was recorded on the Bitou River side of the Peninsula. Although this number, (480 holes/m^2) implies a maximum density of 240 individuals, the actual density is probably much lower. Hill (1967) found that most of the *Upogebia* population was distributed in the region of the LWOST level during a study of some eastern Cape estuaries. This implies that there is no subtidal population which can act as a reservoir against exploitation. Furthermore *Upogebia* is restricted to fine sediment and when viewed in combination with the high numbers that can be taken (70/angler/day), *Upogebia* must be very sensitive to exploitation. Although G F van Wyk (1958, *in litt.)* and Day (unpublished) regarded *Upogebia* as abundant on the Anath Peninsula, few individuals were found during the ECRU survey in March 1984.

The incursion of marine sand into the estuary also affects *Upogebia* distribution by diminishing the areas suitable for burrowing and all these factors make the monitoring of *Upogebia* population levels essential. The effect that exploitation has on bait organisms and *C. kraussi* in particular, is evident when the density on the Keurbooms River side of the Anath Peninsula is compared with the density on the relatively inaccessible island in the river. According to Day (unpublished) *Upogebia* is abundant at the Bitou bridge while *C. kraussi* is common at the Keurbooms bridge.

The blood-worm *(Arenicola)* and razor shell *(Solen)* are fairly common on the sand banks on the northern side of the lagoon with a limited distribution north of the Keurbooms/Bitou confluence. The highest density recorded for *Solen* is 40 holes/m^2 while the maximum for *Arenicola* is only 1 hole/m^2. The density of the benthic fauna in the mouth region was very low during the ECRU survey, probably due to the high current velocity inhibiting larval settlement and habitation.

The 42 aquatic invertebrate taxa recorded in the Keurbooms Estuary are listed in Appendix IV. The list comprises records from Day (unpublished), obtained from surveys in January 1973 and January and July 1974 as well as specimens collected during the ECRU survey in March 1984.

The bivalve *Loripes clausus* was abundant in most parts of the estuary while specimens of the green prawn, *Penaeus semisulcatus* were collected during the ECRU survey. The occurrence of these prawns is an extension of their recognized distribution range (Day, 1981) where Mngazana in the Transkei is regarded as the southernmost limit.

PIESANG

The bait organisms *Solen capensis, Callianassa kraussi* and *Upogebia africana* were fairly common in the tidal sand banks downstream from the Otto du Plessis bridge. *C. kraussi* is dominant in the sandy areas at the mouth while *U. africana* is abundant in the silty mud near the bridge. *Hymenosoma orbiculare* occurs in high densities in the vicinity of the reed, *Phragmites,* between the bridges. Large specimens of the giant mud crab *Scylla serrata* were caught in the gill nets during the ECRU survey, and a specimen of the cuttlefish, *Sepia officinalis vermiculata* was collected by means of a small beam trawl.

4.2.3 Insects

Harrison and Agnew recorded insect species associated with the Keurbooms River during a survey in 1962. A list is given in Appendix V. No data are available for the Bitou and Piesang rivers.

4.2.4 Fish

KEURBOOMS/BITOU

According to Le Roi Le Riche and Hey (1947), *Monodactylus, Barbus* and *Sandelia* spp. were found in the lower reaches of the Keurbooms River while the following freshwater fish species occur in the Bitou and Keurbooms rivers (P Skelton, pers. comm.).

Eastern Cape Redfin	*Barbus afer*
Slender Redfin	*Barbus tenuis*
Cape Kurper	*Sandelia capensis*
Cape Galaxias	*Galaxias zebratus*
Brown Trout	*Salmo trutta*
Longfin Eel	*Anguilla mossambica*

Wallace and Van der Elst (1975) found the following species in the Keurbooms Estuary, during sampling for juvenile estuarine fish species along the east coast:

Groovy Mullet	*Liza dumerili*
Largescale Mullet	*Liza macrolepis*
Cape Stumpnose	*Rhabdosargus holubi*
White Steenbras	*Lithognathus lithognathus*
Southern Mullet	*Liza richardsoni*

The main fishing banks are at the confluence and at the eastern end of the lagoon, while angling above both bridges is poor. This could be due to the restricted channels under the bridges acting as a deterrent to the fish. Mullet occur above both bridges and there are stumpnose *(Rhabdosargus)*, Blacktail-*(Diplodus sargus)*, Zebras *(Diplodus cervinus)* and Tenpounders *(Elops machnata)*. A list of marine and euryhaline fish species occurring in the estuary is given in Appendix VI. This includes records based on anglers reports and unpublished reports on collections made by Day in 1973.

PIESANG

According to Grindley (1980, unpublished) mullet are abundant in the estuary. Approximately 500 juvenile sea barbel *(Galeichthys feliceps)* were caught in a five-minute D-net trawl by the ECRU survey team. The following species were also collected in this net (ECRU survey):

Sea Barbel	*Galeichthys feliceps*
Groovy Mullet	*Liza dumerili*
Southern Mullet	*Liza richardsoni*
Blackhand Sole	*Solea bleekeri*
Cape Stumpnose	*Rhabdosargus holubi*
Knysna Sandgoby	*Psammogobius knysnaensis*
Prison Goby	*Caffrogobius multifasciatus*

4.2.5 Reptiles and Amphibians

A list of reptile and amphibian species (Appendix VII) has been compiled by A L de Villiers of the Cape Department of Nature and Environmental Conservation for the grid squares 3323 CD and 3423 AB (from: Poynton, 1964; Greig and Burdett, 1976; Greig, Boycott and De Villiers, 1979; Boycott, 1982; Broadley, 1983).

The species "likely to occur" were only included when it was established that their distribution ranges and habitat preferences coincided with the area and where there were confirmed distribution records in close proximity to the loci in question. Some of the species listed are not directly associated with the estuaries concerned but are confined more to their catchments. Lizards have been omitted from this list.

4.2.6 Birds

According to Day (1973) the aquatic avifauna is much the same as at other Cape estuaries. During a brief survey, flocks of Yellow-billed Duck and a few Egyptian Geese were observed on the marshes above the Bitou Bridge. No aquatic birds were seen above the Keurbooms Bridge. Colonies of gulls and terns nest on the bare sand spit between the northern end of the lagoon and the sea. Cormorants are present but not common and there are fair numbers of waders on the intertidal sands and muds including Curlew Sandpipers, Little Stints, Whimbrels and White and Grey Herons (Day, 1973, unpublished). Waders are common near the confluence and duck, geese and coot frequent the Bitou marshes (Day, 1981).

A census of the numbers and distribution of waders and other birds in the Plettenberg Bay area was conducted by the Western Cape Wader Study Group in January 1979 (Appendix VIII). The eastern spit contained a large Kelp Gull colony fenced off from the public as part of the Keurbooms Nature Reserve. Little and Cattle Egrets also breed within the fenced area. The blind section of the estuary forms a high tide refuge for waders and other birds while the Plettenberg Bay sewage works also supports a good variety of waders. The Piesang lagoon contained only four wader species due to the high level of disturbance from tourists (Underhill, Cooper and Waltner, 1980).

According to a survey by UCT in September 1981 a total of 262 bird species are thought to occur in the Plettenberg Bay area, 135 being common, 99 rare and 28 vagrant. Of the 262 bird species recorded, 18 have been listed in the South African Red Data Book (Siegfried *et al*, 1976) as being endangered (Appendix IX).

The only birds observed in the Piesang estuary from 22 to 29 April 1979 were two Pied Kingfishers, four Cape Wagtails and 140 Black Backed Gulls (Grindley, 1980, unpublished).

4.2.7 Mammals

Stuart *et al.* (1980) and Stuart (1981) recorded the mammal species occurring in the area surrounding the estuaries while J Breytenbach (Directorate of Forestry, *in litt.*) compiled a list of species occurring in the Outeniqua Mountains which can be taken as being representative for the Keurbooms catchment (Appendix X).

5. SYNTHESIS

KEURBOOMS/BITOU

The Keurbooms/Bitou Estuary is relatively undeveloped at present but a number of proposed or potential developments pose a real threat to its unspoiled character and to its function as a natural system. The long-term effects of the need to supply Plettenberg Bay town with additional water is probably the most serious of these. The summer influx of visitors coincides with the period of lowest rainfall; thus water resources are stretched to the limit. If development continues at the present rate new sources of water will have to be found. Water is presently pumped from the confluence of the Palmiet and Keurbooms rivers to a small storage reservoir in Plettenberg Bay. Short-term, palliative measures that have been considered include the construction of small inline reservoirs along the 20 km pipeline to Plettenberg Bay in order to smooth peaks in demand or to build a dam in the upper catchment of the Piesang River. However, these measures, at best, will only serve to postpone the inevitable demand to construct a major storage dam on the Keurbooms River. A major dam on the Keurbooms River could have serious consequences for the biota of the river and estuary unless it is managed in such a way that adequate water is released for the continued survival of the organisms dependent upon the estuary. Furthermore, dam construction implies a decrease in freshwater inflow into the estuary. This could lead to further marine sediment incursion into the estuary caused by the buffering effect of the dam against natural floods and the resulting absence of scouring (see Section 3.2.1). The main effect of dam construction would be, however, that the cyclic migration of the mouth would cease. If a dam is built, provision should be made in the freshwater release policy for a flush release(s) to breach the spit at the north-east end.

The proposed development of a time-share village on the northern portion of the Anath Peninsula between the Keurbooms and Bitou rivers is likely to contribute to the progressive alteration of the character of the upper estuary. The land earmarked for this development is presently zoned for recreation in the Guide Plan. The proposed development, which despite careful and sensitive design, is effectively a small township and as such, violates both the spirit and intent of the Guide Plan. Unfortunately a serious omission from the Guide Plan is a formal definition of the term "Recreation". The authors of the present report interpret "Recreation" to mean low-key development including open space, camping and caravan sites with the minimum of fixed structures. Furthermore if the Anath development is permitted other land surrounding the Keurbooms and Bitou estuaries may be placed at risk through the precedent created. Land use in the vicinity of South African estuaries urgently requires re-evaluation since the demand for access by the public is bound to increase. In the light of this, developments for exclusive use by few people for a limited period each year should be prevented, particularly if such development also leads to irreversable alteration of the natural environment.

The National Road (N2) bridges across the Keurbooms Estuary are currently being widened as part of the general upgrading of the Garden Route. The additional carriageway is being constructed using a system of temporary pilings which should have little effect on river flow. It is hoped that the upgraded road will avert the need to construct the proposed route across Keurbooms and Bitou estuaries about 1,5 km downstream from the present bridges. This proposed alignment would be an aesthetic disaster, a gross intrusion upon the estuary and surroundings, and irrevocably alter the character of the area. Any proposal to construct this proposed alignment must be accompanied by a full Environmental Impact Assessment. This should be conducted by a panel of experts in order to examine the implications of the proposed alignment in the broadest context possible.

The motor boat population in the Keurbooms River Nature Reserve is controlled by a permit system under the authority of the Cape Department of Nature and Environmental Conservation. This should be extended to include the entire Keurbooms/Bitou estuarine system. Furthermore no moorings other than those already in existence should be permitted. In view of the already crowded conditions that occur on the estuary in summer it is essential that the maximum water surface area is available for recreation activities rather than for the mooring of little-used boats. Adequate launching and dry storage facilities should be made available in preference to moorings and marinas.

Sewage disposal is already a problem in the Plettenberg Bay area mainly as a result of the extreme, seasonal population fluctuations. The discharge from the sewage treatment plant into the Gansvlei Stream seldom meets the General Standard (Section 3.2.6) and has led to the eutrophication (by "luxury" amounts of phosphate) of the stream above Gansvlei (H W Geldenhuys, Town Engineer, Plettenberg Bay, pers comm.). The Gansvlei wetland reduces the level of nutrients before final discharge into the Bitou River thus lowering the impact on the river. The main sewer linking Plettenberg Bay town to the sewage works is forced by topography to run along the blind lagoon portion of the Keurbooms Estuary. As a result there is the everpresent threat of the accidental discharge of raw sewage into one of the biologically richest portions of the entire Keurbooms system. However, this risk should be reduced in the future since the developers of the Robberg township will be required to install a sewer connecting the township with the sewage works via the Piesang valley (H W Geldenhuys, pers. comm.). The sewer will also serve the Piesang Valley thereby reducing the load on the existing pipe. Ultimately the whole Plettenberg Bay - Keurboomsstrand region will have to be reticulated for sewage and served by a major regional sewage works. This proposition is currently being assessed by a firm of consulting engineers.

The management of the highly dynamic mouth of the Keurbooms Estuary is a subject of controversy. Presently the mouth appears to be moving towards the southwest, that is, towards Lookout Rocks. In fact since the ECRU survey in March 1984 the migration of the mouth has led to the complete destruction of the wooden footbridge connecting the caravan park with the Lookout Beach spit. However, evidence obtained from the study of aerial photos clearly shows that the direction of migration of the mouth fluctuates continuously and that this is a natural feature (see Section 3.2.1). It is extremely doubtful whether the enormous natural forces leading to this migration can be successfully controlled and, if so, the cost would be enormous. For this reason the suggestion by Reddering (1983) that the mouth of the estuary should be "fixed" by means of a concrete berm or similar structure cannot be supported. A more realistic approach is to accept the dynamic nature of the mouth, to allow it to migrate back and forth in response to river flow and sea conditions and to adjust development accordingly.

The low-lying area at the base of the northern sand spit should be seen as a natural weak spot which could act as a "safety valve" during extreme floods by allowing the system to open to the sea and should, therefore, be retained as such. However, to prevent sediment movement into the estuary due to wind and high tidal (wash-over) action, other gaps in the barrier west of this weak spot on the same sand spit should be consolidated. The establishment of good vegetation cover here should be expedited and once established, should be protected from unnecessary trampling or destruction by off-road vehicles. The entire sand spit between Look-out Rocks and the high dune at the northern side of the estuary must be seen as a dynamic system. Consequently there should be no attempt to fix the estuary mouth.

PIESANG

The Piesang River catchment is small and has to a great extent been modified by human activities such as farming, recreation (golf course) and residential development. Some riparian owners, notably the Plettenberg Bay Golf Club, draw water from the river. As mentioned above there is the possibility that a storage dam will be built on the river. This dam is not intended to store water from the river itself but rather to hold water pumped from the Keurbooms (H W Geldenhuys, pers. comm.). The lower reaches of the Piesang River are hemmed in by development but despite this the estuary is full of life: a D-net haul in the *Phragmites* lined section about 2 km from the sea yielded several hundred barbel which appear to use the estuary as a nursery. Rubble remaining from construction is present under the road bridge and partially impedes flow. This rubble should be removed to improve flow. During the ECRU field survey in March 1984 a reddish-brown floc was noted in the Piesang River extending downstream from a point approximately 200 m upstream of the road bridge. Mr A Solomon (a resident of Plettenberg Bay) who owns a property on the river stated that the backwash from the municipal water filtration plant is discharged into a stream which enters the river at this point. Thus it seems probable that the floc forms when the organic compounds present in the effluent water from the filtration plant come into contact with the saline estuarine water.

Although terrestrial sedimentation in the estuary is not serious, artificial encroachments into the estuary could impede river run-off during spates. Extensive infilling has been undertaken on the southern river bank at the caravan park. This reduces the area of the natural flood plain and thus decreases the capacity of this plain to absorb floods. The same principle applies to the parking area on parts of the northern sand bar. An aerial photograph from 1980 shows the mouth open along Beacon Island's landward face, but also another blind channel penetrating the sand bar at its northern side, at a location where the parking site is at present. This blind channel has, in the past, provided an additional discharge route from the estuary during river floods. The car park, which now obstructs the channel, requires constant maintenance since any flood tends to erode the wall bordering the river. Since floods have reportedly become more serious during recent years these disturbances can lead to impeded storm water discharge and can contribute to adverse consequences such as the danger of inundation of the narrow upper Piesang Valley.

The Keurbooms, Bitou and Piesang rivers enter the sea in Plettenberg Bay which is a premier coastal holiday resort in the Cape Province. The region is characterized by extreme seasonal population fluctuations, inflated property prices and a relentless demand for the development of seaside accommodation. These severe pressures are concentrated in an area of great natural beauty which consists of sensitive terrestrial, estuarine and marine environments. Consequently, great care must be taken when considering any further development of this region lest the very character which attracts people to the area, is destroyed.

EDITOR'S FOOTNOTE:

The present report highlights a number of points relevant to coastal zone management in South Africa in general:

(i) If the carrying capacity of a coastal town or village and of its surrounding natural features is overstepped, overcrowding is inevitable and this quickly leads to a drop-off in visitors and tourists. The economic implications are severe and there is much concern about this in Plettenberg Bay where some shopkeepers claim that a decline in visitors during peak holiday periods is already clearly evident.

(ii) Water supply is a natural limiting factor which should be accepted. There is a very real danger that the building of a dam on the Keurbooms River will be of permanent ecological and aesthetic detriment to the entire Keurbooms/ Bitou estuarine system. The misgivings about this matter expressed by the authors of the present report must be taken very seriously.

(iii) Besides its estuaries, Plettenberg Bay's beaches and dunes are natural features of great attraction to visitors. Yet large-scale cluster housing development is taking place on the frontal dune ridge to the west of Beacon Island. This is aggravating already severe problems of dune destabilization through trampling and other forms of human interference. Cluster housing developments on the dunes and elsewhere will certainly contribute to the problems of overcrowding, water supply and sewage disposal.

Thus it appears that both the estuarine and the beach/dune environments of this beautiful area are threatened by progressive degradation. The long overdue move by the Plettenberg Bay Town Council to appoint an overall planner is therefore welcomed. It is hoped that his brief encompasses the entire area between Robberg and the Matjies River to the east of Keurbooms. If the town itself has become the focus of over-intensive development, maintenance of the conservation status and ecological viability of its surrounding beaches, dunes, estuaries and catchments, becomes a matter of paramount importance.

A E F HEYDORN

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8. GLOSSARY OF TERMS USED IN PART II REPORTS

ABIOTIC: non-living (characteristics).

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

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

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

ANAEROBIC: lacking or devoid of oxygen.

ANOXIC: the condition of not having enough oxygen.

AQUATIC: growing or living in or upon water.

ARCUATE: curved symmetrically like a bow.

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

BATHYMETRY: measurement of depth of a water body.

BENTHIC: bottom-living.

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

BIMODAL: having two peaks.

BIOGENIC: orginating from living organisms.

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

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

BIOTIC: living (characteristics).

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

CALCAREOUS: containing an appreciable proportion of calcium carbonate.

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

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

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

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

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

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

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

DETRITUS: organic debris from decomposing plants and animals.

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

DYNAMIC: relating to ongoing and natural change.

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

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

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

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

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

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

EPISODIC: sporadic and tending to be extreme.

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

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

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

FLUVIAL (deposits): originating from rivers.

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

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

GEOMORPHOLOGY: the study of land form or topography.

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

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

HALOPHYTES: plants which can tolerate saline conditions.

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

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

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

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

INDIGENOUS: belonging to the locality; not imported.

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

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

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

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

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

LIMPID: clear or transparent.

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

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

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

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

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

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

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

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

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

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

PATHOGENIC: disease producing.

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

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

PHYTOPLANKTON: plant component of plankton.

PISCIVOROUS: fish eating.

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

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

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

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

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

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

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

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

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

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

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

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

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

ZOOPLANKTON: animal component of plankton.

References:

DAY, J.H. (ed.)(1981). Estuarine ecology with particular reference to Southern Africa. Cape Town, A.A. Balkema.

SOUTH AFRICAN TIDE TABLES (1980). Retreat C.P. The Hydrographer. South African Navy.

APPENDIX I: Species composition and physical features of the vegetation mapping units identified at the Keurbooms River.

Mapping Unit	Area* (ha)	% of area studied	Cover (%)	Average height (m)
Saltmarshes	42,90	7,58	80	0,10
Fore Dune Vegetation	20,17	3,56	15	0,20
Secondary Dune Vegetation	7,25	1,28	50	1,50
Hind Dune Scrub	8,95	1,58	100	2,50
Fynbos	26,99	4,77	70	1,20
Alien Dominated Areas	76,15	13,46	100	5,00
Sand	54,42	9,26		
Water	192,07	33,95		
Recreation	44,89	7,93		
Agriculture	94,04	16,63		
Total	565,83			

* Estimated values

Symbols in brackets following each species name, represent Braun-Blanquet classes as follows:

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

Reed Swamps

Cladium mariscus (1); *Phragmites australis* (5)

Saltmarshes

Apium graveolens (1); *Chenolea diffusa* (+); *Juncus acutis* (1); *J. kraussii* (3); *Paspalum vaginatum* (3); *Phragmites australis* (1); *Samolus porosus* (1); *Sarcocornia natalensis* (1); *Stenotaphrum secundatum* (1); *Triglochin bulbosa* (2); *T. striata* (2)

Coastal Dune Vegetation

Fore dunes

Ammophila arenaria (1); *Arctotheca populifolia* (+); *Senecio elegans* (+); *Tetragonia decumbens* (+); *Trachyandra divaricata* (+)

Primary dune area

Acacia cyclops (2); *Cynanchum africanum* (1); *Metalasia muricata* (2); *Myrica cordifolia* (+); *Stoebe plumosa* (+)

APPENDIX I: (cont.)

Behind primary dune

Buddleia saligna (+); *Carpobrotus acinaciformis* (+); *C. edulis* (+); *Cussonia thyrsiflora* (1); *Cynauchum obtussifolium* (1); *Helichrysum crispum* (1); *Heteroptilis suffruticosa* (+); *Lycium afrum* (+); *Metalasia muricata* (+); *Passerina vulgaris* (+); *Restio eleocharis* (2); *Rhus crenata* (1); *R. glauca* (1); *Salvia aurea* (+); *Sideroxylon inerme* (+); *Solanum guineense* (+); *Tetragonia fruticosa* (+)

Riparian forest

Aloe arborescens (+); *Apodites dimidiata* (1); *Buddleia saligna* (+); *Carissa bispinosa* (1); *C. macrocarpa* (1); *Cassine crocea* (+); *C. peragua* (1); *C. tetragona* (2); *Chionanthus foveolata* (1); *Chrysanthemoides monilifera* (+); *Cipparis sepiaria* (2); *Cussonia thyrsiflora* (1); *Grewia occidentalis* (+); *Maytenus heterophylla* (1); *Nuxia floribunda* (1) *Leonotus leonurus* (r); *Metalasia muricata* (1); *Passerina vulgaris* (+); *Podalyria calyptrata* (1); *Rhus crenata* (2); *R. laevigata* (1); *Salvia aurea* (1); *Sideroxylon inerme* (+); *Stoebe vulgaris* (1)

Fynbos

Anthospermum aethiopicum (1); *Bulbostylis humulis* (+); *Carpobrotus acinaciformis* (+); *Chironia baccifera* (+); *Chrysocoma tenuifolia* (+); *Digitaria setifolio* (1); *Eragrostis curvula* (+); *Erica peltata* (2); *Helichrysum teretifolium* (1); - *Pentachistus* sp (1); *Stoebe plumosa* (1); *Thamnochortus glaber* (+); *Ursinia dentata* (1)

APPENDIX II: Species composition and physical features of the vegetation mapping units identified at the Piesang River.

Mapping Unit	Area* (ha)	% of area studied	Cover (%)	Average height (m)
Reed Swamps and Marshes	3,14	2,26	90	2,00
Coastal Dune Vegetation	2,91	2,09	20	1,00
Riparian Scrub Forest	24,81	17,86	100	5,00
Sand	5,94	4,27		
Water	8,50	6,12		
Rocks	0,82	0,59		
Developed Areas	80,60	58,01		
Agricultural Areas	12,23	8,80		
Total	138,95			

* Estimated values

Symbols in brackets following each species name, represent Braun-Blanquet classes as follows:

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

APPENDIX II: (cont.)

Saltmarshes

Chenolea diffusia (3); *Cotula coronopifolia* (2); *Drosanthemum* sp (+); *Juncellus* laevigatus *(+);* Juncus kraussii *(3);* Limonium scabrum *(1);* Plantago carnosa *(+);* Poeciolepis ficoidea *(1);* Salicornia uniflora *(+);* Samolus porosus *(+); Sarcocornia decumbens* (3); *S. perennis* (+); *S. pillansiae* (+); *Sporobolus virginicus* (2); *Sueda caespitosa* (+); *Triglochin bulbosa* (+); *T. striata* (1)

Fore Dune Pioneers

Arctotheca populifolia (2); *Agropyron distichum* (1); *Ammophila arenaria* (2); Heteroptilis suffruticosa *(+);* Ipomea pes-caprae *(+);* Scaevola thunbergii *(1); Senecio elegans* (+); *Tetragonia decumbens* (1)

Secondary Dune Scrub

Acacia cyclops (+); *Carpobrotus acinaciformus* (1); *Chrysanthemoides monilifera* (3); *Cliffortia ilicifolia* (+); *Cynanchum obtusifolium* (+); *Ficinia lateralis* (1); *Gazania rigens* (1); *Gladiolus* sp (+); *Metalasia muricata* (2); *Myrica cordifolia* (1); *Olea exasperata* (+); *Passerina rigida* (+); *P. vulgaris* (+); *Restio eleocharis* (2); *Senecio elegans* (+); *Sporobolus virginicus* (2); *Stenotaphrum secundatum* (+)

Hind Dune Scrub

Acacia cyclops (1); *Aloe arborescens* (+); *Amaranthus hybridus* (+); *Asparagus* sp (+); *Buddleia saligna* (+); *Carpobrotus edulis* (+); *Chrysanthemoides monilifera* (+); *Cliffortia serpyllifolia* (+); *Cynanchum obtusifolium* (1); *Ehrharta villosa* (1); *Grewia occidentalis* (+); *Olea capensis* (2); *Pteracelastrus tricuspidatus* (2); *Rapanea melanophleos* (2); *Rhoicissus digitata* (2); *Rhus glauca* (+); *Rhus lucida* (1); *Salvia aurea* (+); *Scutia myrtina* (1); *Senecio angularis* (2); *Sideroxylon inerme* (+); *Tarchonanthus camphoratus* (1); *Trichocladus crinatus* (1); *Trimeria grandiflora* (+)

APPENDIX III: Zooplankton taxa recorded in the Keurbooms and Piesang estuaries (Grindley, unpublished)

Taxa	Keurbooms	Piesang
Zoea larvae	*	*
Ostracoda	*	*
Isopoda		*
Lamellibranch larvae		*
Pseudodiaptomus hessei	*	*
Harpacticoid copepods	*	*
Foraminifera	*	
Hydroid medusae	*	
Nematodes	*	
Polychaetes	*	
Acartia natalensis	*	
Centropages brachiatus	*	
Corycaeus africana	*	
Labidocera sp.	*	
Oithona nana	*	
Oncea mediterranea	*	
Paracalonus aculeatus	*	
Nauplius larvae	*	
Gastrosaccus brevifissura	*	

APPENDIX III: (cont.)

Taxa	Keurbooms	Piesang
Mesodopsis africana	*	
Cirolana sp.	*	
Austrochiltonia subtenuis	*	
Caprella sp.	*	
Grandidierella bonnieroides	*	
Crab megalopa larvae		*
Amphipoda		*
Palaemon pacificus	*	*
Medusae		*
Gastropod larvae	*	*
Decapod larvae		*
Polychaete larvae	*	*
Paracalanus parvus		*
Cirripede nauplii	*	*
Oithona brevicornis	*	*
Mesopodopsis slabberi		*
Cypris larvae	*	*
Acartia longipatella	*	*
Corophium sp.	*	*
Harpacticus sp.	*	*
Tegastes sp.	*	*
Fish larvae		*
Chironomid larvae	*	
Dipteran larvae	*	
Dipteran pupa	*	
Dipteran adults	*	
Acarina	*	
Bivalve larvae	*	
Fish eggs	*	

APPENDIX IV: Macroinvertebrate taxa recorded in the Keurbooms Estuary. Records from ECRU survey and Day (unpublished)

Cnidaria: Hydrozoa
Hydractinea kaffraria

Nemertea
Gorgonorhynchus sp.

Annelida: Polychaeta
Arenicola loveni
Ceratonereis erythraeensis
Lumbrinerus tetraura
Pomatoleios kraussii
Perinereis cultrifera
P. nuntia vallata

Arthropoda: Crustacea
Cirripedia
Balanus amphitrite amphitrite

Malacostraca: Pericarida
Isopoda
Exosphaeroma sp.
Paridotea ungulata
Ligia dilatata

Cleistostoma edwardsii
C. algoense
Cyclograpsus punctatus
Scylla serrata
Sesarma catenata
Thaumastoplax spiralis

Mollusca: Pelecypoda
Loripes clausus
Solen capensis
Dosinia hepatica
Psammotelina capensis
Perna perna
Macoma sp.
Saxicava sp.
Ostrea algoensis

Gastropoda
Natica tecta Anton
Nassarius kraussianus
Turritella capensis
Notarchus leachi
Assiminea globulus
Siphonaria capensis

APPENDIX IV: (cont.)

Malacostraca: Eucarida
Decapoda
Palaemon pacificus
Pennaeus japonicus
P. semisulcatus
Diogenes brevirostris
Callianassa kraussi
Upogebia africana
Hymenosoma orbiculare

S. deflexa
Littorina knysnaensis
Teredo sp.

APPENDIX V: Insect species associated with the Keurbooms River (Harrison and Agnew, 1962).

Emphemeroptera	Baetidae
	Baetis harrisoni
	Centroptilum sudafricanum
	Pseudocloeon maculosum
	Leptophlebiidae
	Adenophlebia peringueyella
Trichoptera	Hydropsychidae
	Cheumatopsyche afra
	Hydroptiliae
	Hydroptila sp.
Diptera	Simuliidae
	Simulium larvae
	Chironomidae
Coleoptera	Elmidae

APPENDIX VI: Marine and estuarine fish species in the Keurbooms Estuary

SPECIES	COMMON NAME	J Day (unpublished)	J L B Smith Institute
Pomadasys commersoni	Spotted Grunter	*	
Pomatomus saltatrix	Elf	*	*
Lichia amia	Leervis	*	
Diplodus sargus	Blacktail	*	
Diplodus cervinus hottentotus	Zebra	*	
Elops machnata	Tenpounder	*	
Clinus superciliosus	Super Klipfish	*	
Hepsetia breviceps	Cape Silverside	*	
Psammogobius knysnaensis	Knysna Sandgoby	*	*
Rhabdosargus globiceps	White Stumpnose	*	
Trachinocephalus myops	Painted Lizardfish		*
Stromateus fiatola	Blue Butterfish		*
Priacanthus hamrur	Crescent-tail Bigeye		*
Gonorynchus gonorynchus	Beaked Sandfish		*
Arnoglossus capensis	Cape Flounder		*
Solea bleekeri	Blackhand Sole		*
Monodactylus falciformis	Cape Moony		*
Caffrogobius multifasciatus	Prison Goby		*

APPENDIX VI: (cont.)

SPECIES	COMMON NAME	J Day (unpublished)	J L B Smith Institute
Argyrosomus hololepidotus	Kob		*
Rhinoptera javanica	Flapnose Ray		*
Mugil cephalus	Flathead Mullet		*
Syngnathus acus	Longnose Pipefish		*
Hippocampus kuda	Yellow Seahorse		*
Caffrogobius caffer	Banded Goby	*	
Umbrina canariensis	Baardman		*
Caffrogobius nudiceps	Barehead Goby		*
Kyphosus bigibbus	Grey Chub		*
Heteromycteris capensis	Cape Sole		*

APPENDIX VII Reptiles and Amphibians associated with the Keurbooms/Bitou and Piesang estuaries.
(L = likely to occur, X = recorded)

		1:50 000 topographic map Quarter degree square 3323CD	3423AB	REFERENCE
FROGS				
Xenopus laevis	Common platanna	L	L	
Heleophryne regis	Southern Cape ghost frog	X	/	Boycott (1982)
Bufo rangeri	Raucous toad	L	L	
Breviceps fuscus	Plain rain frog	L	L	
Tomopterna delalandii	Cape sand frog	L	L	
Rana angolensis	Common river frog	L	L	
Rana fuscigula	Cape rana	L	L	
Rana fasciata	Striped grass frog	X	L	Greig, Boycott, De Villiers (1979)
Rana grayii	Spotted rana	L	L	
Cacosternum boettgeri	Common caco	L	L	
Cacosternum nanum	Bronze caco	L	L	
Kassina wealii	Rattling kassina	L	L	
Afrixalus brachycnemis knysnae	Golden leaf-folding frog	L	L	
Hyperolius horstockii	Arum lily frog	L	L	
SNAKES				
Typhlops lalandei	Pink earth snake	L	L	
Leptotyphlops nigricans	Black worm snake	L	L	
Lycodonomorphus rufulus	Brown water snake	X	L	Broadley (1983)
Lamprophis aurora	Aurora house snake	L	L	
Lamprophis inornatus	Olive house snake	L	L	
Lamprophis fuliginosus	Brown house snake	L	L	
Lycophidion c. capense	Cape wolf snake	L	L	
Duberria lutrix	Southern slug-eater	L	L	
Pseudaspis cana	Mole snake	L	L	
Amplorhinus multimaculatus	Cape many-spotted snake	L	L	

APPENDIX VII: (cont.)

		1:50 000 topographic map Quarter degree square 3323CD	3423AB	REFERENCE
Psammophylax rhombeatus	Spotted skaapsteker	L	L	
Psammophis notostictus	Whip snake	L	L	
Psammophis crucifer	Cross-marked sand snake	L	L	
Homoroselaps lacteus	Spotted dwarf garter snake	L	L	
Prosymna s. sundevallii	Southern shovel-snout	L	L	
Philothamnus hoplogaster	South-eastern green snake	L	L	
Philothamnus natalensis occidentalis	Western Natal green snake	L	L	
Crotaphopeltis hotamboeia	Herald snake	L	L	
Dispholidus typus	Boomslang	L	L	
Dasypeltis scabra	Common egg-eating snake	L	L	
Hemachatus haemachatus	Rinkals	L	L	
Aspidelaps lubricus	Coral snake	L	L	
Naja nivea	Cape cobra	L	L	
Pelamis platurus	Yellow-bellied sea snake	/	L	
Causus rhombeatus	Rhombic night adder	L	L	
Bitis atropos	Cape mountain adder	L	X	Broadley (1983)
Bitis arietans	Puff adder	L	L	

TORTOISES/TERRAPIN

Geochelone pardalis	Mountain tortoise	L	L
Chersina angulata	Angulate tortoise	L	L
Homopus areolatus	Padloper tortoise	L	L
Pelomedusa subrufa	Water tortoise	L	L

APPENDIX VIII: Counts of waders (Charadrii) and other birds at non-coastal localities near Plettenberg Bay. (Western Cape Wader Study Group).

LOCALITY	34 Piesang River	37 Plettenberg Bay Sewage Works	38 Keurbooms River	39 Bitou River
DATE	79-01-02	79-01-07	79-01-02	79-01-02
TIME	15h00	15h00-16h00	15h00-19h00	15h00-18h00
TIDE	-	-	Flood	-
TYPE	Lagoon	Sewage works	Estuary	Flood plain
Black Oystercatcher			11	
Turnstone			20	
Ringed Plover	1		50	26
White-fronted Plover			34	
Kittlitz's Plover				3
Three-banded Plover		5		10

APPENDIX VIII: (cont.)

LOCALITY	34 Piesang River	37 Plettenberg Bay Sewage Works	38 Keurbooms River	39 Bitou River
DATE	79-01-02	79-01-07	79-01-02	79-01-02
TIME	15h00	15h00-16h00	15h00-19h00	15h00-18h00
TIDE	-	-	Flood	-
TYPE	Lagoon	Sewage works	Estuary	Flood plain
Grey Plover			97	8
Crowned Plover	2			
Blacksmith Plover		2	3	5
Ethiopian Snipe				2
Curlew Sandpiper		42	264	9
Little Stint		13		279
Knot			23	
Sanderling			24	
Ruff		5		382
Common Sandpiper		4	9	6
Marsh Sandpiper				9
Greenshank	1	10	47	22
Wood Sandpiper		19		4
Curlew			4	
Whimbrel			111	6
Avocet		2		
Stilt		32		55
Water Dikkop			6	
Cape Dikkop			8	
Unidentified Waders			65	
TOTAL PALAEARCTIC WADERS	2	93	714	751
TOTAL WADERS	4	134	776	826
Dabchick		15		14
White-breasted Cormorant			7	1
Cape Cormorant			3	
Reed Cormorant			55	20
Darter			2	2
Grey Heron	1	1	5	8
Black-necked Heron			4	16
Purple Heron			2	
Great White Heron			4	
Little Egret	1		13	10
Cattle Egret			112	25
Hadeda				7
Egyptian Goose		5		3
South African Shelduck				9
Cape Shoveler				72
Black Duck				1
Yellow-billed Duck		1	103	249
Red-bill Teal		30		4
Cape Teal				2
Red-Eyed Pochard		8	15	
Black-shouldered Kite				2
African Marsh Harrier				2

APPENDIX VIII: (cont.)

LOCALITY	34 Piesang River	37 Plettenberg Bay Sewage Works	38 Keurbooms River	39 Bitou River
DATE	79-01-02	79-01-07	79-01-02	79-01-02
TIME	15h00	15h00-16h00	15h00-19h00	15h00-18h00
TIDE	-	-	Flood	-
TYPE	Lagoon	Sewage works	Estuary	Flood plain
Purple Gallinule			2	
Moorhen				13
Red-knobbed Coot				55
Kelp Gull	14	4	297	28
Caspian Tern			2	
Common/Arctic Tern			20	
Sandwich Tern			37	
Swift Tern			16	
White-winged Black Tern				2
Pied Kingfisher	1		17	9
Giant Kingfisher				1
Cape Wagtail		5	12	16
TOTAL NON-WADERS	17	69	1 228	571
GRAND TOTAL	21	203	2 004	1 397

APPENDIX IX: Endangered bird species in the Plettenberg Bay area. (The Potential of Plettenberg Bay for Nature Conservation, 1982).

Coastal Birds:
- Fish Eagle
- Jackass Penguin
- Black Stork
- Greater Flamingo
- Caspian Tern
- Pink-backed Pelican
- Lesser Flamingo

Forest Birds:
- Cuckoo Falcon
- Mountain Buzzard

Fynbos birds:
- Booted Eagle
- Martial Eagle
- Crowned Eagle

Endemic birds:
- Knysna Scrub Warbler
- Victorin's Scrub Warbler
- Cape Vulture
- Peregrine

Birds in disturbed areas:
- White Stork
- Hobby

APPENDIX X: Mammal species recorded by Stuart *et al.* (1980) and Stuart (1981) (33° 45′ - 34° 15′S, 23° 15′ - 23° 30′E) in combination with a list of species occurring in the Outeniqua Mountains (Breytenbach, *in litt.*).

Species	Common Name	Stuart	Breytenbach
Epomophorus wahlbergi	Epauletted fruit bat	x	
Rousettus aegyptiacus	Cape fruit bat	x	
Chlorotalpa duthiae	Duthies golden mole	x	

APPENDIX X: (cont.)

Species	Common Name	Stuart	Breytenbach
Papio ursinus	Chacma baboon	x	x
Hystrix africaeaustralis	Cape porcupine	x	x
Cercopithecus aethiops	Vervet monkey	x	
Procavia capensis	Cape dassie	x	x
Potamochoerus porcus	Bushpig	x	
Tragelaphus scriptus	Bushbuck	x	
Otomys irroratus	Vlei rat	x	x
Rhabdomys pumilio	Striped mouse	x	
Mus minutoides	Pygmy mouse	x	
Praomys natalensis	Multimammate rat	x	
Aonyx capensis	Cape clawless otter	x	x
Panthera pardus	Leopard	x	x
Ictonyx striatus	Striped polecat	x	x
Genetta tigrina	Large-spotted genet	x	x
Herpestes ichneumon	Egyptian mongoose	x	
Felis caracal	Caracal	x	x
Herpestes pulverulentus	Cape grey mongoose	x	x
Acomys subspinosus	Cape spiny mouse		x
Aethomys namaquensis	Namaqua rock rat		x
Crocidura flavescens	Red musk shrew		x
Cryptomys hottentotus	Common mole rat		x
Elephantulus edwardi	Cape elephant shrew		x
Eptesicus capensis	Cape serotine		x
Georychus capensis	Cape mole rat		x
Graphiurus platyops	Rock dormouse		x
Miniopterus schreibersi	Schreiber's longfingered bat		x
Myosorex longicaudatus	Long-toed forest shrew		x
Myosorex varius	Forest shrew		x
Praomys verreauxii	Verreaux's rat		x
Rattus rattus	Black rat		x
Rhinolophis clivosus	Geoffreoy's Horshoe bat		x
Otomys laminatus	Laminate vlei rat		x
Lepus saxatilis	Scrub hare		x
Pronolagus crassicaudatus	Red rock hare		x
Felis libyca	African wild cat		x
Felis serval	Serval		x
Mellivora capensis	Honey badger		x
Atilax paludinosus	Marsh mongoose		x
Otocyon megalotis	Bat-eared fox		x
Proteles cristatus	Aardwolf		x
Canis mesomelas	Black-backed jackal		x
Orycteropus afer	Aardvark		x
Sylvicapra grimmia	Grimm's duiker		x
Oreotragus oreotragus	Klipspringer		x
Raphicerus capestris	Steenbok		x
Raphicerus melanotis	Cape grysbok		x
Pelea capreolus	Vaal rhebuck		x

APPENDIX XI: Guide to available information

ESTUARY / RIVERMOUTH / LAGOON: KEURBOOMS/BITOU AND PIESANG

Guide to available information			Barry	Beekman	Boycott	Bremner	Broadley	Cape Provincial Administration	Clark	Day	Day	Drews and van Vuuren	Edington and Edington	Evison and Tosti	Fromme	Greig *et al*	Greig and Burdett	Grindley	Harrison and Agnew	Heydorn and Tinley
YEAR (DATE OF INFORMATION)			1968	1983	1982	1983	1983	1973	1959	1981	1974	1981	1977	1980	1985	1979	1976	1980	1962	1980
MANAGEMENT		Historical							*											
MANAGEMENT		Conservation/Utilization	*					*												*
MANAGEMENT		Management/Planning	*					*				*								*
MANAGEMENT		Legislation																		
MANAGEMENT		Water										*								
BIOTIC		Food webs/Ecosystems																		
BIOTIC	Fauna	Mammals																		
BIOTIC	Fauna	Birds																		
BIOTIC	Fauna	Reptiles					*										*			
BIOTIC	Fauna	Amphibians			*											*				
BIOTIC	Fauna	Fish																		
BIOTIC	Fauna	Molluscs																	*	
BIOTIC	Fauna	Crustaceans																	*	
BIOTIC	Fauna	Other aquatic invertebrates																	*	
BIOTIC	Fauna	Terrestrial invertebrates																		
BIOTIC	Fauna	Zooplankton																*		
BIOTIC	Flora	Terrestrial vegetation																		
BIOTIC	Flora	Semi-aquatic vegetation																		
BIOTIC	Flora	Aquatic vegetation																		
BIOTIC	Flora	Algae																		
BIOTIC	Flora	Phytoplankton																		
BIOTIC		Microbiology		*								*	*	*						
ABIOTIC	Chemistry	Pollution																		
ABIOTIC	Chemistry	Eutrophication																		
ABIOTIC	Chemistry	General Chemistry								*	*							*		
ABIOTIC		Salinity																		
ABIOTIC	Physics	Circulation and mixing																		
ABIOTIC	Physics	Hydrology / Flood regime																		
ABIOTIC	Physics	Oceanography																		
ABIOTIC	Physics	Climate																		
ABIOTIC	Geology	Sedimentology				*									*					
ABIOTIC	Geology	Palaeoenvironment							*						*					
ABIOTIC	Geology	Geology																		
ABIOTIC	Physiography	Morphology				*									*					
ABIOTIC	Physiography	Dams/Obstructions																		
ABIOTIC	Physiography	Catchment characteristics																		

Sources of information

APPENDIX XI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: KEURBOOMS/BITOU AND PIESANG

Guide to available information

		Sources of information	Hill	Keurbooms-en Bitou Rivierbrûe	King	Le Roi le Riche and Hey	Livingston	Midgley and Pitman	Ninham Shand and Partners	Noble and Hemens	Palmer and Pitman	The Potential of Plettenberg Bay	Poynton	Reddering	Reddering and Esterhuyse	River Flow Data	Schulze	Siegfried *et al*	South Africa	Storrar
YEAR (DATE OF INFORMATION)			1967	1975	1963	1947	1982	1969	1967	1978	1972	1982	1964	1981	1983	1978	1965	1976	1983	1982
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																		
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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 XI: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON: KEURBOOMS/BITOU AND PIESANG

Guide to available information

			Stuart	Stuart *et al*	Toerien	Tyson	Underhill *et al*	Wallace and van der Elst	Water Quality Criteria	Watling and Watling	Watling and Watling	Western Cape Wader Study Group
MANAGEMENT		Historical										
		Conservation/Utilization										
		Management/Planning										
		Legislation										
		Water										
BIOTIC		Food webs/Ecosystems										
	Fauna	Mammals	*	*								
		Birds					*					*
		Reptiles										
		Amphibians										
		Fish						*				
		Molluscs										
		Crustaceans										
		Other aquatic invertebrates										
		Terrestrial invertebrates										
		Zooplankton										
	Flora	Terrestrial vegetation										
		Semi-aquatic vegetation										
		Aquatic vegetation										
		Algae										
		Phytoplankton										
		Microbiology							*			
ABIOTIC	Chemistry	Pollution								*	*	
		Eutrophication										
		General Chemistry								*	*	
		Salinity										
	Physics	Circulation and mixing										
		Hydrology / Flood regime										
		Oceanography										
		Climate										
	Geology	Sedimentology										
		Palaeoenvironment										
		Geology			*							
	Physiography	Morphology				*						
		Dams/Obstructions										
		Catchment characteristics				*						
YEAR (DATE OF INFORMATION)			1981	1980	1976	1971	1980	1975	1984	1979	1980	1979

Sources of information

PLATE I:

Piesang Estuary and Beacon Island from an altitude of 150 m (ECRU: 79-10-17).

PLATE II:

The lower reaches of the Keurbooms Estuary at low tide (ECRU: 84-03-08).

PLATE III:

Blind western end of Keurbooms lagoon from an altitude of 450 m (ECRU: 79-10-16).