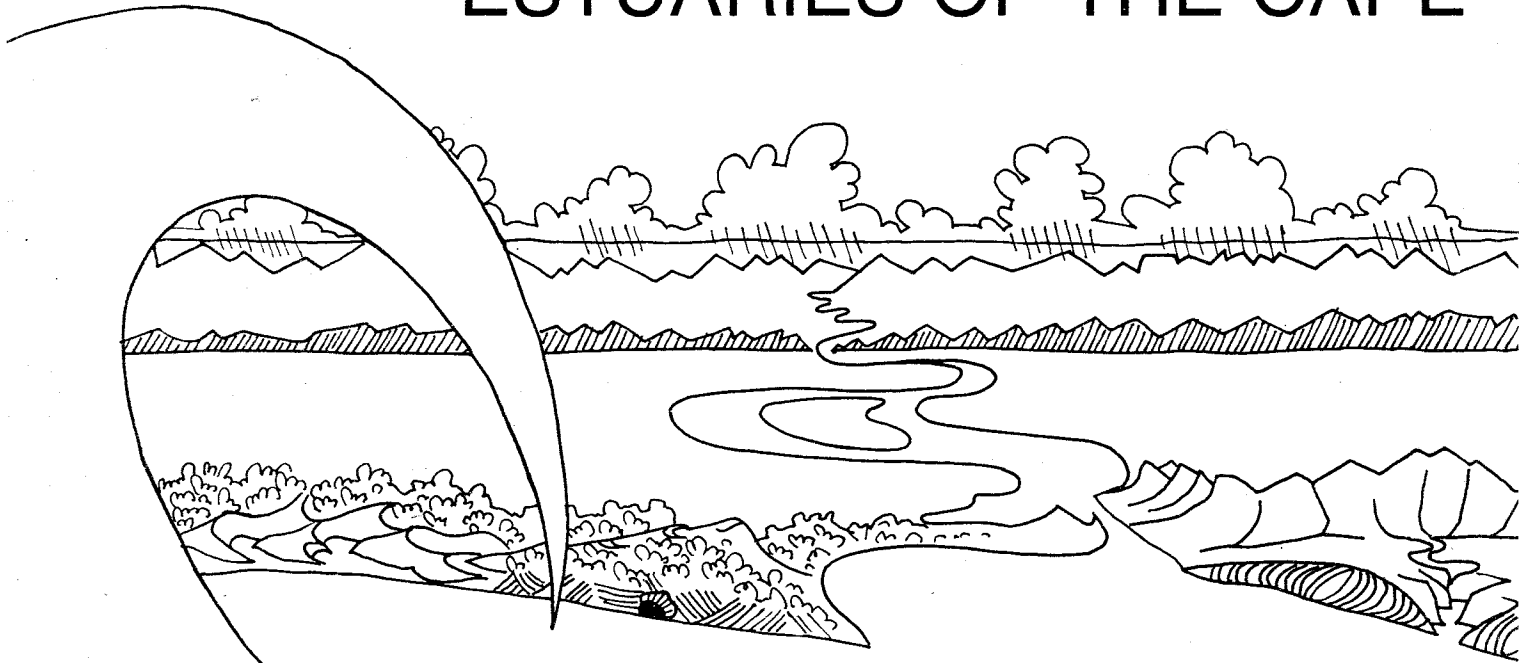


COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY
ESTUARINE AND COASTAL RESEARCH UNIT – ECRU



ESTUARIES OF THE CAPE



PART II

SYNOPSIS OF AVAILABLE INFORMATION
ON INDIVIDUAL SYSTEMS

EDITORS: A E F HEYDORN
J R GRINDLEY

REPORT NO. 10

KOWIE (CSE10)

ESTUARIES OF THE CAPE

PART II: SYNOPSES OF AVAILABLE INFORMATION ON INDIVIDUAL SYSTEMS

REPORT NO. 10: KOWIE (CSE10)

(CSE10 — CSIR Estuary Index Number)



FRONTISPIECE: KOWIE ESTUARY — ALT. 150 m, ECRU 79-10-17

COMPILED BY: T J E HEINECKEN AND
J R GRINDLEY

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PREFACE

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

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

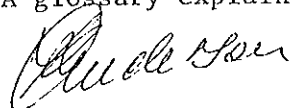
The Unit was established at the request of the Government, and the Department of Environment Affairs contributes substantially to the running costs.

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

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

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

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



FP Anderson
DIRECTOR

National Research Institute for Oceanology
CSIR

*CSIR Research Report 380

KOWIE

1. HISTORICAL BACKGROUND

A detailed account of the history of the Kowie estuary and the attempts to develop a harbour at the mouth of the river are given in the "Basket Work Harbour". (Turpin, 1964).

As far as could be ascertained, the river has always been known as the Kowie River. The settlement established at the mouth of the river in 1821 was originally called Port Kowie. This was changed to Port Frances in 1825 in honour of the wife of Colonel Henry Somerset who was then in charge of the military forces on the Eastern Frontier. In 1860 the name of the town was changed once again, to Port Alfred to honour Prince Alfred, Duke of Edinburgh who was visiting the Frontier at that time.

When the settlement was first established at the mouth of the river, the estuary "consisted of one vast swampy region bounded on the east and west by the hills today known as the East and West Banks. When the tide receded it left exposed a number of sandbanks or islands, and the main outlet to the sea was under the eastern hill, exactly opposite the flats to where it is at present". (Turpin, 1964)(see Figure 1).

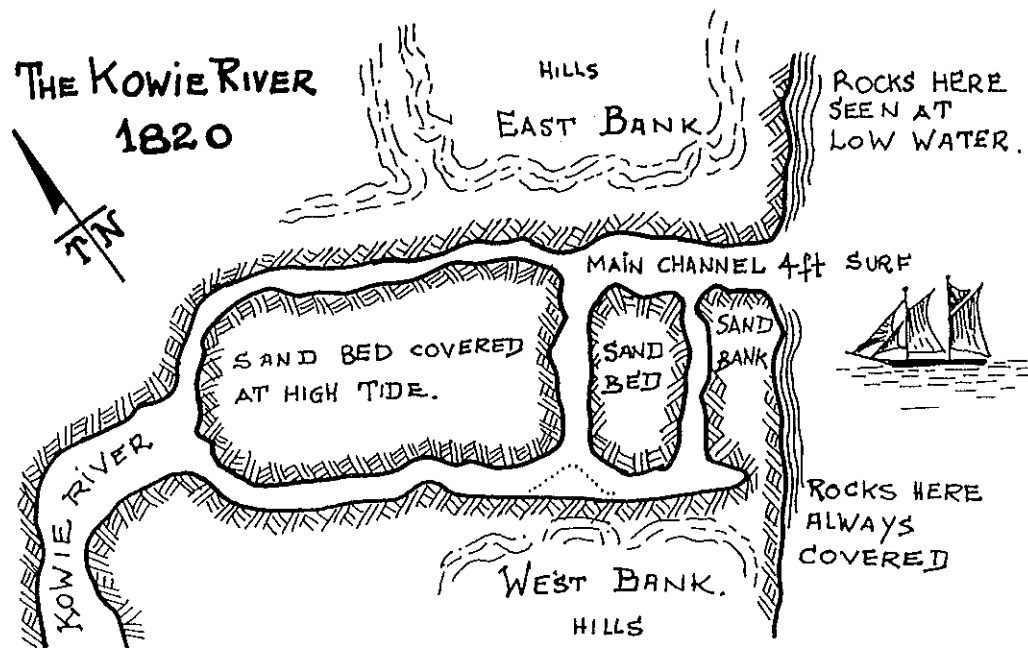


FIG. 1: The Kowie River estuary as it was known to the first harbour-master in 1821 (Turpin 1964)

Originally it was hoped that the Kowie Estuary could be developed into a major port for the interior which had been settled by the British in 1820. The main river channel was diverted to the western side of the estuary and two piers were built, extending out into the surf-zone. This work was initiated by William Cock in 1836 and entailed removal of a "huge sand-hill" opposite the blind western channel of the estuary. The sand was dumped into the shallow lagoons and the channel itself was straightened and directed to the western side by driving rows of stakes into the ground. These were then interlaced and bush packed between the rows. Waste sand was then placed into the bush eventually forming a solid "immovable bank". It was early in 1841 that the western channel was opened and according to press reports of that time, the outgoing tides scoured out the channel depositing the sand on the eastern beach closing up the former mouth. Unfortunately the venture was not to succeed so easily and constant sand encroachment occurred from the west. This necessitated extending the piers with continual dredging and training of the new channel the banks of which were eventually packed with stone quarried from nearby hillsides.

The difficult conditions at the narrow entrance to the river channel together with the sand bar which was always present at the mouth of the channel, made entry to the harbour a hazardous venture in all but perfect conditions. Despite the problems and difficulties associated with the Kowie harbour project, there were times during its heyday when up to a dozen sailing ships were docked in the river either loading or unloading cargo or waiting for favourable conditions to leave the estuary (see Figure 2). According to Turpin (1964) at least 20 ships were wrecked at Kowie and when the paddle-wheel tug "Buffalo" struck the bar in July 1889 the Kowie Harbour Works came to an end. The remains of the "Buffalo" can still be seen today at the first bend in the river.

Turpin (1964) aptly describes the Kowie project as follows: "The story of the Kowie harbour, sadly enough, is one of wrecked ships, lost fortunes, broken hearts and disappointments for everyone who had a hand in its affairs. The two piers at the river-mouth are monuments to misguided enthusiasm and a colossal waste of private fortunes and public money. Yet in this, the twentieth century, there are still individuals and organizations which are clamouring for the re-opening of this ill-fated project."

Zwamborn (1980) states that "river training was carried out and two breakwaters were constructed by the Cape Government in 1877 to improve the navigability of the channel". By 1900 all commercial traffic to the Port Alfred Harbour had stopped. Extensions of 65 m to the western breakwater were made during 1938 - 1941 but after this the work was abandoned.



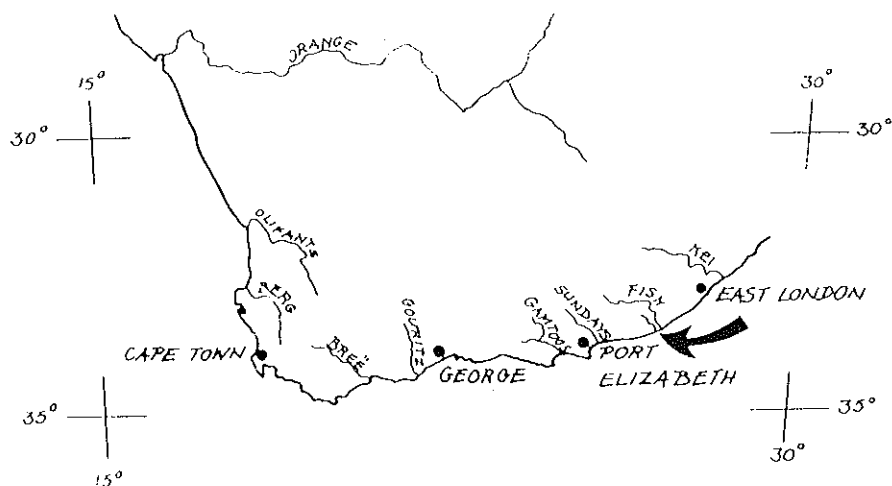
FIG 2: The Kowie River harbour during its heyday with ships at the East Bank Wharf (Turpin, 1964)

2. LOCATION

The estuary mouth is located mid-way between East London and Port Elizabeth at $33^{\circ}36'S$ and $26^{\circ}54'E$.

2.1 Accessibility

Port Alfred and the Kowie River estuary are situated on the main coastal road (Trunk Route 45) between East London and Port Elizabeth. Distances to the nearest major towns are 140 km to East London, 160 km to Port Elizabeth and 58 km to Grahamstown (Zwamborn, 1980). A rail link with the national rail network exists between Port Alfred and Grahamstown.



2.2 Local authorities

The entire catchment and upper part of the Kowie estuary fall within the jurisdiction of the Dias Divisional Council, which is administered from Port Elizabeth. The Divisional Council has a branch office at Port Alfred which attends to the local matters concerning Health services, Divisional road maintenance and nature and environmental conservation. The lower part of the estuary is situated within the Municipality of Port Alfred which extends approximately 4 km inland (see Figure 3).

3. ABIOTIC CHARACTERISTICS

3.1 River Catchment

3.1.1 Catchment characteristics

The area of the Kowie river catchment is given as 576 km² by Day (1981) and the Directorate of Water Affairs in River Flow Data (1978). Noble and Hemens (1978) give the area as 769 km², Ninham Shand (1971) as 712 km² and Ninham Shand (1981) as 730 km².

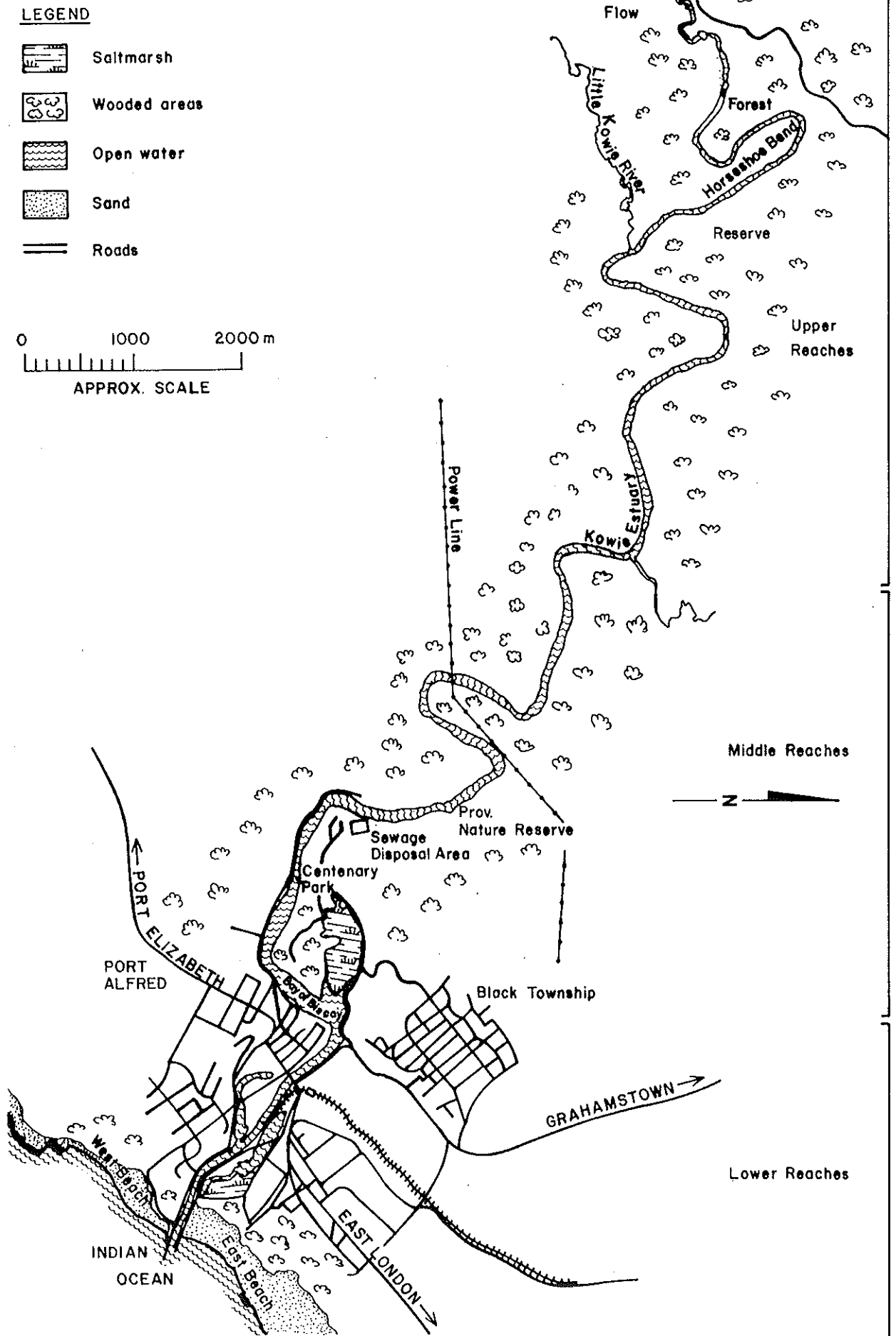
Skelton (1980) classes the Kowie as an "intermediate" river as opposed to systems originating on the Great Escarpment or small coastal rivers. It is therefore one which "extends inland as far as the "intermediate" mountain ranges or hills such as the "Cape Fold Belt mountains". He considers these "intermediate" rivers as of "ancient origin, tracing back to the earliest post-Gondwana drainage region". The significance of this is that in eroding back these rivers could "capture" tributaries of adjacent systems together with the faunistic components of these systems.

In this way, according to Skelton, the Kowie River would have captured the Bloukrans river which was formerly a tributary of the Kap River, which is a tributary of the Great Fish River (see Figure 4). According to Van Wyk (1961) and Day (1981) the Kowie has its source in the hills of the "Grahamstown Heights" from where it flows in a south-easterly direction draining the major part of the Bathurst region. Its major tributaries are the Bloukrans (mentioned above), the Brakrivier and the Lushington (or Torrens) River (1:250 000 Topographical Sheet 3326). The Little Kowie River is a smaller tributary which enters the estuarine portion of the river 14 km from the mouth (1:50 000 Sheet 3326 DB). There are also a number of smaller unnamed streams entering the river along its course.

The total length of the Kowie River as calculated from the 1:250 000 Topographical Sheet is approximately 70 km.

The general topography of the Kowie catchment from the Grahamstown hills which have an average altitude of 600 m is one of a gently sloping coastal plain with undulating hills. The relatively straight coastline is backed by coastal dunes which reach a height of 61 m in places (see Frontispiece).

FIG. 3 The Kowie Estuary up to "Ebb & Flow" showing the main land marks and geomorphological features (drawn from the 1:50,000 sheet 3326 DB)



According to Mountain (1962) the Kowie river has a meandering course which has cut deeply into the Bokkeveld shales which make up most of its catchment.

Van Wyk (1961) states, "The main stream has an unusual number of bends, and the upper reaches of the tidal water lie in a narrow valley, the slopes of which are steep, high and densely wooded".

Geology

The geology of the Kowie and surrounding area has been described by Mountain (1962), and Lock (1974). That the major part of the Kowie river lies within a strip of the Bokkeveld Series which runs along its length down to the coast i.e. in a north-westerly to south-easterly direction (Figure 4). The Bokkeveld Series consists "mainly of shale with subsidiary sandstone bands"; pronounced dipping and folding are evident, as can be seen in the quarries and cuttings of Port Alfred.

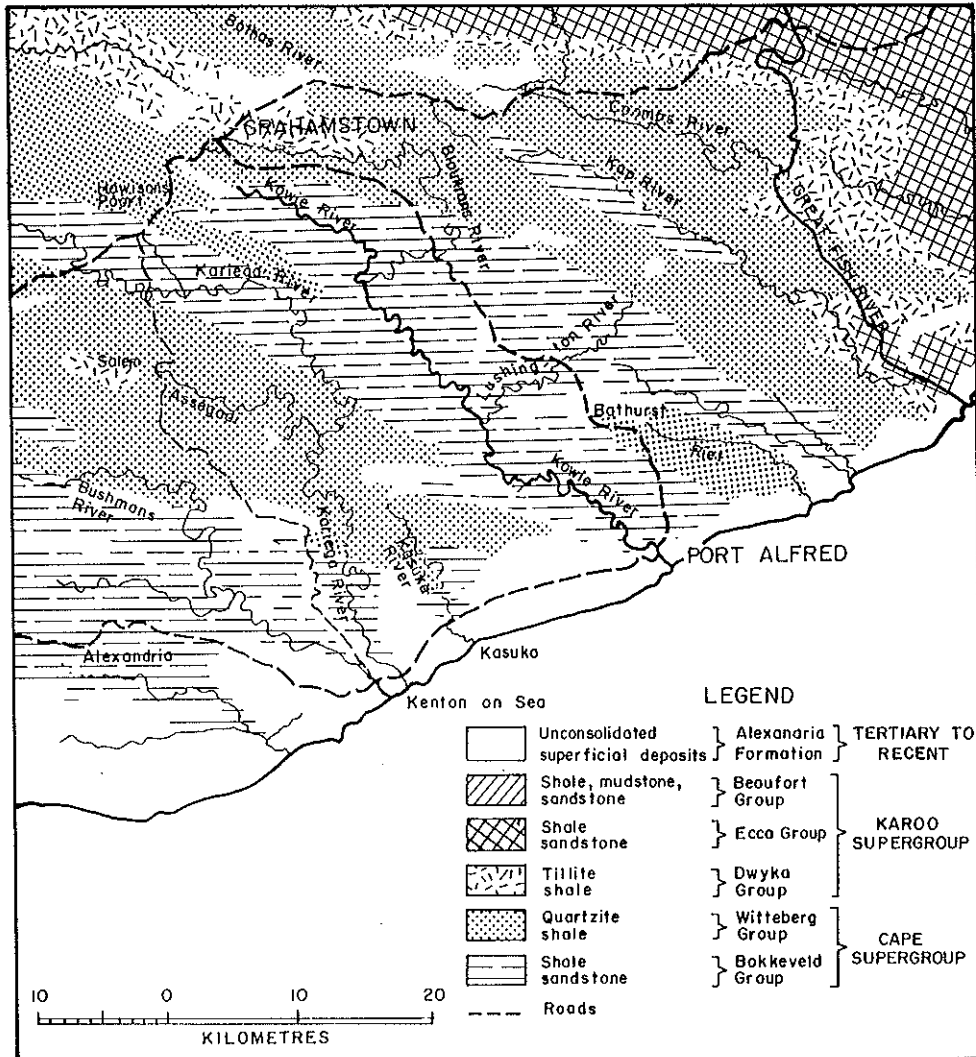


FIG. 4: Geology of the Eastern Cape (After Lock 1974)

Along the coast overlying and resting on the shale, one finds a succession of thin marine sediments which are referred to as the Alexandria Formation. This is exposed in a cliff on the eastern banks of the Kowie River above the Port Alfred railway station as well as along the western bank about 0,8 km from the mouth. Dune rock in turn covers the Alexandria Formation which is apparently not distinguishable lithologically from the calcareous dune rock (Mountain, 1962). The windblown origin of the dune rock is evident in the characteristic layers or bedding one finds in this formation.

Unconsolidated beach deposits and bare dunes occur right at the coast. Along the river, alluvial floodplain deposits are present, for example, in the meander bends and particularly in the lower reaches of the estuary such as the Centenary Park area and the West and East Banks upon which the lower part of the town of Port Alfred has been established (Figure 3).

Climate and run-off

The climate and rainfall of the Kowie river and its catchment are temperate with rainfall occurring mainly during Spring and Autumn (Port Alfred Publicity Association) (see Figure 5). According to Ninham Shand (1981) the mean annual precipitation of 650 mm is distributed evenly over the catchment with 60 percent of the rainfall occurring during the summer months. Giffen (1970) states that almost the entire Kowie River watershed lies within the annual rainfall isohyets of 500 - 600 mm and that the temperature has a minimum of about 1,5°C and a maximum of 39,8°C.

The average annual rainfall for a 30-year period ending in 1960 was 663,3 mm which fell during an average of 74 days of rain per year (McDonald, 1970 unpublished). Midgley and Pitman (1969) give a mean annual precipitation of 638 mm. The average annual maximum and minimum temperatures are 23,3°C and 12,7°C, respectively, with an average daily range of 10,6°C (McDonald, 1970 unpublished); these values correspond closely to temperatures given by Hill (1967).

The flow in most of the Eastern Cape rivers is normally very irregular and although the Kowie river is considered to be perennial, under abnormal drought conditions flow of the river can stop for 2 to 3 months (Stewart et al, 1962), (Hill 1967) and Port Alfred Municipality (pers. comm.). According to Ninham Shand (1971) the flow of the Kowie river is very unreliable and although rain may fall in the catchment this does not necessarily result in an increase in flow of the river. For example, during a 20-month period between 1961 to 1963 there was no apparent flow in the Kowie river at the pumping pool above "Ebb and Flow" (see Figure 3) even though rain fell in the catchment during that period. The river is reported to have a very swift "run down" period resulting in high flow of a short duration.

Mean annual run-off (MAR) figures in million cubic metres for the Kowie are as follows: 23,0 (Noble & Hemens, 1978), 23,6 (Midgley and Pitman, 1969), approximately 17,0 (Ninham Shand, 1971) and 40,6 (calculated from Directorate of Water Affairs flow records). The average monthly flow rate for the gauging station at Wolfscrag for the 12 year period from 1969 to 1981 is given in Figure 5. During this period the records also show that a total monthly run-off of over $50 \times 10^6 \text{ m}^3$ occurred during December 1970, March 1974, July 1979 and August 1979. If these exceptional monthly run-off figures are excluded from the MAR calculations for the Wolfscrag gauging station, the MAR for this station is $20 \times 10^6 \text{ m}^3$ which approximates the calculations of previous workers.

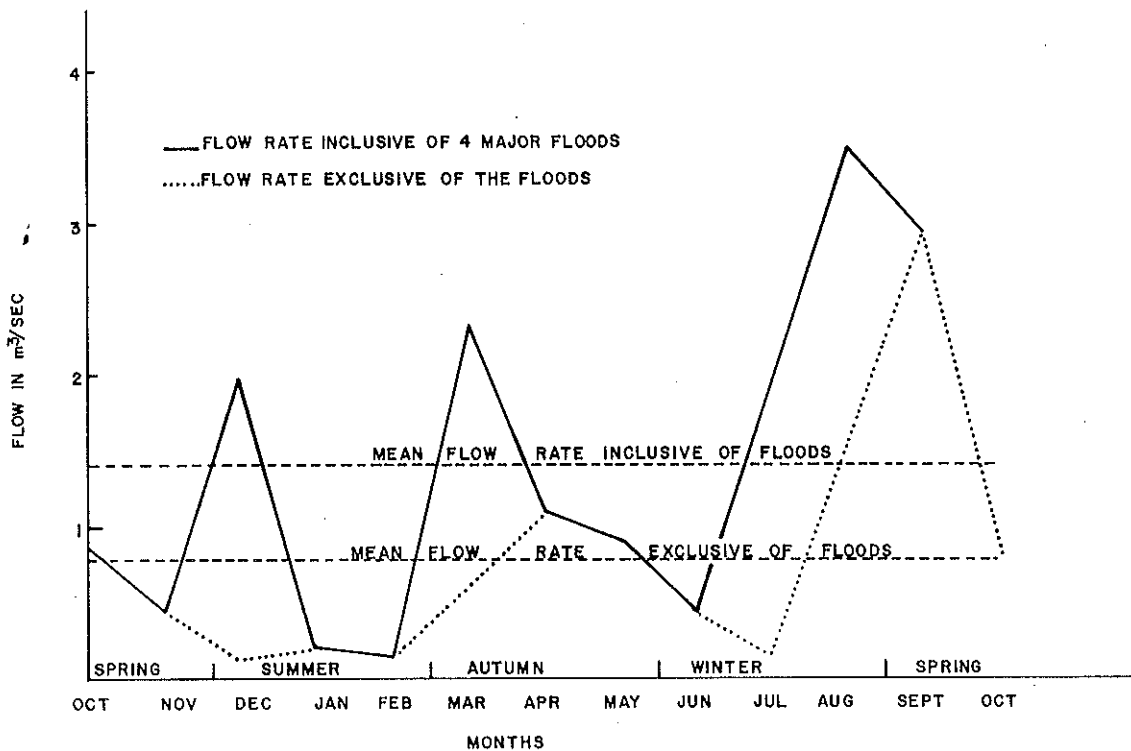


FIG.5: THE AVERAGE MONTHLY FLOW RATE AT THE WOLFSCRAG GAUGING STATION (WATER AFFAIRS-HYDROLOGY DIVISION, UNPUBLISHED)

3.1.2 Land Ownership/Uses

The major part of the Kowie River catchment is made up of privately owned farms. The principal agricultural production of the region consists of pineapples, citrus, chicory, fodder crops, beef cattle and goats (Zietsman and Van der Merwe, 1981).

According to a Memorandum dated 1975-06-06 by Agricultural Technical Services Branch, the farming practices in the Kowie River catchment consist mainly of stockfarming and pineapple production.

The Directorate of Forestry controls two areas of indigenous scrub forest in the Kowie River catchment. The upper area consists of a strip of land approximately 4 000 hectares in extent, situated along the river and another smaller section is situated at the well known "Horseshoe Bend" and "Ebb and Flow" on the Kowie River (Plate I), (1:50 000 Sheet 3326 DB). These two portions of State Forest are separated by the Bathurst village commonage which is a large tract of indigenous Valley Bushveld. This area is soon to be taken over by the Directorate of Forestry in order to consolidate the two existing portions of State Forest. The whole unit will then be declared a State Forest Reserve which is to be managed for the conservation of Valley Bushveld and outdoor recreation purposes (Directorate of Forestry, pers. comm.).

Intensive vegetable farming is carried out in the Belmont Valley which is situated just south of Grahamstown and through which the Bloukrans River, a major tributary of the Kowie, flows (see Figure 4). Sewage effluent from the Grahamstown sewage works also enters the Kowie system via the Bloukrans River.

The town of Port Alfred and smaller townships in the surrounding region suffer from an unreliable and inadequate supply of fresh water. Various schemes involving the pumping of water from the Kowie river and the damming of the river have been considered. Engineering reports covering these schemes indicate that a dam on the Kowie at Curries Drift (approximately 27 km from the mouth) would alleviate the present problems (Stewart et al, 1962 and Ninham Shand, 1971). The only scheme undertaken to date has been the building of a weir across the river a short distance upstream of "Ebb and Flow" (see Figure 3).

The landownership and uses of the lower portions of the river, downstream from "Ebb and Flow", will be given in Section 3.2 which follows.

3.1.3 Obstructions

A number of small bridges cross the Kowie river and its tributaries in the upper catchment. None of these structures appears to impede or obstruct the normal flow of the river.

The railway and Grahamstown road bridges across the Bloukrans and Lushington rivers span the entire watercourses of these tributaries without causing any obstruction to their flow. A substantial weir dams up the Kowie river just above "Ebb and Flow", from which water is drawn for the Port Alfred domestic supply. This water is also used to fill the Mansfield Dam which acts as a standby reservoir for Port Alfred during times of low flow in the Kowie river.

Heavy floods in 1979 washed away the original weir which was rebuilt a short distance upstream of the original site (see Figure 6). In its present form this weir constitutes a major barrier to the migration of fish to the upper reaches of the river. In addition to this major weir, approximately 8 smaller weirs are situated across the river in the catchment retaining water for agricultural purposes (Mr A Randall, pers. comm.). A

few small irrigation and stock watering dams occur in the catchment of the Kowie river. (South Africa, Department of Agricultural Technical Services, 1975.) A certain amount of water is also pumped from natural pools occurring along the river course.



FIG 6: Remains of a weir, damaged in 1979. The weir dammed up the Kowie River for Port Alfred's domestic water supply (ECRU 80-07-06).

3.1.4 Siltation

The Kowie river normally carries a low silt load (South Africa, Department of Agricultural Technical Services, 1975). This is due to the soil type and good vegetation coverage over most of the catchment. According to Mr A Randall (pers. comm.) ploughing in the catchment during the time of the "pineapple boom", caused a large amount of silt to be deposited in the upper part of the river. This situation improved when this land reverted back to pasture.

A general shallowing of the river and in particular of certain deep "holes" in the upper part of the estuary will be dealt with in Section 3.2 under Estuary characteristics. During the ECRU survey of 80-07-09 very little silt was evident in the upper part of the estuary eg. at "Ebb and Flow". Ninham Shand (1971) report that over a 7-month period very little silt was deposited at the Curries Drift weir and this included times of very high flow.

3.1.5 Abnormal flow patterns

The Kowie River is subject to great variations in flow patterns. Day (1981) states "Droughts and floods are not infrequent".

River flow records for the gauging station at Wolfscrag indicate that major floods occurred on the 7th of December 1970 (1182 m³/s), 4th of March 1974 (654 m³/s), in July 1979 and on the 21st of August 1979 (848 m³/s) (Directorate of Water Affairs - River flow records).

An engineering report prepared for the Municipality of Port Alfred in 1962 mentions that rainfall records show that drought conditions prevailed from 1894 to 1899, 1923 to 1929 and 1944 to 1947 (Stewart et al, 1962).

More detailed descriptions of floods and their effects on the estuary are given in Section 3.2 "Estuary characteristics".

3.2 Estuary

(This section is contributed by G Fromme, Sediment Dynamics Division, NRIO.)

3.2.1 Estuary characteristics

The Kowie river estuary as it is today consists of a narrow (50 - 150 m wide), 21 km long, stretch of tidal river. The upper reaches of the estuary begin at "Ebb and Flow" (see Figure 3). At this point the estuary is shallow, (2 - 6 m deep) with steep and occasional rocky banks vegetated right down to the water's edge. This section of the estuary meanders extensively and has a narrow intertidal zone of < 10 m (Day, 1981).

The middle reaches (see Figure 3) broaden out and wind through a steep-sided valley. Here the estuary is between 100 - 150 m wide and approximately 3 m deep. On the bends, depths of up to 8 m have been recorded (Day 1981). The bottom is sandy with intertidal mud banks of up to 100 m wide and more, particularly in the vicinity of the "Bay of Biscay".

The lower part of the estuary consists of an artificial channel approximately 80 m wide flanked by loose stone packed berms which allow a reduced tidal exchange to take place with the three small lagoons and the saltmarshes of the East Flats (see Figure 7 and Plate III). While on the West Bank, two lagoons, (the Civic Centre lagoon and Little Beach lagoon) are fully tidal, being connected to the main channel by an opening in the western berm and culverts under the Port Elizabeth/East London trunk road (see Figure 7 and Plate III). The actual mouth of the estuary consists of two breakwaters, 75 m apart extending out through the surf-zone (see Frontispiece).

The surface area of the estuary above the "Bay of Biscay" has been calculated as 7 km² while the area seaward of this is approximately 1,25 km².

The characteristics of the lower part of the estuary prior to the harbour works and canalisation in the mid-1800's have been described in Section 1, "Historical Background".

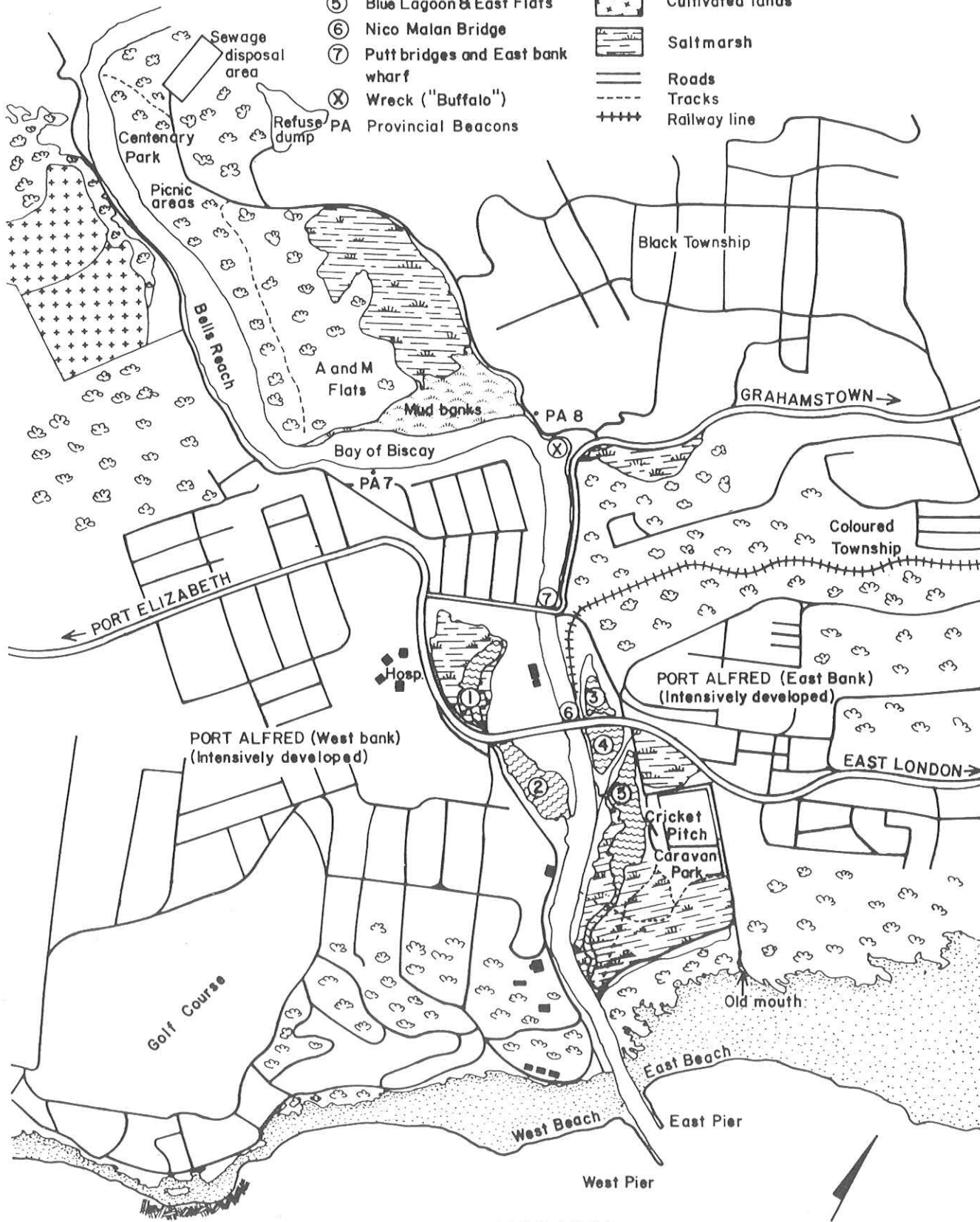
The coast on either side of the estuary consists of a belt of unconsolidated beach and drift sand varying between 150 - 250 m wide on the West Beach and 100 - 600 m on the East Beach. Bare

FIG.7 : The lower reaches of the Kowie Estuary.

LEGEND

- ① Proposed Nature Reserve (Civic Centre Lagoon)
- ② Little Beach
- ③ Upper East Bank Lagoon
- ④ Lower East Bank Lagoon (Proposed Small Boat Harbour)
- ⑤ Blue Lagoon & East Flats
- ⑥ Nico Malan Bridge
- ⑦ Putt bridges and East bank wharf
- X Wreck ("Buffalo")
- PA Provincial Beacons

- Sand
- Open Water
- Mud banks
- Wooded areas
- Cultivated lands
- Saltmarsh
- Roads
- Tracks
- Railway line



0 200 400 600 800 1000 m

APPROX. SCALE

DRAWN FROM AERIAL PHOTOGRAPH Nr.90 OF JOB 374 (DEC 1980)



transverse dunes 5 - 8 m high which encroach partially onto the "West Beach Drive" appear to be a relatively stable feature, apparently due to the reversing winds i.e. SW in winter and NE in summer (see Plate II).

An extensive field of large Barchan dunes, 8 - 15 m high, stretches along the East Beach. Comparisons of aerial photographs taken in 1944, 1955, 1973 and 1980 indicate that no appreciable encroachment by this dunefield is taking place (see Frontispiece). The width of vegetation stabilized dunes opposite the East Flats has increased from approximately 40 m in 1944 to 200 m in 1980.

Bathymetry and bottom materials

In view of the past attempts to develop a harbour at the Kowie estuary and the present proposals for a small-boat harbour, the depth of the lower part of the estuary and its mouth are of paramount importance. A comparison of soundings taken during the ECRU survey in December 1981, with soundings from a Royal Naval Chart drawn in 1876 are given in Table 1. The greater depths are probably due to dredging carried out during the breakwater extension works of 1938 - 1941.

Of particular significance are the comparable depths over the sandbar at the harbour entrance, which can apparently decrease to 0,3 m during extreme low water conditions after south-westerly gales.

TABLE 1: Comparison of Port Alfred harbour channel soundings in 1876 and 1981.

Sounding site	Distance in meters from the end of the West Pier	Depth below Low Water Ordinary Spring Tide		
		1876		1981
		ft	m	m
Nico Malan bridge	1 550	8	2,5	2,95
Little Beach	1 250	7	2,2	6,05
Old Mill	750	12	3,7	6,05
Langdon Hotel	700	10	3,1	8,85
Beach Tea-room (NSRI)	250	10	3,1	4,55
Signal Station	100	8	2,5	3,85
Harbour Entrance	0	7,5	2,5	2,65
Off-shore	300	23,5	7,6	8,39

From Van Wyk (1956, unpublished, and 1961), Hill (1975), Day (1981), Bok and King (1981, unpublished), Grindley (1976, unpublished) and the ECRU surveys of July 1980, it is evident that the depth of the middle and upper estuary varies between 2 and 6 m with deeper "holes" at the bends in the river. Depths of up to 10 m have been recorded (Hill, 1975). Progressive reduction in depth at certain "favourite fishing holes" has been recorded by local fishermen (T Cockbain and R Jubb, pers comm). Cultivation of lands right up to the edge of the riverbanks in the floodplain meanders (see Figure 8) and bank erosion during floods and at high tides caused by passing motor boats are factors contributing to an increased silt load in the estuary.

The 1:10 000 Aerial Photographs Job No 326 and a Rhodes University Honours Project by A Reynders in June 1981 (pers. comm.) indicate a nett accumulation of sediment at the entrance to the Civic Centre Lagoon.

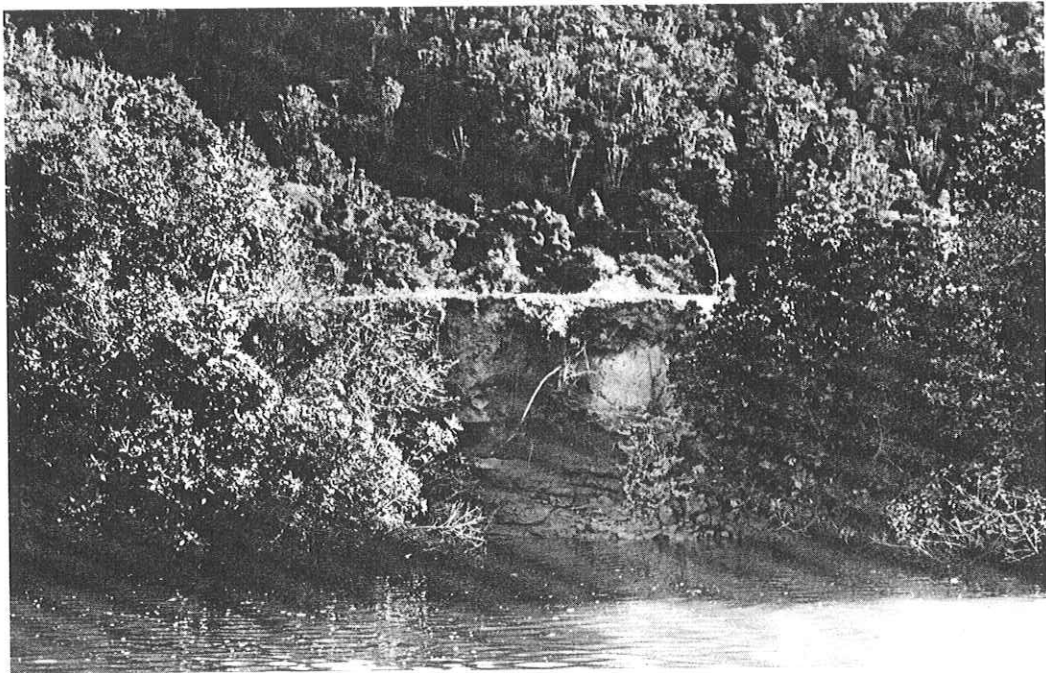


FIG 8: Indigenous bush cleared in floodplain meanders for farming purposes, right up to the riverbanks, leading to increased erosion (ECRU 80-07-09)

Some sediment analyses have been carried out by workers studying the distribution and biology of benthic organisms in the estuary, e.g. Wooldridge (1968) and Hill (1967). From this work as well as that of Day (1981) and Watling (1982) and the ECRU surveys, it is apparent that the bottom materials of the upper estuary consist of very fine sand to silt. The middle reaches have a greater proportion of fine sand and mud on the inter-tidal banks with a sandy bottom in the main channel which is subject to strong tidal flows.

The East Bank Lagoons have fine sand overlying black anoxic mud which is probably derived from calm water conditions with periods of prolific plant growth.

The West Bank Lagoons on the other hand have "clean hard" sand indicating an influx of marine sediments.

Flow and floods

The flow in the estuary is mainly controlled by the tides, and current speeds during outgoing tides are reported to be as follows:

Upper reaches	12 - 20 cm/s	
Middle reaches	up to 12 cm/s	
Lower reaches	up to 25 cm/s	(Day, 1981).

According to Hill (1967) "The bottom of the channels of the Kowie estuary are exposed to continual strong tidal currents, so rapid that even at neap tides a diver has to hold onto a rope to maintain position".

Very strong flow occurs in the lower reaches of the estuary if floods coincide with an outgoing high spring tide (Zwamborn, 1980).

The following accounts of major floods at Port Alfred are available in the literature:

Date	Remarks and source
May 1888	Flats on both sides of river were inundated, "appearance of large lakes" (Turpin, 1964).
December 1889	River 9 ft (2,7 m) above Datum level, moving at 5 knots (2,6 m/sec) (Turpin, 1964).
1953	Highest known flood, river overtopped its banks, water "two feet deep in Main Street" (Ninham Shand, 1981)
June 1967	125 mm rainfall in 48 hrs in catchment, water rose to High Spring Tide Level, only outflow was evident (no tidal effect) level dropped after 3 days (Hill, 1967).
1972/3	Last major flood said to have occurred during this period (Ninham Shand, 1981). This date is however not supported by the River Flow records.
March 1981	Flood coincided with high spring tide, low-lying areas in town and at Blue Lagoon were flooded. (Port Alfred Municipality, pers. comm.)

Ninham Shand (1981) calculated flood levels at Port Alfred to facilitate the planning of the small craft harbour. Levels were established for a 1-in-50 year flood with a flood peak of 460 m³/s and a 1-in-200 year flood with a peak of 690 m³/s. According to this report, overtopping of the banks will occur upstream of the "Old Putt" bridge with a 1 in 50 year flood and the entire lower town could be inundated by the 1-in-200 year flood. This assumes that the openings at the "Old Putt" bridge are not constricted by the accumulation of debris and that the downstream control is the sea level at high spring tide (Ninham Shand 1981).

3.2.2 Mouth dynamics

Waves and surf-zone currents

Currents in the vicinity of the Kowie River mouth are mainly wave driven and data from East London which is the station nearest to Port Alfred where wave observations have been carried out for any reasonable period (Swart and Serdyn, 1981 and Ashby et al, 1973) indicate that the main deep-sea waves originate from the sector between ESE and SSW, with a maximum frequency from the south.

These dominant southerly swells cause a strong north-bound current at the tip of the western breakwater (Zwamborn, 1980).

The NE-flowing longshore current is reported to create an eddy behind the East pier which, according to a Port Alfred lifesaver, and local surfers, generates a powerful rip current running out to sea alongside this pier. At the West pier there is no rip current, but the lifesavers are aware of a strong under-tow in this area. The general configuration of currents and associated rips and eddies, as observed during the ECRU survey of 1981, is shown in Figure 9.

Littoral sediment movement

The normal pattern of littoral sediment drift at Port Alfred has been altered by the piers which extend out through the surf-zone. The sedimentation patterns at the estuary mouth and on the adjacent beaches are an expression of the wave action and surf-zone currents around these artificial obstructions.

From comparisons of a Royal Navy chart of 1876 and recent aerial photographs (Job No 326 of 1979), it appears as if there has been accretion of sand SW of the West pier and a depletion of sand NE of the East pier (see Figure 9). This has apparently been evident since the construction of the piers and more so since the extension of the West pier after 1941.

Using Figure 9, the littoral sediment movement can be summarized as follows:

- (a) Sand accumulating in the corner between the West pier and beach is partially transported seawards by the under-tow current and partially westwards in an eddy driven by the main north-easterly longshore current. At the point where the eddy and the main longshore current meet, a rip current is formed. This has led to the formation of a large beach cusp, 500 m south west of the West pier which can be seen in all aerial

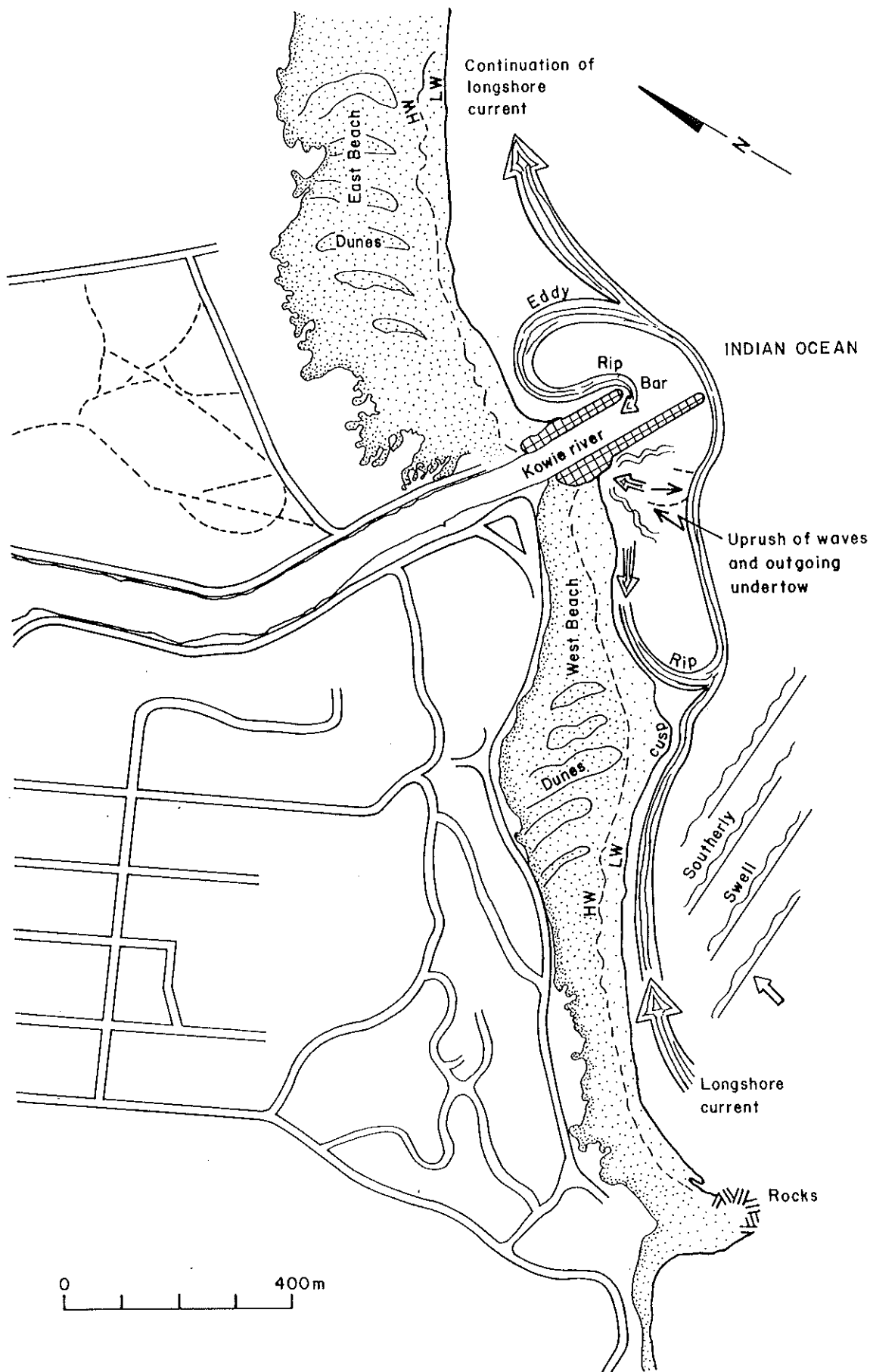


FIG.9 : The Kowie River Estuary mouth drawn from an aerial photograph taken on the 20th of April 1979 (Job nr. 326) giving a schematic representation of the nearshore current regime.

photographs taken between 1944 and 1981.

- (b) The West Beach dunes probably also form part of the sediment "circulation cell" in this area in that sand accumulated in this corner is blown on to the dunes by the strong easterly winds prevalent during summer. The seaward end of the dunes opposite the beach cusp are eroded during high tides and in this way the sand re-enters the "circulation cell".
- (c) That part of the sand not trapped in the West Beach "circulation cell" moves further NE around the West pier and is partially drawn into the eddy and rip current system along the East pier. Where the rip current ends at the tip of the East pier a sandbar is formed. Waves breaking over this bar contribute to a further accretion of sand, so that navigation at the narrow entrance to the estuary can become dangerous.

Tides

As Port Alfred lies midway between Port Elizabeth and East London the tidal data for the estuary are given as a mean of the values for these two ports (S.A. Tide Tables, 1981).

Mean High Water Springs	1,95
Mean Low Water Springs	0,33
Tidal Range	1,62
Mean Level	1,14

(These levels are referred to Chart Datum.)

The Kowie estuary is tidal for 20,8 km i.e. from the mouth to the area known as "Ebb and Flow".

The spring tidal range in the upper reaches of the estuary is given as 1,1 m, middle reaches 1,5 m and lower reaches 1,7 m (Day, 1981). As mentioned previously the West Bank Lagoons are fully tidal being connected to the main channel of the estuary by an unrestricted opening of 20 m at "Sister Peters" bridge (see Figure 7). The East Bank Lagoons are subject to a reduced tidal range of approximately 50 cm (JR Grindley, 1976, unpublished) via a number of seepage areas in the stone-packed berm separating these lagoons from the main channel.

3.2.3 Land Ownership/Uses

The Kowie Estuary forms an integral part of the town of Port Alfred which is situated on either side of the estuary mouth (see Frontispiece). The town is 1 712 hectares in extent, which includes the municipal commonage as well as the Coloured and Black townships. A small Provincial Nature Reserve of approximately 250 hectares adjoins the municipal picnic and recreational area of Centenary Park which lies on the eastern banks of the estuary above the town (see Figure 7). The remainder of the land up to the head of the estuary at "Ebb and Flow" consists of privately owned farms. The steep slopes along the river, which are covered with indigenous vegetation are used for the grazing of small stock where this is practical (Plate I). Cultivation of crops

takes place on the level parts of the floodplain, mainly in the bends of the riverbed meanders.

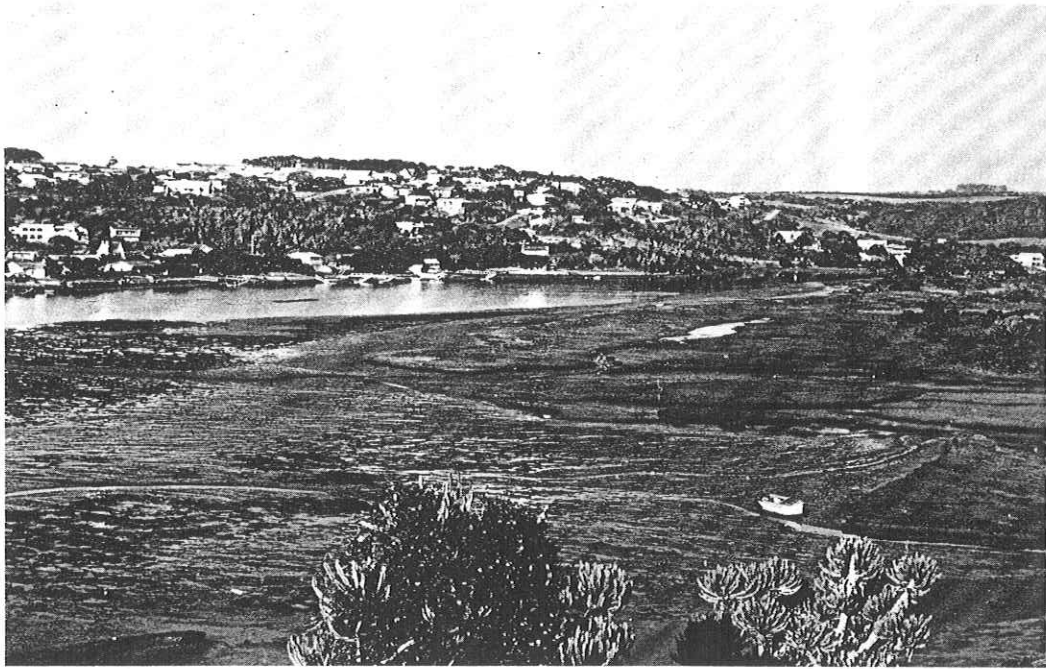


FIG 10: The rich mud banks of the "Bay of Biscay" where commercial bait collection is carried out (ECRU 80-07-10)

The municipal area of Port Alfred consists of approximately 3 000 erven in the White township of which 60 percent are developed, while the black township which is serviced by the Department of Community Development covers an area of 227 hectares consisting of some 1 300 developed erven (Port Alfred Municipality pers. comm.). According to the Municipality, population figures at the time of writing were approximately 3 500 Whites, 1 000 Coloureds and 10 000 Blacks. The population of Whites increases by 10 000 - 15 000 with the influx of holidaymakers for periods during the summer season.

The principal use of the estuary with its 21 km of navigable water is recreational and is orientated around the estuary itself. A certain amount of commercial ski-boat fishing takes place from some 30 registered commercial boats which operate from Port Alfred. In addition to this, approximately 270 pleasure/game fishing craft are registered with the Municipality. Many of these boat owners are members of the Port Alfred River and Ski-boat Club which is situated on the banks of the estuary below the Nico Malan bridge. An additional number of about 200 unregistered boats utilize the estuary during the holiday season.

The use of all boats on the estuary is regulated by a set of municipal by-laws relating to boating on the Kowie river. These regulations are enforced by a full-time river control officer who also assists with nature conservation and maintenance and development projects relating to the estuary. According to the

Municipality they control and administer the water surface and uses of the estuary up to "Ebb and Flow" (Town Clerk, pers. comm.).

On the river the boating activities include fishing, sailing, rowing, powerboating and waterskiing. As many of these activities are not compatible with each other, it was necessary to zone the area for the various uses. These zones are defined by Provincial Proclamation No 357 of 1972. The use of vehicles on the beaches on either side of the estuary is prohibited by Municipal regulation in order to protect the sensitive dune vegetation found in these areas as well as the public utilizing the beaches.

The Kowie estuary is one of the few Cape estuaries where commercial bait collection on the rich mud banks at the "Bay of Biscay" is permitted by a limited number of registered collectors (Figure 10). Bait collection is, however, prohibited by a Provincial proclamation, seaward of two Provincial beacons (PA7 and PA8) situated on either side of the estuary at the "Bay of Biscay" (see Figure 7)(Prov. Proc. No. 357 of 1972). The Provincial Ordinance No 19 of 1974 and Provincial Notices 955 of 1975 provide for the protection of, and regulate the use and capture of, fish and bait organisms in the Kowie as well as other estuaries of the Cape Province.

The saltmarshes and mudflats of the lower estuary which were separated from the main part of the river during the last century (see Section 1) have been developed and utilized for various recreational purposes. For example on the West Bank a small fully tidal lagoon known as "Little Beach" is used as a safe bathing area mainly for small children. This is connected via culverts under the main Port Elizabeth/East London trunk road to another shallow lagoon (the Civic Centre Lagoon) and a saltmarsh area which has been proposed for development as a nature reserve and bird sanctuary (Figure 11). The Municipal Offices and a small Caravan Park have been built on reclaimed land between the river and the two previously mentioned areas (see Figure 7).

The saltmarshes and lagoons on the East Bank include the Upper and Lower East Bank Lagoons (known as the Kaffir Lagoons) bisected, by the Port Elizabeth/East London trunk road, the Blue Lagoon and adjoining East Flats (see Figure 7).

The Upper East Bank Lagoon is a small shallow body of water connected to the East Bank Lagoon by culverts under the trunk road (see Plate III). This lagoon receives the stormwater runoff from a valley behind the railway station and a section of the eastern part of the town. The Municipal market and a railway marshalling yard separates the lagoon from the main river channel. South of the trunk road, the Lower East Bank Lagoon has been proposed for a small boat harbour project to accommodate approximately 200 boats (South Africa - Department of Planning, 1971 and Zwamborn, 1980). Plans for the construction of the proposed harbour, which is being designed by the Fisheries Development Corporation in conjunction with the Department of Environment Affairs and the Port Alfred Municipality, had reached an advanced stage at the time of writing (Fisheries Development Corporation, 1982, unpublished)(see Plate III).



FIG 11: The "Civic Centre Lagoon" which has been proposed as a nature reserve and bird sanctuary.

The Blue Lagoon or Swimming Lagoon which is situated seaward of the Lower East Bank Lagoon is a clean body of water with a maximum depth of approximately 2 m. Together with the East Bank Lagoons it is subject to a reduced tidal exchange via a number of seepage points occurring in the stone-packed berm separating the East Flats from the main river channel. A cafe, a cricket field and a caravan park have been established on the low-lying East Flats area. These developments together with a row of houses just east of the cricket field and caravan park, are all sited below the highest astronomical tidal (HAT) level and would be liable to flooding should the main berm alongside the river be breached or if there is abnormal flooding of the river.

The environmentally healthy condition of the Blue Lagoon and its associated saltmarshes can therefore be attributed to the vital tidal exchange which takes place through the stone packed walls of the main channel as well as to the filtering function of the reed swamp in the north eastern corner of the East Flats area, which receives stormwater run-off from the eastern part of Port Alfred. As its name implies the Swimming or Blue Lagoon is used extensively for swimming while walks have been laid out through the saltmarshes and along the vegetation-lined East Banks of the river.

Along the East Bank above the old Putt Bridge, (see Figure 7) wharfing and off-loading facilities for the commercial fishing boats exist. These facilities are at present inadequate and undesirable in their present form. Plans are, however, being made to either accommodate these facilities within the proposed small boat harbour or re-instate them so as to form a historical feature of that section of the riverbank which dates back to the early days of the Kowie River Harbour (See Section 1 and Figure 2).

Two areas in the bend of the river above Centenary Park (see Figure 7) are used for sewage and refuse disposal (see section on Pollution).

The area below Centenary Park and parts of the saltmarshes at the Bay of Biscay are utilized for the grazing of cattle. Proposals for the establishment of various categories of estuarine reserve have been put forward by Grindley and Cooper (1979) for the Civic Centre Lagoon, the Little Beach area, the A and M Flats (Centenary Park area) as well as the East Flats area with its lagoons. (see Figure 7).

3.2.4 Obstructions

Day (1981) states that the stone berms which contain and concentrate the river and tidal flow of the Kowie estuary constitute a major obstruction to the natural configuration of the estuary and that this has led to a general impoverishment of the system. These berms effectively prevent the distribution of detritus from the saltmarshes of the East Flats reaching the main channel and eliminate their function as a nursery area.

Constant erosion and collapse of sections of the stone walls lining the river bank necessitate continual repair to the damaged sections. This repair work is carried out on a piece-meal basis by the local authority and is partially financed by a subsidy from the Fisheries Development Corporation (Port Alfred Municipality, pers. comm.).

Three bridges cross the estuary, namely, the two Putt bridges and the Nico Malan bridge (see Figure 7). The old Putt bridge which was opened in 1907 and the new Putt Bridge, situated immediately beside it, each have seven supporting piers lined up with each other. According to Ninham Shand (1981) the back-up effect of these bridges during floods, is minimal. They mention, however, that this could increase significantly if debris accumulated against the piers. The Nico Malan bridge opened in 1972 (Port Alfred Publicity Association) is a single-span suspension bridge with a clearance of 5 m offering no obstruction to river or tidal flows.

Associated with private water-front properties situated along the western bank of the lower estuary are numerous slipways and jetties protruding out into the main channel. These jetties together with larger boats moored in mid-stream obstruct and limit the utilization of the main channel. Considerable damage to both boats and jetties has occurred during times of flood (Port Alfred Municipality, pers. comm. and Zwamborn, 1980).

The construction of jetties and slipways is subject to Municipal regulations and approval from the Department of Community Development.

3.2.5 Physico-chemical Characteristics

pH. On 12 June 1956 the pH was 8,4 six miles (10 km) from the mouth (Van Wyk, 1956, unpublished). Giffen (1970) notes that because of the geology, pH values are on the alkaline side, eg 7,6 - 8,6. Bok (1976) confirmed that the pH of river water at stations above the tidal limit was consistently alkaline (7,8 - 8,4 from 1975 - 1976). The alkalinity of the river water varied between 150 - 200 parts per million CaCO_3 (Bok, 1976).

Temperatures. The seasonal temperature range at the mouth is 14 - 22°C, while in the upper reaches it is 11 - 27°C (Day, 1981). Hill (1975) gives temperatures as, summer 20 - 28°C, and winter 12 - 16°C. Hill (1967) and Hill and Allanson (1971) give detailed accounts of temperature fluctuations on the basis of continuous records. In summer, water within the estuary is warmed by the sun and temperatures tend to be higher than in the sea. Thus the incoming tides lower the temperature to values comparable to those in the sea (18 - 23°C). In winter, temperatures are highest at high tide as the temperature of estuary water drops to below that of sea water (14 - 18°C). In summer upwelling of cold water is common along this coast and water with temperatures of below 14°C may appear. The highest temperature recorded in the shallows was 34,5°C.

Inflowing river water is often cold in winter and was 11,3°C at the new weir on 80-07-06 (ECRU survey). However temperatures of river water upstream of the tidal limit in January and March ranged from 19,4 - 25,0°C (Bok, 1976).

Transparency. Turbidity is high (Day, 1981). The Bokkeveld series of rocks yield reddish or brown clayey soils and as a result the river is always somewhat turbid (Giffen, 1970).

Van Wyk (1956, unpublished) recorded a transparency of approximately 6 ft (1,8 m) 6 miles (10 km) from the mouth on 56-06-12. ECRU readings in 1979 ranged from 1,5 to greater than 2 m. In the river upstream of the tidal limit Secchi disc readings varied between 20 and 200 cm, usually about 100 cm with water stained a clear peaty brown (Bok, 1976).

Salinity. Salinity is usually above 30 parts per thousand and may increase to 40 parts per thousand in dry years or decrease to nil at the surface after heavy rains (Day, 1981). During prolonged floods which may last for two to four weeks, the surface water of the whole estuary is almost fresh although the salinity is normally 33 - 35 parts per thousand at the mouth (Day, 1981). Tidal movement influences salinity up to "Ebb and Flow" 13 miles (21 km) from the mouth.

After a flood in June 1967 extensive salinity layering was evident with salinity differences of up to 20 parts per thousand between values at the surface and at 2,5 m (see Table in Hill, 1967). Biota in the higher sections of the estuary have to contend with reduced salinities for at least two weeks after floods while in the lower estuary, organisms are not exposed to low salinities for long. Salinity determinations are included in Giffen (1970), Sharp (1977), Hill (1967, 1975), Day (1981) and Alexander et al (1969).

Salinities in the lagoons adjoining the river may be greater than that of sea water as a result of evaporation in summer. The East Flats lagoon had a salinity of 37 parts per thousand and a temperature of 27,5°C on 81-12-02.

River water entering the Kowie estuary is brackish. On 80-07-06 the salinity of the Lushington river was 2 parts per thousand and the salinity in the Kowie river above the new weir was also 2 parts per thousand. Below the old weir which was built in 1977 and washed away in 1979 the salinity was 6 parts per thousand on 80-07-06. In the reservoir above the new weir the salinity was 5 parts per thousand on 80-07-06 (ECRU survey).

Dissolved oxygen. Surface waters are normally well oxygenated and are often supersaturated with oxygen in sunshine during the day. ECRU readings in July 1980 ranged from 9,8 to 21,0 mg/l.

Influxing river water may be supersaturated with oxygen. Above "Ebb and Flow" near the broken weir, dissolved oxygen concentration was 13,5 mg/l (144 percent saturated) and 11,2 mg/l (110 percent saturated) in the reservoir above the new weir on 80-07-06 (ECRU). Bok (1976) found that in the river upstream of the tidal limit, oxygen concentrations were mainly between one and nine parts per million but large deep pools often have deoxygenated bottom layers and values as low as 0,2 parts per million were recorded.

Nutrients. No data. Enrichment of river water from fertilized agricultural lands and from the Grahamstown sewerage works via the Bloukrans tributary can be expected (see Section on Pollution).

Particulate organic matter. Suspended organic detritus is evident in plankton samples (Grindley, 1976. unpublished data).

3.2.6 Pollution

The gradual *ad hoc* development of Port Alfred and a seasonally fluctuating population has resulted in a piecemeal approach in the planning and construction of sewerage and stormwater drainage systems. The entire sewerage and stormwater situation is at present being investigated by a firm of consulting engineers (Bergman and Partners, 1982).

The present sewage system consists partly of septic and conservancy tanks while a pail system is utilized by the Kowie Hospital and the Coloured township. The effluent from the pails and conservancy tanks is disposed of by burying and spreading out over a night-soil area on the low-lying floodplain above Centenary Park (see Figure 7). A luxuriant growth of kikuyu grass (*Pennisetum clandestinum*) flourishes in this high nutrient area.

The Black township relies on a pit toilet system and other primitive methods of sewage disposal.

Refuse from the town is burned and buried at a Municipal dump situated on higher ground adjacent to the sewage disposal area (see Figure 7).

The majority of stormwater from the residential and business area is channelled directly into the Kowie estuary by numerous drains and via the lagoons on the East and West banks. This together with subterranean seepage from septic tanks and restricted water exchange, has resulted in algal blooms occurring in the shallow

warm waters of these lagoons, particularly during the summer months. (R Jubb and A Bok, pers. comm.), see also Section 4.1.

A preliminary survey to study the trace metal content of the Kowie River by RJ Watling in 1978 indicates that the river is unpolluted with respect to metals. The metal levels obtained suggest that they are derived from the rocks through which the river has cut its course and the metals present in the sediments are likely to be in a stable inorganic form (Watling and Watling, 1982).

While carrying out SCUBA dives in the section of estuary running through the town, Susan Rudd noted that the bottom is littered "with an indescribable amount of garbage", and a large amount of fish offal in the vicinity of the offloading wharves above the Putt bridges (Rudd, 1978). The strong tidal action in the main channel of the estuary fortunately disperses a certain amount of the waste disposed of in the estuary, while fish and an abundance of crabs probably utilize the fish offal. This does, however, not condone the use of the estuary for general waste disposal.

Other forms of potential pollution are run-off from cultivated lands in the upper catchment, sewage effluent from the Grahamstown sewerage works via the Bloukrans tributary and run-off from cattle dipping tanks situated close to the river. Fish kills have been recorded as a result of cattle dip entering the river (R Jubb, pers. comm.).

3.2.7 Public Health Aspects

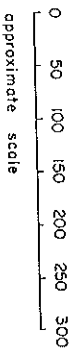
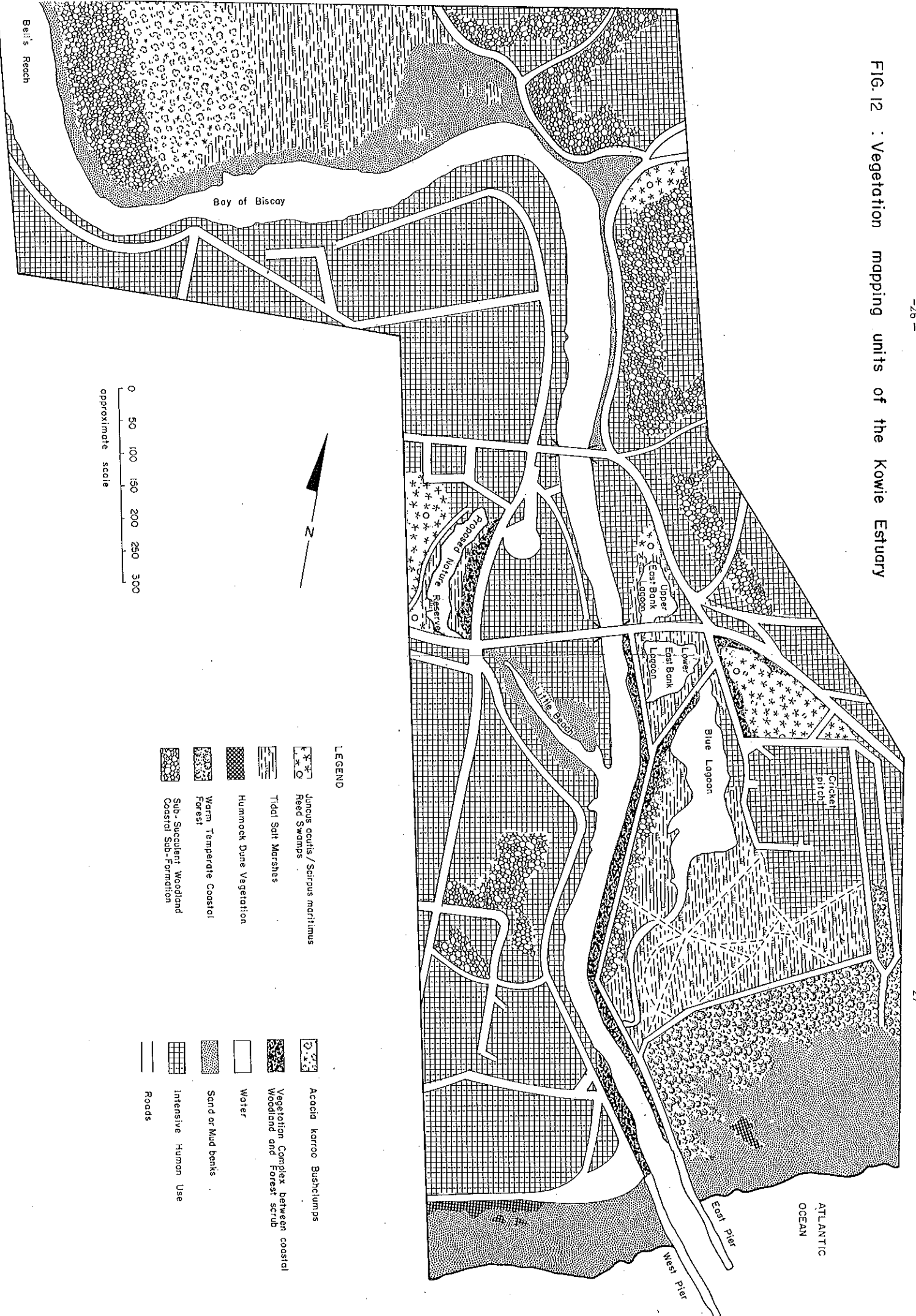
The existing sewage systems and disposal methods being utilized by the Port Alfred authorities constitute a potential health hazard, particularly in times of flooding.

No bacterial counts or testing of the river water takes place in the vicinity of the town; however regular bacteriological sampling of the domestic water pumped from the "Ebb and Flow" weir is carried out by the State Health Department. Records are maintained by the Port Elizabeth office of the Department (Port Alfred Municipality, pers. comm.).

A potential health hazard is the open drain from the Kowie hospital and the stormwater run-off from the business centre which drains into the proposed Nature Reserve lagoon which is in turn connected to the childrens bathing area of Little Beach.

No bilharzia (Schistosomiasis) is reported locally (Port Alfred Municipality, pers. comm.) but the snails which act as host for the parasite, are present in the Kowie system (R Jubb, pers. comm.). Confirmed cases of bilharzia have been recorded as far west as the Uitenhage District.

FIG. 12 : Vegetation mapping units of the Kowie Estuary



LEGEND

- | | | | |
|--|--|--|--|
| | Juniperus acutis / Scirpus maritimus | | Acaacia karroo Bushclumps |
| | Reed Swamps | | Vegetation Complex between coastal Woodland and Forest scrub |
| | Tidal Salt Marshes | | Water |
| | Hummock Dune Vegetation | | Sand or Mud banks |
| | Warm Temperate Coastal Forest | | Intensive Human Use |
| | Sub-Succulent Woodland Coastal Sub-Formation | | Roads |

4. BIOTIC CHARACTERISTICS

4.1 Flora

(This section is contributed by M O'Callaghan of the Botanical Research Unit, Stellenbosch.)

The general configuration of the lower Kowie River is shown in Figure 7. The spatial distribution of the semi-aquatic and terrestrial vegetation mapping units is depicted in Figure 12 while Appendix I shows some of the species and physical features of each unit, as established during the ECRU survey of December 1981.

4.1.1 Phytoplankton/Diatoms

Sharp (1977) and Hill (1967), while discussing the gut contents and diets of the mussel *Musculus virgiliae* and the mud prawn *Upogebia africana*, respectively, mention the presence of benthic diatoms and dinoflagellates.

Giffen (1970) collected diatoms from several stations in the Kowie River and adjacent lagoons and describes approximately 286 species and varieties. A number of these have a cosmopolitan distribution but were not previously recorded from South Africa, while 11 of these species and/or varieties were new to science.

4.1.2 Algae

Numerous algae were found in all the lagoons adjacent to the river. Of these *Ulva* cf *capensis*, *Enteromorpha prolifera* and *Gelidium pristoides* dominate while *Chondria* sp (O'Callaghan 3)⁺, *Centrocerus clavulatum* and *Griffithsia* sp (O'Callaghan 4) were less conspicuous. Blue-green Algae were also found in the Lower East Bank Lagoon (e.g. *Plectonema* sp (O'Callaghan 7), and *Lyngbya majuscula*) which could be an indication of high nutrient levels in these waters.

Alexander and Ewer (1969) report *Gracilaria verrucosa* from the Lower East Bank Lagoon and the proposed Nature Reserve area (see Figure 12), while Giffen (1970) reports dense mats of red algae and *Lyngbya* sp (Cyanophyceae) from the furrows and streams north of the Bay of Biscay.

Nutrient levels in the lagoons may be enhanced by run-off and seepage and sometimes result in high algal production.

Where the "filtering" function of adjacent reed swamps had been disturbed (i.e. in the Upper East Bank Lagoon and proposed Nature Reserve area), the algal growth is more profuse. (see *Juncus acutis/Scirpus maritimus* Reed Swamps.)

⁺O'Callaghan species number, (e.g. O'Callaghan 3) refers to specimens collected by O'Callaghan but not yet identified at the time of writing.

4.1.3 Aquatic Vegetation

Ruppia spiralis and *R. maritima* were found in all the lagoons adjacent to the river. Day (1981) mentions *R. spiralis* from the upper reaches of the river, as well as patches of *Zostera capensis*. *Zostera* beds are present in areas near Bell's Reach and the Bay of Biscay.

Day (1981) points out that the canalization of the river mouth might have led to the depauperation of the flora by destroying *Zostera* and salt marsh beds and increasing the rate of tidal exchange and flow in the river.

4.1.4 Semi-Aquatic Vegetation

Two main semi-aquatic vegetation mapping units were identified around the Kowie estuary. These were: (a) *Juncus acutis/Scirpus maritimus* Reed Swamps; (b) Tidal Salt Marshes.

Brief descriptions of these vegetation mapping units are as follows:

- (a) *Juncus acutis/Scirpus maritimus* Reed Swamps: This vegetation type survives in a relatively undisturbed state only to the east of the Lower East Bank Lagoon. In other areas, this vegetation type has been disturbed by the dumping of rubble, litter, etc. and the encroachment of non-indigenous plants e.g. *Pennisetum clandestinum* (kikuyu).

These swamps (especially to the east of the Lower East Bank Lagoon - see Figure 12) are often inundated with stormwater. They serve to "filter" the water, including absorption of excess nutrients, so preventing this entering the lagoons. The disturbance of these communities could be detrimental to this filtering process and thus facilitate excessive algal growth in the lagoons.

- (b) Tidal Salt Marshes: The major salt marsh, including *Spartina capensis*, *Chenolea diffusa*, *Sarcocornia perenne* and other species, is found to the north of the Bay of Biscay. The distribution of species in this area is described by McDonald (1970). However this area seems to have been disturbed by grazing and substantial encroachment of *Acacia karroo* (sweet thorn) has taken place since 1970 (pers. obs. and comparison of aerial photographs).

Alexander and Ewer (1969) briefly describe the zonation of the salt marshes around the Kowie estuary.

Around the Lower East Bank Lagoon, the proposed Nature Reserve and the upper parts of the Blue Lagoon, the vegetation is dominated by *Sporobolus virginicus* (brakgras) with *Spartina capensis* (strandkweek), *Disphyma crassifolia*, *Salicornia meyerana* and others. South of the Blue Lagoon, the vegetation is largely dominated by *Spartina*.

*Plantago carnos*a and *Cynodon dactylon* (Bermuda quick grass) are abundant to the west of the Blue Lagoon and this drier area also includes *Limonium linifolium*, *Sporobolus virginicus* and others.

The preliminary *Spartina* and *Sarcocornia* (ex *Arthrocnemum*) transplant experiments carried out by Curtis (1976) along Bell's Reach, to try to control riverbank erosion, have only been partially successful, as much erosion of the banks still takes place. During the ECRU survey of December 1981 it was noted that, especially at high tides, wave-wash of the river banks caused by the wakes of passing boats caused erosion and the undermining of vegetation along this section of the river. This indicates the need for stricter enforcement of boat speed restrictions.

4.1.5 Terrestrial Vegetation

The terrestrial vegetation was classified into five main vegetation mapping units, viz: (a) Hummock Dune Vegetation; (b) Warm Temperate Coastal Forest; (c) Sub-succulent Woodland, Coastal Sub-formation; (d) *Acacia karroo* Bushclump; (e) Vegetation Complex between Coastal Woodland and Forest Scrub. These units are described in more detail below.

- (a) Hummock Dune Vegetation: The landward edges of the hummock dunes have a sparse covering of *Agropyron distichum* (sea wheat), *Arctotheca populifolia* (sea pumpkin) and *Tetragonia decumbens* (klappiesbrak). Nearer the inhabited areas, *Cynodon dactylon* (Bermuda quick) and non-indigenous grasses such as *Pennisetum clandestinum* are found.

The vegetation units which follow are also described by Martin and Noel (1960), namely:

- (b) Warm Temperature Coastal Forest: This vegetation type is well established to the east with *Sideroxylon inerme* (milkwood), *Mimusops caffra* (red milkwood), *Brachylaena discolor* (wild silver oak) and others. Nearer the river, however, this coastal forest is more open and stunted or lower growing. Alien trees such as *Eucalyptus globulus* (blue gum) and *Acacia cyclops* (rooikrans) are found here while *Passerina* sp, *Chrysanthemoides monolifera* and *Rhus crenata* are found nearer the beach.
- (c) Sub-succulent Woodland, Coastal Sub-formation: Tree Euphorbias and other succulents are common in this vegetation type as well as *Schotia latifolia* (bush boerboon), *Ptaeroxylon obliquum* (sneeze wood), *Cussonia spicata* (cabbage tree) and others. This vegetation type is described by Acocks (1975) as 'Valley Bushveld, Southern Variation' and is found adjacent to the river well into the catchment, except where the vegetation has been removed by private land owners for crops and grazing. Around the town, this vegetation type survives relatively well, except in areas where some of the woody species have been removed for fuel.
- (d) *Acacia karroo* Bushclump: This vegetation unit is dominated more by *Acacia karroo* than as described by Martin and Noel (1960). At present it tends to form a dense thicket. *Rhus*

tomentosa (wild current) and *Maytenus procumbens* (dune kokoboom) are also found with a number of grasses e.g. *Panicum maximum* (Guinea grass) and *Melica racemosa* (haakgras).

- (e) Vegetation Complex between Coastal Woodland and Forest Scrub: The areas covered by this vegetation unit are too small to define the vegetation accurately. This unit occurs in restricted areas along roadsides and/or tracks, in proximity to water. It consists of relatively open scrub with *Rhus crenata* (dune crow berry), *R. glauca* (blue kuni-bush), *Lycium tetrandrum* (bokdoring) and *Azima tetracantha* amongst others.

4.2 Fauna

4.2.1 Zooplankton

No published data. Day (1981) reported that the zooplankton had not been surveyed but unpublished information is available (JR Grindley, pers. comm.). Zooplankton was sampled at a series of 12 stations through the estuary on 67-12-13 by Grindley. The mean zooplankton biomass was 20,6 mg/m³ (range 5,6 - 42,3 mg/m³). The most abundant zooplankton organisms were the copepods *Acartia natalensis* and *Pseudodiaptomus hessei*. The mysids *Rhopalophthalmus terranatalis* and less abundantly *Gastrosaccus brevifissura* and *Mesopodopsis slabberi* were also common. Among the less abundant copepods were *Acartia longipatella*, *Acartia africana*, *Calanus helgolandicus*, *Harpacticus* sp and other harpacticoids, *Labidocera* sp, *Macrosetella gracilis*, *Oithona brevicornis*, *Oncaea mediterranea*, *Paracalanus parvus*, *Pontella* sp, *Tegastes* sp, *Tortanus capensis* and nauplius larvae of copepoda. Other crustacea included Ostracoda, Cirripede nauplii and cypris larvae, the cumacean *Iphinoe truncata*, the Isopod *Circolana* sp and *Leptanthura laevigata*, the Amphipoda *Austrochiltonia capensis* and *Grandidierella bonneiri*, the shrimps *Palaemon pacificus*, the crown crab *Hymenosoma orbiculare* and decapod mysids, megalopa and zoea larvae. Among the remaining organisms were hydroid medusae, siphonophores, polychaete larvae, gastropod larvae, lamellibranch larvae, the pipefish *Syngnathus acus*, fish eggs and fish larvae. In all a total of 39 species of zooplankton organisms were recorded (Grindley, 1976, unpublished).

4.2.2 Aquatic Invertebrates

The benthic fauna has not been surveyed but Day (1981) reports that it appears to be poor apart from a few species. The rocky retaining walls are colonised by several marine forms, including the sea urchin *Parechinus angulosus* which is devastated by periodic floods (Day, 1981). At higher tidal levels gastropod molluscs such as *Oxysteles tigrina*, *O. variegata*, *Littorina knysnaensis* and the crab *Cyclograpsus punctatus* are common (Day, 1981). The serpulid polychaete *Picopomatus enigmatica* is common on hard substrata right up to the head of the estuary at "Ebb and Flow" (ECRU surveys).

The feeding and distribution of the bivalve mollusc *Musculus virgiliae* has been studied in the Kowie estuary and they have been recorded in salinities ranging from 0 parts per thousand at the top of the estuary to 34 parts per thousand lower down (Sharp, 1977). Muddy substrata in the lower estuary appear to limit the distribution of *Musculus* whereas *Lamya capensis* is often found virtually submerged in soft mud, yet still attached to rocks. *Musculus virgiliae* appears to be found predominantly where the substrata are firmer and coarser.

The mudbanks in the middle reaches have a richer fauna than the hard substrata have. The mud prawn *Upogebia africana* may reach 600/m² (see also page 31) and with it are the mollusc *Nassarius kraussianus*, the crab *Cleistostoma edwardsii* and in softer mud *Cleistostoma algoense*. The crab *Sesarma catenata* is common towards the high tide levels. The main invertebrates in the upper reaches are *Sesarma eulimene* and at lower levels the bivalves *Solen corneus* (up to 150/m²) and *Musculus virgiliae* both of which are preyed on by the swimming crab *Scylla serrata*. Smaller forms such as amphipods, isopods, hydrobiid gastropods and polychaete worms have not been investigated (Day, 1981).

The crabs *Sesarma catenata* and *Cyclograpsus punctatus* both occur in the Kowie estuary. *C. punctatus* is adapted to living under stones and has therefore been able to establish itself among the stones of the walls and dykes lining the river, while both species live together in the muddy banks of the river (Alexander and Ewer, 1969). The osmoregulatory ability of three grapsoid crabs *Cyclograpsus punctatus*, *Sesarma catenata* and *Sesarma eulimene* are described in relation to their penetration of the estuarine system by Boltt and Heeg (1975). The shrimp *Palaemon pacificus*, the amphipod *Grandidierella* sp., the isopod *Sphaeroma* sp., and the tiny mollusc *Assimineia ponsonbyi* occur in the East Flats Lagoons (ECRU survey 81-12-02).

The amphipod *Corophium* and a hydrobiid mollusc occur right up to "Ebb and Flow" (Reavill, pers. comm.). The freshwater mussel *Unio caffer* occurs in the Kowie river but recent surveys suggest that they are not as common in rivers as recorded by Connolly (1939) in his monograph. The glochidia larvae of *Unio* become attached to fish until metamorphosis takes place to the mussel (Jubb, 1967).

Hill (1975) studied the abundance, breeding and growth of the crab *Scylla serrata* in the Kowie estuary. He found that females mate in summer at a carapace width of 103 to 148 mm, and males at 141 to 166 mm. After mating, females migrate out of the estuary to spawn. The heart rate of *Scylla serrata* has been studied (Hill and Koopowitz, 1975).

Burrows of the sand prawn *Callinassa kraussi* are present in several sandy areas of the estuary including at the Boat Club wharf and in the West Lagoons. However, they are now rare in the Little Beach area where GF van Wyk reported them in 1956 but a few were found near the head of this lagoon (ECRU survey, July 1980). *Callinassa kraussi* abundance recorded in July 1980 was: Little Beach 3,25/core, 256 holes/m²; East Flats 4/core, 576 holes/m²; Blue Lagoon 7/core, 496 holes/m² (C Gaigher, pers. comm.).

The ecology of the mudprawn *Upogebia africana* has been studied by Hill (1967). It is often the dominant animal in the lower intertidal zone and between 5 000 and 48 000 are removed from the Kowie estuary every fortnight with very little effect on the total population. *Upogebia* feeds on detritus and micro-organisms living in the mud. Their burrowing habit results in the substrata being irrigated and aerated. They are an important food source for estuarine fish. The influence of temperature, salinity and oxygen on the biology of *Upogebia* in the Kowie estuary has been described. Four different parasites of *Upogebia* have been found from the Kowie estuary (Hill, 1967).

The commercial exploitation of the mud prawn *Upogebia africana* in the Kowie estuary has been described by Hill and Bok (1977). The current collecting method using tins to force the prawn from its burrow appears to be the most favourable, since few egg-bearing females are caught and there is little disturbance to the environment. Prawns of one and a half to three years of age are taken. It is suggested that protecting areas for alternate seasons may not be necessary and furthermore it is recommended that no digging should be allowed but that populations should be monitored (Hill and Bok, 1977).

Upogebia africana abundance recorded in July 1980 was: In closed bait area 13 - 17/100 holes, 384 - 603 holes/m²; in open bait area 20/100 holes, 272 - 504 holes/m² (C Gaiger, CPA Nature Conservation Notes to be published). Bait controls include a notice at the West Lagoon and East Flats lagoons stating 'Closed bait area, No fishing or netting.

4.2.3 Fish

GF van Wyk in his 1956 notes drew attention to the presence of many juvenile fish in the shallow lagoons adjoining the estuary. The fish fauna includes mullet, juvenile stumpnose, *Rhabdosargus holubi* and shoals of white Steenbras, *Lithognathus lithognathus*. Spotted grunter, *Pomadourys commersonni* appear in late summer. The resident species include Gobies, and the Silversides, *Gilchristella aestuarius* and *Hepsetia breviceps* (Day, 1981). Stumpnose, White Steenbras and Kob, *Argyrosomus hololepidotus*, all prey on *Upogebia africana* (Hill, 1967). Marine fish do occur right up to the head of the estuary at "Ebb and Flow" 21 km from the sea. These include White Steenbras, Spotted Grunter, Southern Mullet, *Liza richardsoni*, the Goby, *Gobius maxillaris*, and even the Kingfish, *Caranx sexfasciatus* (A Bok, pers. comm.). Fish observed at "Ebb and Flow" during the ECRU visit on 80-07-06 included Cape Moony, *Monodactylus falciformis*, the Goby, *Glossogobius giurus* and the Flathead Mullet *Mugil cephalus*.

The distribution of freshwater fish in the Kowie river system is described by Jubb (1967). Many features of their distribution depend on the evolution of the river drainage patterns through geological time as well as through human manipulations as discussed by Skelton (1980).

Mullet used to migrate up to the Bloukrans pool on the Kowie river but weirs now prevent this movement. Eels, however, are still able to migrate up to the head waters of the river (A Bok, pers. comm.).

Myxus capensis is recruited into the fresh water of the river upstream of the tidal limit virtually all year round but *Mugil cephalus* have been caught only in the fresh water of the river in the summer months between November and April. Details of size composition of *Myxus capensis* (10 - 440,5 mm) and *Mugil cephalus* (15,5 - 310,5 mm) and their growth and breeding status are recorded (Bok, 1976).

4.2.4 Reptiles and Amphibians

According to A de Villiers of the Cape Department of Nature and Environmental Conservation a total of 11 species of frog, 20 species of snake and 4 species of tortoise have been recorded from the area, of these the African Python is listed in the SA Red Data Book for Reptiles and Amphibians (McLachlan, 1978), (see Appendix II).

4.2.5 Birds

The birds of the Kowie estuary have been recorded by a number of workers. According to Underhill et al (1980) the mud flats and marsh areas of the Kowie estuary constitute ideal habitat for water birds. They remark that the largest concentration of Greenshank occurring between Port Elizabeth and the Kei River is found at the Kowie estuary. On 5/6 January 1979 the Western Cape Wader Study Group counted a total of 601 waders of 17 species as well as an additional 111 other birds also from 17 species (Underhill et al, 1980)(see Appendix III).

Mr AD Boddam-Whetham, from Port Alfred has recorded the water-associated birds of the Kowie and Bathurst District from 1973 - 1982. His records of up to 93 species, include 35 species of waders which frequent the mudbanks and saltmarshes of the estuary while the remaining 58 species are found along the upper reaches of the Kowie river, on the beaches and alongside local dams and waterbodies.

During the ECRU Survey on 9 July 1980, 29 species were observed from the mouth of the estuary up to "Ebb and Flow".

Of all the bird species observed at the Kowie estuary, the following have been listed in the South African Red Data Book-Aves as species requiring conservation (Siegfried et al, 1976). White-backed Night Heron, Black Stork, Greater Flamingo, African Fish Eagle, Baillon's Crake and Finfoot.

4.2.6 Mammals

A detailed account of the distribution and status of mammals of the Bathurst district is at present being compiled by the Senior Nature Conservation Officer of the Dias Divisional Council (P Coetzee, pers. comm.). Preliminary data indicate that 20 species are present on the properties adjoining the Kowie River estuary up to "Ebb and Flow" (see Appendix IV).

According to Stuart *et al* (1980, unpublished) and Stuart (1981) an additional 9 species have been recorded in the area covered by the 1:50 000 Topocadastral Sheet 3326 DB Port Alfred, in which the Kowie estuary is situated (see also Appendix IV).

Of the total of 31 species of mammals recorded at or near the Kowie estuary, 6 have been listed in the South African Red Data Books as being threatened or rare. These are the Tree dassie, Antbear, Striped Weasel, Honey badger, Oribi and the Blue duiker (Meester, 1976) and (Skinner et al, 1977). Overall habitat alteration or destruction is probably the most significant factor leading to the present status of these animals.

5. SYNTHESIS

The Kowie river and estuary in their natural state were typical of many Eastern Cape systems. The river is relatively short with a small, well vegetated catchment which has cut a steep-sided meandering course through a shale substrate. The flow in this river can be very erratic, varying from long periods of virtually no flow to short periods of violent flooding which can cause tremendous erosion and threaten any developments in low-lying areas. The estuary which is tidal for 21 km broadens out towards the sea and it is here where the major man-made changes have been made. In trying to establish a harbour at the mouth of the estuary the river course was straightened and canalized between two stone-packed berms extending out into the surf zone (see Sections 1, 3.1 and 3.2).

The harbour venture never succeeded but the attractive environment with a temperate climate resulted in the town of Port Alfred developing into a popular holiday resort and retirement village. The town is situated on the low-lying floodplain and hills surrounding the estuary.

Some of the features which give the estuary its unique characteristics and quality are:

- (a) The town and surroundings are steeped in history and dates back to the 1820 Settlers.
- (b) A series of lagoons situated on either side of the main channel, which although radically altered by man-made structures continue to function as viable systems.
- (c) A fully tidal estuary with rich prawn beds and a high diversity of marine fish and other organisms which utilize this habitat.
- (d) The surrounding country covered with indigenous Valley bushveld and Coastal forest.

Overall population growth and improved accessibility is resulting in ever-increasing pressure on all recreational facilities as well as the natural environments. This trend is reflected at the Kowie Estuary where the existing facilities both on the estuary and in the town of Port Alfred have become totally inadequate to cope with the annual influx of holidaymakers. This situation is

likely to be further aggravated by a proposed Casino at the Fish River mouth in Ciskei only 25 kilometers from Port Alfred.

The Municipality of Port Alfred is aware of the problems and is taking steps to improve facilities both on the estuary and in the town. The construction of a small boat harbour is underway (see Section 3.2 Landownership/Uses) and improvements to the sewage and stormwater drainage systems are being planned as well as improvements to the domestic water supply (see Section 3.2, Pollution and Public health Aspects).

The natural features of the Kowie Estuary, which give Port Alfred its unique character, allow the environment to cope with floods, present levels of pollution and the onslaught of wind and waves on the coastline adjacent to the estuary mouth. In order to retain these capabilities, the following recommendations are made:

- (a) The East and West Banks Lagoons which are healthy viable systems and integral parts of the estuary should be protected against over-utilization. The number of footpaths in the East Flats saltmarshes should be reduced and only one vehicular access to the East Pier allowed around the outer edge of the Flats. The lease for the existing caravan park should not be renewed once the present lease expires. Alien vegetation on this site and around the cricket field should gradually be replaced with indigenous vegetation and the area used for low intensity recreation and conservation purposes. This low-lying area is subject to flooding and is a natural flood "safety valve" for the adjacent areas (Heydorn & Tinley, 1980: 52 and 68).

The ecological significance and value of the East Flats area for the Kowie Estuary would be much greater if the East berm was removed seaward of the Nico Malan bridge. However, because of developments below High Water Spring Tide levels which include several private houses and the Blue Lagoon Cafe, this would not be possible without costly expropriations.

- (b) The vegetation stabilized dunes adjacent to East Flats saltmarshes should be protected and, in particular, access to the fore-dune area should be only via a limited number of "boardwalks" to cut down wind erosion in this sensitive area. The protected back-dune areas could be considered for low-intensity recreational development such as picnic sites and parking areas (Heydorn & Tinley 1980, p 54, 68 and 69).
- (c) A small-boat harbour should be developed according to plans put forward by the Fisheries Development Corporation. These plans call for the design of a functional small-craft harbour in harmony with the environment and in such way that the carrying capacity of the estuary is not exceeded and the town does not lose its character and aesthetic appeal (Fisheries Development Corporation, 1982). As well as controlling numbers of boats using the estuary, the speed of motorboats needs to be strictly limited to avoid further bank erosion.

- (d) The proposal of the Port Alfred Municipality to declare the "Civic Centre Lagoon" on the West Bank as a bird sanctuary with an environmental education and information centre is strongly recommended. Polluted stormwater and runoff from the business centre and the Kowie hospital must not be allowed to enter this lagoon. This is particularly relevant as this lagoon drains into the "Little Beach" lagoon utilized for children's bathing.
- (e) The ecological functions of the upper East Bank lagoon (i.e. above the trunk road) which at present acts as a stormwater buffer/filter and a source of nutrients, will cease to exist with the blocking-off of the culverts under the trunk road during construction of the small-boat harbour. In this event, this area could be utilized for surplus dredge material and an area established for certain facilities associated with the new harbour. This would reduce the necessity for excessive reclamation of the marsh area east of the proposed harbour.

Alternative drainage for stormwater normally entering the upper East Bank lagoon will have to be provided by piping the water directly into the Kowie river just above the trunk road bridge.

- (f) The proposal to conserve the East Bank wharf and the old buildings in that area as an historical feature is supported.
- (g) The rich mud-prawn beds of the Bay of Biscay should be carefully conserved and monitored to guard against overexploitation of this resource.
- (h) The filtering and nutrient production functions of the marsh area at Berrington Cove, adjacent to the Grahamstown road should be retained if at all possible (Heydorn & Tinley, 1980: 68).
- (i) The low-lying area of Centenary Park and the A & M Flats should be planned for low-intensity recreational purposes with the retention of as much indigenous vegetation as possible. This would be supplementary to the Provincial Nature Reserve which is adjacent to Centenary Park.
- (j) In the planning of the sewage and stormwater systems the natural filtering function of reedbeds and marsh areas should be recognized and utilized as much as possible.

With the intensive recreational utilization of the estuary and the possible deleterious effects of excessive enrichment of the estuary water, sewage effluent discharged into the estuary should be of the highest possible standard. The scheme to re-utilize sewage effluent as a flushing water supply (Bergman and Partners, 1981) should be seriously considered.

- (k) The plans to consolidate the existing Directorate of Forestry Reserves in the upper reaches of the estuary and to manage these as conservation areas is welcomed in view of the presence of certain rare and endangered species which

are found within these habitats. Recommendations made by Heydorn and Tinley (1980, p88) regarding Reserve status for the inland vleis south of Port Alfred, should be considered.

In this report an attempt has been made to present a synopsis of available information on the Kowie estuary. However much of the work done consists of in-depth fundamental research, details of which could not be included. The results of these projects can however be obtained by consulting the original references.

6. ACKNOWLEDGEMENTS

One of the reasons for the publication of this report is that baseline data are required for the planning and development of a small boat harbour at Port Alfred.

The initiative of the Port Alfred Municipality, and in particular the Mayor, Mr A Randall and the Town Clerk, Mr H Chapman aimed at ensuring that all available information is considered prior to proceeding with the small boat harbour project is acknowledged with appreciation; as is the co-operation, assistance and hospitality of all the Municipal officials during the ECRU survey.

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The publishers, Howard Timmins are thanked for their permission to reproduce Figures 1 and 2 from the book "Basket Work Harbour" by EW Turpin.

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7.

GLOSSARY OF TERMS USED IN PART II REPORTS

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

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

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

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APPENDIX I: Species composition and physical features of the vegetation mapping units of the area studied at the Kowie estuary

Mapping Unit	*Area (ha)	% of area studied	Cover (%)	Average height (m)
<i>Juncus acutis/Scirpus maritimus</i> Reed Swamps	6,36	2,02	80	1,20
Tidal Salt Marshes	35,20	11,17	70-90	0,20-0,30
Hummock Dune Vegetation	0,76	0,24	10	0,90
Warm Temperature Coastal Forest	10,10	3,20	100	2,00
Sub-Succulent Woodland, Coastal Sub-Formation	27,54	8,74	100	2,50
<i>Acacia karroo</i> Bushclump	11,06	3,51	100	1,50
Vegetation complex between Coastal Woodland and Forest Scrub	7,01	2,22	60	1,30
Water	43,08	13,67		
Sand	33,99	10,78		
Intensive Human Use	140,05	44,45		
Total	315,15			

(*estimated areas)

Juncus acutis/Scirpus maritimus Reed Swamp

Juncus acutis (3); *Linum afrum* (r); *Scirpus maritimus* (3).

Also found on verges:

Comiza ivifolia (r); *Rhus crenata* (r); *Stenotaphrum secundatum* (1).

Tidal Salt Marshes

North-west of Bay of Biscay

(from McDonald (1970) and personal observations)

Aster sp (r); *Chenolea diffusa* (3); *Chironia baccifera* (+); *Disphyma crassifolia* (+); *Limonium scabrum* (2); *Salicornia meyerana* (+); *Samolus porosus* (r); *Sarcocornia decumbens* (r); *S. perenne* (3); *S. pillansii* (+); *Spartina capensis* (1); *Sporobolus virginicus* (2); *Suede maritima* (+); *Triglochin bulbosa* (+).

To south of Blue Lagoon

Chenolea diffusa (+); *Disphyma crassifolia* (1); *Juncellus laevigata* (1);
Salicornia meyerana (+); *Samolus porosus* (+); *Sarcocornia pillansii* (+);
Spartina capensis (4); *Sporobolus virginicus* (1); *Stenotaphrum secundatum* (1);
Triglochin bulbosa (+).

To west of Blue Lagoon

Carex ecklonii (+); *Chenolea diffusa* (2); *Felicia ficoidea* (r);
Limonium linifolium (2); *Plantago carnosus* (4); *Salicornia meyerana* (+);
Samolus porosus (+); *Sarcocornia pillansii* (+); *Sporobolus virginicus* (3);
Triglochin bulbosa (r).

Hummock Dune Vegetation

Agropyron distichum (+); *Arctotheca populifolia* (r); *Chrysanthemoides*
monolifera (r); *Cynodon dactylon* (1); *Pennisetum clandestinum* (1);
Tetragonia decumbens (r).

Warm Temperate Coastal Forest

(from Martin and Noel (1960) and personal observations)

Acacia cyclops (1); *Aloe ferox* (r); *Anthospermum littoreum* (+);
Asparagus sp (1); *Azima tetracantha* (r); *Brachylaena discolor* (2);
Capparis sepiaria (3); *Carissa bispinosa* (+); *Carpobrotus edulis* (r);
Cassine peragua (+); *Chrysanthemoides monolifera* (1); *Cordia caffra* (+);
Cussonia thyrsoflora (1); *Dovyalis caffra* (3); *D. rhamnoides* (2);
Eucalyptus globulus (1); *Euclea racemosa* (1); *Ficinia ramosissima* (+);
Grewia occidentalis (+); *Haemanthus albiflos* (+); *Lagurus ovatis* (1);
Lycium afrum (+); *Maerua* cf *racemulosa* (2); *Maytenus heterophylla* (+);
M. procumbens (1); *Melilotus indica* (r); *Panicum maximum* (1); *Passerina*
sp (1); *Pavetta natalensis* (+); *Pterocelastrus tricuspis* (1); *Rhus*
crenata (2); *R. incisa* (+); *R. lucida* (+); *R. undulata* (2); *Rhynchosia*
caribaea (2); *Scutia myrtina* (+); *Schotia afra* (+); *Senecio* cf *triangularis* (2);
Sideroxylon inerme (3); *Solanum quadrangulare* (+); *S. rigescens* (r);
Tetragonia decumbens (+); *Veltheimia viridifolia* (r); *Xanthoxylon*
capensis (1).

Sub-succulent Woodland, Coastal sub-formation

(from Martin and Noel (1960); Acocks (1975); Curtis (1976) and personal observation)

Acacia karroo (1); *Aloe ciliaris* (1); *A. ferox* (+); *A. speciosa* (1);
Asparagus africanus (r); *A. asparagoides* (+); *A. racemosus* (1); *A.*
suaveolus (+); *Azima tetracantha* (+); *Behnia reticulata* (+); *Capparis*
sepiaria (+); *Carex glomerata* (r); *Cassine aethiopica* (1); *Cheilanthes*
hirta (r); *Clusia daphnoides* (+); *Cordia caffra* (+); *Crassula perforata* (+);
Cynanchum natalitium (r); *Disphyma crassifolia* (+); *Dovyalis rhamnoides* (+);
Ehrharta erecta (+); *Euclea undulata* (+); *Euphorbia grandidens* (2); *E.*
triangularis (2); *Exomis microphylla* (+); *Fagara capensis* (+); *Ficinia*
repens (r); *Galenia secunda* (+); *Harpephyllum caffrum* (r); *Hypoestes* cf
verticillaris (+); *Lycium afrum* (+); *Maytenus natalensis* (+); *M.*
nemerosa (r); *M. procumbens* (+); *Melica racemosa* (1); *Opuntia ficus-*
indica (+); *Panicum maximum* (3); *Pelargonium peltatum* (+); *Plectranthus*

spp (1); *Portulacaria afra* (1); *Putterlickia pyracantha* (+); *Ptaeroxylon obliquum* (1); *Rhoiacarpus capensis* (1); *Rhoicissus digitata* (+); *Rhus longispina* (+); *Salvia scabra* (r); *Scjotia afra* (r); *S. latifolia* (1); *Senecio angularis* (+); *Sideroxylon inerme* (2); *Stenotaphrum secundatum* (+); *Tetragonia decumbens* (1); *Viscum obscurum* (r).

Acacia karroo Bushclumps

(from Martin and Noel (1960); Curtis (1976) and personal observations)

Acacia karroo (3); *Asparagus racemosus* (r); *A. suaveolus* (r); *Aster capensis* (r); *Atriplex vestita* (r); *Capparis sepiaria* (r); *Ficinia repens* (1); *Gnidia squarosa* (r); *Knowltonia capensis* (r); *Lycium afrum* (1); *Maytenus procumbens* (1); *Melica racemosa* (2); *Panicum maximum* (2); *Phyllanthus verrucosus* (r); *Plectranthus ecklonii* (r); *Putterlickia pyracantha* (r); *Rhoiacarpus capensis* (+); *Rhus tormentosa* (+); *Setaria perennis* (+); *Sporobolus virginicus* (1); *Stenotaphrum secundatum* (1); *Tetragonia decumbens* (1).

Vegetation Complex between Coastal Woodland and Forest Scrub

Acacia cyclops (1); *Arctotheca populifolia* (r); *Azima tetracantha* (+); *Brachylaena discolor* (+); *Carpobrotus edulis* (+); *Cassine sphaerophyllum* (r); *Chrysanthemoides monolifera* (3); *Crassula nudicaula* (r); *Galenia secunda* (r); *Helichrysum teretifolium* (+); *Hypoxis cf rooperi* (r); *Lycium tetandrum* (+); *Mytenus natalensis* (r); *Rhus crenata* (+); *R. glauca* (r); *Scutia myrtina* (r); *Senecio elegans* (r); *Sideroxylon inerme* (r); *Solanum rigescens* (r); *Stenotaphrum secundatum* (+); *Sutherlandia frutescens* (r); *Tarconanthus camphoratus* (+); *Tetragonia decumbens* (+).

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

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

APPENDIX II: A checklist of reptiles and amphibians recorded from the area covered by the 1:50 000 Topocadastral Sheet 3326 DB Port Alfred (A de Villiers, pers. comm.)

Amphibians

Cape sand frog	<i>Tomoptorna delalandii</i>
Striped grass frog	<i>Rana fasciata</i>
Bronze caco	<i>Cacosternum nanum</i>
Leopard toad	<i>Bufo pardalis</i>
Common caco	<i>Cacosternum boettgeri</i>
Yellow striped reed frog	<i>Hyperolius semidiscus</i>
Spotted rana	<i>Rana grayii</i>
Snoring puddle frog	<i>Phrynobatrachus natalensis</i>
Painted reed frog	<i>Hyperolius marmoratus</i>
Common river frog	<i>Rana angolensis</i>
Rattling kassina	<i>Kassina weallii</i>

Reptiles

Bibron's blind snake	<i>Typhlops bibronii</i>
Pink earth snake	<i>Rhinotyphlops lalandei</i>
Black earth snake	<i>Leptotyphlops nigricans</i>
African python	<i>Python sebae</i>
Aurora house snake	<i>Lamprophis aurora</i>
Olive house snake	<i>Lamprophis inornatus</i>
Common brown house snake	<i>Boaedon fuliginosus</i>
Green bush snake	<i>Philothammus semivariegatus</i>
Natal green snake	<i>Philothammus natalensie</i>
Mole snake	<i>Pseudaspis cana</i>
Southern slug-eater	<i>Duberia lutrix</i>
Southern brown egg-eater	<i>Dasypeltis inornata</i>
Rhombic egg-eater	<i>Dasypeltis scabra</i>
Boomslang	<i>Dispholidus typus</i>
Spotted skaapsteker	<i>Psammophylax rhombeatus</i>
Cross-marked grass snake	<i>Psammophis crucifer</i>
Rinkals	<i>Hemachatus haemachatus</i>
Common sea snake	<i>Pelamis platurus</i>
Rhombic night adder	<i>Causus rhombeatus</i>
African puff adder	<i>Bitis arietans</i>

APPENDIX III: Waders and other birds recorded on the Kowie River and adjoining wetlands on the 5th and 6th of January 1979 (from Underhill et al, 1980).

Roberts Number	Species	Sites				Totals
		Kowie River (Upper Estuary)	Bay of Biscay (marsh)	Centenary Park/Bells Reach (marsh)	Blue Lagoon (vlei and marsh)	
232	Turnstone		3	4		7
233	Ringed Plover		17	8	10	35
235	White-fronted Sandplover		6		8	14
238	Three-banded Sandplover		2	7		9
241	Grey Plover		2	8		10
245	Blacksmith plover	3				3
251	Curlew Sandpiper				15	15
253	Little Stint		6	11	3	20
254	Knot		2	18	6	26
255	Sanderling	27	24		15	66
256	Ruff			10	170	180
257	Terek Sandpiper					
258	Common Sandpiper	33	12	2		47
262	Marsh Sandpiper	1			5	6
263	Greenshank	35	51	14	11	111
264	Wood Sandpiper		5	23	15	43
268	Whimbrel	7	2			9
47	White-breasted Cormorant		1		1	2
50	Reed Cormorant	7	4		2	13
54	Grey Heron	3			1	4
58	Great white Egret		1			1
59	Little Egret			2	5	7
61	Cattle Egret	18				18
79	Black Stork			1		1
81	Sacred Ibis			1		1
86	Greater Flamingo			1	1	2
89	Egyptian Goose	2				2
97	Red-bill Teal				9	9
129	Yellow-billed Kite	2		1		3
152	Jackal Buzzard				1	1
287	Southern Black-backed Gull	9	19		1	29
394	Pied Kingfisher	3	1			4
395	Giant Kingfisher	2	1			3
686	Cape Wagtail	No account	5	7		12

APPENDIX IV: Mammals occurring on properties adjacent to the Kowie Estuary up to "Ebb and Flow" (P Coetzee, pers. comm.)

Bushpig	<i>Potamochoerus porcus</i>
Bushbuck	<i>Tragelaphus scriptus</i>
Velvet monkey	<i>Ceropithecus pygerythrus</i>
Blue duiker	<i>Cephalophus monticola</i>
Rock dassie	<i>Procavia capensis</i>
Grey duiker	<i>Sylvicapra grimmia</i>
Tree hyrax	<i>Dendrohyrax arboreus</i>
Grysbuck	<i>Raphicerus melanotis</i>
Antbear	<i>Crycteropus afer</i>
Caracal (lynx)	<i>Felis caracal</i>
Porcupine	<i>Hystrix africaaustralis</i>
Cape wild cat	<i>Felis libyca</i>
Cane rat	<i>Thryonomys swinderianus</i>
Large spotted genet	<i>Genetta tigrina</i>
Scrub hare	<i>Lepus saxatilis</i>
Water mongoose	<i>Atilax paludinosus</i>
Springhare	<i>Pedates capensis</i>
Cape grey mongoose	<i>Herpestes pulverulentus</i>
Chacma baboon (only as far down as (Ebb and Flow"))	<i>Papio ursinus</i>
Honey badger (ratel)	<i>Mellivora capensis</i>

Additional species recorded by Stuart et al (1980, unpublished)
and Stuart (1981)

Dwarf shrew	<i>Suncus etruscus</i>
Oribi	<i>Ourebia ourebi</i>
Multimammate rat	<i>Praomys natalensis</i>
Striped polecat	<i>Ictonyx striatus</i>
Yellow mongoose	<i>Cynictis penicillata</i>
Red musk shrew	<i>Crocidura flavescens</i>
Vlei rat	<i>Otomys irroratus</i>
Black rat	<i>Rattus rattus</i>
Striped weasel	<i>Poecilogale albinucha</i>

APPENDIX V: (Cont.)

ESTUARY / RIVERMOUTH / LAGOON	Sources of information	Summary of available information												YEAR (DATE OF INFORMATION)					
		ABIOTIC						BIOTIC											
		Physio graphy	Geomor- phology	Chemistry	Other	Flora	Fauna	Food Webs											
KOWIE (Estuary)	Port Alfred Publicity Assoc.	*			*														
	River flow data		*																
	River flow data (to be published)		*																
	Rudd																		
	Sharp				*														
	Siegfried									*									
	Skelton																		*
	Skinner																		
	South Africa, Republic Dept. Agr. Techn. Serv.																		*
	South Africa, Republic Dept. Planning									*									
	South African tide tables									*									
	Stewart, Swiridov and Oliver																		*
	Stuart, Lloyd and Herselman									*									*
	Stuart										*								
	Swart and Seryn																		*
	Turpin																		*
	Underhill															*	*		
Van Wyk															*	*		*	

PLATES I, II AND III OVERLEAF

PLATE I: The "Horseshoe Bend" in the upper reaches of the Kowie estuary showing the narrow meandering course. The steep slopes are covered with typical "Valley Bushveld" Vegetation (JR Grindley, July 1980).



PLATE II: High dunes on the West Beach which periodically encroach on the "West Beach Drive". The seaward end of these dunes contribute sand to the West Beach sediment "circulation cell" (ECRU 81-12-04).

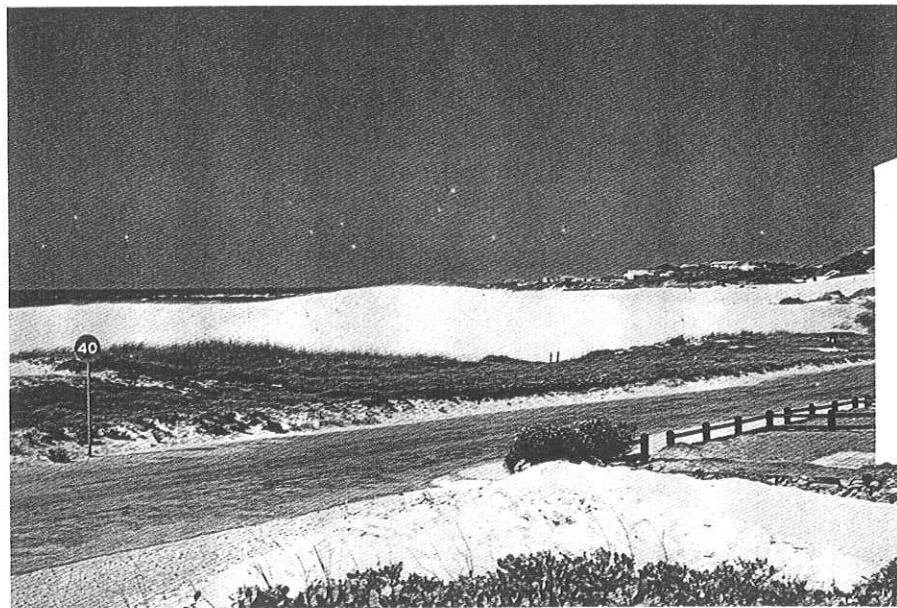


PLATE III: The lower reaches of the Kowie Estuary showing the Nico Malan bridge on the trunk road between Port Elizabeth and East London. In the foreground the Upper East Bank Lagoon has been cut off from the East Bank Lagoon which is the proposed small boat harbour site. The Blue Lagoon and East Flats' saltmarshes which were separated from the main channel by a stone-packed berm during the mid 1800's can be seen to the far left of the photograph. (Protea colour prints (Pty) Ltd)

