DEVELOPMENT OF AN ESTUARINE MANAGEMENT PLAN FOR THE KOWIE ESTUARY

SITUATION ASSESSMENT REPORT

FINAL REPORT

Province of the
EASTERN CAPE
ECONOMIC DEVELOPMENT,
ENVIRONMENTAL AFFAIRS AND TOURISM

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Report Details

Report Title	Development of an Estuarine Management Plan for the Kowie Estuary: Final Situation Assessment Report
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Purpose of this Report	This Situation Assessment Report (SAR) provides a summary of the biophysical, socio-economic, institutional and legal *status quo* pertaining to the Kowie Estuary, and will be used to inform the development of the Estuarine Management Plan (EMP) and associated management of the estuary. This SAR addresses the minimum requirements as set out in the 2021 National Estuarine Management Protocol (NEMP), and will also serve as a baseline against which the outcomes of future monitoring can be assessed.
Prepared For	Eastern Cape Department of Economic Development, Environmental Affairs and Tourism (DEDEAT)
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Executive Summary

Introduction

The Kowie Estuary is an artificially permanently open system that meanders in a south-easterly direction for about 21 km towards its mouth that dissects the coastal town of Port Alfred, within the Ndlambe Local Municipality, Eastern Cape province. In accordance with the National Estuarine Management Protocol (NEMP), developed in line with the National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008, as amended by Act 36 of 2014) (ICM Act), an Estuarine Management Plan (EMP) must be developed for the Kowie Estuary. This document is the Situation Assessment Report (SAR) which provides detailed background information in preparation for the management planning process.

Catchment Characteristics

The Kowie River and its estuary fall within three (3) quaternary catchments, namely P40A, P40B and P40C, covering a total area of approximately 75 748 ha (757 km^2). The area of the Kowie Estuarine Functional Zone (EFZ) constitutes approximately 485 ha (4.85 km^2) and extends 21 km up the river. The river catchment originates at a point which is approximately 760 m above sea-level, while the upper reaches of the EFZ catchment is at about 200 m above sea-level. The majority of the Kowie River intersects the Weltevrede Subgroup of the Witteberg Group (Cape Supergroup). Port Alfred has a temperate climate where the average temperatures are moderated by the Indian Ocean, meaning that minimum and maximum temperatures have a smaller range (approximately 12 °C in July to 20 °C in February). An annual precipitation of approximately 600 mm is recorded in the climate records, but the Eastern Cape is currently facing a devasting drought. In Port Alfred, land uses include business, retail, residential, industrial, commercial and community/health facilities. Most of the business land uses are located in the CBD of the town, which is located directly south-west of the Kowie Estuary and split by Main Street. The CBD, due to its position below the 20 m contour, is subject to flooding and is the area most likely to be affected by sea level rise resulting from climate change

Abiotic Function

The Kowie Estuary consists of a relatively long (approximately 21 km), meandering tidal channel, varying in width between 30 m and 150 m. The weir above the 'ebb and flow' point noted by Heinecken and Grindley (1982) is the main obstruction to flow in the estuary. There has been little change in the mean annual runoff (MAR) to the estuary. However, it is estimated that there has been a 1.5 % reduction in MAR from 31.8 Mm^3/a to 30.3 Mm^3/a as a result of fresh water being pumped to the off-channel Sarel Hayward Dam. By virtue of the open mouth and generally low regional rainfall, water movement through the system is predominantly controlled by the tidal exchange. Sediment transport into the Kowie Estuary from the catchment is reported to be minimal and this is attributed to the regional soil type and good vegetation coverage. Overall, metal concentrations in the water and sediment samples suggested an unpolluted river system. The upstream sites exhibited higher metal concentrations ascribed to the natural weathering and leaching of metal rich soils in the catchment and not human impacts and sources.

Biotic Function

Very little historical information is available on the algae of the Kowie Estuary. Species richness and diversity indices were found to be consistently low in the upper reaches and high in the middle reaches of the estuary. Overall, the phytoplankton biomass was considered to be extremely low and well below nuisance levels for algal blooms. Total phytoplankton biomass was dominated by nanophytoplankton, and this group accounted for 60 % of the total biomass in the estuary. The algal communities of the Kowie Estuary were found to be strongly driven by high salinities, very turbid water and depth. For the Kowie Estuary, a significant area of intertidal salt marsh vegetation was lost with the development of the town of Port Alfred, the Port Alfred marina and small craft harbour, and houses with jetties, amounting to approximately 48 ha (480 000 m^2), or 58% of the original extent. The remaining main salt marsh area occurs within the broad floodplain adjacent to the Bay of Biscay, comprising predominantly intertidal salt marsh, with interspersed areas of reeds and sedges, fronted by a broad mud bank. In respect of terrestrial vegetation present within the EFZ, these included five main vegetation types, namely, Hummock Dune Vegetation, Warm Temperate Coastal Forest, Sub-succulent Woodland, Coastal Sub-formation, *Vachellia karoo* Bushclump and Vegetation Complex between Coastal Woodland and Forest Scrub. There is a substantial and growing body of modern fish research for the Kowie Estuary covering various topics such as, ichthyoplankton and juvenile fish communities. The shallow water habitats ('lagoons') in the lower reaches were noted for their importance as nursery areas for many juvenile fish. Overall, the Kowie Estuary was found to have greater diversity of waterbirds, but a relatively low density in comparison to other South African estuaries.

Ecological Health Status, Importance and Recommended Future State

The overall ecological health of the Kowie Estuary is a C Category (moderately modified). The Kowie Estuary is not part of the core set of priority estuaries in the National Biodiversity Assessment (NBA) National Estuary Biodiversity Plan, but was ranked as the 33rd most important estuary out of 256 estuaries assessed. The importance rating was given as 'Important to Very Important'. Furthermore, the Kowie Estuary is among the list of very important nursery areas, in terms of overall fish biodiversity, and particularly for juvenile Dusky Kob species and Spotted Grunter. Given that a large portion of the estuary has been irreversibly transformed with urban impacts and the likelihood of implementing major changes that would not be detrimental to socio-economics of the area is fairly low, the REC for the Kowie Estuary was prescribed as Category C.

Ecosystem Services

Recreational use of the system is high, with the main activities being power-boating, water skiing, recreational and subsistence fishing and bait harvesting, kayaking/canoeing, and swimming. Commercial value of the estuary waterbody is related to the property market associated with the town of Port Alfred, the Royal Alfred Marina and the berthing of vessels in the small craft harbour. In terms of the economic value of estuaries and the ecosystem goods and services they provide, estuaries are globally recognised as being one of the most productive ecosystem types. The estimated values for the Kowie Estuary are as follows: Subsistence value of R 183 912 / annum; Property value of R 613.1 million; Recreational/tourism value of R 20 million / annum; and Nursery value of R 7.8 million / annum. The recreational and property values, in particular, are among the highest of the estuaries of the temperate coastline.

Impacts and Potential Impacts

There are numerous activities and developments that pose a threat to the future health state of the estuary. Amongst these impacts are climate change, flooding, drought, urban development, dredging, road infrastructure, weirs, agricultural activities, altered flow regimes, invasive terrestrial alien plant species, water quality deterioration, illegal fishing (overfishing), bait harvesting, livestock grazing, recreational use, RO plants and alien fish species.

Socio-economic Context

The population of the Ndlambe Local Municipality increased by 1.12 % over the ten year period between 2001 and 2011. The bulk of the migration patterns experienced within the municipality are due to holiday makers (approximately 33 000) in the peak season. The influx of seasonal holiday makers equates to approximately 56 % of the permanent resident population and places tremendous pressure on the available infrastructure of the area. The economic activities of the municipality are largely focussed on the tourism and agricultural sector as the main economic drivers, with the services sector providing numerous permanent positions. Of the economically active youth (15 to 34 years old), 39 % are unemployed. The value of the Kowie Estuary is linked to its recreational use, which peaks in holiday seasons. The estuary is a key fishing and bait collection area and is a nursery ground for many marine fish species. Public access to the estuary is thus of great importance, but due to the largely built-up nature of the lower reaches of the Kowie Estuary, a number of areas remain inaccessible to the public.

Legislative Instruments and relevant Strategies, Plans and Policy Directives

The legislative framework specific to estuarine management is the Integrated Coastal Management Act and the accompanying National Estuarine Management Protocol. The Protocol provides national policy and ensures alignment by providing a national vision and objectives for achieving effective integrated management of estuaries. The Protocol identifies the responsible management authority per estuary, in this instance the Eastern Cape Department of Economic Development, Environmental Affairs and Tourism (DEDEAT).

Opportunities and Constraints

A number of strengths, weaknesses, opportunities and threats have been identified with the Kowie Estuary and its current situation and management. Stakeholders have suggested that, in order to prevent further habitat loss and reduce cumulative impacts, any development within the EFZ (outside of the existing urban edge) should be severely restricted. From an infrastructure point of view, stakeholders have indicated that the priority should be the maintenance and reconstruction of the collapsing stone wall banks between the Nico Malan Bridge and the river mouth, as this will become a navigational problem and will be unsightly. Other restoration should include the cleaning of the salt marsh areas especially on the eastern bank adjacent to the Nico Malan Bridge.

Information Gaps and Recommendations

Recommendations regarding future studies include bathymetry studies of the whole system, additional benthos studies, studies on marine megafauna, determination of the ecological reserve, long-term monitoring of invertebrates, monitoring of catch and effort data for recreational and small-scale fisheries and studies on the extent and importance of the River-Estuarine Interface (REI).

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List of Abbreviations

amsl	Above Mean Sea Level
CARA	Conservation of Agricultural Resources Act
CBD	Central Business District
Cd	Cadmium
CMA	Catchment Management Agency
CMP	Coastal Management Programme
Co	Cobalt
CPUE	Catch per unit effort
Cu	Copper
CWAC	Co-ordinated Waterbird Counts
DALRRD	Department of Agriculture, Land Reform and Rural Development
DEA	Department of Environmental Affairs
DEDEAT	Eastern Cape Department of Economic Development, Environmental Affairs and Tourism
DFFE	Department of Forestry, Fisheries and the Environment
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EA	Environmental Authorisation
EDC	Environmental Data Centre
EFZ	Estuarine Functional Zone
EIA	Environmental Impact Assessment
EMP	Estuarine Management Plan
FAO	Food and Agriculture Organization of the United Nations
Fe	Iron
GIS	Geographic Information System
Ha	Hectares
ICM Act	National Environmental Management: Integrated Coastal Management Act
IDP	Integrated Development Plan
ISRIC	International Soil Reference and Information Centre
IWMP	Integrated Waste Management Plan
MAP	Mean annual precipitation
MAR	Mean annual runoff
MMP	Maintenance Management Plan
MPA	Marine Protected Area
MPRDA	Minerals and Petroleum Resources Development Act
N/A	Not Applicable
NBA	National Biodiversity Assessment
NEMA	National Environmental Management Act
NEM:BA	National Environmental Management: Biodiversity Act
NEMP	National Estuarine Management Protocol
NEM:PAA	National Environmental Management: Protected Areas Act
NEM:WA	National Environmental Management: Waste Act
NFA	National Forests Act
NHA	National Health Act
NHRA	National Heritage Resources Act
Ni	Nickel
NMU	Nelson Mandela University
NSRI	National Sea Rescue Institute
NTU	Nephelometric Turbidity Unit

NWA	National Water Act
Pb	Lead
PES	Present Ecological State
psu	Practical salinity unit
REC	Recommended Ecological Category
REI	River-Estuarine Interface
RO	Reverse Osmosis
SANBI	South African National Biodiversity Institute
SAR	Situation Assessment Report
SD	Standard Deviation
SDF	Spatial Development Framework
SOTER	Soil and Terrain
SPLUMA	Spatial Planning and Land Use Management Act
WMA	Water Management Area
WWTW	Wastewater Treatment Works
Zn	Zinc

1. Introduction

1.1 Background

The Kowie Estuary is an artificially permanently open system that meanders in a south-easterly direction for about 21 km towards its mouth that dissects the coastal town of Port Alfred, within the Ndlambe Local Municipality, Eastern Cape province (Figure 1.1).

Figure 1.1: Locality of the Kowie Estuary, Port Alfred, Eastern Cape.

A key feature of the Kowie Estuary is the relatively large urban environment, including the Royal Alfred Marina, which is located within the lower reaches of the estuarine functional zone (EFZ). In addition to the marina and other existing developments located below the floodplain, there are also a large number of different land uses further upstream, including agricultural farming, game farming, tourism, bait collection and reverse osmosis (RO) plants. These, together with a large salt marsh area and an artificial permanently open river mouth, makes the Kowie Estuary a particularly complex system that will require a variety of management measures to be incorporated into the plan.

The Present Ecological State (PES) of the estuary is categorised as 'C' (Moderately Modified). While the Kowie Estuary is not a national priority estuary, it is regarded as vulnerable due to the poor protection of the system (not formerly conserved and this estuary category is poorly conserved at a national level). However, the estuary is categorised as 'highly important' and is ranked 33rd in terms of biodiversity importance.

In accordance with the National Estuarine Management Protocol (NEMP), developed in line with the National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008, as amended by Act 36 of 2014) (ICM Act), an Estuarine Management Plan (EMP) must be developed for the Kowie Estuary. This document is the Situation Assessment Report (SAR) which provides detailed background information in preparation for the management planning process.

1.2 Estuary Management Process

The process to be undertaken will comply with the ICM Act and the 2021 NEMP. The latter has identified distinct components (minimum requirements) that must be included in the process of developing and implementing an EMP (Figure 1.2), and these are further detailed in the EMP Guidelines (DEA, 2015).

The minimum requirements of an EMP include:

1. A Situation Assessment;
2. A geographical description and a map of the estuary indicating the EFZ;
3. The setting of Visions and Objectives;
4. The identification of Management Objectives and Activities/Actions collated into action plans;
5. The spatial zonation of activities in a GIS map format;
6. The compilation of a detailed integrated monitoring plan with a list of performance indicators; and
7. Details of the institutional capacity and necessary arrangements to ensure the implementation of the plan and its constituent actions and projects.

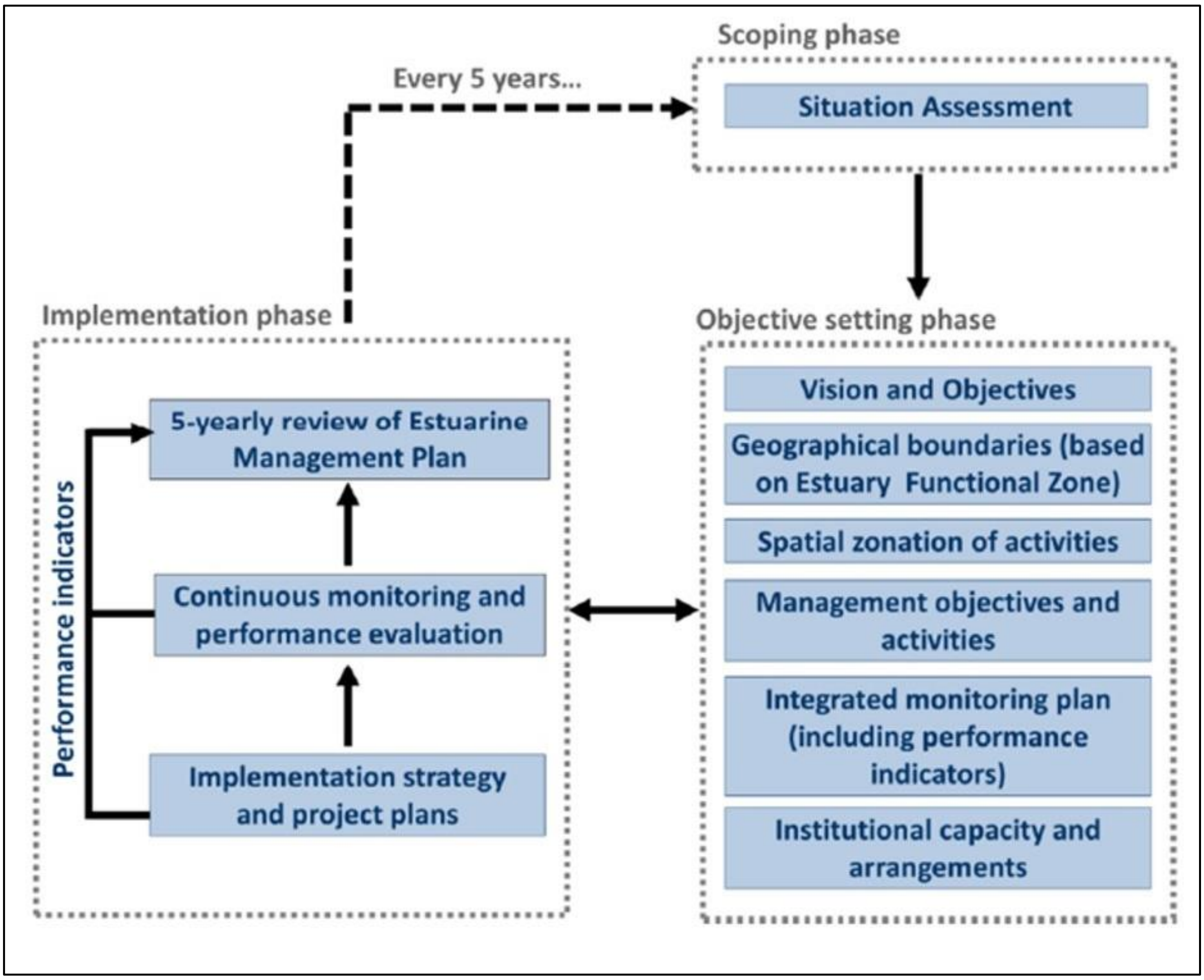

Figure 1.2: A framework for integrated estuarine management in South Africa (DEA, 2015).

The project will proceed through two (2) main phases as prescribed in the 2021 NEMP and EMP Guideline document. Phase 1 will entail the compilation of the SAR, while Phase 2 will focus on the compilation of the EMP.

1.3 Purpose of the Situation Assessment

In the initial stages of developing an EMP, it is important to conduct a situation or *status quo* assessment by collating and evaluating key information about the estuary that would inform and/or influence management decisions. In this instance, the SAR will address the minimum requirements of the 2021 NEMP. Once the EMP is implemented, the Situation Assessment will serve as a baseline against which the outcomes of future monitoring can be assessed.

According to the 2021 NEMP, the SAR should at a minimum:

- Describe legislative instruments that are currently applicable for the effective management of the estuary, including existing and planned management strategies/plans (i.e. catchment management strategies, IDP, SDF, Coastal Management Programmes (CMPs), etc.) and their relevance to the proposed management of the estuary;
- Provide a detailed understanding of the structure (abiotic and biotic components), functioning and state of the estuary, including the underlying processes and drivers;
- Describe the socio-economic context (demographic, economic profile, etc.) and the level(s) of dependence of local communities on the estuary, including the assessment of opportunities and constraints within the ecological system; and
- Identify the goods and services or human use activities and their impacts or potential impacts on the PES of the estuary.

These findings are captured in a succinct executive summary for later inclusion in the EMP.

1.4 Structure of the Report

This SAR is structured as follows:

- **Chapter 2** provides a description of the broader catchment within which the Kowie Estuary is located, including geology and geomorphology, climate change, runoff, and catchment land-use;
- **Chapter 3** details the current status of the estuary through an assessment of the ecological characteristics and functioning of the system;
- **Chapter 4** unpacks the ecological goods and services provided by the Kowie Estuary;
- **Chapter 5** locates the Kowie Estuary within the broader socio-economic context of the region and describes the social uses and activities that are supported by the system;
- **Chapter 6** seeks to identify the current impacts and the potential impacting activities or threats to the ecological functioning of the system;
- **Chapter 7** unpacks that legal instruments, as well as the related strategies and plans that govern the management of the estuary;
- **Chapter 8** provides an assessment of the opportunities and constraints to identify, at a later stage during the EMP process, the necessary responses or actions to effectively utilise the strengths and opportunities for a sustainable future and also to prevent or mitigate vulnerabilities and future threats; and
- **Chapter 9** provides a summary of any initial recommendations brought forward by the project team, the key stakeholders and/or the authorities during the SAR process. It also looks to identify information gaps where potential further research could be undertaken in the future for a better understanding of the functioning of the estuary.

1.5 The Project Team

In addition to the in-house team, Habitat Link Consulting has included a number of specialists in the EMP who have contributed to various aspects of the process (Table 1.1).

Table 1.1: EMP project team.

Team Member	Qualifications	Experience (in years)
Christelle du Plessis Habitat Link Consulting *(Project Manager)*	• MSc Zoology	10
Roberto Almanza Habitat Link Consulting *(Report Writing and Public Participation)*	• MSc Geology	6
Tandi Breetzke Coastwise Consulting *(EMP Specialist)*	• BA Honours (Geography)	25
Catherine Meyer Coastwise Consulting *(Estuarine Ecologist)*	• BSc (Environmental Biology and Geology)	10
Susan Meiring SMC Consulting *(GIS Specialist)*	• MSc GIS	15
Mlu Matebese Leesa Social Facilitators *(Social Facilitator)*	• BA Communication	5

A close relationship between Habitat Link Consulting, their project team, the DEDEAT and their elected representatives, as well as the Ndlambe Local Municipality, will be maintained during the execution of the study.

2. Catchment Characteristics

2.1 The Kowie River Catchment

The Kowie Estuary is located at the interface between the Kowie River and the Indian Ocean and falls within the Mzimvubu-Tsitsikamma Water Management Area (WMA 7). The Kowie River and its estuary fall within three (3) quaternary catchments, namely P40A (south-east of the Grahamstown/Makhanda area), P40B (north-west of Bathurst) and P40C (Port Alfred and adjacent interior). However, the P40C quaternary catchment does not solely drain into the Kowie River and is divided into a number of sub-catchments, one of which drains into smaller coastal rivers including the Kasouga River. Therefore, for the purposes of this study, the Kowie catchment will only include two of the three sub-catchments of the P40C quaternary catchment, as well as the entire P40A and P40B quaternary catchments (Figure 2.1).

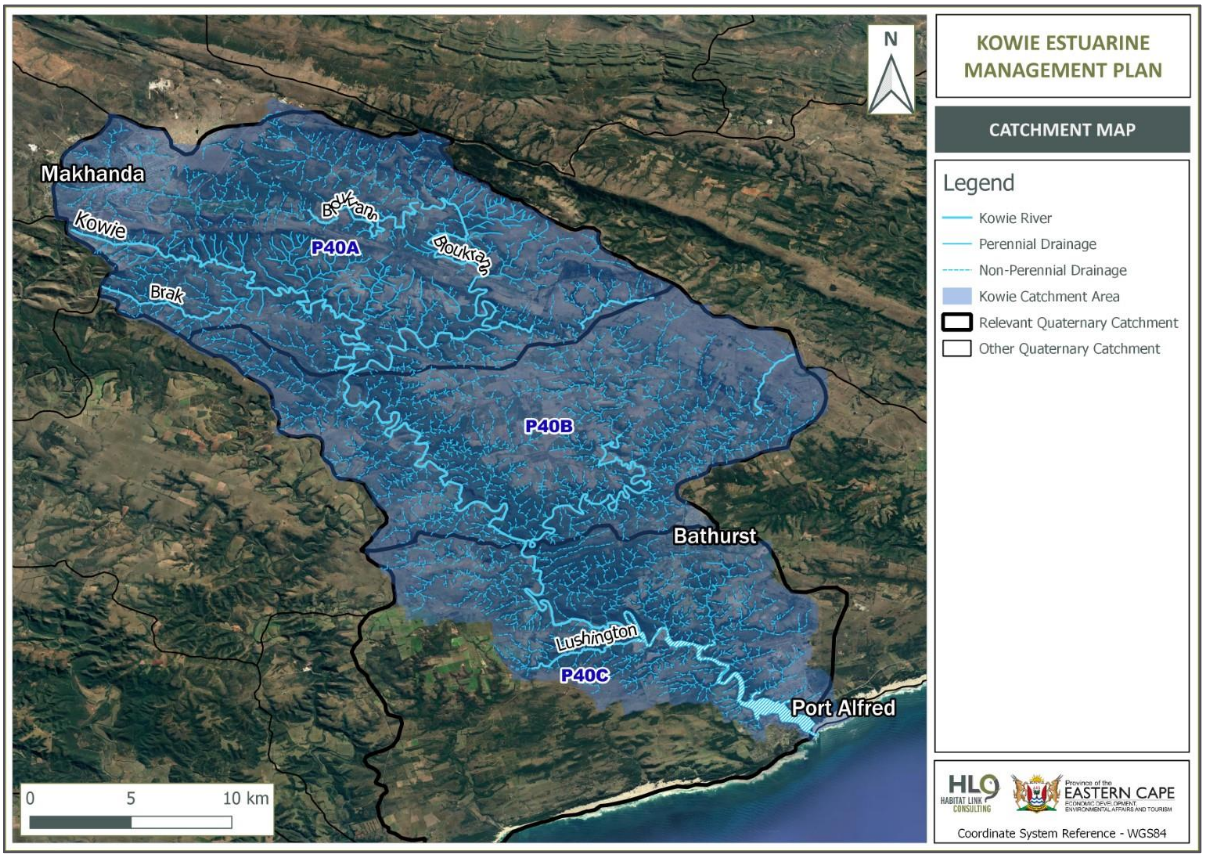

Figure 2.1: Quaternary catchments relevant to the Kowie River.

The modified catchment, as described above, covers a total area of approximately 75 748 ha (757 km^2). The major tributaries of the Kowie River are the Bloukrans River, the Brak River and the Lushington River (or Torrens River). The Kowie Estuary itself flows in a south-easterly direction draining the major part of the Bathurst region, reaching the Indian Ocean at the coastal town of Port Alfred.

The Little Kowie River is a smaller tributary which enters the estuarine portion of the river at approximately 14 km from its mouth. There are also a number of smaller unnamed streams entering the river along its course (DWAF, 2005). The area of the Kowie EFZ constitutes approximately 485 ha (4.85 km^2) and extends 21 km up the river.

2.2 Geology and Geomorphology

The Kowie River originates in the hills of the 'Grahamstown Heights', a mountainous area near Makhanda (formerly Grahamstown). These hills are associated with the Cape Fold Belt mountains, meaning that the Kowie River is classified as an 'intermediate' river, as opposed to the large river systems that originate in the Great Escarpment or the small coastal rivers that only extend a few kilometres inland (Heinecken and Grindley, 1982). The river catchment originates at a point which is approximately 760 m above sea-level, while the EFZ catchment is at about 200 m above sea-level. Along the length of the Kowie River, the average slope is 1.3 % (1 m drop in altitude for every 77 m along the river course), with the steepest section (11 % gradient) near the source. The middle reaches of the river are predominantly flat, after which there is a slight gradient increase from the upper reaches of the EFZ to the mouth (2.2 % average slope) (Figure 2.2 and Figure 2.3).

The majority of the Kowie River intersects the Weltevrede Subgroup of the Witteberg Group (Cape Supergroup) (Figure 2.4). The Weltevrede Subgroup consists of sandstone, siltstone and shale, is 1 000 m thick and forms part of a series of folded mountains in this region. The shale strata can be fossil-rich and include trace fossils of *Zoophycos*, *Spirophyton* and *Skolithos* from the Devonian Age (416 million to 358 million years ago) (Thamm and Johnson, 2006). The lower reaches of the estuarine catchment area also intersect the Nanaga Formation, Alexandria Formation and Schelm Hoek Formation of the Algoa Group. These are mostly calcareous sandstones associated with relatively recent geological deposits (Council for Geoscience, 1995).

The Soil and Terrain (SOTER) database, as published by the International Soil Reference and Information Centre (ISRIC, 2008), identifies 'Eutric Regosols' (RGe) as the predominant soil type within the Kowie River catchment (Figure 2.5). Regosols are soils that do not fall within any particular soil group due to their lack of definite horizons. They are weakly developed mineral soils located within unconsolidated material that are generally found in extensive eroding lands, particularly in arid and semi-arid areas as well as mountain regions (FAO, 1998). The term 'eutric' means fertile and non-acidic (Catling, 1992).

2.3 Climate and Runoff

The Ndlambe Local Municipality has a sub-tropical climate as a result of its location along the Indian Ocean coastline, with wind reducing the heat and humidity in summer (Lubke *et al*., 1988). The municipality, similar to many others in the Eastern Cape, is currently facing a devasting drought, which, according to Jury and Levy (1993), occurs in cycles every 3.5 to 18 years. The nearest official weather station to the source of the Kowie River is located in Makhanda, while the climate of the middle and lower reaches of the river will be similar to that of the towns of Bathurst and Port Alfred respectively.

Makhanda has a warm and temperate climate that, according to the Köppen and Geiger classification system, is classified as 'Cfb' (subtropical highland climate). This area generally experiences rainfall throughout the year, although the majority is expected during the summer months. The mean annual precipitation (MAP) of Makhanda is 590 mm, with the lowest average rainfall in June/July (24 mm) and the highest in February (67 mm). The average maximum temperatures range from 19.4 °C in July to 26.9 °C in February, while the average minimum temperatures range from 6.7 °C in July to 16.3 °C in February, with the mean annual temperature sitting at approximately 16.6 °C (Climate Data, 2021).

The town of Bathurst, which is located approximately 5 km north-east of the upper reaches of the Kowie Estuary, has a similarly warm and temperate climate, classified as 'Cfa' (humid subtropical). This town also has the majority of its rainfall during the summer months.

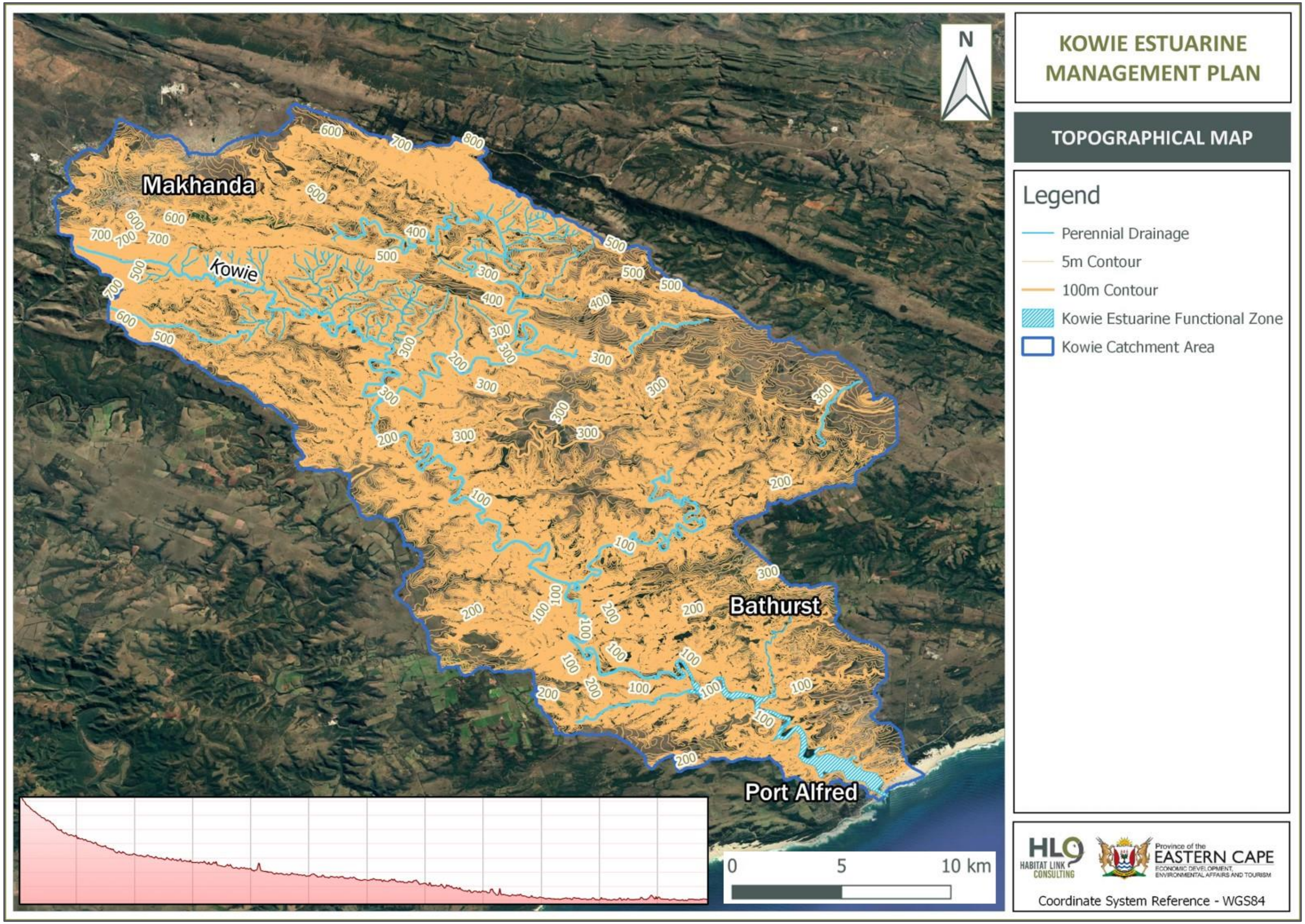

Figure 2.2: Topographical map of the Kowie River catchment.

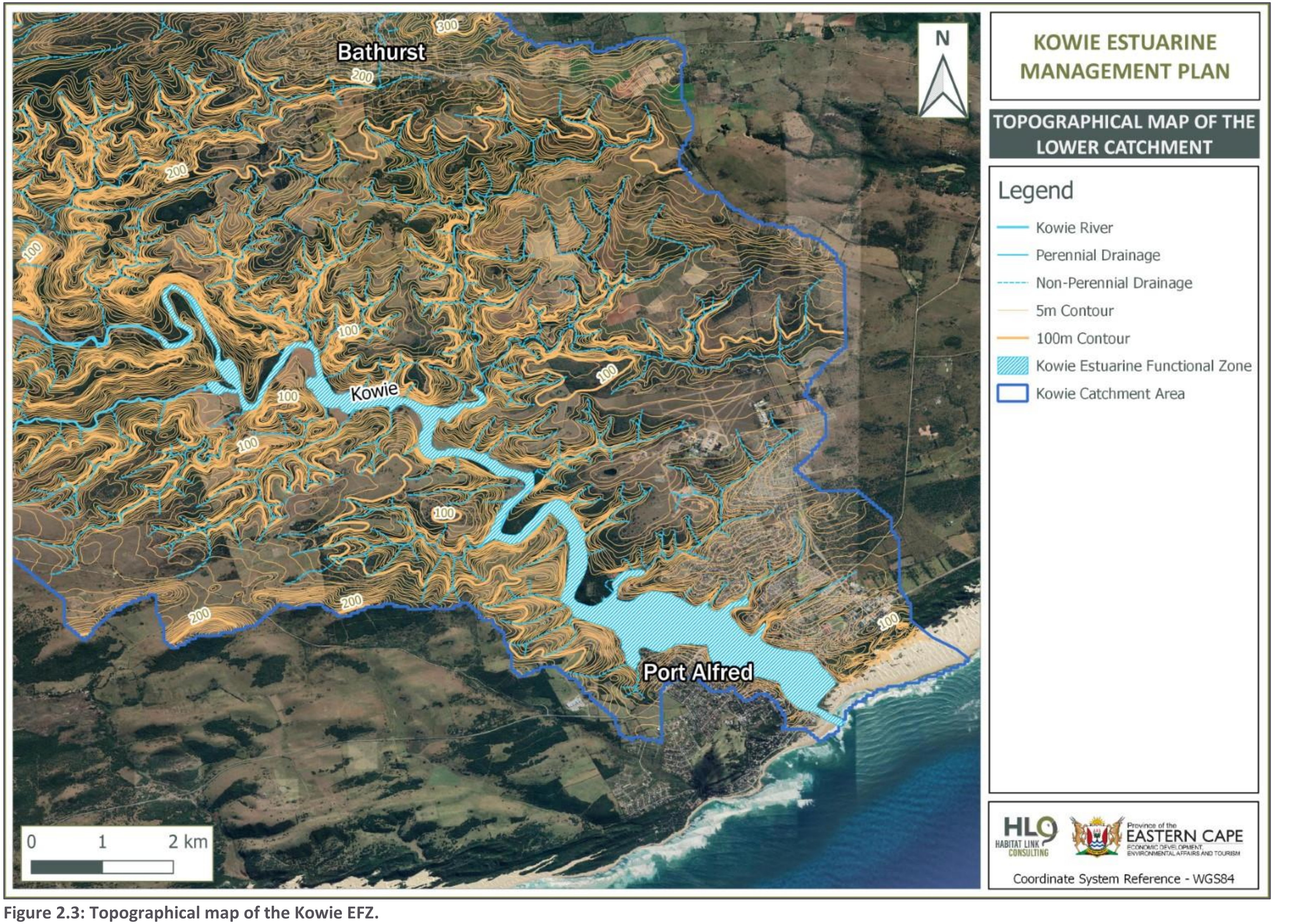

Figure 2.3: Topographical map of the Kowie EFZ.

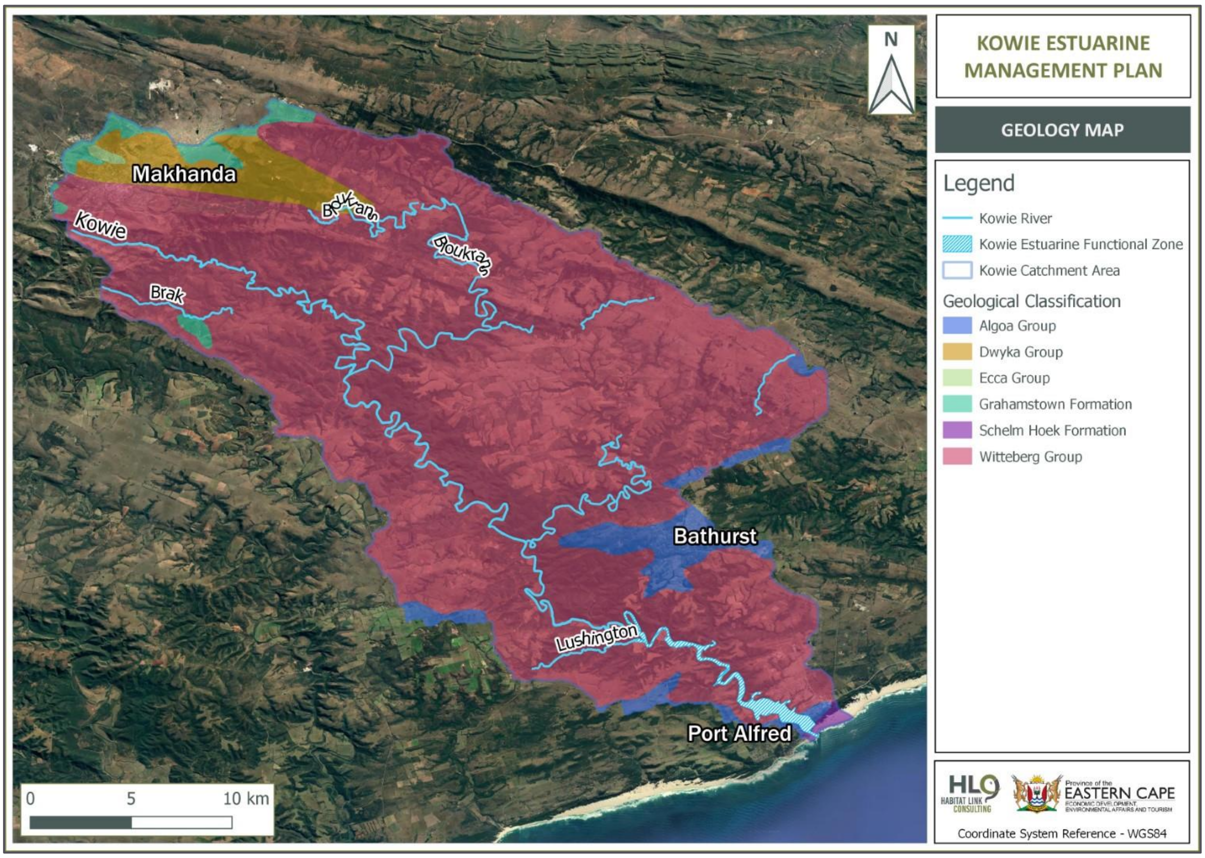

Figure 2.4: Geological map of the Kowie River catchment.

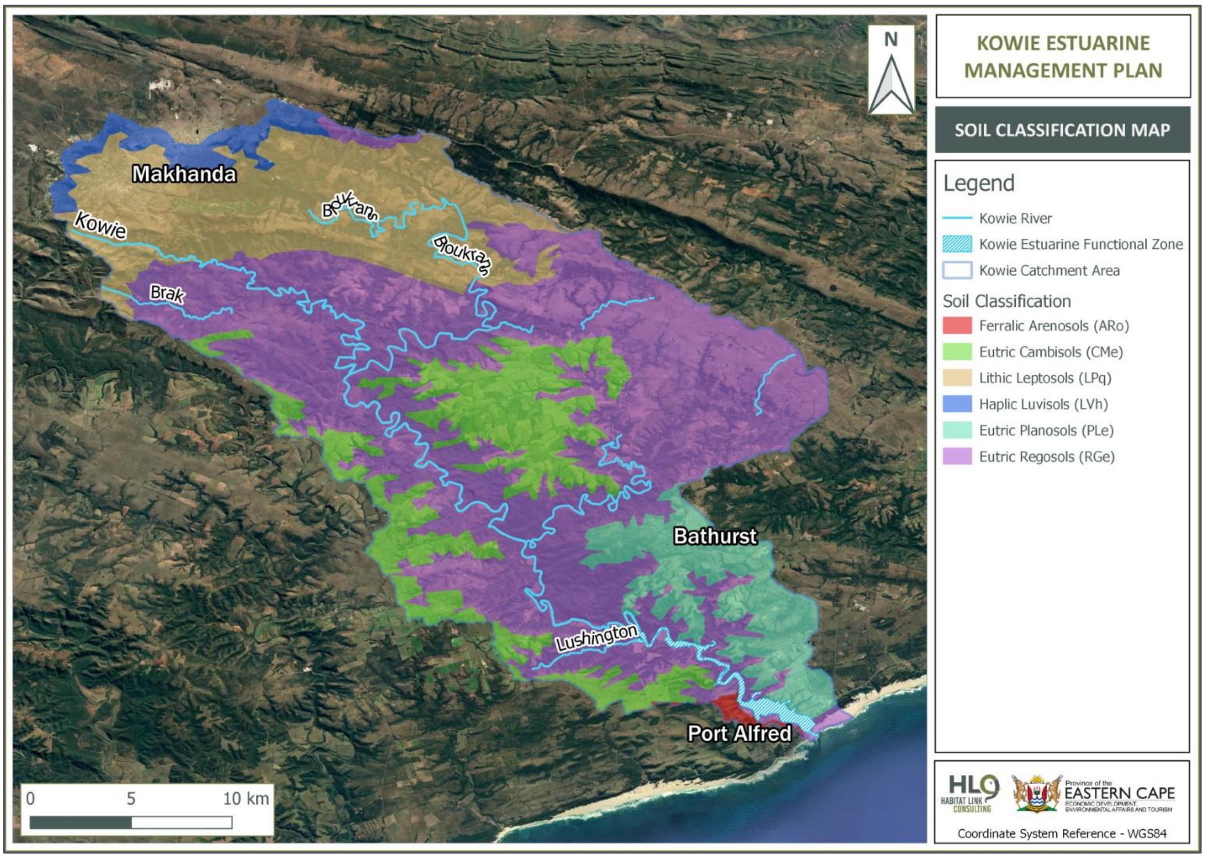

Figure 2.5: Soil classification map of the Kowie River catchment.

Figure 2.6: The average annual temperature and rainfall range for Makhanda (left) and Bathurst (right) (from Climate Data, 2021).

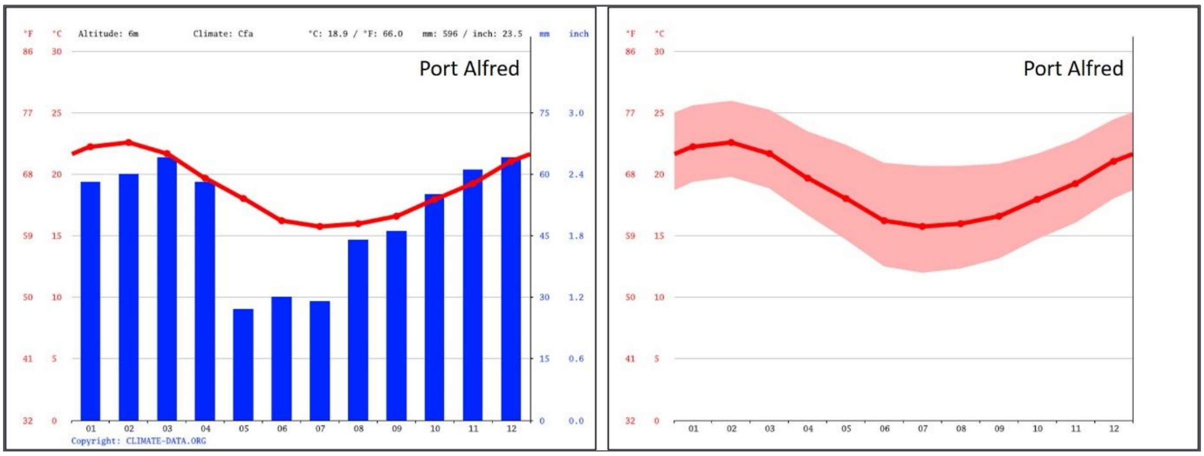

Figure 2.7: The average annual rainfall (left) and average annual temperature range (right) for Port Alfred (from Climate Data, 2021).

The MAP of Bathurst is 594 mm, with the lowest average rainfall in May (26 mm) and the highest in December (66 mm). Port Alfred's climate is similar to Bathurst, but the average temperatures are moderated by the Indian Ocean, meaning that minimum and maximum temperatures have a smaller range (approximately 12 °C in July to 20 °C in February) (Climate Data, 2021) (Figure 2.6 and Figure 2.7).

According to Heinecken and Grindley (1982), the flow of the Kowie River is irregular and unreliable, regardless of rainfall in the upper catchment. This is due to its short time of concentration where high flow occurs over a short duration. There are several figures provided for the mean annual run-off (MAR) of the Kowie River, as measured in millions of cubic metres (Mm^3). Some sources suggest a modest MAR of 23 Mm^3 (Noble and Hemens, 1978), 23.6 Mm^3 (Midgley and Pitman, 1969) and 17 Mm^3 (Ninham, Shand and Partners 1971), while others show a slightly higher value such as 40.6 Mm^3 (Heinecken and Grindley, 1982) and 46 Mm^3 (Wasserman and Strydom, 2011).

2.4 Land Use

The coastline, rivers and estuaries have shaped the development of settlements and towns within the Ndlambe Local Municipality. The south-western areas along the coast have been transformed by urban development and land between Kenton-on-Sea and Port Alfred has been degraded mostly by agriculture. Agriculture takes place throughout the municipality but more intensely in and around areas such as Bathurst and adjacent parts of the interior (Ndlambe Municipality, 2013) (Figure 2.8).

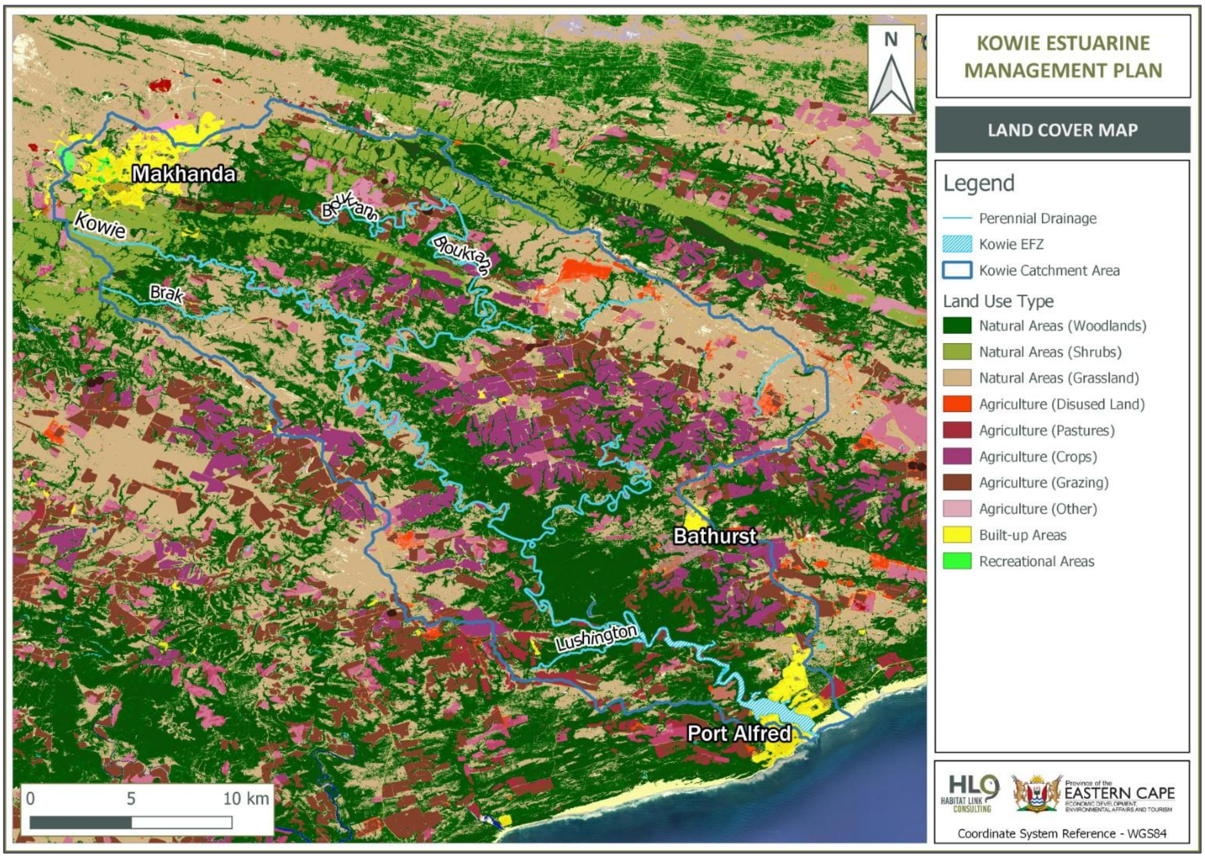

Figure 2.8: Land cover map of the Kowie River catchment.

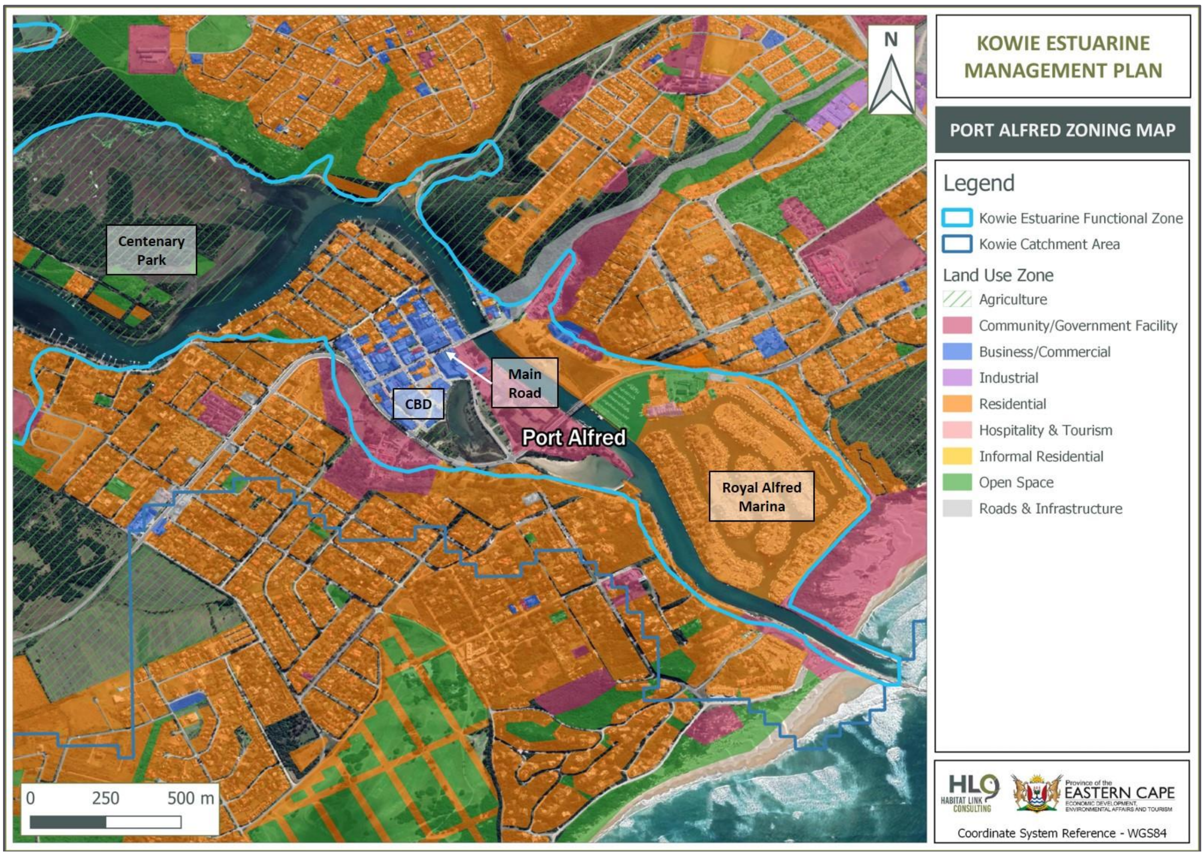

Figure 2.9: Land cover map of the Kowie River catchment.

In Port Alfred, land uses include business, retail, residential, holiday/hospitality, industrial, commercial and community/health facilities. Most of the business land uses are located in the central business district (CBD) of the town, which is located directly south-west of the Kowie Estuary and split by the Main Street. The CBD, due to its position below the 20 m contour, is subject to flooding and is the area most likely to be affected by sea level rise resulting from climate change (Figure 2.9).

The dominant land use in Port Alfred is residential, which consists mainly of low density single-story detached houses south-west of the CBD and the Kowie Estuary. Directly north-east of the estuary mouth, the Royal Alfred Marina consists of over 200 residential stands all developed within an artificial quays within the Kowie River floodplain. Further upstream of the river mouth, there are approximately 10 properties zoned as residential dwellings located on the eastern bank of the estuary in the area referred to as 'Centenary Park', of which 4 include existing houses. Industrial and commercial areas in Port Alfred are generally situated along the R72 regional road, further north-east of the CBD and away from the estuary. These consist of light and medium industries such as warehousing and airport-related activities associated with the air school. Most local government facilities are located in Port Alfred as it is the administrative centre of the municipality. Schools, police stations, post offices and municipal buildings are all located at various areas throughout the town and some are in relatively close proximity to the EFZ.

2.5 Catchment Management

The Department of Water and Sanitation (DWS), formerly the Department of Water Affairs (DWA) have defined nine (9) catchment management areas in South Africa, including the Mzimvubu-Tsitsikamma WMA, and have proposed the establishment of a catchment management agency (CMA) to manage each catchment. The Mzimvubu-Tsitsikamma WMA forms part of the long-term plan as outlined in the 2018 National Water and Sanitation Master Plan, but a CMA has yet to be established. The objective of the CMA will be to play a supportive role in managing the WMA, with the overall aim of taking over much of the function of the DWS in terms of the following goals:

- Ensuring effective management of water use;
- Catchment management, rehabilitation and land use management;
- Enhancing the quality of the water resources;
- Enhancing stakeholder participation in management of water resources;
- Ensuring financial viability and administrative effectiveness;
- Accessing high quality information that is critical for effective catchment management; and
- Ensuring effective governance mechanisms

As WMA 7 is very large, it has been proposed that the area be divided into four (4) subregions based on hydrological boundaries. Responsibility for the management of water supply and the management of the Kowie Estuary itself, falls almost entirely to the Ndlambe Local Municipality, specifically the environmental division of the Community Protection Services department. The Kowie River catchment includes a number of small farm dams, as well as a few municipal dams, the largest being the Sarel Hayward Dam, which provides the main water supply to Port Alfred and surrounding areas (DWS, 2021).

3. Ecological Function and State of the Estuary

3.1 Delineation

The National Water Act (NWA) defines an estuary as "*a partially or fully enclosed water body that is open to the sea permanently or periodically, and within which the seawater can be diluted, to an extent that is measurable, with freshwater drained from land*". The ICM Act defines an estuary as "*a body of surface water -*

a) that is permanently or periodically open to the sea;
b) in which a rise and fall of the water level as a result of the tides is measurable at spring tides when the body of surface water is open to the sea; or
c) in respect of which the salinity is higher than fresh water as a result of the influence of the sea, and where there is a salinity gradient between the tidal reach and the mouth of the body of surface water".

According to the 2014 EIA Regulations, the 'estuarine functional zone' means "*the area in and around an estuary which includes the open water area, estuarine habitat (such as sand and mudflats, rock and plant communities) and the surrounding floodplain area, as defined by the area below the 5 m topographical contour (referenced from the indicative mean sea level)*". The NEMP acknowledges these EFZs as the geographical boundaries of an estuaries in South Africa. The Kowie Estuary is a relatively large, permanently open estuary that extends 21 km upstream where its tidal influence ends at the 'Old Weir' (Table 3.1 and Figure 3.1 and Figure 3.2).

Table 3.1: Geographical boundaries of the Kowie Estuary.

Downstream boundary	33°36'13.053" S; 26°54'5.882" E
Upstream boundary	33°32'40.98" S; 26°47'53.62" E
Lateral boundaries	5 m contour above Mean Sea Level (amsl) along each bank

3.1.1 Existing Infrastructure and Developments

The EFZ is the area where human activities, if properly directed and implemented, have the greatest potential to sustain the ecological functioning of the estuary. Equally, human activities within the boundaries of the EFZ, if carelessly undertaken, have the greatest potential to damage, degrade, or even destroy elements of the ecological functioning of the estuary.

Sanitation and Stormwater

Due to the extensive urban settlement around the mouth of the Kowie Estuary, there is subsequently a concentration of sewage reticulation infrastructure in close proximity (and within) the EFZ. There are a number of sewage pump stations along the banks of the Kowie Estuary as well as pipelines that cross the river at various points. All sewage effluent from Port Alfred is reticulated to the Port Alfred wastewater treatment works (WWTW), which is located approximately 500 m from the bank of the estuary at 5.5 km upstream from the river mouth. Treated effluent from the plant is discharged back into the river at this point (Figure 3.3). It is likely that effluent discharge began prior to any environmental discharge permitting requirements, but new legislation may require permitting of this discharge point or, at very least, water quality monitoring of the discharged effluent. According to the Ndlambe Municipality IDP (2021), the Community Needs Assessment for the town of Port Alfred lists that sewerage leaks are located all over town almost every day. One particular sewage leak that was reported to the DEDEAT concluded that sewage pipes in one particular area were too small and could not accommodate the pressure from the commercial area of the town (DEA, 2019).

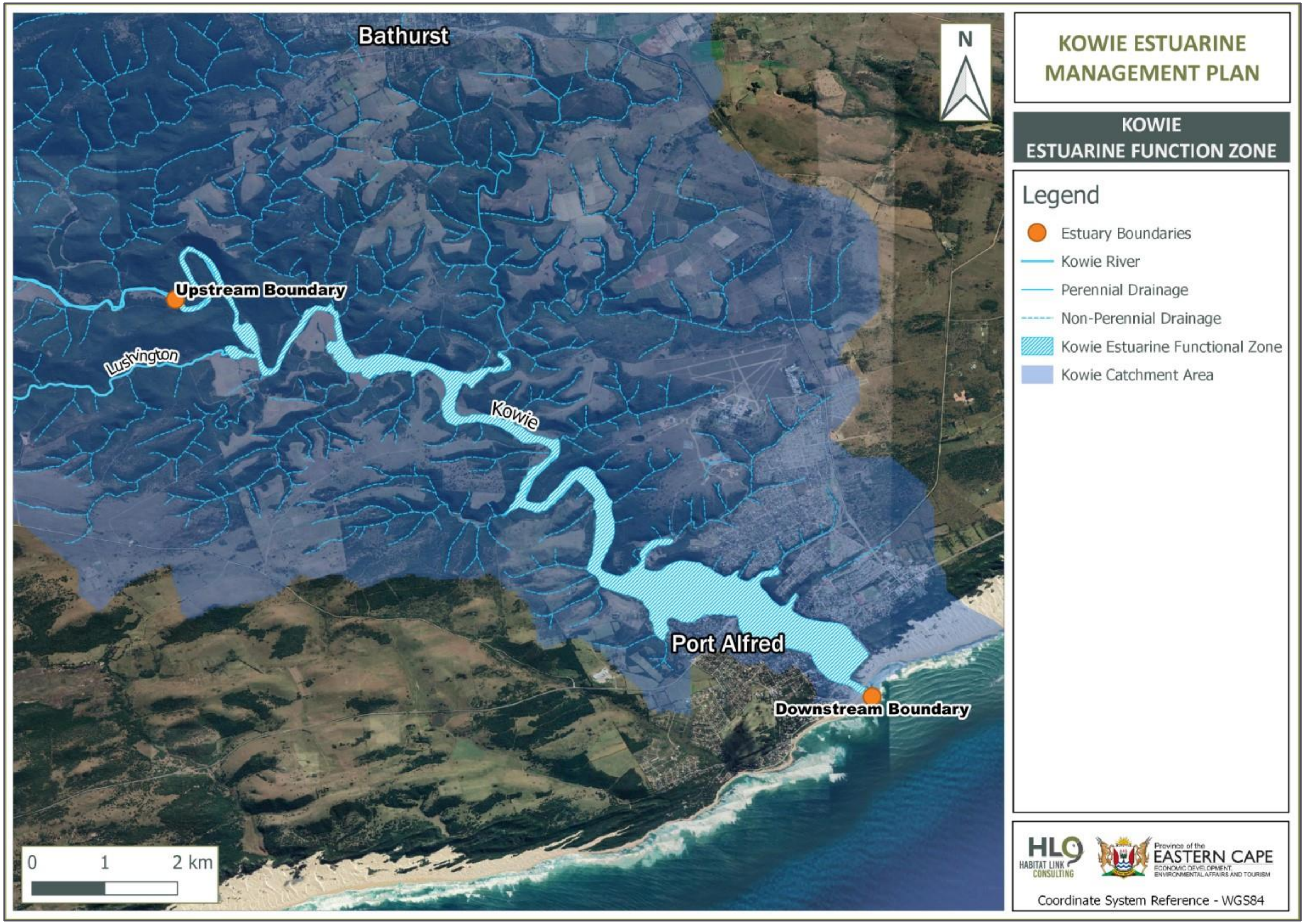

Figure 3.1: Geographical boundaries of the Kowie Estuary corresponding to the 5 m amsl contour, and as captured in the 2018 National Biodiversity Assessment (Van Niekerk *et al*., 2019).

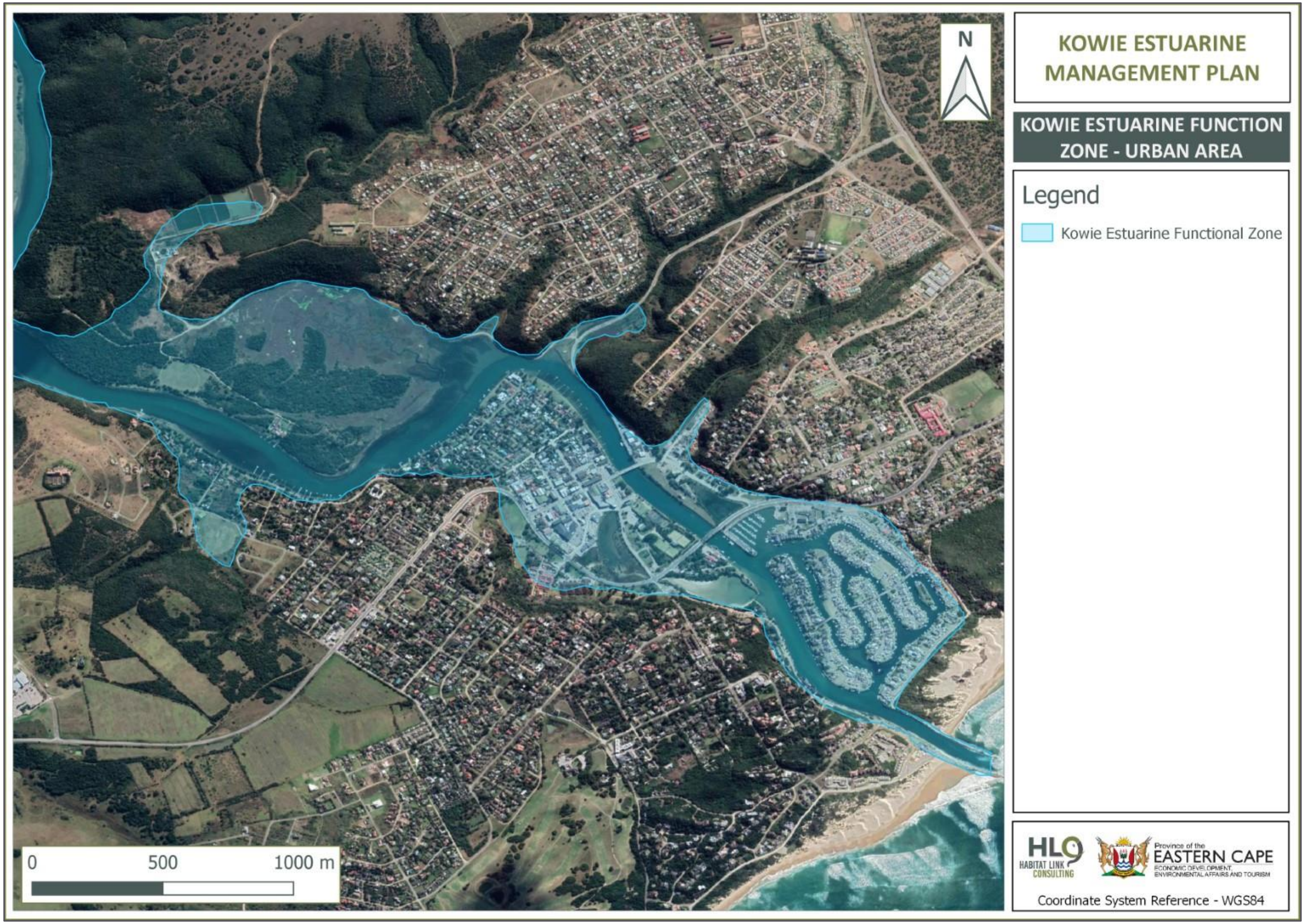

Figure 3.2: Geographical boundaries of the lower reaches of the Kowie Estuary corresponding to the 5 m amsl contour, and as captured in the 2018 National Biodiversity Assessment (Van Niekerk *et al.*, 2019).

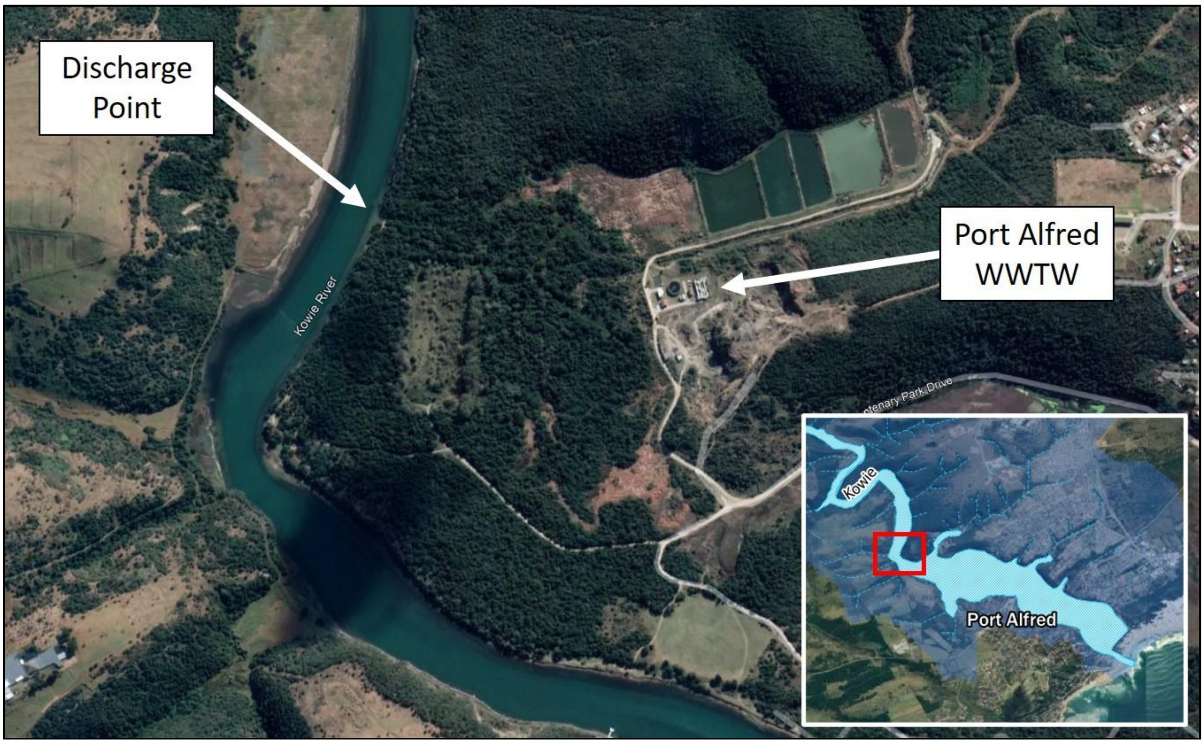

Figure 3.3: Location of the Port Alfred wastewater treatment works (WWTW) and associated discharge point in relation to the Kowie Estuary.

Figure 3.4: Stormwater pipeline outlet located near the mouth of the Kowie Estuary.

Further to this, the Nkwenkwezi area likely contributes to pollution of the estuary due to its defective sewerage system. This is proposed to be remedied via a recently authorised project to upgrade the sewerage system (see Section 3.1.2 below).

Similar to the sewerage infrastructure, stormwater infrastructure within Port Alfred is complex due to the density of the urban areas. All stormwater is directed into the Kowie Estuary via various channels, roads and stormwater pipelines. A number of the pipeline outlets observed along the estuary do not appear to have any mesh fencing or other means to prevent litter and other objects from being discharged into the estuary (Figure 3.4).

Roads and Bridges

The R72 regional road crosses the Kowie Estuary approximately 1.5 km upstream of the mouth, while Port Alfred's Main Street crosses at 2 km. The next upstream crossing is via a low-level farm road, outside the EFZ, at approximately 22 km from the river mouth. Within Port Alfred there are a number of roads located directly adjacent to the banks of the estuary, namely Beach Road (extending from the R72 along the western bank to the mouth), Wharf Street (on the eastern bank, extending from Main Street towards the Nkwenkwezi settlement) and Mentone Road (on the western bank, directly across the river from Centenary Park).

The two bridges traversing the Kowie Estuary provide optimal view points of the lower reaches of the river. The Main Street bridge, named Putt Bridge, was the first reinforced concrete bridge built in South Africa and was completed in 1907, with several reconstructions occurring throughout the 1900s. This would have previously been the only access across the estuary up until the construction of the Nico Malan Bridge (on the R72) in 1972. The latter is a tied-arch bridge that supports two lanes of traffic as well as pedestrian access on either side. An additional pedestrian bridge, the Saint Peters Bridge, spans the entrance to the Kidds Beach lagoon and dates back to the 1930s (Kowie Museum, 2021) (Figure 3.5).

Figure 3.5: Bridges extending over the Kowie Estuary: A – Putt Bridge, B – Nico Malan Bridge and C – Saint Peters Bridge.

Dams

The Kowie River catchment includes a number of small farm dams, as well as a few municipal dams, the largest being the off-channel Sarel Hayward Dam, which is the main water source for Port Alfred (DWS, 2021). However, there are no major instream dams located along the length of the Kowie River, with only a small number of old farm weirs located at various points upstream of the EFZ.

Waste management

The Ndlambe Local Municipality has four landfill sites, which include Port Alfred and Bathurst that account for approximately 8 000 tonnes per annum and 2 500 tonnes per annum respectively. The Port Alfred site is approximately 8 ha (80 000 m^2) and appears to drain directly towards a tributary of the Kowie River (Ndlambe IWMP, 2017) (Figure 3.6).

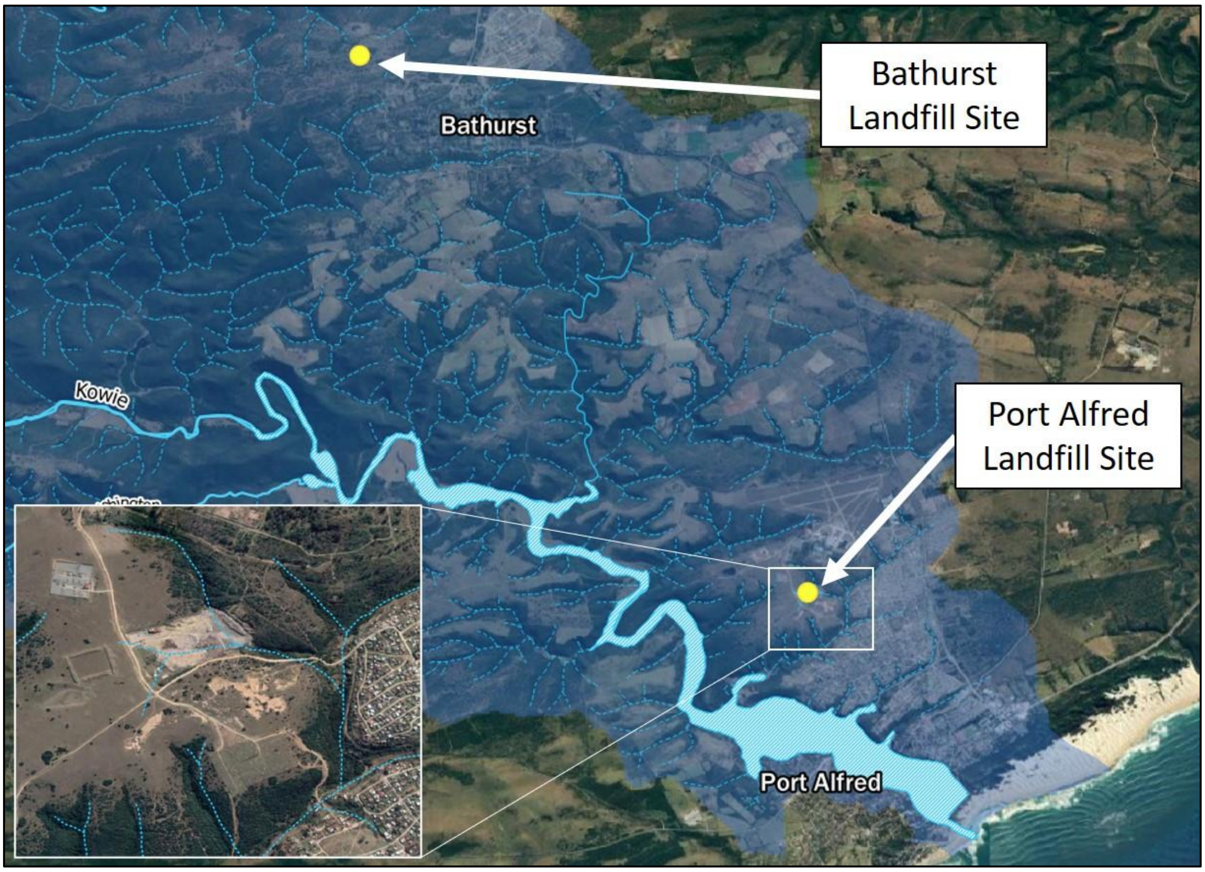

Figure 3.6: Map showing the location of the Port Alfred and Bathurst landfill sites in relation to the Kowie Estuary and associated tributaries. Inset shows Port Alfred landfill site in proximity to the tributary.

Buildings

There are numerous residential, business, commercial, governmental and recreational buildings located along the banks of the Kowie Estuary. Along the western bank, seawards of the Nico Malan Bridge, the main buildings include the large structure at the mouth currently occupied by Guido's restaurant, as well as the Port Alfred River and Skiboat Club and National Sea Rescue Institute (NSRI) buildings located closer to the bridge. North-west of the bridge, most buildings are residential dwellings that often double as guest houses and hospitality facilities and there are also some commercial and governmental buildings closer to the bridge. There are a large number of residences, as well as a number of commercial buildings and a hotel, on the western bank upstream of the Putt Bridge, with many of these immediately adjacent or very close to the river bank (Figure 3.7).

On the north-eastern side of the river, buildings near the mouth consist entirely of residential dwellings associated with the Royal Alfred Marina, although many of these remain vacant outside of the summer holiday season and put pressure on the existing municipal services when fully occupied during December and January. This is reflected throughout Port Alfred and not only in the marina, as a number of the properties throughout the town are only occupied over the holiday periods. At the Small Boat Harbour, located adjacent to the Nico Malan Bridge, there is one relatively large building currently utilised as a restaurant, with a number of hospitality venues set further back into the main sections of the marina. Inland of the bridge, buildings are sparser on the eastern bank and there are a few business and commercial properties located on Wharf Street that are some of the oldest buildings in Port Alfred.

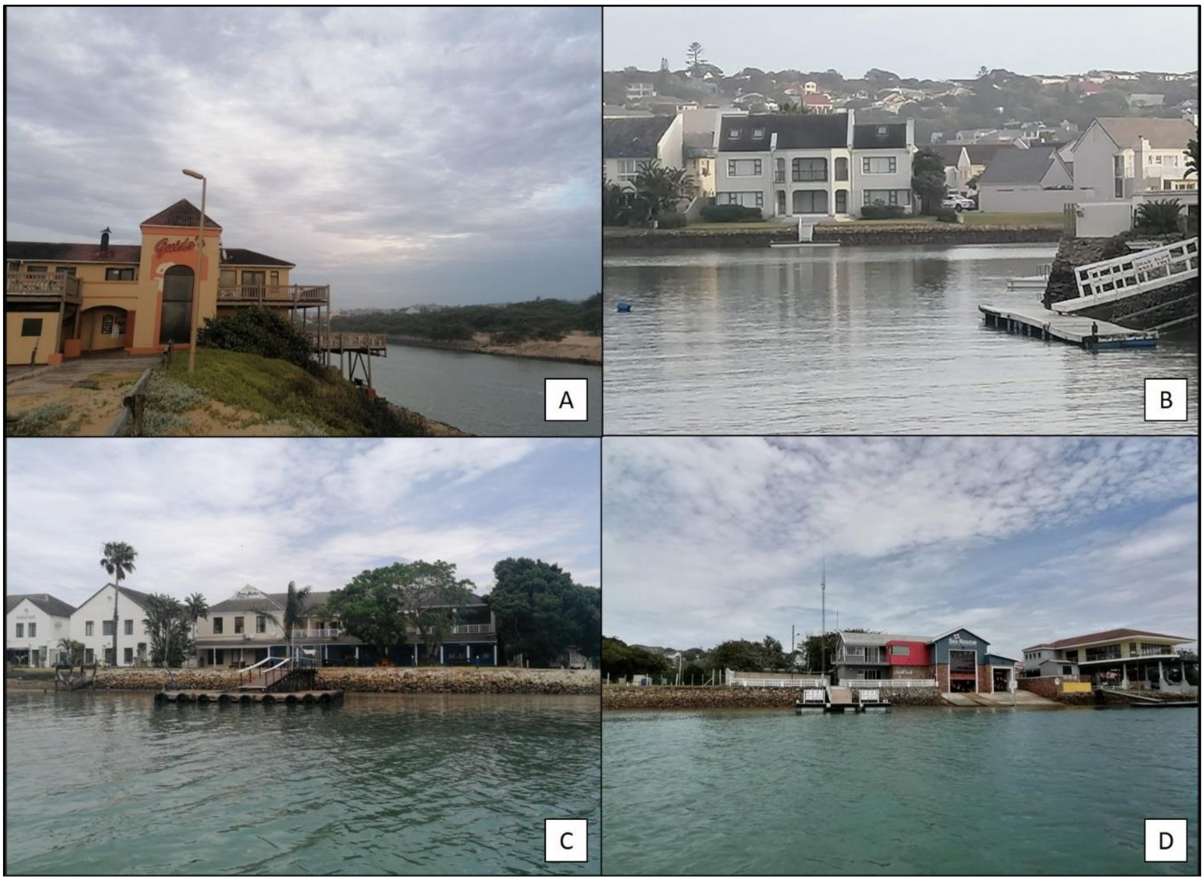

Figure 3.7: Buildings located along the banks of the Kowie Estuary: A – Restaurant at the river mouth, B – Royal Alfred Marina houses, C – Hospitality and commercial buildings near the old town and D – Ski Boat Club and NSRI buildings near the Nico Malan Bridge.

At 4.5 km upstream from the mouth, there are four residential houses located within Centenary Park, on the eastern side of the estuary, with the Riverview Waterfront Estate directly opposite on the western bank. From this point upstream, buildings are no longer prevalent along the river banks other than a few private game reserve hospitality venues on the upper reaches of the EFZ. Although set back from the river bank, the suburbs of East Bank, Station Hill and Nkwenkwezi consist of higher density residential dwellings, some of which overlook the Kowie Estuary (Figure 3.8).

Harbours and Marinas

The Kowie River was originally blocked by a sand bar and was artificially opened by the 1820 Settlers specifically for the debarkation of goods and passengers as well as for the exportation of surplus produce. As early as 1823, it was suggested that the artificial opening of the river mouth should be straight from the sand bar to the deeper part of the river (Kowie Museum, 2021). This would allow the tide to have a straight influx and reflux, which would carry the loose sand out to the sea. This was eventually realised in 1839 and by 1841, South Africa's first man-made harbour was opened on the Kowie Estuary (Bond, 1957).

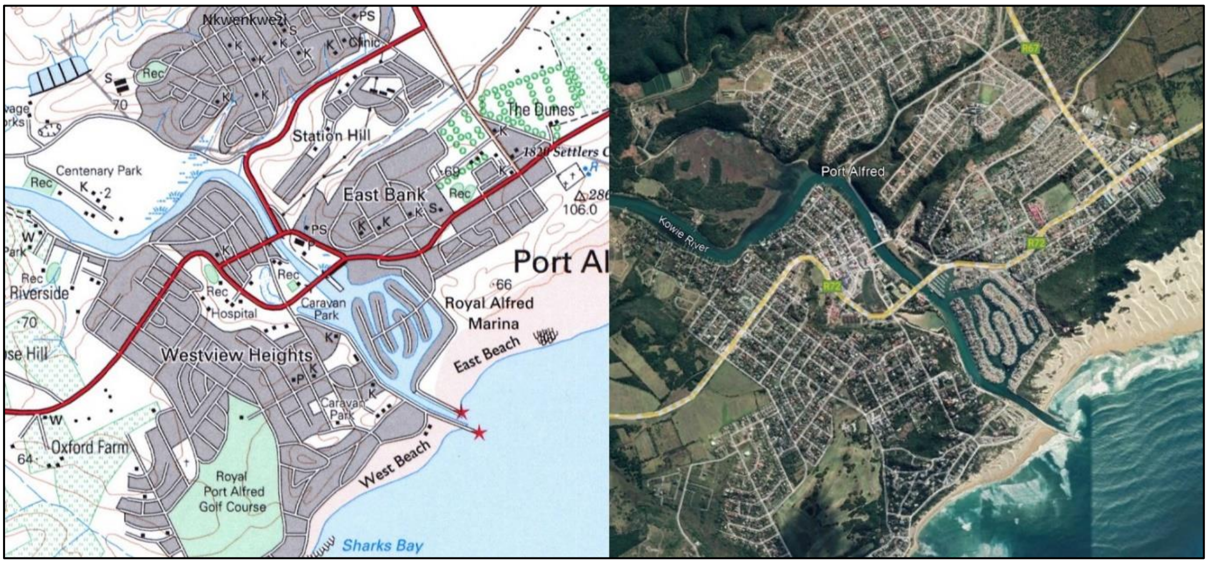

Figure 3.8: Street map of Port Alfred showing main suburbs and landmarks surrounding the Kowie Estuary.

The town of Port Alfred grew and thrived around its harbour, but as a result of surrounding areas developing better harbour facilities (e.g. Port Elizabeth and East London), the port fell into disuse in the 1890s. In 1989, the Royal Alfred Marina was developed to cater for recreational crafts and has since established itself as a high-end residential area managed by a separate homeowners association (Marais, 2021). The marina, along with the Small Boat Harbour, were constructed and now supplement the hospitality and tourism industry within Port Alfred, which is predominantly a holiday destination during the summer months. The Royal Alfred Marina covers an area of approximately 40 ha (400 000 m^2) and is located between East Beach and the R72, on the eastern bank of the river. The Small Boat Harbour occupies an additional 2.5 ha (25 000 m^2) and is situated directly east of the Nico Malan Bridge (Figure 3.9).

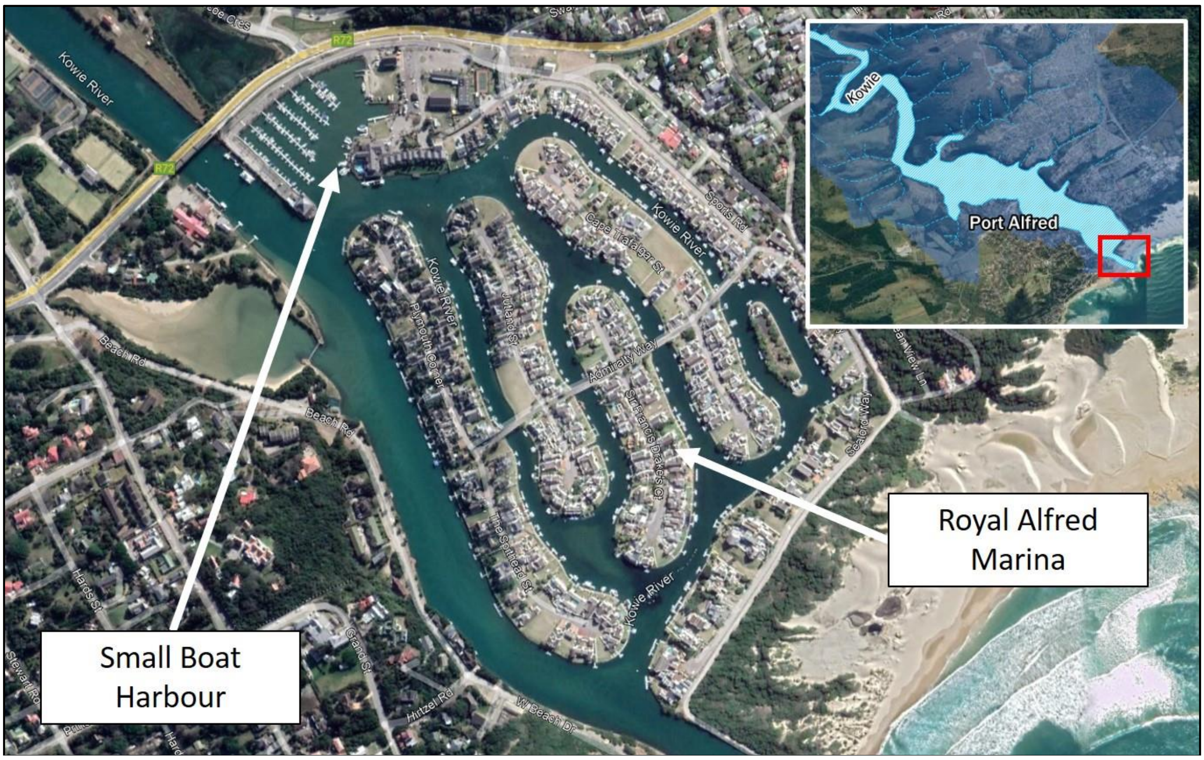

Figure 3.9: Aerial view of the Royal Alfred Marina and Small Boat Harbour.

Banks, Jetties and Slipways

Due to the artificial nature of the Kowie Estuary mouth, a number of bank reinforcement structures have been established on both sides of the river to prevent erosion and stabilise the banks to protect the urban structures. The reinforcements, which consist of tightly packed stones and rocks forming a vertical bank, extend from the estuary mouth to the Nico Malan Bridge. Further upstream, similar bank reinforcements are utilised at strategic points on either side of the estuary. It is evident that a number of the historical reinforcements have fallen into disrepair and will require maintenance and upgrading in certain places. According to an Environmental Authorisation (EA) and Maintenance Management Plan (MMP) issued by the DEDEAT in 2020, the pier at Port Alfred's West Beach has been repaired due to damage caused by storm events, and sand deposition in the various car parks is a continuous problem. The EA and MMP do not make specific provision for the repair and/or maintenance of the bank reinforcements along the Kowie River.

There have been numerous jetties established along the lower reaches of the Kowie Estuary, with the majority located on the western bank along the section of river between the Main Street bridge and Centenary Park. A jetty survey of the Kowie River was conducted by the DEDEAT on October 2015 and concluded that 88 jetties were present along the estuary. A number of these jetties were found to be in poor condition and required maintenance or should be removed. There are also numerous jetties positioned along the Royal Alfred Marina that did not form part of the survey. In addition to the jetties, there are also several slipways along the Kowie Estuary, which are utilised by recreational boat owners, the municipality and the NSRI (Figure 3.10). Although most slipways and boat launch sites are located east of the R72, there is one municipal public boat launch site along Riverside Drive, directly across from Centenary Park.

Figure 3.10: A – Broken stone banks near the river mouth, B – Municipal slipway near Main Street, C – Jetties upstream from Main Street and D – Jetties near the mouth associated with the Royal Alfred Marina.

Heritage Sites

The Buffalo, an iron paddle-driven steam-powered tug dating back to 1889, remains as a wreck within the Bay of Biscay. There are at least an additional 24 vessels that have wrecked near the mouth of the Kowie river and due to the dynamic nature of the marine environment, there is aways a chance that their wrecks may lie within the Kowie Estuary today. Further upstream, an old stone jetty and old mill are some of the additional heritage sites that date back to well before urbanisation of the town began to take place (Figure 3.11). There are several other historical buildings and heritage resources surrounding the Kowie Estuary that fall within the EFZ and therefore must be protected as per the relevant heritage laws and regulations (refer to Section 7.1.12).

Other Existing Infrastructure

Other existing infrastructure within the EFZ include the following (Figure 3.12):

- Port Alfred Tennis and Bowling Club;
- RO plants;
- Caravan parks, camping sites and braai stands;
- Centenary Park cricket field; and

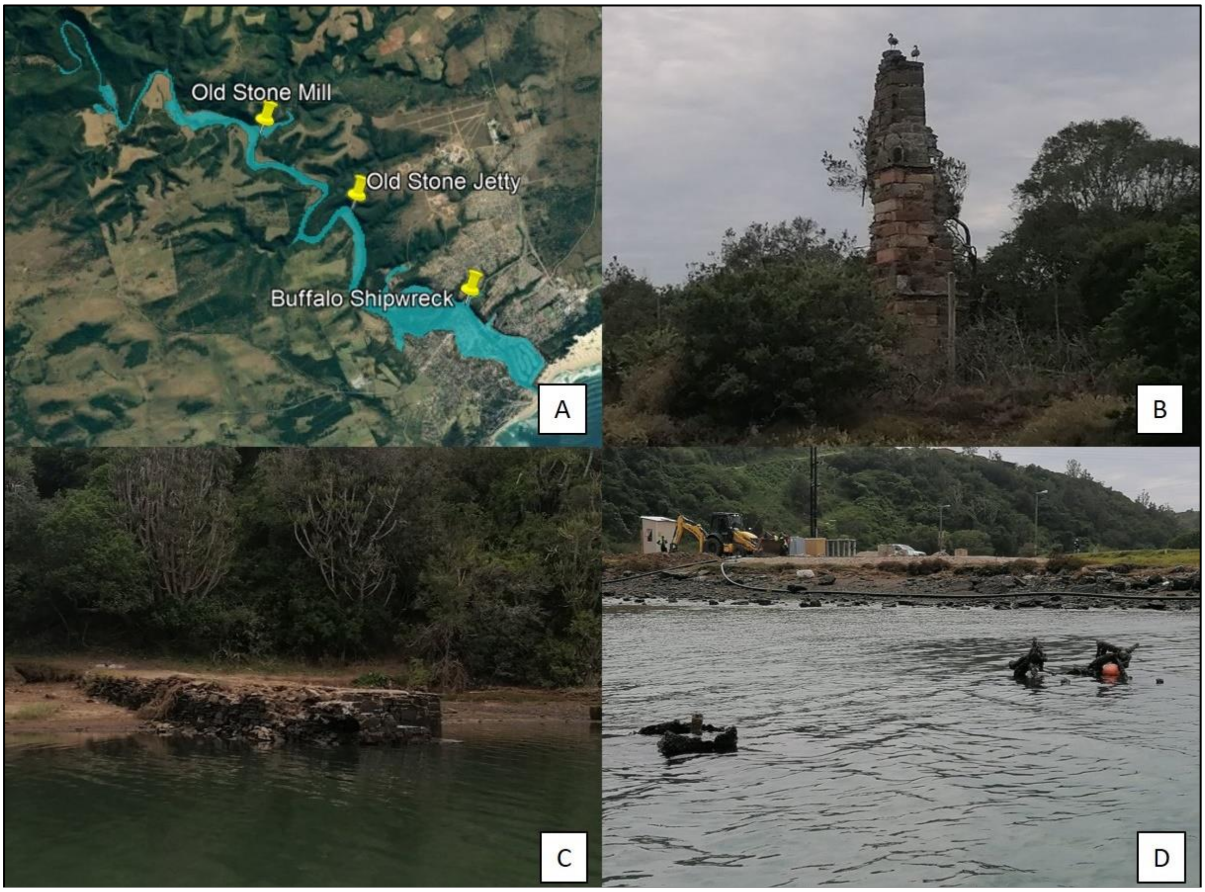

Figure 3.11: A – Map showing the location of heritage features along the Kowie River, B – Old stone mill, C – Old stone jetty and D – *Buffalo* shipwreck located at the Bay of Biscay.

Figure 3.12: Other infrastructure and features located along the lower reaches of the Kowie Estuary.

3.1.2 Planned Future Developments

Due to the fact that the town of Port Alfred is already established and that there is limited space available for future development, it is unlikely that any significant new developments will be undertaken within the lower 4 km of the EFZ. That being said, an Environmental Impact Assessment (EIA) was undertaken in 1996 for a proposed housing development and small boat harbour at Pascoe Crescent and Eastern Lagoon. It was proposed that the Eastern Lagoon would be converted into a second small boat harbour, while the open space between the two bridges be developed into a residential estate (SAB Institute for Coastal Research, 1996). The entire development would cover an area of approximately 4.6 ha (46 000 m^2), but has not been realised to date. Any EA for such development would certainly have lapsed since the completion of the EIA.

At the Bay of Biscay, a new RO plant is currently been developed and will serve to supplement the town's water supply. The plant has a footprint of 200 m^2. On the outskirts of the urban area, along the western bank, the Riverview Waterfront Estate is a 320 ha (3.2 km^2) eco-estate which extends 7 km further up the estuary (Riverview Waterfront Estate, 2012). Although development is currently concentrated adjacent to the town, there is potential for the estate to expand in the future and could result in several additional houses along the middle reaches of the EFZ. This property is indeed already zoned as residential in terms of the local zoning scheme, but would require the necessary EIA and associated authorisations for future development (Figure 3.13).

Although not located entirely within the EFZ, and also a reasonable distance from the main river channel, the Krantz Recreational Area located on the western bank (directly south of the R72) is proposed to be upgraded with new ablution facilities, paved roadways, benches, bins, braai stands and fencing.

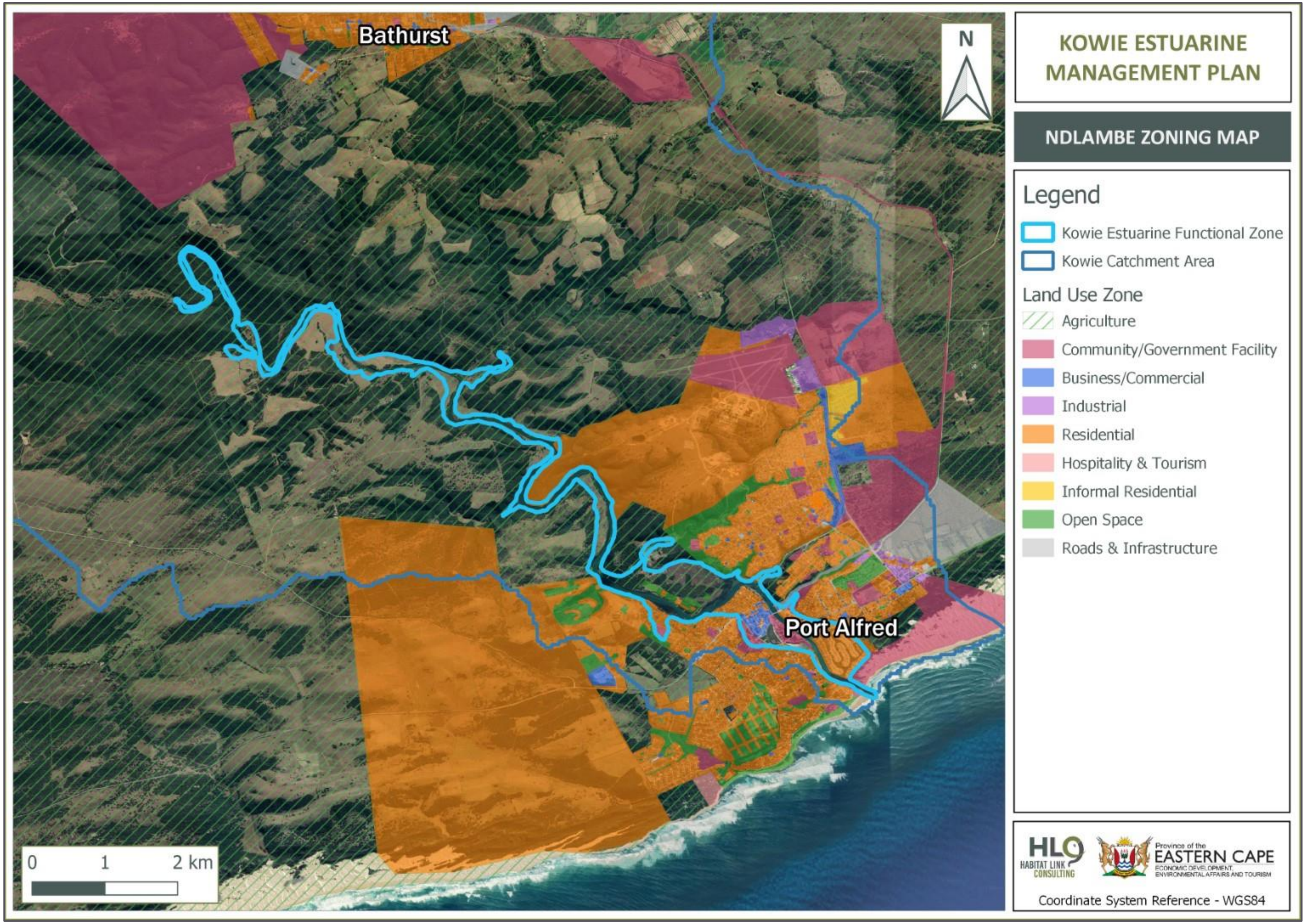

Figure 3.13: Zoning map of the lower reaches of the Kowie EFZ.

On 11 February 2022, the DEDEAT granted authorisation for the proposed Thornhill Ministerial Housing Project (Phase 2). This development will be located north-east of Port Alfred, opposite the existing Nemato Township and adjacent to the R67, between Port Alfred and Grahamstown (i.e. outside the EFZ). Covering an area of approximately 280 ha, this development is notable as the sewerage from this new development will all need to be integrated into the municipal system (van Ryneveld, 2007). According to a local resident, 440 houses have been built to date and a further 550 have been given environmental approval. The entire development is planned to eventually comprise 5 000 dwellings.

According to the DEDEAT EA (2022), the sanitation upgrades include the construction of a link gravity sewer system for the Thornhill Housing Development and all catchment areas downstream, eliminating multiple pump stations and draining sewage to one central point from where it is pumped to the WWTW. The existing east bank sewerage pump station (SPS) immediately upstream of Putt Bridge is proposed to be demolished and sewage is to gravitate via a new sewer from a point near the railway station, along Wharf Road, to the new SPS site.

3.2 Abiotic Function

3.2.1 Physical Characteristics

The Kowie Estuary consists of a relatively long (approximately 21 km), meandering tidal channel, varying in width between 30 m and 150 m, which passes through the steep valleys of the Waters Meeting Nature Reserve, privately owned land and nature reserves in the upper reaches, and through the coastal town of Port Alfred in the lower reaches, before discharging into the ocean through a narrow port entrance created by two breakwaters. The lower reaches comprise an artificially straightened channel linked to The Royal Alfred Marina via two entrances. Water depths in the estuary mouth channel are usually between 2.7 m and 6.5 m at spring high tide (Heinecken and Grindley, 1982; Schumann *et al.*, 2001). Depth at the first marina entrance and main estuary channel above this are between 3.5 m and 4 m (Schumann *et al.*, 2001). Bottom materials in the lower reaches comprise aeolian and marine-derived sand with shell fragments (Schumann *et al.*, 2001). A tidal sandy beach area ('Little Beach') occurs on the western bank opposite the marina and is a remnant of the historical system prior to construction of the marina. Upstream and connected to Little Beach, is an area known locally at the 'Duck Pond', which is a municipal conservation area containing reed swamp and intertidal salt marsh vegetation. Another remnant wet area occurs on the eastern bank, upstream of the Nico Malan Bridge, and is linked to the small craft harbour by a large double-pipe culvert. On the upper margin of the urban edge, in the area known as the Bay of Biscay, is an extensive saltmarsh and mudflat area (first main bend). The intertidal mudflats in this region of the estuary can be more than 100 m wide (Heinecken and Grindley, 1982).

The middle reaches broaden out to approximately 100 m to 150 m wide, with a depth of around 3 m in the main channel. Intertidal saltmarsh and mud banks are prevalent along much of the estuary and can attain a width of more than 50 m. The bottom materials in the middle reaches comprise predominantly of sand, and water depths can reach 8 m, with numerous deep points that provide optimal fishing spots. The upper reaches are confined between steeply sided, and often rocky, densely wooded hillsides. In this region, the intertidal zone is particularly narrow (less than 10 m wide). Water depth ranges between 2 m and 6 m and the substrate is comprised of very fine sand and silt (Heinecken and Grindley, 1982). The size of the estuary, as defined by the EFZ (5 m contour), is approximately 457 ha (4.57 km^2) with an estimated open water area of 146 ha (1.46 km^2) (Van Niekerk *et al*., 2015).

3.2.2 Hydrology

The flow of the Kowie River is reported as being highly variable, where flood and drought conditions are not uncommon. Even if rainfall occurs in the catchment, this does not necessarily translate to increased flow of the Kowie River (Heinecken and Grindley, 1982). Grange *et al*., (1992) state that extremely low flow and cessation of flow are characteristic of the estuary for most of the year, despite classification as a perennial river. Flow has been known to cease for two to three months during severe drought conditions (Sale *et al*., 2009). Episodic flood events reportedly occurred every 3 to 5 years and the estimated flood peak for a 1:50 year flood is given as 460 m^3/s and a 1:200 year flood as 690 m^3/s (Heinecken and Grindley, 1982). Flood discharges in excess of 1 000 m^3/s have been recorded at the Wolfscrag gauging station on the Kowie River (Whitfield *et al*., 1994). The last major flood occurred during October 2012, as a result of 12 days of heavy rainfall (418 mm) (Dalu *et al*., 2016). Prior to the flood event, the estuary volume and discharge rate were 60 000 m^3 and 0.7 m^3/s, respectively, and reached a flood peak of 60 million m^3 and 699.14 m^3/s within seven days (Dalu *et al*., 2016a).

The weir above the 'ebb and flow' point noted by Heinecken and Grindley (1982) is the main obstruction to flow in the estuary. This was previously used to supply water for domestic use at Port Alfred and the Mansfield Dam, which was a standby storage facility during periods of low river flow (Heinecken and Grindley, 1982). The Sarel Hayward Dam was constructed in 1988 and is an off-stream municipal reservoir that resulted in little change in the mean annual runoff (MAR) to the estuary (Grange et. al., 1992). However, Van Niekerk *et al*. (2015) estimated that there has been a 1.5 % reduction in MAR from 31.8 Mm^3/a to 30.3 Mm^3/a, with a slight decline in monthly average flows across all months (Table 3.2 and Figure 3.14). This is not unexpected given the absence of any large instream dams or significant abstraction within the catchment, yet there are several smaller weirs and dams located that are used for irrigation and stock watering purposes.

Table 3.2: Summary of the hydrological change to the Kowie Estuary (Van Niekerk *et al*., 2015).

PARAMETER	SUMMARY OF CHANGE IN FLOW PARAMETERS
Reference MAR (million m^3/a)	31.8
Present MAR (million m^3/a)	30.3
% MAR similarity	95
% Base flow similarity	66
% Median flow similarity	85
Change in high flow months	No, December
Change in base flow variance	Yes, minor shift
Change in low flow duration	No, 2 months
Change in high flow onset month	No, June

In 2010, the Kowie Estuary Emergency Desalination Plant was constructed in response to increased potable water demands within the town of Port Alfred (SCA, 2011). The plant had a total potable water production capacity of 0.45 Mℓ/day. The volume of brine produced and discharged back to the estuary was between 50 % and 70 % of the total intake volume, depending on the salinity of the intake water. The plant was a temporary installation and was decommissioned in 2011 (SCA, 2011).

Following the extended drought period in recent years and the severe water crisis in the region, a new RO plant was constructed in 2021 alongside the Port Alfred Waste Water Treatment Works, with production capacity of 2 Mℓ/day. This facility, together with a 3 Mℓ/day waste water reclamation plant that was also constructed, are part of the long-term solution to the ongoing water crisis, but the latter is largely dependent on adequate volumes of wastewater to produce a good yield of potable water and is not yet operational. A second smaller RO system (1 Mℓ/day) is to be constructed in the near future, in the same location as the first emergency desalination plant at the Wharf Street bend on the Kowie Estuary (Houzet, 2021).

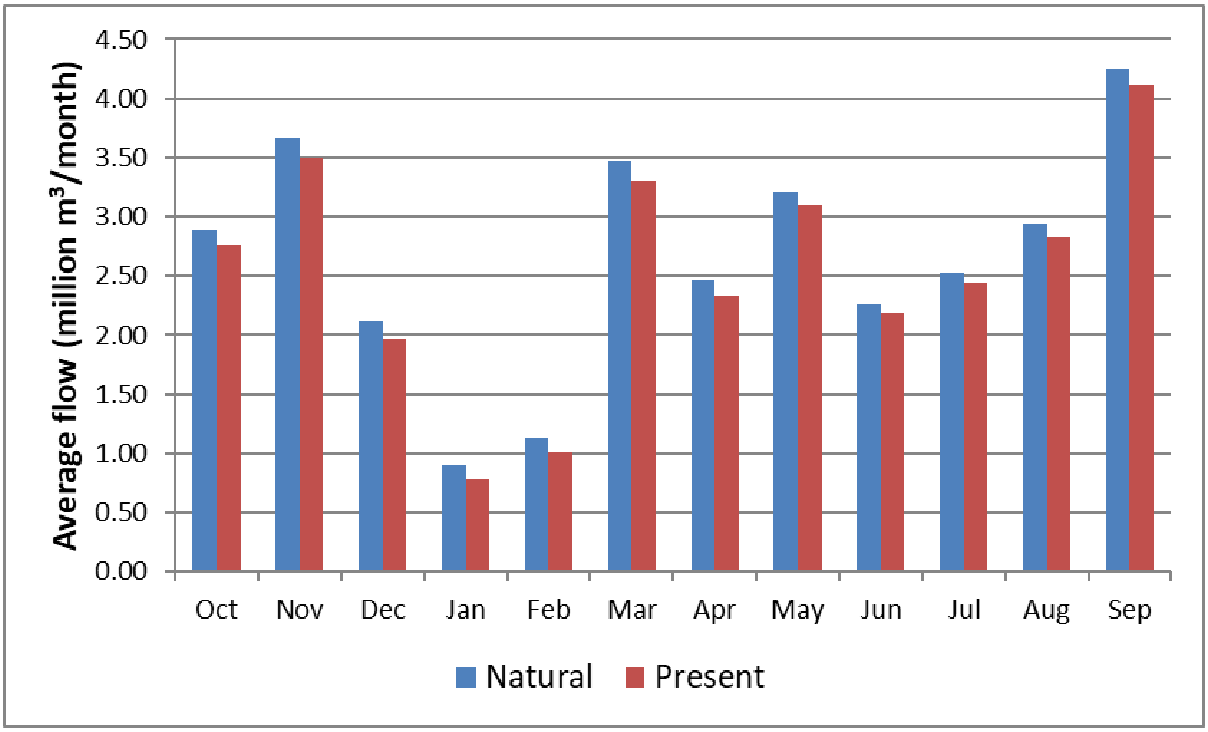

Figure 3.14: Natural (blue) and Present (red) monthly flow distribution for the Kowie Estuary showing a slight decrease in river inflow to the estuary (Van Niekerk *et al.*, 2015).

3.2.3 Hydrodynamics and Sedimentary Processes

According to a historical account of the Kowie Estuary from 1821 in Heinecken and Grindley (1982), the lower reaches of the estuary once "'*consisted of one vast swampy region bounded on the east and west by the hills today known as the East and West banks*". A number of sandbanks or islands were exposed at low tide, and the main outlet channel was against the eastern shoreline. Around the mid 1830's, work began to convert the estuary into a major port, beginning with the diversion of the main river channel to the western side through dredging and channel straightening by means of two stone-packed berms, and ultimately the construction and extension of two permanent piers or breakwaters. Due to persistent sediment deposition in the estuary mouth and difficulty in navigating the narrow channel, commercial traffic ceased and the harbour was abandoned by 1890. The last breakwater extension of 65 m was completed in 1941 (Heinecken and Grindley, 1982) (Figure 3.15).

In 1989, the extensive saltmarsh area along the eastern bank was dredged and converted into what is today known as the Royal Alfred Marina, and small boat harbour, covering approximately 45 ha (450 000 m^2) (Whitfield *et al.*, 1994). In the present day, the Kowie Estuary still functions as a predominantly open estuarine system (Van Niekerk *et al.*, 2019), albeit modified from its original mouth configuration, with permanent open mouth conditions maintained by the harbour breakwaters.

The Kowie Estuary is tidal for approximately 21 km up to the 'ebb and flow' point recognised by Heinecken and Grindley (1982). Based on the tidal data for Port Elizabeth and East London, the system exhibits an estimated tidal range of 1.62 m and has an estimated mean level of 1.14 m. The mean high and low spring tide levels are given as 1.95 m and 0.33 m, respectively (Heinecken and Grindley, 1982). The spring tidal range in the lower reaches is approximately 1.7 m, the middle reaches 1.5 and the upper reaches 1.1 m (Whitfield *et al.*, 1994).

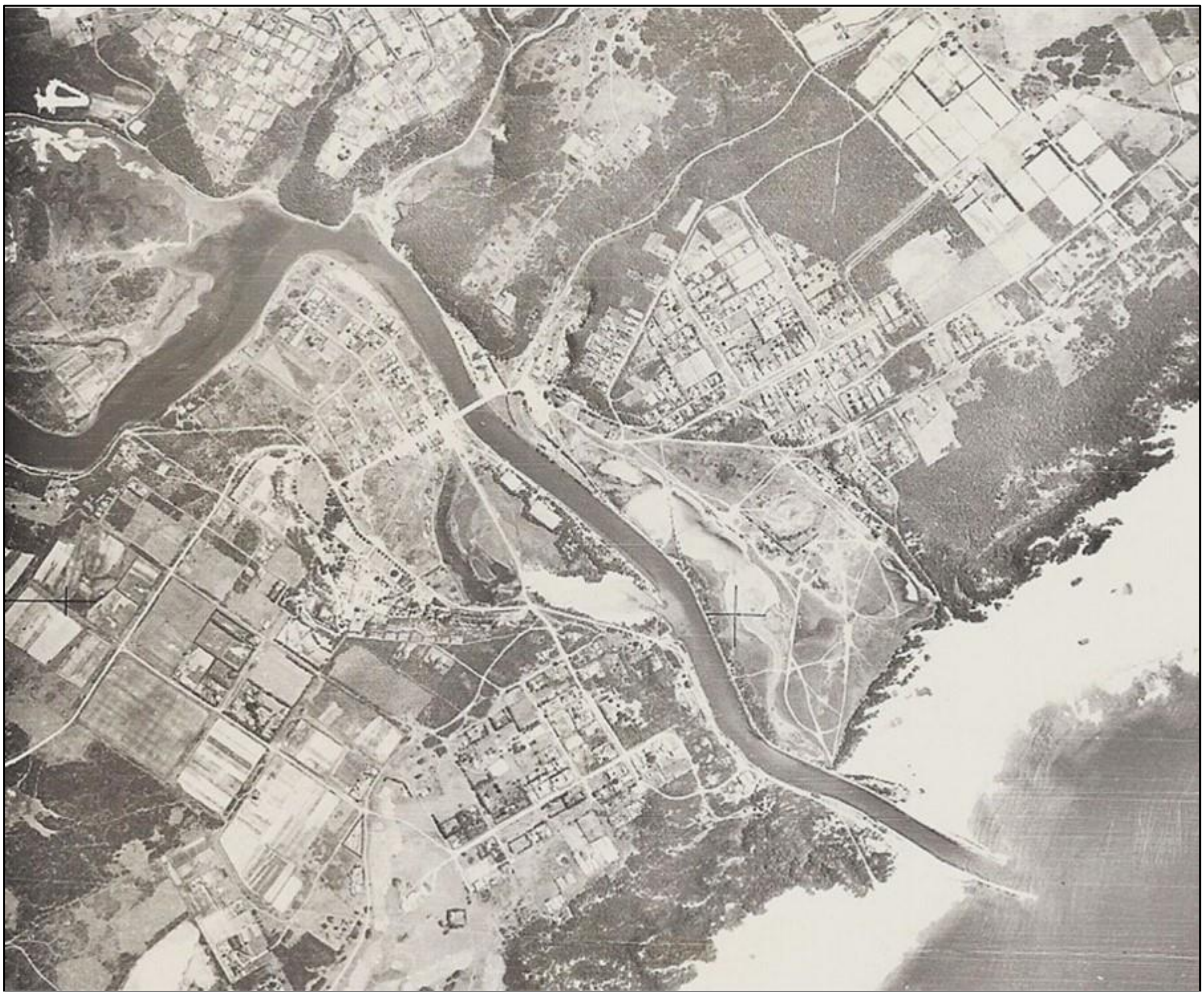

Figure 3.15: Configuration of the Kowie Estuary and surrounding development in 1942 (NRIO-CSIR, 1942).

By virtue of the open mouth and generally low regional rainfall, water movement through the system is predominantly controlled by the tidal exchange. In the lower reaches, ebb current speeds reach 25 cm/s and, even in the upper reaches, strong currents between 12 cm/s to 20 cm/s have been recorded (Heinecken and Grindley, 1982). Schumann *et al*. (2001) illustrated that the flow dynamics of the lower portion of the estuary have been modified by the construction of the marina, which has resulted in sedimentation between the marina entrances. Current speeds measured in the estuary channel reached 1.5 m/s at spring tide, and decreased to 1 m/s at neap tide, with spring-tide water level variation given as approximately 1.3 m and neap-tide variation as approximately 0.7 m (Schumann *et al*., 2001). Very strong flows (greater than 2 m/s) occur in the lower reaches of the estuary if river floods coincide with an outgoing high spring tide (Heinecken and Grindley, 1982). Schumann *et al*. (2001) calculated the tidal prism (the amount of seawater exchanged over a tidal cycle) to be between 900 000 m^3 at neap tides increasing to 2.6 million m^3 at spring tides, and reported complete exchange of marine and estuary water over the tidal cycle in the lower reaches. It was also noted that the marina has its own tidal prism, but this was calculated to be less than 5 % of that of the estuary, and therefore of minimal importance (Schumann *et al*., 2001).

Sediment transport into the Kowie Estuary from the catchment is reported to be minimal and this is attributed to the regional soil type and good vegetation coverage (Heinecken and Grindley, 1982). Changes in agricultural practices in the catchment over the years have episodically affected the silt loads reaching the estuary (Heinecken and Grindley, 1982). In contrast, marine ingress of sediment through estuary mouth has been a major concern ever since the historical construction of the harbour. This problem persists today for users of The Royal Alfred Marina and small boat harbour (Heinecken and Grindley, 1982; Breen and McKenzie, 2001). The harbour breakwaters have effectively altered nearshore tidal currents and coastal sediment dynamics (i.e. the normal pattern of sediment movement up the coastline), resulting in continuous sediment accumulation in the harbor mouth and the main estuary channel, creating a shallow and dangerous passage for boats trying to enter the estuary. The sediment dynamics of the adjacent beaches have also been affected (Heinecken and Grindley, 1982).

An investigation into the sedimentation of the Kowie Estuary by Schumann *et al*. (2001) showed that the tidal flow and sediment dynamics of the lower estuary have been altered by the increased flow area created by the two marina entrances. The study found that during both flood and ebb-tides, the flow was sub-divided at the entrances causing reduced flow speeds in the estuary (Schumann *et al*., 2001). Consequently, during a flood-tide, sediment was deposited at the entrances, and on the ebb-tide, the division of out-going flow between the estuary and marina prevented effective scouring of accumulated sediment. This in turn lead to the build-up of the central sand bank, which in itself was considered to be a flood-tide delta that separated flood- and ebb-tide channels, further affecting the scouring potential. Increasingly more flow was being diverted through the marina further contributing to sedimentation of the estuary (Schumann *et al*., 2001). An artificial barrier was proposed as a means to prevent the ebb-flow from entering the upper marina entrance, forcing it to flow only through the estuary, and thereby scouring the sediment between the two entrances to the marina. It was estimated that 120 000 and 200 000 m^3 of sediment needed to be removed (Schumann *et al*., 2001). In the present day, the lower reaches of the estuary, in the vicinity of the marina, are regularly dredged to alleviate this problem (Figure 3.16).

Figure 3.16: Dredge pipeline observed within the Kowie Estuary mouth.

3.2.4 Sediment Characteristics

The presence and distribution of metals in the Kowie Estuary was investigated prior to the marina development (Watling and Watling, 1983). Water samples, surface sediment and sediment core samples were analysed. Overall, metal concentrations in the water and sediment samples suggested an unpolluted river system. The upstream sites exhibited higher metal concentrations ascribed to the natural weathering and leaching of metal rich soils in the catchment and not human impacts and sources (Watling and Watling, 1983). The surface sediment samples yielded high concentrations of iron and aluminium, which were indicative of the presence of clay and hydrated iron minerals (Watling and Watling, 1983). Surface sediment samples at the upper sites yielded concentrations of several metals that were "*higher than would be expected from an unpolluted river*" (viz. copper, lead, zinc, cobalt, nickel, cadmium and chromium), but the sediment cores did not indicate any long-term metal accumulations (Watling and Watling, 1983).

According to Orr (2007), the sediments of the Kowie Estuary comprise predominantly fine and medium grained sands, with little variation in grain size along the length of the estuary (Figure 3.17). While the percentage organic content was fairly low, ranging between 1 % to 7 %, higher proportions were noted in the middle and upper reaches of the estuary (sites P4 to P7), that is from the Bay of Biscay to the region of the Terry Fitzgerald Private Nature Reserve (Orr, 2007). Sediment metal concentrations increased significantly from the mouth to the upper reaches of the estuary, and all metals were positively correlated with the total organic content, mud and fine sand fraction of the sediment (Orr, 2007). Apart from cadmium, all metal concentrations were markedly lower than previously reported (Watling, 1988 cited in Orr, 2007). Overall, the results were considered typical of is typically characteristic of uncontaminated sediments, except for cadmium. Cadmium concentrations decreased moving upstream and exhibited a moderate level of enrichment (Orr, 2007) (Table 3.3).

Table 3.3: Absolution concentrations (mg/kg, dry weight) of metals in sediment across eight sites in the Kowie Estuary.

	Cd	Co	Cu	Fe	Ni	Pb	Zn
Mean	2.18	2.31	4.27	5659	4.13	4.93	10.67
SD	±1.21	±1.58	±3.30	±3140	±2.60	±1.68	±8.35

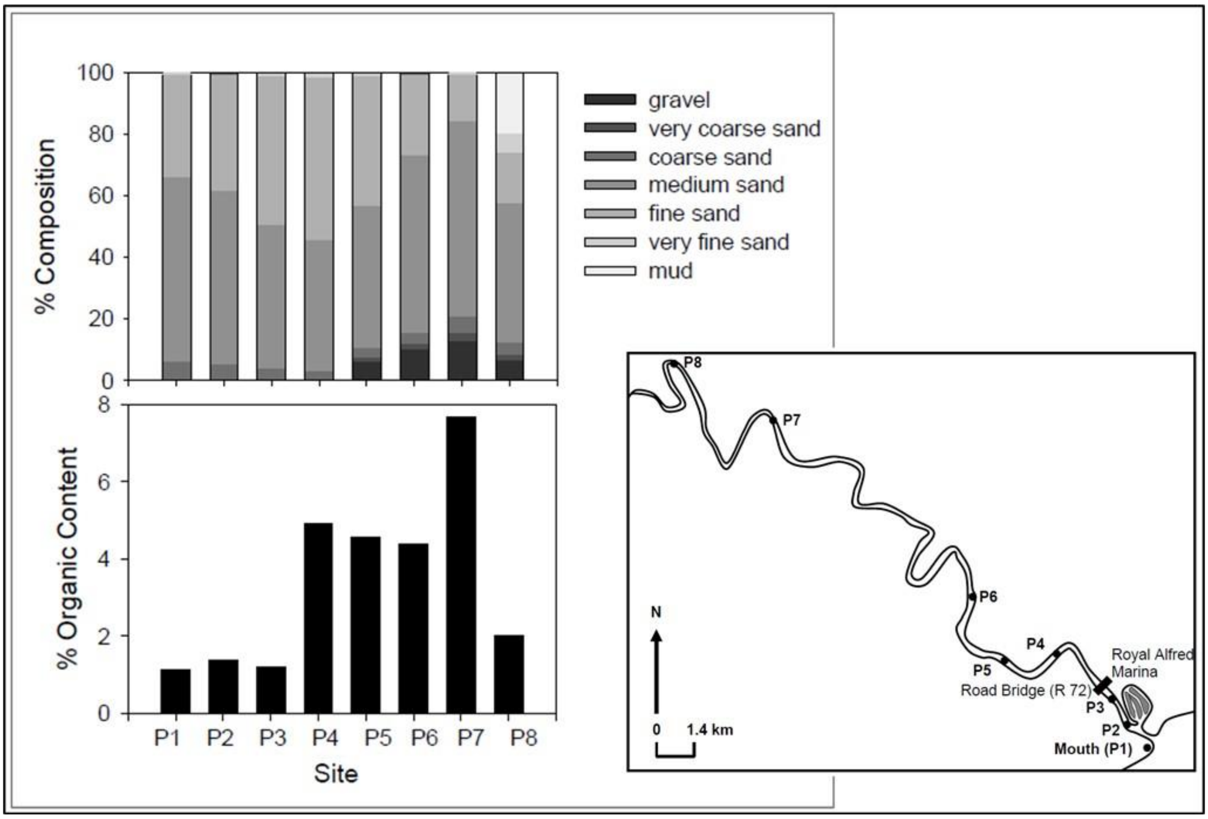

Figure 3.17: Grain size composition and organic content of the sediments at eight sites along the Kowie Estuary (insert shows location of samples sites along the estuary) (Orr, 2007).

3.2.5 Water Quality

<u>Historical Research</u>

Early accounts of the water quality of the Kowie Estuary are provided by Heinecken and Grindley (1982), Grange et al., (1992) and Whitfield et al., (1994). This early research indicates that the system was tidal for its entire length up to the 'ebb and flow' point near the headwater region of the estuary (Heinecken and Grindley, 1982).

As a marine dominated system, salinities in the estuary were generally above 30 psu (Heinecken and Grindley, 1982). Grange *et al*., (1992) recorded a salinity range of between 19 – 37 psu over a ten-month period between 1990 and 1991. A slight salinity gradient was generally present along the estuary during winter months due to low river inflow; however, during summer drought periods, salinities of 40 psu were recorded at the upper extent as a result of evaporative loss (Heinecken and

Grindley, 1982; Grange *et al*., 1992). Salinities in the shallow marginal habitats occasionally exceeded 35 psu during summer for the same reason (Heinecken and Grindley, 1982). Marked salinity stratification was observed during heavy rainfall and prolonged flood conditions when surface salinities were reduced to zero, even in the lower reaches (Heinecken and Grindley, 1982; Grange *et al*., 1992). Following major flood events, salinity stratification persisted for several weeks in the lower and middle reaches (Grange *et al*., 1992; Whitfield *et al*., 1994).

pH values of the estuary ranged between 7.6 to 8.6 (Heinecken and Grindley, 1982; Grange *et al.*, 1992). Grange *et al.,* (1992) noted that pH was uniform throughout, and no seasonal trends were observed. The alkaline conditions were attributed to the geology of the region (Heinecken and Grindley, 1982). The relatively high turbidity levels recorded in the Kowie River were similarly ascribed to the geology, which yields clay-rich soils (Heinecken and Grindley, 1982). Transparency readings above the tidal limit ranged from 20 cm – 200 cm, with a mean of 100 cm (Heinecken and Grindley, 1982). The river water entering the estuary was peat-stained (brown) by dissolved organic matter, which also limits light penetration (Heinecken and Grindley, 1982; Whitfield *et al.*, 1994). The estuary was reported to be relatively clear, with transparency measurements ranging from 1.5 m to more than 2 m (Heinecken and Grindley, 1982).

Water temperatures followed a clear seasonal trend ranging from 15.5 °C in August to 28 °C in February (Grange *et al.,* 1992). Slight temperature stratification was also recorded by Whitfield *et al*., (1994), where bottom waters in the estuary were on average 0.7 °C cooler than surface waters. Slightly warmer temperatures occurred in the upper reaches in comparison to the lower reaches during summer due to the shallow and narrower channel (Grange *et al.*, 1992) and cooler temperatures occurred at the mouth as a result of the tidal influx ,which lowers water temperatures to that of the incoming seawater (Heinecken and Grindley, 1982). Schumann *et al*., (2001) also noted the influence of marine upwelling, whereby inflowing seawater was markedly cooler than the estuary water (up to 12 °C cooler) during summer.

The Kowie estuarine system was found to be generally well oxygenated and this was likely attributed to strong tidal flushing. The incoming river was periodically supersaturated, up to 13.5 mg/ℓ (144% saturation); however, poor oxygen conditions (0.2 mg/ℓ) existed in large deep pools (Heinecken and Grindley, 1982). Dissolved oxygen concentrations ranged between 9.8 mg/ℓ and 21.9 mg/ℓ (Heinecken and Grindley, 1982).

Nutrients are introduced to the headwaters of Kowie Estuary via agricultural return flows containing fertilisers, effluent discharged into the Bloukrans tributary via the Grahamstown sewerage works (Heinecken and Grindley, 1982). During sampling of the system between August 1990 and May 1991, nitrate levels ranging from 0.0496 mg/ℓ to 0.9796 mg/ℓ were recorded (Grange *et al*., 1992). A horizontal gradient was evident with the lowest nitrate concentrations occurring in the upper reaches, intermediate levels in the middle reaches, and the highest levels at the mouth (Grange *et al.,* 1992). Concentrations were also highly variable in the mouth region, which was ascribed to the influx of alternately nutrient-rich and nutrient-poor sea water related to marine upwelling and downwelling events (Grange *et al.,* 1992). Nitrate levels exhibited seasonal fluctuations related to runoff through point source and diffuse inputs, and these were most evident in the lower reaches. Marked decreases in nitrates were attributed to spring and summer algal blooms (Grange *et al.,* 1992). Nitrite concentrations ranging from 0.0092 mg/ℓ to 0.1141 mg/ℓ were recorded, with no apparent horizontal gradient, i.e. nitrite was evenly distributed along the length of the estuary (Grange *et al.,* 1992). A seasonal increase in nitrite concentrations was noted and this appeared to be related to the increase in temperatures during the warmer months (Grange *et al.,* 1992). Phosphate concentrations ranged between 0.0098 mg/ℓ and 0.0340 mg/ℓ. During winter months, a weak horizontal gradient was noted, with slightly lower phosphate concentrations recorded in the upper reaches (0.015 mg/ℓ and 0.025 mg/ℓ). In summer however, a reverse gradient was well developed, where higher levels of phosphate (0.002 mg/ℓ and 0.035 mg/ℓ) occurred at the headwaters (Grange *et al.,* 1992).

Faecal bacterial loads (*E. coli*) in the Kowie Estuary between 1990 and 1991 were found to be low (Grange *et al*., 1992). Approximately 3 % of the samples had concentrations greater than 100 counts / 100 mℓ, and the maximum concentration was 4 800 counts / 100 mℓ recorded once-off at the mouth (Grange *et al*., 1992). There were no differences in concentrations between the upper and lower estuary sites, where the lower sites were expected to be affected by human/urban settlement. Furthermore, the results did not show a correlation to rainfall and run-off, however the study was undertaken during a particular low rainfall and river flow period (Grange *et al*., 1992).

Modern Research

By and large, the physico-chemical characteristics and dynamics of the Kowie Estuary are expected to remain unchanged in comparison to that reported in the earlier research because the hydrodynamics and functioning of the system, as a permanently open estuary that is subject to strong tidal variations, have not been altered. The tidal extent of the system remains unchanged and the system is saline to the first weir within the Waters Meeting Nature Reserve (Wasserman and Strydom, 2011). This instream barrier restricts saline intrusion further upstream, and the system exhibits freshwater to low salinities from this point upwards since the rivers that feed into the estuary are also brackish (Heinecken and Grindley, 1982).

James and Harrison (2010) reported a gradual horizontal salinity gradient, with salinity decreasing moving upstream; surface and bottom salinities ranged between 24.7 and 32.9 psu. Wasserman and Strydom (2011) found that salinities in the headwaters of the system were highest in winter, reaching a maximum of 28.6 psu and lowest in summer, at a minimum of 1.4 psu. Water quality data obtained by Dalu *et al.,* (2016a) are presented in Table 3.4 and recent monitoring data collected through the DFFE (formerly DEA) coastal monitoring programme (November 2016 – September 2021) are provided in Table 3.5 (overleaf). A horizontal salinity gradient is evident, although salinities reported by Dalu appear slightly lower in comparison. While Wasserman and Strydom (2011) and Dalu et al., (2016a) found salinities to be highest during winter and lowest during spring, the latest monitoring data show that salinities throughout the estuary can approximate seawater in Spring (e.g. 32.90 – 34.75 psu in Spring 2021).

Table 3.4: Mean physico-chemical variables measured across three sites per season between spring 2012 and winter 2013 (Dalu et al., 2016a).

Variables	Early spring			Late spring			Summer			Winter		
	Up	Mid	Low	Up	Mid	Low	Up	Mid	Low	Up	Mid	Low
Chemical factors												
Total dissolved solids (ppt)	2.8	4.9	18.4	2.9	2.9	23.7	3.4	5.9	24.0	4.7	9.8	29.1
Salinity (ppt)	2.0	3.8	16.0	2.2	2.2	21.2	2.5	4.6	21.5	3.8	8.0	27.4
Temperature (°C)	18.2	19.2	19.6	25.1	25.8	24.4	26.9	25.0	23.6	12.5	13.1	14.1
Conductivity (µS cm^{-1})	4.1	7.9	27.5	4.3	4.4	35.5	5.0	8.8	36.1	7.5	14.8	36.8
pH	8.0	8.1	8.0	6.5	6.9	7.5	7.8	7.5	7.3	8.1	8.1	8.0
Physical factors												
Water depth (m)	2.3	3.4	5.0	3.3	4.1	6.6	2.5	3.2	5.0	2.1	3.1	4.9
Water flow (m s^{-1})	0.2	0.2	0.0	0.3	0.2	0.1	0.3	0.2	0.2	0.1	0.3	0.4
Nutrients												
Ammonia (mg L^{-1} NH_4^+)	0.2	0.1	1.0	0.3	0.2	0.4	0.7	0.6	0.4	0.5	0.9	0.6
Phosphate (mg L^{-1} PO_4^{3-})	0.1	0.1	6.2	0.3	0.3	0.1	0.1	0.3	0.0	0.7	0.4	2.9
Nitrate (mg L^{-1} NO_3^-)	0.0	0.0	0.0	1.2	7.3	2.5	8.3	24.4	7.3	0.0	8.9	0.0

Dalu *et al.,* (2016a) (Table 3.4) and the DFFE monitoring data (Table 3.5) indicate similar trends in water temperature and pH to James and Harrison (2010) and Wasserman and Strydom (2011), including a general horizontal gradient of increasing temperature and pH moving upstream, as well as seasonal fluctuations. Total dissolved solids and conductivity were highest in the lower reaches (Dalu *et al.,* 2016) and mouth region (DFFE). This is likely attributed to proximity to the marine environment and the ingress of seawater and dissolved solids through wave and tidal activity.

For those variables not indicated in Table 3.4, such as dissolved oxygen, James and Harrison (2010) recorded concentrations in the estuary bottom water ranging from 6.6 mg/ℓ to 7.6 mg/ℓ, and surface concentrations ranging from 6.8 mg/ℓ to 7.9 mg/ℓ. At the time of sampling, the estuary was relatively well mixed, however bottom oxygen concentrations were slightly lower indicating weak vertical stratification. Supersaturation (148%) as well as oxygen-poor conditions (7.9%) have been reported in the headwater region (Wasserman and Strydom, 2011). The recent DFFE monitoring data (Table 3.5) indicate that the Kowie system is well oxygenated, and dissolved oxygen concentrations are generally highest at the mouth and decrease moving upstream. Bottom waters at all sites maintained dissolved oxygen concentrations above 8.0 mg/ ℓ.

For water clarity, Harrison (2004) recorded a low average turbidity level in the estuary, measuring approximately 6.9 NTU, which is common in open, marine-dominated, warm-temperature estuarine systems. Measurements collected during September 2021 (DFFE) indicated markedly higher turbidity at the mouth (261 NTU). This high reading may well be attributed to estuary circulation and tidal currents, as well as wave activity entering through the mouth, which would cause resuspension of bottom sediments, compounded by the influx/outflow of suspended matter. This would be exacerbated by any dredging activities or vessel propeller wash. Turbidity readings in the middle and upper reaches were lower at the time at 23 NTU and 45 NTU, respectively.

In terms of nutrient levels, Scherman, Colloty and Associates (SCA) (2011) recorded nitrate concentrations between 0.25 mg/ℓ to 0.38 mg/ℓ. Higher levels were recorded at sites along the urban environment (except near the mouth), and this was attributed to discharges from the Port Alfred WWTW and urban stormwater entering the system. Ammonia levels ranged from 0.01 mg/ℓ to 0.04 mg/ℓ, while nitrite concentrations at all sample sites and depths to be below the detection limit (i.e. less than 0.1 mg/ℓ) (SCA, 2011). During autumn in 2011, overall similar phosphate concentrations were measured in the lower to middle reaches ranging from 0.01 mg/ℓ to 0.02 mg/ℓ.

According to Dalu, et al., (2016a) (Table 3.4), mean ammonia concentrations in the estuary range from 0.1 to 0.9 mg/ℓ (winter, middle reaches), phosphate concentrations in the estuary range from 0.0 to 6.2 mg/ℓ (early spring, lower reaches), mean nitrate concentrations from 0.0 to 24.4 mg/ℓ (summer, middle reaches). There were no apparent trends in terms of horizontal gradient or seasonality. In a second study investigating the impact of land use patterns on water quality and benthic diatom community structure, Dalu *et al*., (2016b) found nutrient concentrations in the Kowie Estuary to be markedly higher than previously reported by Grange *et al*., (1992). Elevated phosphate (~2.2 mg/ ℓ) and nitrate (~10.15 mg/ℓ) concentrations were found in the upper middle reaches, and the lower reaches just upstream of the urban edge, respectively, which were attributed to agricultural impacts and WWTW discharge (Dalu *et al*., 2016b). The estuary exhibited higher ammonia concentrations (~0.4 mg/ℓ – 0.6 mg/ℓ) relative to the freshwater riverine environment (~0.14 mg/ℓ – 2.0 mg/ℓ). Ammonia levels were also variable within the estuary (e.g. 0.59 ± 0.31 mg/ℓ). Based on these results, the nutrient status of the Kowie Estuary could be considered hypertrophic, with anticipated severe negative effects on the biota (DWAF, 1996a).

Between November 2017 and August 2018, the DFFE monitoring programme found nitrate concentrations to be excessive, ranging from 805.1 mg/ℓ (November 2017, upstream of the WWTW) to 52 160.23 mg/ℓ (August 2018, upper reaches) (Table 3.5). In July 2019, a detailed nutrient analysis was undertaken, and nitrates were only detected in low concentration (0.11 mg/ℓ) in the middle reaches, and negligible concentrations at other sites. The discrepancy between these results is a major concern and needs urgent verification through consistent repeat sampling and analyses at an accredited laboratory. In the same nutrient analyses, average ammonia concentrations were comparable to those reported by Dalu *et al.*, (2016b), ranging from 0.55 mg/ℓ in the middle reaches to 0.77 mg/ ℓ in the lower reaches. These levels are borderline toxic (DEA, 2019). Nitrites were only detected in the lower reaches at 0.02 mg/ℓ.

Table 3.5: Mean physico-chemical variables measured across five sites (upper [U], middle [M], upstream of the waste water treatment works [u/s WW], lower [L], mouth [Mo]) per quarterly sample period between November 2017 and September 2021 (DFFE Coastal Water Quality Monitoring Programme).

	Season	Spring				Autumn				Winter				Spring			
	Date	Nov-17				May-18				Aug-18				Nov-18			
	Region	M	u/s WW	L	Mo	U	M	L	Mo	U	M	L	Mo	M	u/s WW	L	Mo
Temperature	°C	21.70	22.90	17.35		18.82	18.70	18.27		14.60	14.60	15.20	15.85	21.27	21.20	18.70	16.55
pH						8.23	8.36	8.45		8.30	8.48	8.43	8.47	8.19	8.21	8.44	8.56
Dissolved oxygen	mg/L	7.97	8.33	8.50		8.34	8.83	8.78		8.87	9.43	9.29	9.38	7.23	7.02	8.06	9.35
Conductivity	mS/m	45.93	45.90	47.28		34.71	45.42	45.54		25.27	34.61	44.13	45.91	37.03	42.29	43.97	44.97
Total dissolved solids	g/L	29.85	32.09	30.73		22.56	29.52	29.60		16.42	22.49	28.68	29.84	24.07	27.49	28.58	29.23
Salinity	psu	29.75	30.30	30.75		21.81	29.40	29.44		15.38	21.74	28.48	29.74	23.43	27.15	28.36	29.05
Nitrates	mg/L	819.40	805.10	968.30		3746.3	5082.5	13930		52160	19609	20814	27339		27457	26528	29825
Chlorophyll-*a*	µg/L	43.83	75.62	2.02		5.61	0.00	0.00									
Temperature	°C	19.73	19.47	18.53	17.70	14.50	15.23	16.20	17.55			20.03		17.54	16.85	16.90	17.55
pH		7.81	7.90	8.01	8.23	7.98	8.21	8.23	8.24			7.90		8.40	8.84	8.50	8.42
Dissolved oxygen	mg/L	8.22	8.11	8.05	8.94	9.22	9.05	8.80	8.88			4.76		7.80	10.00	7.90	7.50
Conductivity	mS/m	37.88	39.91	41.10	42.57	33.22	37.80	42.44	43.35					52.30	51.60	52.60	50.10
Total dissolved solids	g/L	24.62	25.94	26.71	27.66	21.59	24.57	27.58	28.18			28.49		33.40	33.00	33.60	32.10
Salinity	psu	24.03	25.45	26.30	27.36	20.78	23.96	27.25	27.92			33.93		34.51	34.00	34.75	32.90
Chlorophyll-*a*	µg/L											2.05		4.20	8.20	1.00	6.20
Turbidity	NTU											35.27		23.00	45.00	8.00	261.00
Phycoerythrin	µg/L											2.70		3.20	4.50	0.65	5.50
Nutrients																	
Ammonia (NH_4^+)	mg/L					0.59	0.55	0.77	0.59								
Chloride (Cl^-)	mg/L					5574.5	5791.5	6067.8	6097.2								
Fluoride (F^-)	mg/L					0.29	0.32	0.35	0.34								
Nitrate (NO_3^-)	mg/L					<0.1	0.11	<0.1	<0.1								
Nitrite (NO_2^-)	mg/L					0.00	0.00	0.02	0.00								
Sulphate (SO_4^{2-})	mg/L					42159	2405	2756	2835								

Sulphate concentrations decreased gradually from the mouth to the middle reaches (2 834.55 mg/ℓ to 2 405.03 mg/ℓ) but peaked in the upper reaches with a concentration of 42 159.30 mg/ℓ. Although chlorides and sulphates are major constituents of salts that make up seawater, the high concentration of sulphates entering the head of the estuary should be monitored. While higher nutrients levels are expected for the Kowie Estuary given the level of anthropogenic disturbance surrounding the estuary and in the catchment (also influenced by marine upwelling that periodically brings nutrient rich waters into the estuary), the nutrient status of the Kowie Estuary is a concern and suggests toxic exposure to estuarine organisms based on the available water quality guidelines (DWAF, 1996a, DEA 2018).

In respect of bacterial loading of the system, analyses are undertaken as part of the DFFE monitoring programme. The data collected between 2016 and 2021 illustrates that bacterial count generally increases moving upstream and there was a significant increase that occurred in July 2019 in the upper reaches (Figure 3.18). While it is known that tributaries to the Kowie River in the upper catchment contribute significantly to the bacterial loading of the river system and estuary (DWAF, 2005), no explanation for this significant peak was given; although there are records of a sewage spillage in the lower reaches in February 2019, but is unlikely to be related. The data also indicate that the most recent bacterial loads (2021) are the lowest since the commencement of the monitoring programme in 2016. Although the bacterial load within the Kowie Estuary is variable, it is within acceptable limits according to the DFFE monitoring reports. In addition, concentrations of phycoerythrin (Table 3.5), a pigment associated with cyanobacteria, indicated the presence of cyanobacteria within estuary in September 2021, with the lowest concentration 0.65 µg/ℓ recorded in lower reaches and the maximum concentration of 5.50 µg/ℓ recorded at the mouth. Ongoing monitoring it required for early detection of harmful algal blooms.

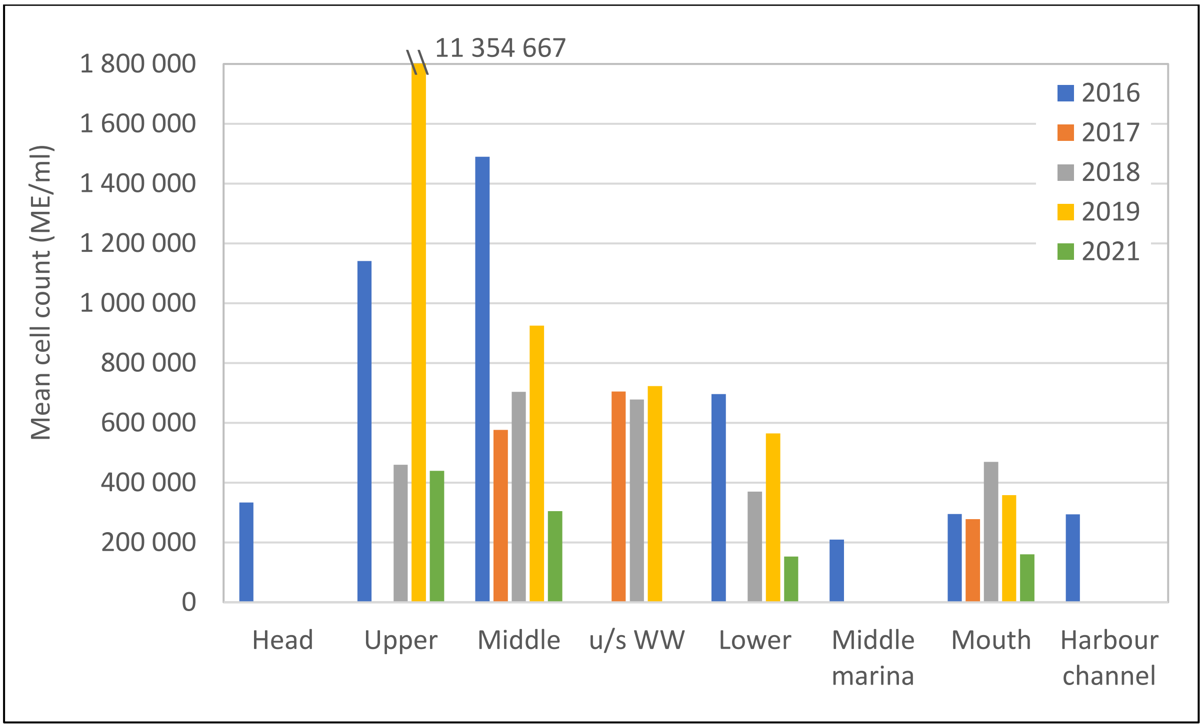

Figure 3.18: Mean bacterial cell counts collected from eight sites in the Kowie Estuary between November 2016 and September 2021 through the DFFE Coastal Water Quality Monitoring Programme.

To compliment this data, water quality sampling on the Kowie River (i.e. inflowing water from the catchment) conducted by the Ndlambe Municipality indicated that, between January 2018 and June

2021, *E. coli* and faecal coliforms concentrations were less 130[1] cfu/100ml in 67% and 57% of the samples respectively, 130-500 cfu/100ml in 20% and 30% of the samples, and the remaining samples contained >1000 cfu/100ml (DWAF, 1996b). Bacterial levels within the estuary can be exacerbated by effluent discharged by the Port Alfred WWTW when the system is malfunctioning or not operating according to specification, with *E. coli* and faecal coliform levels frequently well over 1 000 cfu/100ml (Figure 3.19), particularly during peak holiday periods e.g. January 2021 where E. coli levels exceeded 200 000 cfu/100ml. Blockages and spillages from damaged infrastructure, and areas without formal sanitation systems, also contribute to faecal contamination. Bacterial loading in terms of *E.coli*, within the estuary needs to be assessed and best undertaken as part of the coastal monitoring.

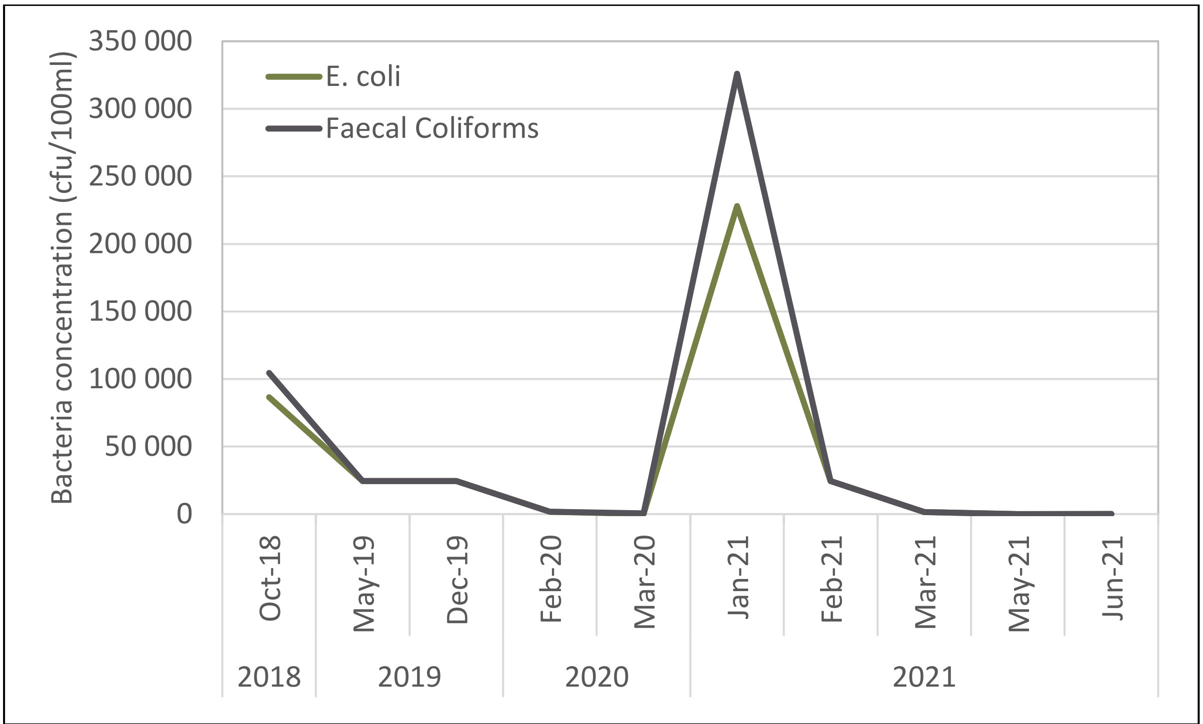

Figure 3.19: Concentrations of *E.coli* and faecal coliforms in the final effluent discharged from the Port Alfred Waste Water Treatment Works between 2018 and 2021.

The DFFE monitoring programme also includes an assessment of the toxicity of estuary waters to aquatic organisms. Since the commencement of the programme, only 11 samples exhibited toxicity; eight were extremely toxic, one very toxic and two moderately toxic. Three of these were isolated samples, however, the remaining samples seemed related to a specific event that occurred in May 2018 that affected all four sampling regions in the estuary, with most samples returning as extremely toxic. The reason or source of this toxic event is unknown.

Studies on metals have also been undertaken in the Kowie Estuary. Orr (2007) investigated the presence of cadmium and lead in the estuary water. The average concentrations of these metals were 0.18 µg/ℓ and 1.65 µg/ℓ, respectively (Orr, 2007), and both fell well below the limits given in the South African Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). It was therefore established that that the Kowie Estuary at the time was uncontaminated by these metals (Figure 3.20). They exhibited similar concentration gradients and were significantly correlated suggesting they were potentially from the same source (Orr, 2007). Higher concentrations were noted at the mouth (P1) and just downstream of the Nico Malan Bridge (P3) in particular, and additionally at Bay of Biscay (P4)

[1] The Recreational water quality guideline limits for full contact recreation is <130 cfu/100ml for both E.coli and Faecal coliforms (DWAF, 1996b)

for lead (Orr, 2007). The suggested sources of these metals included contaminated run-off from the national road, parking lots, dump sites and boating activities (Orr, 2007).

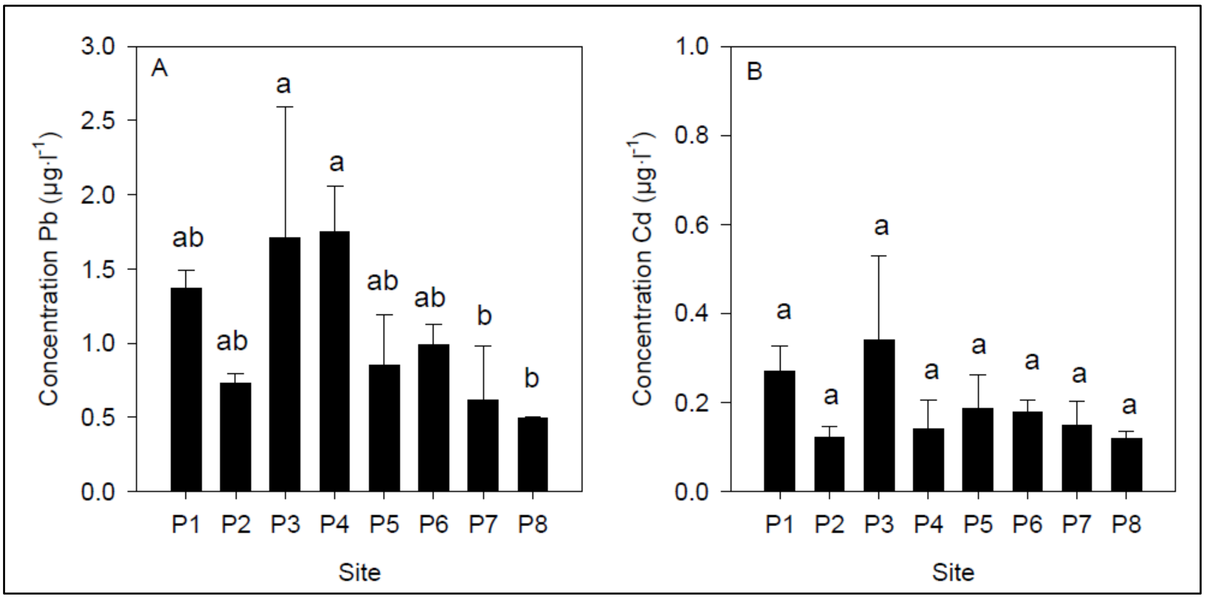

Figure 3.20: Spatial variations in the mean (± SD) concentrations of Pb and Cd in the water of the Kowie Estuary. Different superscript letters denote significant differences within columns ($p < 0.05$) (Orr, 2007).

Table 3.6: Summary of metal analyses for the Kowie Estuary from water samples collected in August 2018 and May 2019 (upper [U], middle [M], upstream of the waste water treatment works [u/s WW], lower [L], mouth [Mo]). Note: The upper reaches were not sampled in May 2019, but rather upstream of the Port Alfred WWTW discharge point.

Date	August 2018					May 2019				
Region	U	M	u/s WW	L	Mo	U	M	u/s WW	L	Mo
Ag							0.01	0.02	0.01	0.03
Al	0.64	17.48		12.14	3.64		1.05	1.23	0.79	0.46
As	0.00	0.30		0.52	0.30		0.11	0.16	0.19	0.21
Ba	5.67	12.04		3.40	0.82		6.31	4.73	2.55	1.42
Be	0.00	0.00		0.06	0.00					
Bi							0.26	0.30	0.34	0.38
Cd	0.01	0.00		0.01	0.00		0.01	0.01	0.00	0.02
Co							0.00	0.01	0.01	0.02
Cr	0.04	0.00		0.00	0.00		0.05	0.06	0.04	0.07
Cs							0.05	0.08	0.07	0.07
Cu	0.00	0.06		0.00	0.00		0.07	0.10	0.07	0.08
Fe							0.33	0.40	0.58	0.31
Ga							0.00	0.02	0.02	0.04
Hg										
In							0.14	0.19	0.22	0.25
Mg	39736	191808		243050	22095					
Mn	2.20	7.41		12.17	198.13		0.02	0.05	0.14	0.09
Ni	0.00	0.02		0.00	0.00		0.05	0.06	0.04	0.06
Pb	0.00	0.22		0.05	0.00		0.05	0.07	0.04	0.06
Pd							36.14	18.07	36.14	63.25
Rb							5.54	7.30	10.16	12.66
Se										
Sr							426.56	561.43	712.27	848.59
Th							0.03	0.05	0.04	0.03
Tl							0.01	0.01	0.01	0.04
U							0.52	0.56	0.64	0.61
V							0.09	0.15	0.18	0.19
Zn	0.00	0.00		0.86	0.00		0.11	0.16	0.12	0.17

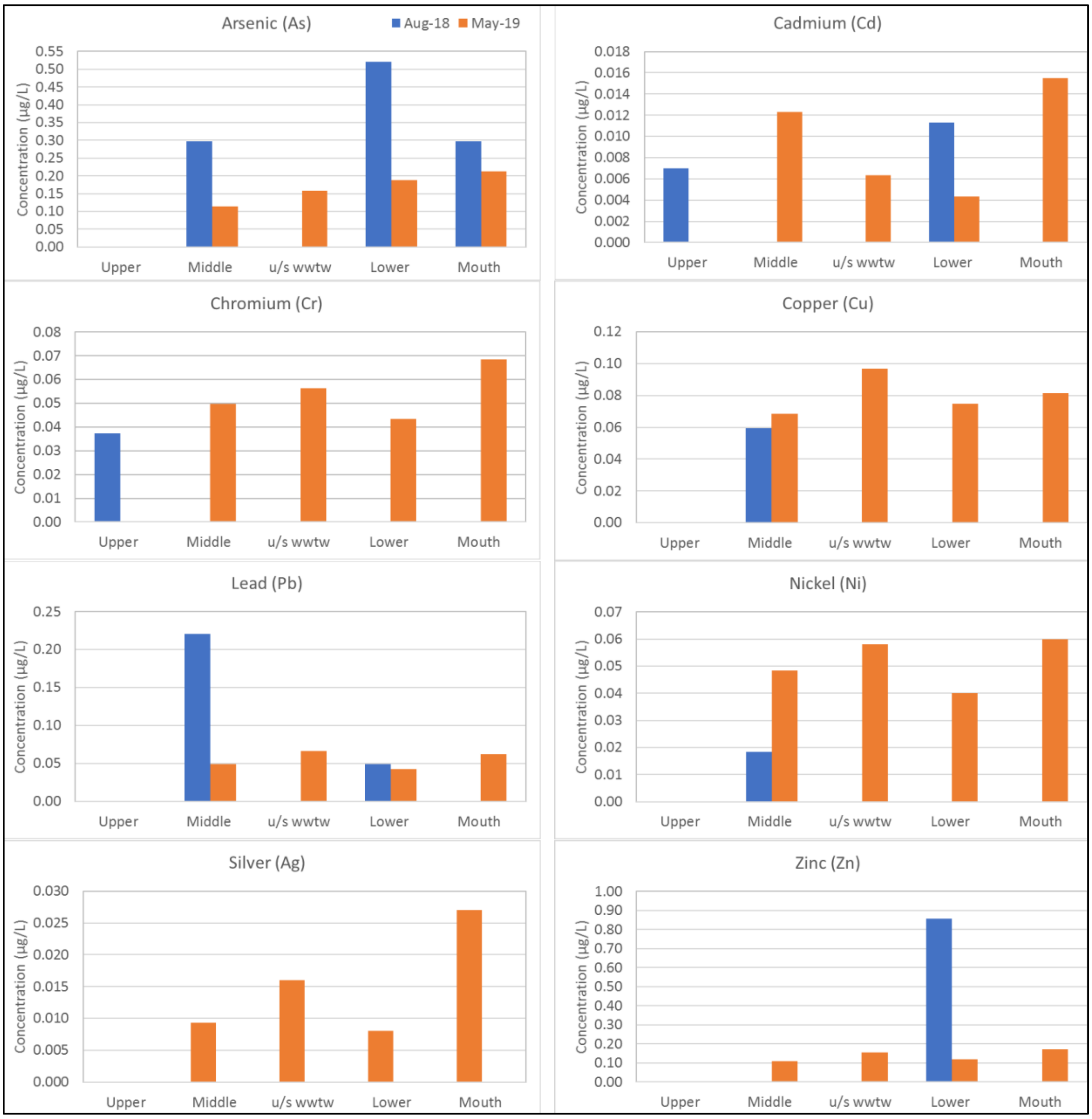

Figure 3.21: Mean concentrations of known toxic metals detected in the Kowie Estuary in August 2018 and May 2019. Note: The upper reaches were not sampled in May 2019, but rather upstream of the Port Alfred WWTW discharge point.

Metal analyses were also conducted in the August 2018 and May 2019 sample periods under the DFFE coastal water quality monitoring programme (Table 3.6). Of those metals considered to be toxic to marine life (DEA, 2018), the concentrations of arsenic, cadmium, chromium, copper, lead, nickel, silver, and zinc, were well below the prescribed limits as per the 2018 South African Water Quality Guidelines for Coastal Marine Waters (Natural Environment) (DEA, 2018) and for cadmium and lead, the average concentrations were below those reported by Orr (2007) (Figure 3.21). Most of these metals were detected throughout the Kowie Estuary in 2019, but the concentrations of arsenic, cadmium, lead and zinc were generally lower in comparison to August 2018 concentrations. Spatially, higher metal concentrations were often measured at the mouth and upstream of the Port Alfred WWTW discharge point. This may suggest that the WWTW is a potential source of these heavy metals in the middle region of the system, while contaminated urban run-off and the impacts of boating activities are the likely sources at the lower end of the estuary, as suggested by Orr (2007). Overall, although these metals have been detected in the Kowie Estuary they are below levels considered detrimental to the marine and estuarine environments.

It is evident from the water quality data and anecdotal reports, that the Kowie Estuary periodically experiences poor water quality conditions characterised by high nutrient levels and *E. coli* concentrations, and isolated toxic conditions.

3.3 Biotic Function

3.3.1 Algae

Very little historical information is available on the algae of the Kowie Estuary. Heinecken and Grindley (1982) reported that approximately 286 species and varieties of benthic diatoms occurred throughout the estuary and the interconnected lagoons, and 11 of these were new discoveries at the time. Numerous algae were recorded in all the marginal lagoons associated with the estuary (Heinecken and Grindley, 1982). The dominant species were *Ulva* cf *capensis*, *Ulva* (*Enteromorpha) prolifera* and *Gelidium pristoides*, with *Chondria* sp., *Centrocerus clavulatum* and *Griffithsia* sp. being less common. Other species recorded included *Gracilaria verrucosa*, *Lyngbya* sp. (Cyanophyceae) and red algae. Blue-green algae (*Plectonema* sp. and *Lyngbya majuscula*), which are indicators of nutrient enrichment, were noted in the lower eastern lagoon (Heinecken and Grindley, 1982).

Dalu *et al*. (2016a) sampled benthic diatoms from three sites on the Kowie Estuary, representing the lower, middle and upper reaches. A total of 89 diatom species from 42 genera were recorded (Dalu *et al*., 2016a). The numerically dominant species included *Entomoneis paludosa* (W Smith) Reimer, *Nitzschia reversa* W Smith, *Nitzschia closterium* (Ehrenberg) W Smith, *Pleurosigma elongatum* W Smith, *P. salinarum* (Grunow) Grunow, *Staurosira elliptica* (Schumann) DM Williams and Round, *Surirella brebissonii* Krammer and Lange-Bertalot, and *Surirella ovalis* Brébisson. While, there were no distinct indicator species representing the different sites, these were rather found representing the different seasons. Species richness and diversity indices were found to be consistently low in the upper reaches and high in the middle reaches of the estuary (Dalu *et al*., 2016a). Nutrient (ammonia, nitrate) concentrations, hydrology (water depth and flow) and pH were the key factors affecting the benthic diatom community dynamics (Dalu *et al*., 2016a). In a separate study to assess the impact of different pollution sources in the catchment (urban and agricultural sources), diatom communities of the Kowie Estuary were found to fall into two distinct groups, namely moderately (upper and middle reaches) and highly impacted (lower reaches) (Dalu *et al*., 2016b). The latter was indicative of sewage effluent discharge and positively associated with ammonium, nitrates and conductivity; while the moderately impacted assemblage was associated with high temperature and ammonium (Dalu *et al*., 2016b) (Table 3.7).

Table 3.7: Diatom assemblages defining moderately and highly impacted sites in the Kowie Estuary (Dalu *et al*., 2016b).

Moderately impacted	Highly impacted
Cyclotella meneghiniana Kützing	*Tryblionella apiculata* Gregory
Melosira varians Argadh	*Pleurosigma elongatum* W Smith
Navicula gregaria Donkin	*Diploneis vacillans* (Ant Schmidt) Cleve
Nitzschia sigma (Kützing) W Smith	*Diatoma vulgaris* Bory
Tryblionella littoralis (Grunow) DG Mann	*Staurosira elliptica* (Schumann)

In respect of phytoplankton, Grange *et al*., (1992) recorded chlorophyll-*a*[2] (chl-*a*) concentrations ranging from 0.078 µg/ℓ to 1.639 µg/ℓ over one year of sampling. Chlorophyll-a concentrations were evenly distributed along the length of the estuary during winter months. During the summer months, concentrations were generally higher owing to higher water temperatures and increased light. Algal

[2] Chlorophyll-a, a pigment extracted from phytoplankton, is a widely used proxy of phytoplankton concentrations or biomass present (Dalu *et al*., 2014).

blooms occurred in the lower reaches of the system during spring and summer (Grange *et al*., 1992). Overall, the phytoplankton biomass was considered to be extremely low and well below nuisance levels for algal blooms (Grange *et al*., 1992). Nitrate concentrations were found to be the limiting factor for algal growth (Grange *et al*., 1992).

In the SCA (2011) study, the recorded average chlorophyll-*a* (chl-*a*) concentrations were similar to Grange *et al* (1992), ranging from 0.83 µg/ℓ at the upper entrance to the marina to 1.9 µg/ℓ 500 m upstream of the Port Alfred WWTW. This horizontal gradient was attributed to the quick response of phytoplankton communities to increased nutrient introduced through elevated river flows after a high rainfall event. Maximum chlorophyll-a readings ranging from 9.13 µg/ℓ to 9.30 µg/ℓ were recorded at the two sample sites below the WWTW discharge point (SCA, 2011). This was most likely due to nutrient and freshwater inputs from the works. Overall, the phytoplankton concentrations recorded, were considered typical of marine dominated systems (SCA, 2011). In November 2017, the DFFE monitoring programme recorded average chlorophyll-a concentrations of 2.02 µg/ℓ in the lower reaches, and 43.8 µg/ℓ and 75.6 µg/ℓ in the middle reaches and upstream of the discharge point, respectively (Table 3.5). Conversely, in September 2021 a maximum average concentration of 8.02 µg/ℓ was recorded in the middle reaches. The fluctuations in phytoplankton and chlorophyll-a concentrations are affected by various environmental factors (e.g. water temperature, light, marine upwellings etc.) and anthropogenic factors (e.g. pollution inputs, nutrient loading etc.).

Dalu *et al*., (2014) investigated the phytoplankton community along the river-estuary continuum between 2012 and 2013. A total of 98 species (55 genera, 3 sites) were recorded in the estuary and 141 species (67 genera, 5 sites) in the river. The study found that the highest species richness was observed in spring, ranging from 29 to 31 and 27 to 33 for the estuary and river, respectively (Dalu *et al*., 2014). Species richness was lowest in autumn (range = 23 to 26) and winter (range = 17 to 25) for the estuarine and riverine sites. Estuarine community was distinctly different from the riverine community and species richness varied significantly between seasons. Total chl-a concentration ranged from 1.1 mg/m^3 to 7.9 mg/m^3 (river mean 4.5 mg/m^3) and 1.8 mg/m^3 to 3.3 mg/m^3 (estuary mean 2.5 mg/m^3) (Dalu *et al*., 2014). Total phytoplankton biomass was dominated by nanophytoplankton, and this group accounted for 60 % of the total biomass in the estuary. The concentration of nanophytoplankton for the estuary was 1.0 mg/m^3 to 2.3 mg/m^3, and picophytoplankton 0.05 mg/m^3 to 0.7 mg/m^3 (Dalu *et al*., 2014) (Table 3.8).

Table 3.8: Dominant phytoplankton species relative percentage abundances collected in four different seasons in the Kowie Estuary Dalu *et al*, 2014).

Species	Spring	Summer	Autumn	Winter
Diploneis vacillans	0.0	3.3	0.0	0.0
Entomoneis sp.	0.0	4.1	3.3	0.0
Gyrosigma attenuatum	3.9	0.0	0.0	0.0
Kirchneriella sp. 2	0.0	0.0	0.0	4.5
Melosira dubia	6.1	0.0	0.0	0.0
Nitzschia sp. 1	0.0	0.0	3.2	0.0
Nitzschia reversa	4.7	0.0	0.0	0.0
Pleurosigma elongatum	16.0	39.8	2.6	0.0
Pleurosigma salinarum	5.4	10.7	64.3	47.6
Phacus sp.	0.0	0.0	0.0	7.2
Tabularia fasciculata	0.0	0.0	0.0	3.1
Trachelomonas hispida	0.0	0.0	0.0	5.4
Staurosira elliptica	3.1	5.4	0.0	0.0
Surerilla brebissonii	12.5	0.0	0.0	0.0
Surerilla ulva	8.0	0.0	0.0	0.0
Surirella ovalis	0.0	4.7	0.0	0.0

Microphytoplankton accounted for less than 32 % of the total biomass for the estuary. Total mean chl-a concentration in the estuary was lower (2.5 mg/m^3) than the river portion (4.5 mg/m^3) (Dalu *et al*., 2014). This was similar to concentrations reported in the estuary by Grange *et al*., (1992), SCA (2011) and Kruger and Strydom (2011). For the estuary, the highest chl-a concentrations were recorded during summer (5.27 mg/m^3) in the middle reaches, and the lowest in winter in the lower reaches (Dalu *et al*., 2014). The former was attributed to stability of the water column and increased nutrient availability, while the overall low concentration at the mouth, was ascribed to low freshwater input, high salinity and limited nutrient loading (Dalu *et al*., 2014). The communities of the estuary sites were mostly structured by salinity, ammonia concentrations and depth (Dalu *et al*., 2014). This was reflected in the community composition in the prevalence of saline tolerant species, e.g. *Pleurosigma salinarum* and *P. elongatum*. In terms of species composition, diatoms were the most dominant group, as also found by Kruger and Strydom (2011). The decrease in phytoplankton abundance and diversity (and therefore lower chl-a concentration) relative to the riverine environment is mainly due to the increase in total dissolved solids in the estuary, salinity and other factors, such as sedimentation, grazing and washout (Dalu *et al*., 2014).

In a study of the macroalgae occurring in estuaries of the Eastern Cape coastline, Prinsloo (2012) documented 10 species in the Kowie Estuary. The low number of species was attributed to few species being able to tolerate the high salinities present in the system. The algae group of Rhodophytes were significantly more abundant in the lower reaches of the Kowie (less than 12 km from the mouth) than in other estuaries, and constituted approximately 70 % of the area coverage in the lower reaches (Prinsloo, 2012). The species, *Polysiphonia kowiensis* (a filamentous red algae) was most abundant in the middle reaches of the system. *Rhizoclonium riparium* and *Rhizoclonium lubricum* were collected from rock substrata in the middle and upper reaches, while *Centroceras clavulatum* was found growing among saltmarsh vegetation in the lower and middle reaches (Prinsloo, 2012). Marine seaweeds, such as *Bryopsis africana, Gelidium pristoides, Gelidium reptans, Hypnea rosea, Porphyra capensis* and *Endarachne binghamiae*, were found on buoys and jetties (Prinsloo, 2012). The algal communities of the Kowie Estuary were found to be strongly driven by high salinities (32 to 37 psu), very turbid water (0.5 m – 0.9 m transparency) and depth (generally 2.5 m and 3.5 m) (Prinsloo, 2012).

3.3.2 Aquatic and semi-aquatic macrophytes habitats

Macrophytes within estuaries fulfil various important roles including providing habitat to a diversity of wildlife and serving as a protective buffer against erosion and the effects of flooding from both inland and seaward environments (Adams *et al*., 1999 and Western Cape Government, 2019). Submerged macrophytes, such as *Zostera capensis*, *Ruppia maritima* and *R. spiralis,* which colonise mudflats and sandflats, stabilise and build-up these habitats by trapping sediment. They produce oxygen for the aquatic and serve as a source of food and habitat for many fish and bird species (Adams *et al*., 1999). Reeds and sedges provide a similar function of stabilisation and sediment entrapment but also help to filter or polish the water of excessive nutrients and some contaminants. Salt marsh habitats are commonly found in permanently/predominantly open estuaries, such as the Kowie Estuary. Intertidal salt marsh occurs below mean high water spring level and supratidal salt marsh above this. Salt marshes typically display distinctive zonation, which is a product of the tolerance of the different species to varying environmental conditions, such as salinity, inundation (intertidal vs supratidal), sediment characteristics, and depth to groundwater (Adams *et al*., 1999). Few species are adapted for this stressful environment, and thus species diversity of salt marshes is typically low (Adams *et al*., 1999).

For the Kowie Estuary, a significant area of intertidal salt marsh vegetation was lost with the development of the town of Port Alfred, the Port Alfred marina and small craft harbour, and houses with jetties, amounting to approximately 48 ha (480 000 m^2), or 58% of the original extent (Adams, 2020). For the remainder of the system, the present vegetation of the Kowie Estuary generally reflects that detailed by Heinecken and Grindley (1982).

As previously described, the estuary mouth has been permanently stabilised in support of a port environment. Early assessments suggest that historical canalisation of the estuary channel and increased tidal exchange adversely affected *Zostera capensis* and salt marsh beds of the former system (Heinecken and Grindley, 1982). *Ruppia maritima* and *Ruppia spiralis* were noted in the adjacent marginal areas ('lagoons'), with *R. spiralis* as well as *Zostera* in the lower-middle to upper reaches of the system (Heinecken and Grindley, 1982). *Zostera* beds occurred in the region of Biscay Bay and are still present today and also along Centenary Park (Figure 3.22).

Figure 3.22: View into the Kowie Estuary showing artificial stabilisation of the estuary mouth (left) and *Zostera capensis* beds presence in the lower reaches of the estuary (right).

Figure 3.23: Remnant saltmarsh and reed swamp habitat on the eastern bank (top left), the western bank at the Duck Pond (top right), the main salt marsh and mud flat habitat at the Bay of Biscay (bottom left) and the semi-enclosed Little Beach (bottom right).

Juncus acutis/Scirpus maritima reed swamp occurred in isolated areas associated with the marginal lagoons on both the eastern and western shorelines (Heinecken and Grindley, 1982). On the eastern shoreline, the main area of reed swamp was removed during the marina development, and only a small area remains within what was once known as the Upper East Bank Lagoon along Pascoe Crescent. On the western shoreline, reed swamp still persists together with intertidal salt marsh species within the municipal conservation area (the 'Duck Pond') upstream of 'Little Beach' (Figure 3.23).

The remaining main salt marsh area occurs within the broad floodplain adjacent to the Bay of Biscay, comprising predominantly intertidal salt marsh, with interspersed areas of reeds and sedges, fronted by a broad mud bank. The main species described by Heinecken and Grindley (1982), were *Spartina capensis*, *Chenolea diffusa*, *Sarcocornia perenne* and others. This area was disturbed by terrestrial vegetation encroachment and cattle grazing, which persists today (Figure 3.24). In the smaller marginal areas, the conspicuous species of the salt marsh areas included *Sporobolus virginicus*, with *S. capensis*, *Disphyma crassfolia*, and *Salicornia meyeriana* and others (Heinecken and Grindley, 1982). Salt marsh habitat also extends into the upper reaches of the estuary, occurring intermittently in a narrow margin, primarily associated with sand and mud bank habitat. A fairly large area of supratidal salt marsh once occurred in the bend upstream of Centenary Park, but this is observed to have been severely degraded/transformed by agriculture.

Figure 3.24: One of numerous stretches of salt marsh habitat found in the middle and upper reaches of the Kowie Estuary.

The most recent assessment of estuarine macrophyte habitats and their extent in the Kowie Estuary is depicted in Figure 3.25 (NMU, 2021), together with the area coverage in Table 3.9. A list of the predominant species is provided in Table 3.10 (Adams *et al*., 2019). The area mapped as 'developed' (128 ha or 1.28 km^2) represents areas of estuarine habitat lost to the system. This is the town of Port Alfred and the developed areas include residential, commercial (e.g. retails centres, businesses, offices) and industrial establishment (petrol stations, vehicle and boat repair businesses), recreational facilities and open spaces (e.g. parks, sports grounds), roads, parking areas and urban infrastructure (e.g. bulk services, pump stations). It also includes areas lost to agriculture.

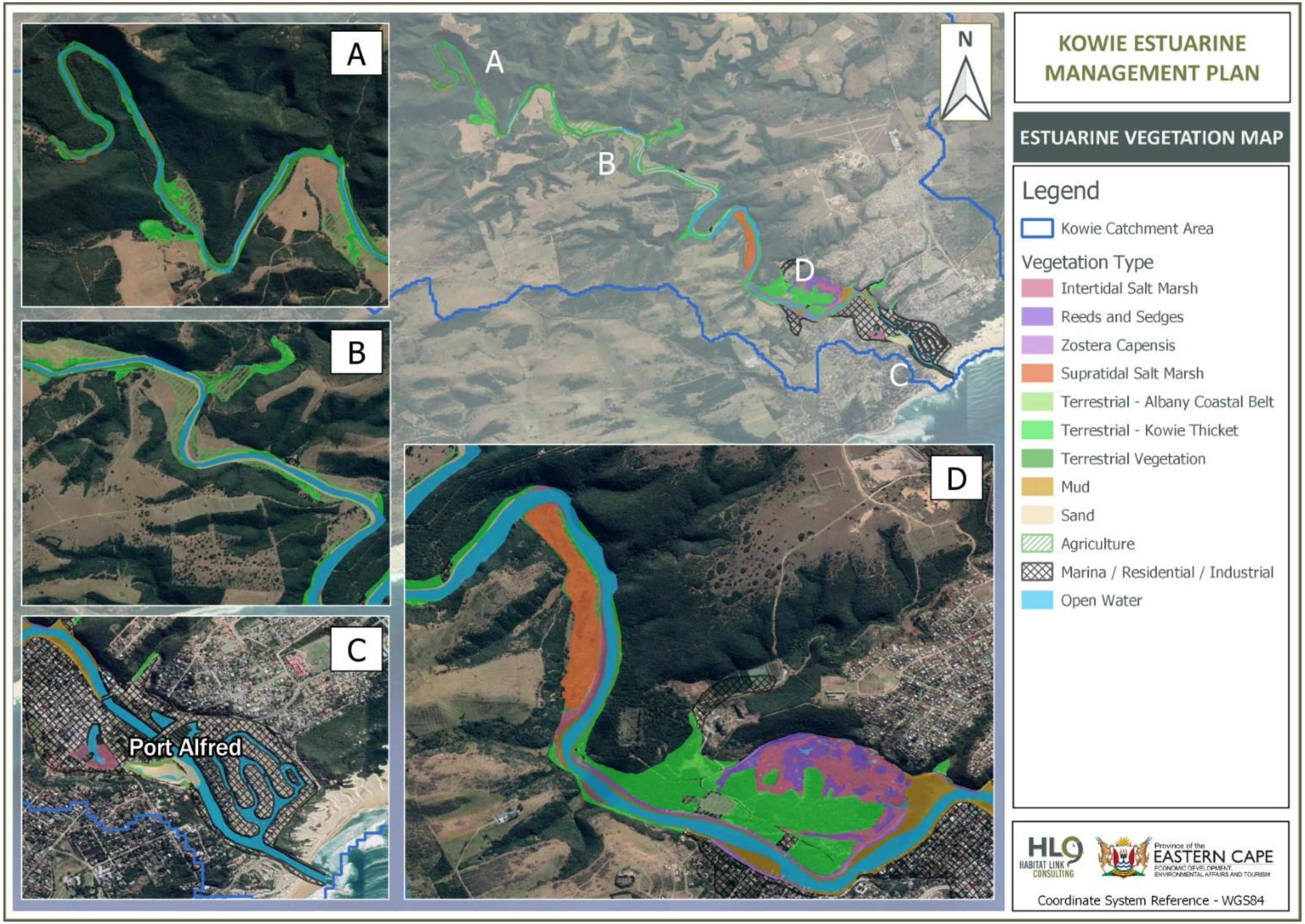

Figure 3.25: Distribution of macrophyte habitats of the Kowie Estuary (NMU, 2021).

Table 3.9: Area covered by macrophyte habitats in the Kowie Estuary (Adams *et al*., 2019).

MACROPHYTE HABITAT	AREA (ha)
Intertidal salt marsh	35.2
Supratidal salt marsh	26.5
Submerged macrophytes	8.2
Reeds and sedges	6.4
Sand and mud banks	29.7
Open water	129.5
Total habitat	235.4
Developed	128

Table 3.10: Predominant species characterising the aquatic and semi-aquatic macrophyte habitats of the Kowie Estuary (Adams *et al*., 2019).

Lower intertidal salt marsh	*Salicornia meyeriana* *Sarcocornia tegetaria* *Sarcocornia capensis* *Spartina maritima* *Triglochin bulbosa* *Triglochin elongata* *Triglochin striata*	Supratidal salt marsh	*Sarcocornia pillansii* *Disphyma crassifolium* *Bassia diffusa* *Juncus kraussii* *Sporobolus virginicus* *Stenotaphrum secundatum*
Upper intertidal salt marsh	*Limonium scabrum* *Cotula coronopifolia*	Submerged macrophytes	*Ruppia maritima* *Zostera capensis* *Potamogeton pectinatus*
		Reeds and sedges	*Phragmites australis*

3.3.3 Terrestrial macrophytes

In respect of terrestrial vegetation present within the EFZ, the early account by Heinecken and Grindley (1982) included five main vegetation types, namely, Hummock Dune Vegetation, Warm Temperate Coastal Forest, Sub-succulent Woodland, Coastal Sub-formation, *Vachellia karoo* Bushclump and Vegetation Complex between Coastal Woodland and Forest Scrub. Table 3.11 below provides a summary description of these vegetation types.

Table 3.11: Summary of the vegetation types of the Kowie Estuary (after Heinecken and Grindley, 1982).

Hummock Dune Vegetation	Primary species: *Agropyron distichum* (sea wheat), *Arctotheca populifolia* (sea pumpkin) and *Tetragonia decumbens* (klappiesbrak). *Cynodon dactylon* (Bermuda grass) and exotic grass, *Pennisetum clanestinum* found in disturbed and inhabited areas.
Warm Temperate Coastal Forest	Primary species: *Sideroxylon inerme* (milkwood), *Mimusops caffra* (red milkwood) and *Brachylaena discolor* (wild silver oak), and *Passerina* sp., *Chrysanthemoides monolifera* and *Rhus crenata*, noted closer to the beach. Invasive species noted close to the river: *Eucalyptus globulus* (blue gum) and *Acacia cyclops* (rooikrans).
Sub-succulent Woodland and Coastal Sub-formation	Primary species; *Schotia latifolia* (bush boerboon), *Ptaeroxylon obliquum* (sneeze wood) and *Cussonia spicata* (cabbage tree)
Vachellia karoo Bushclump	Dominated by *Vachellia karoo* but also included *Rhus Tomentosa* (wild current) and *Maytenus procumbens* (dune kokoboom), Grass species: *Panicum maximum* (Guinea grass) and *Melica racemosa* (haakgras)
Vegetation Complex between Coastal Woodland and Forest Scrub	Open scrub comprising *Rhus crenata* (dune crow berry), *R. glauca* (blue kunibush), *Lycium tetrandrum* (bokdoring) and *Azima tetracantha* (bee-sting bush)

According to the 2018 South African National Vegetation Map (SANBI, 2006-2018), the terrestrial vegetation types in and around the Kowie Estuary include: Albany Mesic Thicket (Kowie Thicket), Kasouga Dune Thicket, and Cape Seashore Vegetation.

3.3.4 Invertebrates

Zooplankton

Information on the zooplankton of the Kowie Estuary is limited. Heinecken and Grindley (1982) reported a total of 39 species of zooplankton organisms collected from the Kowie Estuary in 1967, with a mean zooplankton biomass of 20.6 mg/m^3 ranging from 5.6 mg/m^3 – 42.3 mg/m^3. A list of the recorded zooplankton species is provided in Table 3.12 below. The most abundant copepod species were *Acartia natalensis* and *Pseudodiaptomus hessei,* while *Rhopalopthalamus terranatalis* was the most abundant mysid species. Numerous other crustaceans and taxa from a variety of groups were recorded.

The study by Kruger and Strydom (2011), provides a broad account of the zooplankton in the lower reaches of the Kowie Estuary associated with frontal systems. A total zooplankton density of 127 741 per m^3 was recorded in 2008, comprising nine different taxa. Copepoda was the overriding dominant component of the zooplankton catch (97 %) (Table 3.13). While zooplankton density was higher outside of the convergence zone (yet not significantly), only Megalopa was found to be significantly higher in the convergence zone. Amphipoda, Zoea, Megalopa, Isopoda and Mysidacea were more abundant in the convergence zone, while Copepoda and Decapoda were predominantly found outside of the convergence zone (Kruger and Strydom, 2011). The study also found that zooplankton species richness and diversity were higher outside of the convergence zone. While fontal systems are suggested to be areas of increased productivity and plankton accumulation, the current study did not yield statistical evidence in support of this (Kruger and Strydom, 2011).

Table 3.12: List of zooplankton species in the Kowie Estuary (after Heinecken and Grindley, 1982).

<table>
<tr><td>Copepods</td><td>Acartia natalensis
Pseudodiaptomus hessei
Acartia longipatella
Acartia Africana
Calanus helgolandicus
Harpacticoids
Harpacticus sp.
Labidocera sp.
Macrosetella gracilis
Oithona brevicornis
Oithona mediterranea
Paracalanus parvus
Pointella sp
Tegastes sp
Tortanus capensis
Nauplius larvae</td><td>Other crustacea</td><td>Ostracoda
Cirripede nauplii
Cypris larvae
Iphinoe truncata (cumacean)
Circolana sp (isopod)
Leptanthura laevigata (isopod)
Austrochiltonia capensis (amphipod)
Grandidierella bonneiri (amphipod)
Palaemon pacificus (shrimp)
Hymenosoma orbiculare (crab)
Decapod megalopa and zoea larvae</td></tr>
<tr><td>Mysids</td><td>Rhopalopthalamus terranatalis
Gastrosaccus brevifissura
Mesopodopsis slabberi</td><td>Other organisms</td><td>Hydroid medusa
Siphonophores
Polychaete larvae
Gastropod larvae
Lamellibranch larvae
Syngnathus acus (pipefish)</td></tr>
</table>

Table 3.13: Species composition and density of zooplankton in and out of the convergence zone in the Kowie Estuary (Kruger and Strydom, 2011).

		% Contr.	Total	In	Out
Zooplankton (no./100 m^3)			**12 7741**	**46 544**	**81 197**
Amphipoda		0.48	609	579	30
Brachyura	Megalopa	1.45	1 851	1 847	4
	Zoea	0.23	293	221	72
Copepoda		97.47	124 509	43 604	80 905
Decpoda (prawn)	*Upogebia*	0.17	221	56	165
Isopoda		0.17	214	207	7
Mysidacea		0.02	22	15	7
Chaetognath		0.02	22	15	7
Medusa		0	0	0	0

Benthic macroinvertebrates

Heinecken and Grindley (1982) provided a fair account of the distribution of conspicuous benthic invertebrate species across the various habitats found within the Kowie Estuary. Overall, Day (1981, cited in Heinecken and Grindley, 1982) considered benthic community to be poor at the time. Typical marine life forms, including *Parechinus angulosus* (sea urchin) and gastropod molluscs including *Oxystele tigrina*, *O. variegate* and *Littorina knysnaensis*, as well as *Cyclograpsus punctatus* at higher tidal levels, colonised the rocky retaining walls in the lower reaches (Heinecken and Grindley, 1982). Several species were found throughout the estuary right up to head of the system, including *Ficopomatus enigmatica*, a serpulid polychaete found on hard substrata, and the amphipod crustacean *Corophium* and an unnamed hydrobiid mollusc (Heinecken and Grindley, 1982). The bivalves *Solen corneus* (up to 150 per m^2) and *Musculus virgiliae* occur in the upper reaches at low tide levels, together with the crab *Sesarme eulimene* at higher levels. *Musculus virgiliae* has a broad salinity tolerance (0-34), and has been recorded throughout the system, with a preference for firm and coarse sediments. Both species of bivalve are important food items for the predacious mud crab, *Scylla serrata,* together with small gastropods and crabs (Heinecken and Grindley, 1982; SCA, 2011). Female *S. errata* migrate out of the estuary to spawn and recruitment into the Kowie Estuary, mostly as the megalopa stage, is dependent on ocean currents, flood or drought events, and potentially general freshwater input to the estuary (SCA, 2011).

The sandprawn, *Callianassa kraussi*, occurred in sandy areas of the estuary, with records of abundance ranging from 3.25/core with 256 holes/m^2 at Little Beach, to 4/core and 576/m^2 at East Flats (before the marina development) (Heinecken and Grindley, 1982). However, a decline in abundance was noticed at Little Beach, and the presence of *C. kraussi* was considered 'rare' in this area. The East Flat Lagoons were also important habitat for the shrimp, *Palaemon pacificus*, the amphipod *Grandidierella* sp., isopod *Sphaeroma* sp. and the mollusc *Assiminea ponsonbyi* (Heinecken and Grindley, 1982).

Species inhabiting the mudbanks in the middle reaches included the mudprawn *Upogebia africana*, the mollusc *Nassaruis kraussianus*, the crabs *Cleistostoma edwardsii* and *Cleistostoma algoense,* with the crab *Sesarma catenate* being common toward the high tide levels (Heinecken and Grindley, 1982). The bivalve mollusc, *Lamya capensis*, was also present in muddy areas of the system, often fully submerged in soft mud yet still attached to rocks. Overall, the species richness of the mudbanks was higher than hard substrata habitats (Heinecken and Grindley, 1982).

Upogebia africana was described as the most dominant species in the lower intertidal zone and densities in the middle mudbanks reached 600 per m^2 (Heinecken and Grindley, 1982). This species is a well-known ecosystem engineer, causing bioturbation which assists in nutrient cycling but also causes disturbance to some benthic invertebrates (Pillay, 2019). This species was once commercially exploited in the Kowie Estuary, with between 5 000 and 48 000 prawns removed every fortnight. This reportedly had little impact on the total population. Records of abundance from July 1980 showed 13 – 17 per 100 holes and 384 – 603 holes per m^2 in the closed bait area and 20/100 holes with 275 – 504 holes per m^2 in the open bait area (Heinecken and Grindley, 1982; SCA, 2011).

Sampling of macrobenthic invertebrates was undertaken by SCA (2011) in the lower and middle reaches of the system in March and April 2011. The results yielded 16 different taxa and indicated that the macrobenthic community is dominated by polychaete worms, and select crustacean forms, namely, copepods, isopods and brachyura, which were recorded at most sites (SCA, 2011). The highest biomass was recorded in the lower reaches, at the brine discharge point in the Bay of Biscay (1.439 g; 1.002 g) and 200 m downstream of the Nico Malan Bridge (1.124 g; 0.854 g) (SCA, 2011).

The taxa observed at these sites were predominantly marine associated species, characteristic of sandy substrates. The biomass recorded at the remaining upstream sites was substantially lower (0.001 – 0.1 g) (SCA, 2011). The highest number of taxa (12 taxa) was also recorded in the lower reaches, and decreased moving upstream of Centenary Park. While the highest number of individuals was also generally found at the lower most sites (64.3 – 77.6), a relatively high abundance (61.4) was recorded at a site 1 500 m upstream of the WWTW discharge point (SCA, 2011). No trends in the benthic community data could be linked to any water quality changes related to the brine discharge from the desalination plant (SCA, 2011) (Table 3.14).

Table 3.14: Distribution of macrobenthic taxa recorded during brine plume monitoring in March (Survey 1) and April 2011 (Survey 2) (SCA, 2011).

	Survey 1				
	Sites (ind/m2)				
	1	2	3	4	5
Cnidaria					
Anemone	0	0	0	0	0
Pennatulacea	0	0	0	0	0
Worms					
Polychaeta	0	0	0	4.8	32
Sipunculida	0	0	0	0	2.4
Nemertea	1	1	0	0	6
Platyhelminthes	0	0	0	1.5	0
Crustaceans					
Copepoda	0.2	0.6	1.2	31	42
Ostracoda	0.1	0	0.5	0	1.2
Cumacea	0.1	0	0.5	0	0
Tanaidacea	0	0	0	0	0
Isopoda	0	0	0	0.5	0.2
Amphipoda	0	0	0	1.2	0
Natantia	0	0	0	0	0.2
Anomura	0	0	0	0.4	0
Brachyura	0.2	0.5	1.2	0.5	1.5
Echinodermata					
Ophiuroidea	0	0	0	0	1.6
Mollusca					
Bivalva	0	0	1	2.5	3.2
Gastropoda	0	0	0.5	1.6	0.2
Other					
Pycnogonida	0	0	0	0	0.1
Cephalochordata	0	0	0	0	0
Biomass (g)	0.01	0.006	0..01	1.439	1.124
Number of indiv.	61.4	3	2.5	8	77.6
Number of taxa	5	3	5	8	12

	Survey 2				
	Sites (ind/m2)				
	1	2	3	4	5
Cnidaria					
Anemone	0	0	0	0	0
Pennatulacea	0	0	0	0	0
Worms					
Polychaeta	0	0	0	24	26
Sipunculida	0	0	0	0	2.4
Nemertea	1.5	1.6	0	0	6
Platyhelminthes	0	0	0	2.8	0
Crustaceans					
Copepoda	6.5	2.5	4.5	26	3.7
Ostracoda	1.5	0	0	0	1.7
Cumacea	1.5	0	0	0	0
Tanaidacea	0	0	0	0	0
Isopoda	0	0	0	0.5	0.4
Amphipoda	0	0	0	1.2	0
Natantia	0	0	0	0	0.3
Anomura	0	0	0	5.4	0
Brachyura	1.2	2.5	1.5	2.6	18
Echinodermata					
Ophiuroidea	0	0	0	0	1.6
Mollusca					
Bivalva	0	0	1.2	2.6	4
Gastropoda	0	0	2.7	1.2	0.1
Other					
Pycnogonida	0	0	0	0	0.1
Cephalochordata	0	0	0	0	0
Biomass (g)	0.002	0.001	0.1	1.002	0.854
Number of indiv.	12.2	6.6	9.9	66.3	64.3
Number of taxa	5	3	5	8	12

3.3.5 Fish

Historical fish data on Kowie Estuary is drawn from Heinecken and Grindley, (1982) and Whitfield *et al*., (1994). In Heinecken and Grindley, (1982), resident species in the Kowie Estuary, included gobies estuarine roundherring (*Gilchristella aestaurius*), and Cape silverside (*Atherina breviceps*) (Table 3.15). Several marine species were noted at the head of the estuary, namely white steenbras (*Lithognathus lithognathus)* spotted grunter *(Pomadasys commersonni),* southern mullet (*Chelon richardsoni),* goby (*Gobius maxilaris*), tank goby (*Glossogobius giurus)*, kingfish (*Caranx sexfasciatus*) Cape moony (*Monodactylus falciformis*) and flathead mullet, *Mugil cephalus* (Heinecken and Grindley, (1982).

Table 3.15: Historical checklist of fish recorded at the Kowie Estuary (Heinecken and Grindley, 1982; Whitfield *et al*., 1994).

FAMILY NAME	SPECIES NAME	COMMON NAME	EDC[3]	Heinecken and Grindley 1982	Whitfield *et al.* (1994)
Ambassidae	*Ambassis gymnocephalus*	Bald glassy	Ib		X
Ariidae	*Galeichthys feliceps*	White sea catfish	IIb		X
Atherinidae	*Atherina breviceps*	Cape silverside	Ib	X	X
Blenniidae	*Omobranchus woodi*	Kappie blenny	Ia		X
Carangidae	*Caranx sexfasciatus*	Big-eye Kingfish	IIb	X	X
	Lichia amia	Leervis	IIa		X
	Trachurus capensis	Cape Horse mackerel	III		X
	Unidentified				X
Chanidae	*Chanos chanos*	Milkfish	IIc		X
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	IV		X
Clinidae	*Unidentified*		?		X
Clupeidae	*Gilchristella aestuaria*	Estuarine round-herring	Ia	X	X
	Etrumeus whiteheadi	Redeye round-herring	III		X
Elopidae	*Elops machnata*	Ladyfish	IIa		X
Engraulidae	*Engraulis capensis*	South African anchovy	III		X
	Engraulis japonicus	Cape Anchovy	III		X
Fistulariidae	*Fistularia petimba*	Rough flutemouth	III		X
Gobiidae	*Caffrogobius spp.*		?		X
	Redigobius dewaali	Checked goby	IV	X	
	Glossogobius giuris	Tank goby	Ib	X	
	Glossogobius callidus	River goby	Ib		X
	Psammogobius knysnaensis	Knysna sandgoby	Ia		X
Gobiesocidae	*Unidentified*		?		X
Haemulidae	*Pomadasys commersonnii*	Spotted grunter	IIa	X	X
	Pomadasys olivaceum	Piggy	III		X
Hemiramphidae	*Hyporhamphus capensis*	Cape halfbeak	Ia		X
	Hemiramphus far	Spotted halfbeak	IIc		X
Monocanthidae	*Stephanolepis auratus*	Porky	III		X
Monodactylidae	*Monodactylus falciformis*	Cape moony	IIa	X	X
Mugilidae	*Chelon dumerilii*	Groovy mullet	IIb		X
	Chelon richardsonii	Harder	IIc	X	X
	Chelon tricuspidens	Striped mullet	IIb		X

[3] Environmental Data Centre.

	Mugil cephalus	Flathead mullet	IIa	X	X
	Pseudomyxus capensis	Freshwater mullet	IIa	X	X
	Moolgarda buchanani	Longfin mullet	IIc		X
	Unidentified		?		X
Ostraciidae	*Lactoria fornasini*	Thornback cowfish	III		X
Pomatomidae	*Pomatomus saltatrix*	Elf	IIc		X
Sciaenidae	*Argyrosomus japonicus*	Dusky Kob	IV	X	X
Scombridae	*Scomber japonicus*	Chub mackerel	III		X
Siganidae	*Siganus sutor*	Whitespotted rabbitfish	III		X
Soleidae	*Heteromycteris capensis*	Cape sole	IIb		X
	Solea bleekeri	Blackhand sole	IIb		X
Sparidae	*Diplodus capensis*	Blacktail	IIc		X
	Diplodus hottentotus	Zebra	III		X
	Lithognathus lithognathus	White steenbras	IIa	X	X
	Rhabdosargus globiceps	White stumpnose	IIc		X
	Rhabdosargus holubi	Cape stumpnose	IIc	X	X
	Rhabdosargus sarba	Natal stumpnose	IIb		X
	Spondyliosoma emarginatum	Steentjie	III		X
Syngnathidae	*Syngnathus acus*	Longsnout pipefish	Ib		X
Tetraodontidae	*Amblyrhynchotes honckenii*	Evileye blaasop	III		X

The shallow water habitats ('lagoons') in the lower reaches were noted for their importance as nursery areas for many juvenile fish, such as Cape stumpnose (*Rhabdosargus holubi*), white steenbras, mullet species and spotted grunter, which was present in late summer (Heinecken and Grindley, (1982). Dusky Kob (*Argyrosomus japonicus*) was also noted occurring in the system associated with mudprawn beds (Heinecken and Grindley, 1982). In respect to freshwater species, the freshwater mullet (*Pseudomyxus capensis*) occurred in the Kowie River upstream of the tidal limit throughout the year, while *M. cephalus* was only present during in the summer months. The migration of mullet into the upper catchment was hindered by weir construction on the Kowie River (Heinecken and Grindley, (1982). Subsequent construction of a fish ladder enabled the migration patterns of this species, and others catadromous species to resume (Whitfield, 2019).

During a study undertaken in 1981, Whitfield *et al.* (1994) recorded a total of 52 species (including 4 unidentified) across 31 families (Table 3.16), including 22 larval fish species and 40 species using seine and gill nets. Whitfield *et al*., (1994) attributed the relatively high fish species richness of the Kowie Estuary in comparison similar neighbouring estuarine systems, to the wide range of available habitats, and therefore the variety of food sources and available shelter (Whitfield *et al*., 1994). In terms of larval fish assemblages, Gobiidae was the dominant family of estuarine spawners[4] or residents, with *Caffrogobius spp.* as the most abundant taxa (more than 10 individuals per 100 m^3), followed by the Knysna sandgoby (*Psammogobius knysnaensis*) (Whitfield *et al.*,1994). The study found that larger size classes of the fish fauna were dominated by marine migrants[5], which is expected of permanently open estuaries (Strydom *et al*., 2003), specifically the families Mugilidae and Sparidae. *Rhabdosargus holubi*, *Chelon dumerilii* and *Chelon tricuspidens* were the most abundant marine migrants. The most abundant size classes of *R. holubi* and *C. dumerilii* is given as 100 mm to 149 mm, and *C. tricuspidens,* 40mm to 59 mm. Overall fish abundance was greatest in the upper reaches of the estuary (Whitfield *et al*., 1994).

[4] Euryhaline species of marine origin which breed in estuaries (Whitfield *et al*., 1994).

[5] Euryhaline species spawned at sea that use estuaries as feeding grounds and nursery areas estuaries (Whitfield *et al*., (1994).

There is a substantial and growing body of modern fish research for the Kowie Estuary covering various topics such as, overall ichtyhofauna community (James and Harrison, 2010); ichthyoplankton and juvenile fish communities (e.g. Kruger, 2010; Kruger and Strydom, 2010; Kruger and Strydom, 2011), fish movement and estuary connectivity (Murray *et al*., 2015; 2018), species-specific research (e.g. Carassou *et al*., 2016; Murray *et al*., 2018), predation by alien fish species (e.g. Weyl and Hylton, 2006; Magoro *et al*., 2015), food web structure and dynamics (Bergamino *et al*., 2014), studies cited in Whitfield (2019) and numerous others.

Detailed studies have been conducted on the ichythoplankton on the Kowie Estuary (Kruger, 2010; Kruger and Strydom, 2010). A total of 38 taxa of larval fishes, covering 23 families were recorded. Estuarine resident species made up 91 % of the total catch, and the dominant families were Gobbiidae and Clupeidae, which contributed 47 % and 25 % to the total catch, respectively (Kruger and Strydom, 2010). Species density and diversity of larval and juvenile fishes fluctuated on a seasonal basis (Strydom *et al*., 2003), corresponding to temperature variations (Kruger and Strydom, 2010). Certain species were found to dominate specific areas of the estuary; *Caffrogobius gilchristi* dominated the lower reaches, whilst the upper reaches were dominated by *G. aestuaria* (Kruger, 2010). A study of the headwater region showed that the transitional area between the freshwater and estuarine environment (the REI) was vitally important for juvenile estuarine residents and estuary-dependent marine species (Wasserman and Strydom, 2011). Conversely, older stage larvae and early juvenile fish were absent from the estuary mouth and the marina, and this was attributed to the absence of shallow water nursery habitat in these areas as a result of the steep walls of the artificial channels (Kruger and Strydom, 2010).

An ichthyofauna survey of the estuaries on the southeast coast of South Africa by James and Harrison in October/November 1991 provides the most comprehensive account of the fish community of the Kowie Estuary (James and Harrison, 2010), and is cited below. A total of 5 040 specimens were caught representing 32 species and 15 families (Table 3.16). The total number of species recorded in the Kowie Estuary was 46, taking into account previous studies (Whitfield *et al*., 1994). The high species richness of the Kowie Estuary relative to other permanently open estuaries has been attributed to the low turbidity of the lower estuary allowing for the presence of marine stragglers, and also a greater diversity of habitats; but the low abundance and biomass of fishes was attributed to the comparatively low MAR, and limited input of riverine-derived organic input, resulting in lower primary productivity (Whitfield *et al*., 1994; Strydom *et al*., 2003; James and Harrison, 2010).

The dominant families in the Kowie Estuary were Mugilidae and Sparidae (6 species each) followed by Gobiidae (4 species) (James and Harrison, 2010). The most abundant species caught was *G. aestuaria* that comprised 39.4 % of the catch, followed by *G. callidus*, *C. dumerili*, *R. holubi*, and *P. commersonnii*. A total species mass of over 81 kg was recorded, dominated by *A. japonicus*, *P. commersonnii*, and *C. tricuspidens*, *L. amia*, *C. dumerili*, *E. machnata*, *M. buchanani*, *R. holubi*. Approximately 57.3% of the total catch numerically and 3.4 % by mass, were estuarine-resident species; these included seven species, namely, *A. breviceps, C. gilchristi, C. nudiceps, C. superciliosus, G. aestuaria, G. callidus* and *P. knysnaensis* (James and Harrison, 2010). This highlights the importance of the Kowie Estuary as habitat for estuarine-resident species. Estuarine-dependent marine species accounted for 41.6 % of the catch numerically and 96.5 % by mass, and included 22 species, namely A*. berda, A. japonicus, D. capensis, E. machnata, G. feliceps, Hemiramphus far, H. capensis, L. amia, L. lithognathus, C. dumerili, C. richardsonii, C. tricuspidens, M. falciformis, P. cephalus, M. capensis, P. commersonnii, P. saltarix, R. globiceps, R. holubi, S. salpa, S. bleekeri and M. buchanani* (James and Harrison, 2010).

Most specimens of *R. holubi, L. dumerili, P. commersonnii* and *M. cephalus* comprised newly recruited individuals (James and Harrison, 2010), while Carassou *et al*., (2016) found that *R. holubi* utilises different habitats within the Kowie Estuary during different stages of its lifecycle. These findings highlight the importance of the Kowie Estuary in providing nursery habitat for estuarine dependent marine species, as well as the relative importance of habitat and food diversity within the estuary for maintaining different life stages for different species.

Two alien fish species have been recorded in the Kowie Estuary, namely Mozambique tilapia (*Oreochromis mossambicus)* (Whitfield *et al*., 1994) and Largemouth bass (*Micropterus salmoides)* (Murray *et al*., 2015). Weyl and Hylton (2006) documented predation by *M. salmoides* on three indigenous migratory estuarine species (*M. falciformis*, *M. cephalus* and *M. capensis*). Further research on this species shows that it migrates into the warm upper reaches of the estuary during the autumn and winter cooler months (Murray *et al*., 2015). The presence of alien species therefore raises concerns about predation pressure on juvenile native fish species that utilise the estuary as a nursery area, as well as the migratory success of indigenous species between the estuary and the freshwater river environment (Murray *et al*., 2015).

Table 3.16: Relative abundance (%n) and biomass (%g) of fishes captured in seine (S) and gillnets (G) in the Kowie Estuary in October/November 1991 (adapted from James and Harrison, 2010). Dominant species (> 5 % of catch) indicated in bold.

Species	Relative abundance				Species	Relative biomass		
	S	G	%n			S	G	%g
Acanthopagrus berda	1	0	0		*Acanthopagrus berda*	1.9	0	0
Amblyrhynchotes honckenii	1	0	0		*Amblyrhynchotes honckenii*	1.1	0	0
Argyrosomus japonicus	0	42	0.8		***Argyrosomus japonicus***	**0**	**19 490**	**24**
Atherina breviceps	148	0	2.9		*Atherina breviceps*	269.9	0	0.3
Caffrogobius gilchristi	2	0	0		*Caffrogobius gilchristi*	5.3	0	0
Caffrogobius nudiceps	4	0	0.1		*Caffrogobius nudiceps*	17	0	0
Chelon dumerilii	**591**	**3**	**12**		***Chelon dumerilii***	**5 623**	**545**	**7.6**
Chelon richardsonii	101	12	2.2		***Chelon richardsonii***	**1 099**	**4 790**	**7.3**
Chelon tricuspidens	10	20	0.6		***Chelon tricuspidens***	**45.9**	**8 957**	**11**
Clinus superciliosus	8	0	0.2		*Clinus superciliosus*	9.1	0	0
Diplodus capensis	23	0	0.5		*Diplodus capensis*	8.8	0	0
Elops machnata	0	4	0.1		***Elops machnata***	**0**	**5 952**	**7.4**
Galeichthys feliceps	0	7	0.1		*Galeichthys feliceps*	0	3203	4
Gilchristella aestuaria	**1 987**	**0**	**39**		*Gilchristella aestuaria*	1637	0	2
Glossogobius callidus	**714**	**0**	**14**		*Glossogobius callidus*	808.3	0	1
Hemiramphus far	5	0	0.1		*Hemiramphus far*	39	0	0
Heteromycteris capensis	11	0	0.2		*Heteromycteris capensis*	3.8	0	0
Lichia amia	0	5	0.1		***Lichia amia***	**0**	**6 270**	**7.8**
Lithognathus lithognathus	10	0	0.2		*Lithognathus lithognathus*	365.5	0	0.5
Monodactylus falciformis	17	18	0.7		*Monodactylus falciformis*	31.8	1236	1.6
Moolgarda buchanani	0	4	0.1		***Moolgarda buchanani***	**0**	**5 671**	**7**
Mugil cephalus	158	0	3.1		*Mugil cephalus*	117.4	0	0.1
Juvenile mugilids	150	0	3		*Juvenile mugilids*	145.9	0	0.2
Pomadasys commersonnii	**357**	**28**	**7.6**		***Pomadasys commersonnii***	**305.6**	**9 851**	**13**
Pomadasys olivaceus	52	0	1		*Pomadasys olivaceus*	35.8	0	0
Pomatomus saltatrix	2	0	0		*Pomatomus saltatrix*	3.5	0	0
Psammogobius knysnaensis	27	0	0.5		*Psammogobius knysnaensis*	29.8	0	0
Pseudomyxus capensis	45	0	0.9		*Pseudomyxus capensis*	17.1	0	0
Rhabdosargus globiceps	3	0	0.1		*Rhabdosargus globiceps*	0.4	0	0
Rhabdosargus holubi	**462**	**1**	**9.2**		***Rhabdosargus holubi***	**4 073**	**39**	**5.1**
Sarpa salpa	1	0	0		*Sarpa salpa*	1.1	0	0
Solea bleekeri	5	0	0.1		*Solea bleekeri*	7.2	0	0

Trachurus	1	0	0		*Trachurus*	0.7	0	0
Nets	15	10			Nets	15	10	
Total individuals	4 896	144			Total mass	14 704	66 004	

Use of Kowie Fishery Resources

The marine living resources of the Kowie Estuary are used extensively by recreational and subsistence fishers and bait collectors. Pradervand and Baird (2002) determined that the recreational linefishery is characterised by predominantly shore angling activities rather than boat-based angling, with more anglers (fishing effort) encountered on weekends (average 17.8 anglers). Fishing is mostly undertaken by white anglers, using bait organisms as opposed to lures or fly-fishing (Pradervand and Baird, 2002). A total of 17 fish species and a total catch of 148 individuals, were recorded, with the most commonly caught species being *R. holubi* (33 %), *P. commersonnii* (32 %), and *A. japonicus* (10)%); however *A. japonicus* dominated the catch in terms of mass (28 %), followed by *P. commersonnii* (26 %), *L. amia* (13 %) and *L. lithognathus* (11 %) (Pradervand and Baird, 2002). The catches rates peaked during summer and were lowest during winter. The catch per unit effort (CPUE) for the main species are given as follows: *R. holubi,* 0.04 fish/angler/hour; *P. commersonnii,* 0.04 fish/angler/hour; and *A. japonicus,* 0.02 fish/angler/hour. The average size of *P. commersonnii and L. lithognathus* were on average smaller than the minimum size limit, which is anticipated given the nursery function of estuaries. The study raised concerns regarding the catches of *A. japonicus*, which despite most specimens being above the size limit, were in actual fact juveniles, which poses a significant threat to the population of this popular fish (Pradervand and Baird, 2002).

Cowley *et al*., (2003) conducted a study on the Kowie Estuary fishery (linefishery and bait fishery) and assessed the sustainability of resource use. The study found that approximately 84 % of the total annual fishing effort on the Kowie Estuary is for recreational purposes, and the remaining 16 % constitutes subsistence use. Fishing activity followed a seasonal trend as found by Pradervand and Baird (2002). An estimated 16 240 fish (or 5.9 tons) are harvested from the system on an annual basis, with 69 % of this annual catch collected by recreational anglers. A total of 25 fish species from 15 families were recorded, with the most commonly caught species being *R. holubi* (62 %), *P. commersonnii* (17 %) and *A. japonicus* (7 %) (Cowley *et al*., 2003), which is similar in composition to the previous assessment (Pradervand and Baird, 2002), although catches of *P. holubi* were higher and *P. commersonnii* lower. The latter was the dominant species by weight (60% of the total catch). The dominant size classes for *P. commersonnii* (32 %) and *A. japonicus* (49 %) were 300 – 399 mm TL and < 200 mm TL (80 %) for *R. holubi* (Cowley *et al*., 2003). Shore-based angling is largely restricted to the lower reaches of the estuary, largely as a result of restricted access by private landownership, whilst boat-based recreational fishing is more evenly spread throughout the system. Overall catch rates are given as 0.57 fish/angler/hour or 0.298 kg/angler/hour. Whilst boat-based recreational anglers returned the highest catch by mass (0.427 kg/angler/hour), subsistence fishers returned the highest numbers of fish caught (1.13 fish/angler/hour). The overall CPUE for the dominant species, taking all three sectors into account, were: *R. holubi,* 0.313 fish/angler/hour; *P. commersonnii,* 0.089 fish/angler/hour; and *A. japonicus,* 0.034 fish/angler/hour. These values are higher than those reported by Pradervand and Baird (2002), particularly for *R. holubi*. It was also reported that only 19 % of *R. holubi* was above the minimum legal size, with 21 % estimated for *P. commersonnii* and 25% estimated for *A. japonicus* (Cowley *et al*., 2003).

The historical commercial exploitation of the mudprawn, *U. africana* was reported by Heinecken and Grindley (1982, and others cited therein). Large numbers of mudprawns were harvested fortnightly (see 'Benthic Invertebrates' above). The resource was protected through timing of harvesting, and open and closed bait collection areas. The traditional method of collection was by means of a tin can. This method causes the least amount of habitat disturbance and reportedly few egg-bearing females were harvested (Heinecken and Grindley, (1982). Illegal harvesting using spades, which causes significant habitat damage, was noted.

U. africana remains the principal bait species harvested, however mullet (Mugilidae), sandprawn (*Callianassa kraussi*), *R. holubi* and swimming prawn (*Penaeus indicus*) which are caught from the estuary, are also used as bait in the linefishery (Cowley *et al*., 2003). The current methods of prawn collection include the traditional tin can, prawn pumps, and spades and pitch forks (illegal) (*pers. observ*.). Approximately 75 % of the annual bait collection effort is undertaken by subsistence fishers, who also account for 64 % of the total annual harvested, which is estimated at 260 648 prawns. Bait collection effort was highest during December and April, with the most popular site for collection being the Bay of Biscay (Cowley *et al*., 2003). Almost 50 % of the harvesters sold their mudprawns, generating an estimated R 2 700.00 over the survey period. Overall, the characteristics of the Kowie Estuary bait fishery is a reflection of the socio-economic condition of the surrounding population, and is used as a means of generating income for poor communities (Cowley *et al*., 2003).

Based on the work by Cowley *et al*., (2003), Nsubuga (2004) went on to assess the sustainability of the three fishery sectors, Using 13 different indicators. The overall sustainability of all three was rated as low, with more than 70 % of the indicators performing poorly, particularly in respect to the subsistence sectors (Nsubuga, 2004). The following management changes were recommended for the Kowie Estuary fishery (Nsubuga, 2004):

- formulation of an effective and integrated management plan;
- identification of the key stakeholders in the fishery;
- inclusion of fishers in management;
- the protection of the *Zostera capensis* beds; and
- the establishment of a research and monitoring programme for the fishery.

3.3.6 Birds

Historical records of the birds at the Kowie Estuary given by Heinecken and Grindley (1982) report numerous bird species ranging from 29 to 93 species; a large portion of the latter were waders (up to 35 species). One record documented 601 waders from 17 species. The Kowie Estuary was once deemed to host "*the largest concentration of Greenshank occurring between Port Elizabeth and the Kei River*" (Heinecken and Grindley, 1982). The mudflats and salt marsh habitats were of greatest importance for wading bird species.

Turpie *et al*. (1995) reported 30 species of wading birds occurring in the Kowie Estuary with a total count of 696, and the system was ranked within the top 10 of 42 estuaries in terms of species diversity (i.e. having a good evenness of species populations). The Co-ordinated Waterbird Counts (CWAC, 2021) for the Kowie Estuary, initiated in 1998, provides a list of 52 water-associated species (shore birds and water fowl). The last documented survey was in 2008, with 34 species recorded and an estimated total count of 773.

According to Hean *et al*., (2017), the waterbird assemblage of the Kowie Estuary is dominated by 17 water-associated bird species (Table 3.17). In terms of feeding guilds, more than half of these were invertebrate feeders (52 %), four (24 %) were mixed feeders (crustaceans and fish), and two were piscivorous (12 %) and omnivorous (12 %). Non-migratory shorebirds dominated the assemblage for much of the year, except for during summer, when piscivorous birds (egrets, herons, cormorants) were dominant (up to 289 individuals) (Hean *et al*., 2017). The total count of birds was highest in December (513) and lowest in July and August (133). There was a notable seasonal trend, with the highest diversity and density of waterbirds occurring during spring and summer, and this was thought to be related to higher fish productivity during the same seasons. Overall, the Kowie Estuary was found to have greater diversity of waterbirds, but a relatively low density (2.6 ± 0.4 individuals ha^{-1} during peak abundance) in comparison to other South African estuaries. This was attributed to limited number of large mudflats in the Kowie system (Hean *et al*., 2017).

Table 3.17: Bird species recorded at the Kowie Estuary (Heinecken and Grindley, 1982 and Hean *et al.*, 2017).

Species	Kowie River (upper estuary)	Bay of Biscay (marsh)	Centenary Park/ Bells Reach (marsh)	Blue Lagoon (east bank vlei and marsh)	Total	Hean *et al.* 2017
Turnstone		3	4		7	
Ringed Plover		17	8	10	35	X
White-fronted Sandplover		6		8	14	
Three-banded Sandplover		2	7		9	
Grey Plover		2	8		10	
Blacksmith Plover	3				3	X
Curlew Sandpiper				15	15	X
Little Stint		6	11	3	20	
Knot		2	18	6	26	
Sanderling	27	24		15	66	
Ruff			10	170	180	X
Terek Sandpiper						
Common Sandpiper	33	12	2		47	X
Marsh Sandpiper	1			5	6	
Greenshank	35	51	14	11	111	X
Wood Sandpiper		5	23	15	43	
Whimbrel	7	2			9	
White-breasted Cormorant		1		1	2	
Reed Cormorant	7	4		2	13	X
Grey heron	3			1	4	X
Great white Egret		1			1	
Little Egret			2	5	7	X
Cattle Egret	18				18	X
Black Stork			1		1	
Sacred Ibis			1		1	
Greater Flamingo			1	1	2	
Egyptian Goose	2				2	X
Red-bill Teal				9	9	
Southern Black-backed Gull	9	19		1	29	
Pied Kingfisher	3	1			4	
Giant Kingfisher	2	1			3	
Cape Wagtail		5	7		12	
Black headed Heron						X
African Spoonbill						X
Cape Shoveller						X
Cape Teal						X
Yellow-billed Duck						X
Black-winged Stilt						X

3.4 Ecological Health Status

The health status of South Africa's estuaries has been assessed through the National Biodiversity Assessment (2011 second iteration, 2018 third iteration). During these assessments, the health condition of each estuary (also known as the PES) was determined at a desktop level (or confirmed if updated regional studies were available, e.g. Van Niekerk *et al*., 2015) using the Estuarine Health Index (EHI), in which the current conditions of various abiotic and biotic components (see Table 3.7) were rated as a percentage of the probable pristine condition. The resultant health score was then described using one of six categories (Table 3.18), ranging from natural (A) to critically modified (F) to describe the PES (Van Niekerk *et al*., 2019).

Van Niekerk *et al*., (2019) explain that in most cases, degradation means loss of processes or loss of biological functionality, e.g. the estuarine space is filled with a different salinity condition or different species composition. This loss of functionally happens on a continuum. Estuaries in Excellent condition or Natural state are those which retain more than 90% of their natural processes and pattern, whereas as Poor or Severely/Critically modified estuaries are those which have degraded to less than 40% of their natural functionality (Van Niekerk *et al*., 2019). The overall ecological health of the Kowie Estuary is a **C Category**, with the individual component ratings summarised below in Table 3.19.

Table 3.18: Estuary health scoring system indicating the relationship between the six Ecological Categories and the loss of ecosystem condition and functionality (Van Niekerk *et al*., 2019).

Condition (% of pristine)	≥91%	90-75	75 - 61	60 - 41	40-21	≤20
Continuum	A A/B B B/C C C/D D D/E E E/F F					
Ecological Management Category (DWS)	A Natural	B Largely natural / few changes	C Moderately modified	D Largely modified	E Highly degraded	F Extremely degraded
NBA Ecological modification	Natural/Near natural		Moderate	Heavily	Severe/Critical	
Functionality	Retain Process & Pattern (Representation)		Some loss of Process & Pattern	Significant loss of Process & Pattern	Little Process & Pattern	
Restoration cost	None/ Low		Low/ Medium	High	Very high, potentially irreversible structural changes	

Category	Description
A	**Unmodified, approximates natural condition.** The natural abiotic processes should not be modified. The characteristics of the resource should be determined by unmodifed natural disturbance regimes. There should be no human induced risks to the abiotic and biotic processes and function.
B	**Near natural with few modifications.** A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged.
C	**Moderately modified.** A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
D	**Heavily modified.** A large shift natural processes and ecosystem functions and/or loss of habitat, biota have occurred.
E	**Severely modified.** The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	**Critically modified.** Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural abiotic processes and associated biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Table 3.19: Ecological condition (out of 100) of the Abiotic and Biotic Components of the Kowie Estuary (Van Niekerk *et al.*, 2015; Van Niekerk *et al.*, 2019).

COMPONENT	CATEGORY
Hydrology	B
Hydrodynamics and mouth condition	B
Water quality	B
Physical habitat alteration	D
Habitat Health Score	B
Microalgae	B
Macrophytes	D
Invertebrates	D
Fish	C
Birds	D
Biotic Health Score	C
PRESENT ECOLOGICAL STATE (PES)	C

3.5 Estuarine Biodiversity and Conservation Importance

3.5.1 Conservation Importance

As part of the 2011 National Biodiversity Assessment (NBA) (Van Niekerk and Turpie, 2012; Turpie *et al*., 2012), a biodiversity plan for the estuaries of South Africa was developed that prioritised and established which estuaries should be assigned partial or full protected area status. The plan indicated that a total of 133 systems require protection to meet the national estuarine biodiversity targets. A total of 70 priority estuaries fall within the Temperate region, and 32 of these require full protection (Van Nierkerk *et al*., 2015).

Based on the systematic assessment of pattern, process and biodiversity persistence of all estuaries, the Kowie Estuary is not part of the core set of priority estuaries in the National Estuaries Biodiversity Plan (Turpie *et al.*, 2012, Van Niekerk *et al*., 2019).

3.5.2 Biodiversity Importance

Turpie *et al*. (2002) prioritised South African estuaries based on their conservation importance derived from various factors including size, type, biogeographical zone, habitat and biodiversity (plants, invertebrates, fish and birds). In the subsequent prioritisation (Turpie and Clark, 2007). The Kowie Estuary received a score of 80 (out of 100), and was ranked as the 33rd most important estuary out of 256 estuaries assessed (Table 3.20) (Turpie, and Clark, 2007).

Table 3.20: Kowie Estuary importance rating (Turpie and Clark 2007).

CRITERION	WEIGHT	SCORE
Estuary Size	15	90
Habitat Diversity	25	80
Zonal Rarity Type	10	20
Biodiversity Importance	25	88.5
Weighted Estuary Importance Score		**80**
Importance rating		**Important to Very Important**

The importance rating was given as 'Important to Very Important'. Furthermore, the Kowie Estuary is among the list of very important nursery areas, in terms of overall fish biodiversity, and particularly for juvenile Dusky Kob species and Spotted Grunter (Van Niekerk *et al*., 2015).

3.6 Recommended Ecological Condition

3.6.1 Recommended Ecological Category (or Desired State)

The Recommended Ecological Category (REC) signifies the level of protection assigned to an estuary from a flow perspective. The REC for an estuary is dependent on the estuary importance and the level of protection (conservation importance) of a particular estuary. While the Kowie Estuary was rated as being Very Important, it is not one of the national priority estuaries. Given that a large portion of the estuary has been irreversibly transformed with urban impacts and the likelihood of implementing major changes that would not be detrimental to socio-economics of the area is fairly low, the REC for the Kowie Estuary was prescribed as **Category C**. Key interventions required to maintain the condition of the Kowie Estuary as a Category C include (Van Niekerk *et al*., 2015; 2019):

- Restore/protect base flows to ensure that freshwater still reaches the estuary;
- Improve water quality (monitor and reduce/reuse waste water);
- Rehabilitate riparian areas/ wetlands;
- Remove alien vegetation;
- Control recreational activities impacting on birds;
- Remove/reduce fishing pressure/ bait collection; and
- Investigate eradication of alien fish.

3.6.2 Ecological Specifications and Thresholds of Potential Concern for the Estuary

A Provisional EcoClassification Study was undertaken for the estuaries of the temperate bioregion (Van Niekerk *et al*., 2015). This was done at a desktop level, and as such, ecological specifications and thresholds of potential concern have not yet been determined for the system.

A regional Water Resource Classification study was recently initiated (November 2021) by the DWS for the Keiskama and Fish to Tsitsikamma catchment. The development of Resource Quality Objectives[6], which include Ecological Specifications, will be determined for the estuaries in the study area including the Kowie Estuary. The outcomes of the study must be incorporated into subsequent updates of the Kowie EMP.

[6] Resource Quality Objectives (RQOs) are the specific environmental flows and goals that are set to preserve the quality of a water resource. Ecological Specifications (EcoSpecs) are clear and measurable specifications of ecological attributes (in the case of estuaries - hydrodynamics, sediment dynamics, water quality and different biotic components) that define a specific ecological category, in the case of the Kowie Estuary, a Category C.

4. Ecosystem Services Provided by the Estuary

Ecosystem services, also known as ecosystem goods and services, are the products that emerge from the natural environment through various biological, chemical, and physical processes and functions, which are typically used by people and contribute to enhanced societal wellbeing. The types of ecosystem services include provisioning services (such as food, water and other resources), regulating services (e.g. climate regulation, as well as air and water purification), life-support services (such as nutrient cycling and soil formation) and cultural services (e.g. aesthetic, spiritual, recreational, educational and cultural benefits) (Millennium Ecosystem Assessment, 2005; Van Niekerk and Turpie, 2019).

Municipalities benefit by generating substantial revenue from higher rates that result from elevated property values along estuary shores and related economic activities, such as estuary tourism. As a consequence of these benefits, coastal communities, tourists and local governments along the coast depend on estuaries as an important source of revenue. Because estuaries are natural features, the opportunities that they provide are free. Estuary services are just like any other that may be bought, except that these are generated through the functioning of the estuary ecosystem. These services can be used directly or indirectly, or they can be left as an option for future use. However, estuaries are seldom considered a municipal asset, even though they can generate considerable revenue for local government and communities. Because of the failure to appreciate their value, little is spent on their management. Estuaries should be regarded as an asset and managed to maintain their value. Failure to do so can have major cost implications for local governments (Lamberth and Turpie, 2003).

Estuarine habitats and the species they contain provide a host of important ecosystem services. Table 4.1 provides basic list of the main services provided by the Kowie Estuary to highlight the benefits society derives from this system. Ecological regulation, waste treatment, and export of materials and nutrients are rated as medium. The provision of disturbance regulation (e.g. flood control) has been greatly reduced by the loss and transformation of the floodplain due to the development of the town, the marina and canalisation of the system. The nursery area function and the cultural/societal value, related to the biological communities present and the aesthetic appeal, are rated as high. However, Kruger (2010) reports that the nursery function is diminished by urban impacts and pollution, lack of freshwater input, and artificial channelling that creates deep water habitat.

Recreational use of the system is high, with the main activities being power-boating, water skiing, recreational and subsistence fishing and bait harvesting, kayaking/canoeing, and swimming. Commercial value of the estuary waterbody is directly related to the property market associated with the Royal Alfred Marina, and the berthing of vessels in the small craft harbour. There are only two commercial marine fishing charters on record for the port (Nel, 2021[7]; *pers. comm.*). There are also several tourism operators who hire out craft for leisure/sightseeing/party cruises and fishing charters on the estuary. In addition to this, non-water related commercial activities include businesses and retail outlets, as well as holiday accommodation as part of the town of Port Alfred.

In terms of the economic value of estuaries and the ecosystem goods and services they provide, estuaries are globally recognised as being one of the most productive ecosystem types. According to Costanza *et al*., (1997), the average global value of estuaries is approximately US$ 22 832 per hectare per annum (in 1997 values), which is more than any other ecosystem type (Turpie and Clark, 2007; Van Niekerk *et al*., 2012). Within South Africa, estuaries contribute significantly to the local and national economy (Lamberth and Turpie, 2003; Turpie and Clark, 2007; Van Niekerk *et al*., 2019).

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[7] Mr W. Nel, Environmental Officer, Ndlambe Municipality.

Table 4.1: Important ecosystem services provided by the Kowie Estuary (adapted from Costanza *et al*., 1997 and Turpie and Clark, 2007).

ECOSYSTEM SERVICES		DESCRIPTION	RATING
Provisioning Services (goods)	**Water**	Provision of water for subsistence and agricultural use (only applicable in fresher upper reaches)	N/A
	Food, medicines	Production of fish and food plants; medicinal plants	Medium
	Raw materials	Production of craftwork materials, construction materials, fodder and biofuel	Low
Regulating Services	**Climate regulation**	Carbon sequestration, oxygen and ozone production, urban heat amelioration	Low
	Disturbance regulation	Flood control, drought recovery, refuges from pollution events	Low
	Water regulation	Provision of dry season flows for agricultural, industrial and household use (only applicable in fresher upper reaches)	N/A
	Erosion control and sediment retention	Prevention of soil loss by vegetation cover and capture of soil, e.g. reeds and sedges preventing bank erosion	Low
	Ecological regulation	Regulation of malaria, bilharzia, liver fluke, black fly, invasive plants as salinity assist with pest control.	Low
Supporting Services	**Waste treatment**	High retention makes it effective in breaking down waste and detoxifying pollution. Tidal and fluvial flushing assist with dilution and transport of unwanted pollutants	Medium
	Refugia/ Nursery areas	Critical habitat for migratory fish and birds, important habitats or nursery areas for species	High
	Export of materials and nutrients	Export of nutrients and sediments to marine ecosystems	Medium
	Genetic resources	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species	Low
Cultural Services (Attribute)	**Structure and composition of biological communities**	The characteristics, including rarity and beauty, that lend an area its aesthetic qualities or make it attractive for recreational, religious or cultural activities	High

Turpie and Clark (2007) estimated the economic values of all temperate estuaries to inform conservation planning in the region. The assessment included evaluations of the subsistence, recreational/tourism, nursery and existence values for each estuary (Turpie and Clark, 2007). In all evaluations except scenic/existence value, the Kowie Estuary ranked among the top 20 estuaries.

The estimated values are as follows (Turpie and Clark, 2007):

- Subsistence value: R 183 912 / annum;
- Property value: R 613.1 million;
- Recreational/tourism value: R 20 million / annum; and
- Nursery value: R 7.8 million / annum.

The recreational and property values, in particular, are among the highest of the estuaries of the temperate coastline (Turpie and Clark, 2007). In a more recent assessment of South Africa's ecosystem services, the subsistence value and fisheries support value of estuaries along the section of coastline from approximately Cape Padrone to the Great Fish River is estimated to be between R 500 – R 1 000 per ha/annum and R 50 000 – R 100 000 per ha/annum, respectively (Turpie *et al*., 2017)[8].

[8] Using Hedonic Pricing Model taking property variables, neighbourhood variables, accessibility variables and environmental variables into account.

5. Overview of the Socio-Economic Context

It is widely recognized that ecosystems directly or indirectly contribute to human well-being through the supply of vital ecosystem services (Millennium Ecosystem Assessment, 2005 and Díaz *et al*., 2015). The Millennium Ecosystem Assessment (2005), the Economics of Ecosystems & Biodiversity (2014) and the Intergovernmental Platform on Biodiversity & Ecosystem Services (2006) have brought the ecosystem services concept into broader environmental planning and policy arenas. This has been possible because of the development of new conceptual and analytical frameworks that analyse the complex relationships between biophysical and social systems (Ban *et al*. 2013). These frameworks recognize that biophysical and social systems are interdependent and form social-ecological systems (SESs) (Liu *et al*. 2007 and Ostrom, 2009). Ostrom (2007, 2009) developed a general framework to explore sustainability through the analysis of interdependencies and complex linkages in SESs. Recent SESs have incorporated land-based stressors in their analyses of coastal issues related to nutrient runoff, bacterial pollution and management of species to represent explicit links in between land and sea (Refulio-Coronado, 2021).

5.1 Demographics

The catchment of the Kowie Estuary extends over Wards 5, 6, 7, 8, 9 and 10 within the Ndlambe Local Municipality, as well as Wards 2, 3, 4, 5, 6 7, 8, 9, 10, 11 and 12 within the Makana Local Municipality, both of which are seated within the Sarah Baartman District Municipality of the Eastern Cape province (Figure 5.1). Since the EFZ and adjacent catchment is located a significant distance from the Makana Local Municipality, the socio-economic context of the area associated with the Kowie Estuary is restricted to the Ndlambe Local Municipality.

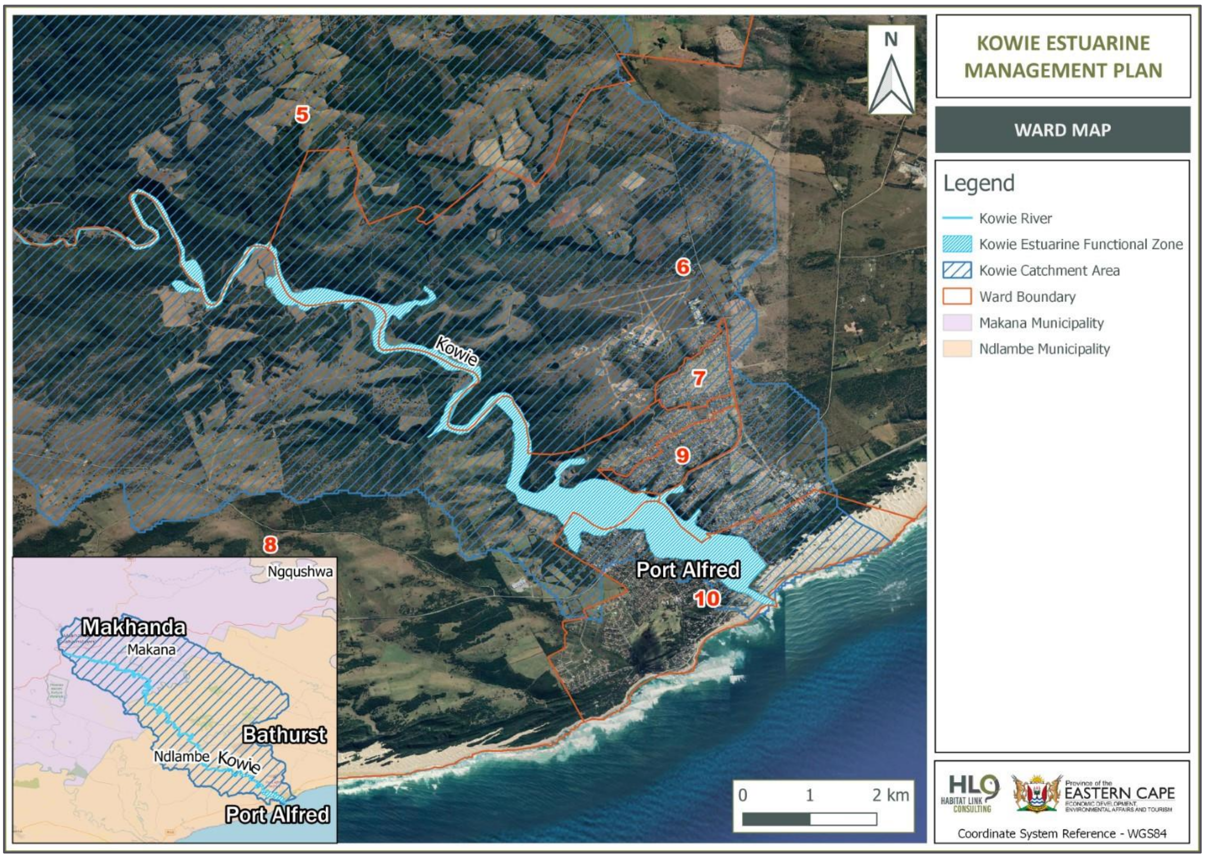

Figure 5.1: Ward map showing relevant municipal wards of the Ndlambe Local Municipality and Makana Local Municipality.

According to Statistics South Africa (2011 Census Data), this municipality has a total population of 61 176, a population density of 33 people per square kilometre, and a gender ratio of 90.3 males to every 100 females. The population increased by 1.12 % over the ten year period between 2001 and 2011. Children aged 0 to 14 years old make up 25.2 % of the population and the elderly (65 years or older) make up 9.9 %. The remaining 64.8 % of the population are aged between 15 and 64 years old (working age). 77.7 % of the population are Black African, 14.2 % are White and 7.3 % are Coloured. Of the people aged 20 years and older, 7.1 % have completed primary school, 32 % have some secondary education, 8.4 % have completed matric and 1.2 % have some form of higher education. 2.3 % of people aged 20 years and older have no form of schooling (Stats SA, 2011 Census Data).

There are 19 331 households in the Ndlambe Local Municipality, which equates to an average of 3.1 people per household of which 83.6 % live in formal dwellings and 42.6 % are headed by females. In terms of services, 86.3 % of households have access to electricity for lighting. 36.1 % of households have access to piped water which is accessible from within the dwelling, 35.5 % have a flush toilet connected to the sewerage line and 78.5 % have access to weekly refuse removal (Stats SA, 2011 Census Data). According to the Ndlambe IDP (2021), the bulk of the migration patterns experienced within the municipality are due to holiday makers (approximately 33 000) in the peak season. The influx of seasonal holiday makers equates to approximately 56 % of the permanent resident population and places tremendous pressure on the available infrastructure of the area. Although undocumented, the Municipality is also dealing with an influx of farm workers to urban centres as well as people from neighbouring municipalities seeking new economic opportunities. This is placing increasing pressure on the housing delivery program and efforts to eradicate informal settlements.

5.2 Economic Profile

Within the Ndlambe Local Municipality, there are 21 777 people who are considered ‘economically active’ of which 30.3 % are unemployed. Of the economically active youth (15 to 34 years old), 39 % are unemployed (Stats SA, 2011). The economic activities of the municipality are largely focussed on the tourism and agricultural sector as the main economic drivers, with the services sector also providing numerous permanent positions. Agriculture is less diversified, with key farming activities being dairy farming, chicory and pineapple farms. Most of the farming activities within the area are pursued by commercial farmers with local communities utilised as sources of labour. A significant portion of the trade sector is supported by tourism and a major part of the construction industry in the wider municipality is engaged in the construction of holiday homes (Ndlambe IDP, 2021).

5.3 Social Considerations

The direct and indirect benefits derived from estuarine ecosystem services are manifested directly or indirectly in tangible income and employment (Turpie and Clark, 2007). While particularly important at the national level, these factors are also important for local economic development. Understanding the value of estuaries, and managing and conserving them for sustainable use, is therefore vital in the face of increasing human pressure. Locally, estuaries are recognised to play an important role in the management of water quality and quantity, controlling erosion and providing wildlife habitat within the Ndlambe Local Municipality. The value of the Kowie Estuary is linked to its beauty and recreational use, which peaks in holiday seasons. The estuary is a key fishing and bait collection area and is a nursery ground for many marine fish species. Public access to the estuary is thus of great importance, but due to the largely built-up nature of the lower reaches of the Kowie Estuary, a number of areas remain inaccessible to the public. That being said, even though some areas are not accessible, access is not a problem relative to other similar estuarine systems. Key socio-economic issues associated with the area include the implementation of municipal land use planning, socio-economic investment to alleviate poverty and improvement in low-income housing opportunities. These will all need to take into consideration their impact on the Kowie Estuary.

6. Impacts or Potential Impacts to the Estuary

The biophysical environment was fundamental in shaping the socio-economic environment of Port Alfred as the establishment of the town was chosen for its location on the estuary. However, this ultimately has resulted in anthropogenic impacts on the environment (specifically the estuary), which ultimately has (and will continue to) impact on the socio-economic environment.

The Kowie Estuary is currently in a moderately modified state. It is evident that the system has experienced a loss and change in natural habitat and biota, although the basic ecosystem functions and processes are largely unchanged. There are numerous activities and developments that pose a threat to the future health state of the estuary. Amongst these impacts are climate change, flooding, drought, urban development, dredging, road infrastructure, weirs, agricultural activities, altered flow regimes, invasive terrestrial alien plant species, water quality deterioration, illegal fishing (overfishing), bait harvesting, livestock grazing, recreational use, RO plants and alien fish species. These are discussed in more detail below.

6.1 Natural Hazards

Natural hazards posing a potential threat to the goods and services provided by estuaries include drought, floods and climate change. Given the semi-arid, low rainfall climate of the region, baseflow supply to the Kowie Estuary is already limited, but it remains close to natural. Notwithstanding, increased future demand during low flow periods and drought will affect freshwater flow reaching the estuary. The Ecological Water Requirement ("Reserve") is yet to be determined for the system, and once determined, should be maintained to ensure the preservation of the system in times of drought.

Although floods are relatively infrequent, the modification of the system through canalisation, and the extensive development in the EFZ, renders the system vulnerable to severe flood damage and unnatural erosion.

In light of the potential impacts of climate change, the following possible stress factors could affect the coastal region of the Eastern Cape province, and the Kowie Estuary, over the period 2021 to 2050 (DEDEA, 2011; DEA/GIZ, 2021):

- An increase in the annual average temperature by around 2 °C, resulting in increased evaporation rates and increased drought intensity and duration, thus affecting water and food security;
- An increase in average annual rainfall around 0 mm to 200 mm and shift in rainfall seasonal pattern;
- A potential increase in annual average number of extreme rainfall days, resulting in an increase in intense storms and flooding events;
- An increase in mean sea level and associated storm waves and surges; and
- A shift from Albany Thicket biome to Savanna biome, and resultant changes in species diversity and interactions.

As a tidally-driven system, the Kowie Estuary is particularly sensitive to changes in marine conditions. Climate change impacts, which affect sea level rise and increase the propensity for storm surges, will have a significant impact on the functioning of the estuary within the confines of the modified channel (e.g. potential influx of larger volumes of marine sediment into the system) including physico-chemical changes that could affect biological communities (e.g. intertidal and supratidal salt marsh communities, larval fish communities etc.).

6.2 Land-Use and Infrastructure Impacts

Issues identified linked to land-use and infrastructure development include urban development, dredging, road infrastructure, weirs and agricultural activities.

Urban development

Extensive development occurs within the lower reaches of the Kowie EFZ. The coastal town, Port Alfred and the associated Royal Alfred Marina, has severely modified the banks of the estuary through canalisation of the main channel and stabilisation of the mouth, and large scale removal of saltmarsh habitat to provide for the development of the marina and small craft harbour. The marina has altered the sediment dynamics and scouring potential of the system. The prevalence of jetties, slipways as well as old derelict structures add to the artificial structures present within the estuary channel and loss of habitat. Failing bank stabilisation presents a navigation hazard, and in some areas threaten the safe usage of waterside roads, and requires urgent maintenance. There are also several pipelines (sewage, bulk water services) which traverse the bed of the estuary in different locations. The system is subject to very high noise pollution from numerous anthropogenic sources which translates into habitat disturbance for the fauna utilising the system, including birds and fish.

Dredging

As a result of the change in coastal sediment dynamics caused by the construction of the harbour breakwaters, marine sediment is continuously deposited in the estuary mouth. In addition, the development of Royal Alfred Marine has altered the sediment dynamics within the lower estuary, resulting in sediment deposition in the channel, specifically in the vicinity of the marina. This must be dredged on an ongoing basis to improve the navigability of the system. It was observed that the dredged material is currently discharged to the back-beach dune environment on the eastern shoreline.

Road infrastructure

There are two main bridges which span the lower estuary, the Putt Bridge and the iconic Nico Malan Bridge, both of which are observed to have a negligible impact on the flow through the system. Remnant saltmarsh habitat on the eastern bank is separated from the main estuary body by the R72 road, with two large pipe culverts allowing for seawater ingress during high tide.

Weirs

The weir above the 'ebb and flow' point, constructed to capture water supply to the off-channel Sarel Hayward Dam, is the main obstruction to flow between the estuary and the freshwater environment. This marks the headwater region and upper limit of the system. There are no major instream dams in the catchment, but there are several smaller agricultural weirs.

Agricultural activities

Historically, changes in crops and farming methods in the catchment have likely affected the sediment load entering the river and estuary. This remains a concern, as it is possible that agricultural activities and trampling by livestock within the EFZ contributes to siltation, poor water quality and habitat degradation and fragmentation, although currently there are no available studies to confirm this possibility.

6.3 Water Quantity and Quality

Issues identified linked to water quantity and quality are anthropogenically altered flow regime, invasive terrestrial alien plant species and water quality deterioration.

Altered flow and flood regime

The Kowie Estuary currently receives 95 % of the natural MAR, and baseflows are 66 % similar to the natural state. Evidently there has been some modification to the baseflow through abstraction in the catchment both for agriculture and potable water supply (e.g. Sarel Haywards Dam). However, this has not resulted in shifts in prominent flow patterns (van Niekerk *et al*., 2015). The variability of floods has slightly increased which may be a function of change in land-use, combined with additional inputs, such as wastewater discharge and brine effluent. In addition, saline water is being abstracted from the Kowie Estuary by the small RO plant (2 Mℓ/day), and a second small system (1 Mℓ/day) is due to be constructed in the near future. Brine effluent is discharged back into the estuary.

Invasive Alien Plant Species (IAPs)

Terrestrial alien vegetation species within the Kowie River catchment contributes to the reduction in freshwater flow reaching the estuary.

Waste Management

Inadequate waste management, especially within urban environments, can have a significant negative impact on water flow and quality. One of the biggest impacts of waste on water in urban areas is as a result of littering. Litter causes blockages in stormwater systems, which can result in flooding of built-up areas. Decomposition of organic waste in landfills is one of the main causes of leachate which, if not managed properly, can lead to both surface and groundwater pollution. Rainfall is also a contributing factor to leachate as the rain percolates through the waste body, dissolving contaminants and acting as transport medium for pollution into the surrounding environment.

Water quality deterioration

Agricultural return flows (containing fertilizers, herbicides and pesticides), urban run-off and stormwater pollution, effluent discharges including treated sewage (Port Alfred WWTW) and brine effluent, malfunctioning/damaged sewage infrastructure, domestic solid waste and litter, and water pollution from vessels, are contributing to a decline in water quality in the Kowie Estuary (Ntombini *et al*., 2020). Residents have reported numerous sewage leaks from the CBD as well as odours from Centenary Park to the Nico Malan Bridge, suggesting possible leaks along the sewerage lines that are in close proximity to the estuary. In addition, Increased nutrient inputs has resulted in visible macroalgal blooms in areas with reduced connectivity to the main channel (e.g. remnant small lagoon at Pascoe Crescent).

6.4 Exploitation of Natural Resources

Issues linked to exploitation of living and non-living resources are fishing, bait harvesting, urban development, livestock grazing, recreational use, RO plants and alien fish species.

Fishing and bait harvesting

The Kowie Estuary is used extensively for recreational fishing and subsistence fishing. Fishing effort as well as bait harvesting pressure, specifically for mudprawns, is high, particularly during peak holiday periods (Nel, 2021[9]; *pers. comm.*). Illegal harvesting of mudprawns and harvesting methods are prevalent and can cause noteworthy damage to intertidal habitat.

Urban development

The natural assets of the area have been exploited for their tourism and aesthetic value. This has resulted in extensive urban development in the EFZ and the resultant loss of estuarine habitat, as well as fragmentation and degradation of the remaining habitat.

Livestock grazing

It was observed that the main saltmarsh area as well as some areas in the middle to upper reaches are impacted by cattle grazing. Cattle movement exacerbates bank erosion and also results in habitat trampling and fragmentation.

Recreational use

It was observed that intensive recreational use of the estuary, namely powerboating and skiing results in the erosion of estuary banks, salt marsh vegetation and sensitive *Zostera* beds, and disturbance to wading bird populations.

Reverse Osmosis plant

Abstraction of saline water from the lower middle reaches of the system to augment potable water supply is not appearing to have a notable effect on the habitat quality or functionality of the Kowie Estuary (e.g. drawn down, or change in mouth state). However, the return of hypersaline concentrate to the estuary may have negative impacts on the estuary water quality. A new smaller RO plant is to be constructed in near future (Nel, 2021[8]; *pers. comm.*).

Alien fish species

Two species of alien fish (Mozambique tilapia and Largemouth bass) have been noted in the system. These pose a threat to the indigenous species of the Kowie Estuary, particularly larval and juvenile life stages that would serve as prey food resources.

[9] Mr W. Nel, Environmental Officer, Ndlambe Municipality.

7. Legislative Instruments

The development of the EMP as well as the management of activities taking place in and around the EFZ is subject to various legislative requirements in terms of South African environmental law. The revision of the EMP is required to be undertaken every five years and should allow for updates relating to changes in legislation and/or regulations. The relevant legislation is set out below and includes national, provincial and local legislation, with additional policies and guidelines that must be taken into consideration.

7.1 National Legislation and Policies

This section provides an overview of the legislation and policies applicable to the management of estuaries in South Africa and specifically to the Kowie Estuary. The following national legislation is relevant to the development of an EMP for this estuarine system:

- The Constitution;
- National Environmental Management Act (No. 107 of 1998);
- National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008);
- National Water Act (No. 36 of 1998);
- Marine Living Resources Act (No. 18 of 1998);
- Minerals and Petroleum Resources Development Act (No. 28 of 2002);
- Spatial Planning and Land Use Management Act (No. 16 of 2013);
- National Environmental Management: Protected Areas Act (No. 57 of 2003);
- National Environmental Management: Biodiversity Act (No. 10 of 2004);
- Conservation of Agricultural Resources Act (No. 43 of 1983);
- National Forests Act (No. 84 of 1998);
- National Environmental Management: Air Quality Act (No. 39 of 2004);
- National Environmental Management: Waste Act (No. 59 of 2008);
- National Heritage Resources Act (No. 25 of 1999);
- National Health Act (No. 61 of 2004); and
- Local Government: Municipal Systems Act (No. 32 of 2000).

7.1.1 The Constitution

The Constitution of South Africa is the supreme law of the Republic of South Africa. It provides the legal foundation for the existence of the republic, it sets out the rights and duties of its citizens, and defines the structure of the Government. Section 24 of the Constitution (Environment) states the following:

"*Everyone has the right-*

(a) to an environment that is not harmful to their health or well-being; and
(b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that
    (i) prevent pollution and ecological degradation;
    (ii) promote conservation; and
    (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development."

This lays the basis for environmental law in South Africa and is a very important justification for the wise use of estuarine biodiversity.

7.1.2 National Environmental Management Act

The Department of Forestry, Fisheries and the Environment (DFFE), formerly the Department of Environmental Affairs (DEA) is the lead agent for the National Environmental Management Act (NEMA) (Act No. 107 of 1998, as amended). NEMA provides for co-operative environmental governance through the establishment of national environmental management principles and procedures for their incorporation into decisions affecting the environment. NEMA emphasizes co-operative governance and assists in ensuring that the environmental right and related rights in the Constitution are protected. NEMA requires the DFFE to be the lead agent in ensuring the effective custodianship of the environment. In particular, NEMA provides that sensitive, vulnerable, highly dynamic or stressed ecosystems, such as estuaries, require specific attention in management and planning procedures, especially those subjected to significant human resource usage and development.

Various activities listed in the NEMA EIA Regulations relate to the coastal zone and require an EA before they can proceed. The EIA Regulations regulate procedures and criteria for the submission, perusal, consideration and decision of applications for the EA of specified activities. These regulations are especially pertinent to estuaries as many estuaries are situated within rapidly expanding development nodes along the South African coast and are under tremendous pressure from human activities.

7.1.3 Integrated Coastal Management Act

The ICM Act is the key legislation relevant to the planning and the control of activities within the coastal zone, including estuaries. The following section provides a brief summary of those chapters of the ICM Act that are particularly relevant to the current Kowie EMP.

Chapter 2 of the ICM Act defines the components of the coastal zone in South Africa. It also deals with the spatial aspects, definitions and legal status of these various components. The ICM Act focuses on regulating human activities within, or that affect the “coastal zone” (Figure 7.1).

The coastal zone is defined as the area comprising:

- Coastal public property (mainly Admiralty Reserve and land below the high water mark);
- Coastal protection zone (an area along the inland edge of coastal public property);
- Coastal access land (which the public may use to gain access to coastal public property);
- Special management areas; and
- Any aspect of the environment on, in and above the above areas.

Chapter 4 of the ICM Act (Act No. 24 of 2008, as amended), aims to facilitate the efficient and coordinated management of all estuaries, in accordance with:

a) The NEMP (or ‘the Protocol’) (Section 33) approved by the Ministers responsible for the environment and water affairs; and
b) EMPs for individual estuaries (Section 34).

The NEMP, which was promulgated in 2013 and amended in 2021, provides a national policy for estuarine management and guides the development of individual EMPs. It must be ensured that the EMPs are aligned with the NEMP and the National Coastal Management Programme (CMP) as well as any provincial CMPs. The NEMP lays out the following:

a) The strategic vision and objectives for achieving effective integrated management of estuaries in South Africa;
b) The standards for the management of estuaries;
c) The procedures regarding how estuaries must be managed and how the management responsibilities are to be exercised by different organs of state and other parties;

d) The minimum requirements for EMPs;
e) Who must prepare EMPs and the process to be followed in doing so; and
f) The process for reviewing EMPs to ensure that they comply with the requirements of the ICM Act.

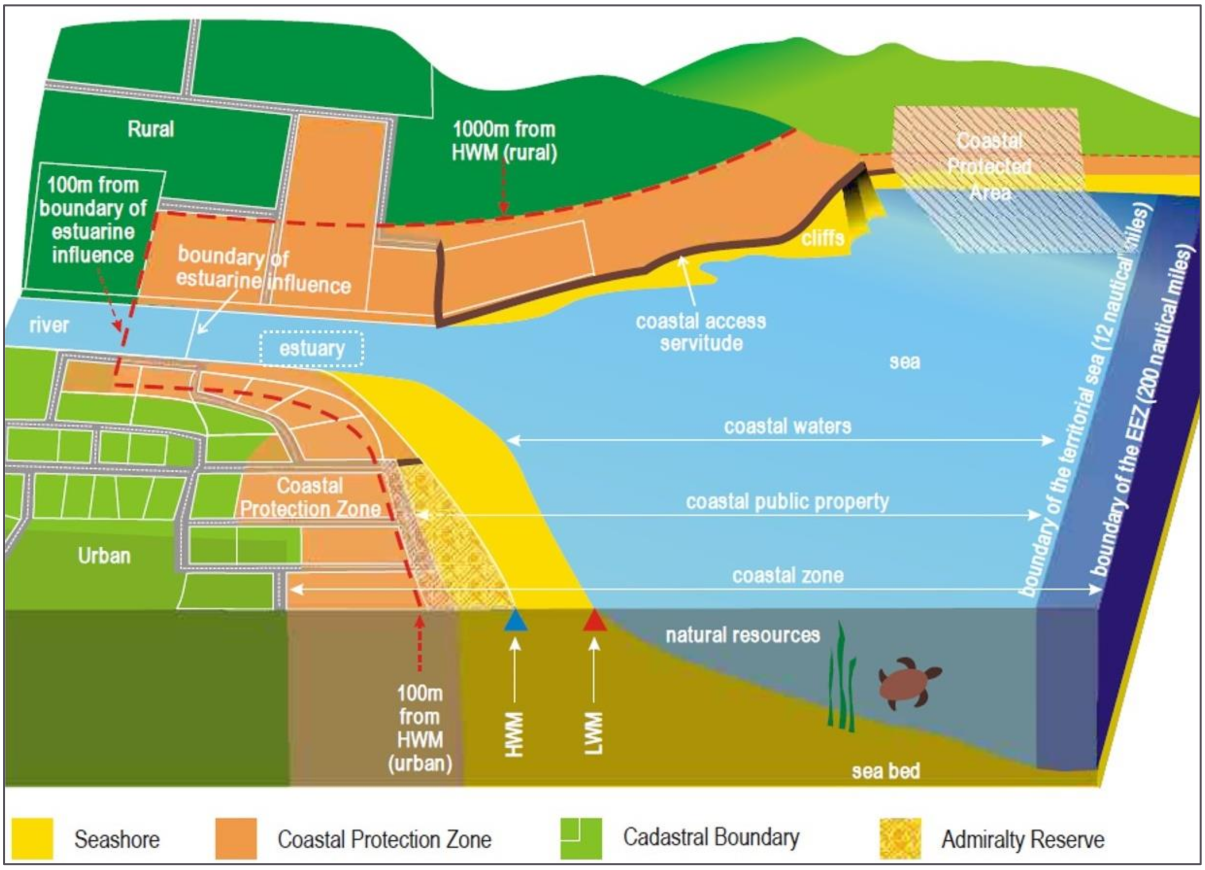

Figure 7.1: The components of the coastal zone as defined by the ICM Act (Celliers *et al.*, 2009).

The responsible body contemplated in Section 33(3)(e) who develops an EMP must:
a) follow a public participation process in accordance with Part 5 of Chapter 6 of the ICM Act; and
b) ensure that the EMP and the process by which it is developed are consistent with:
   (i) the Protocol; and
   (ii) the National CMP and with the applicable provincial CMP and CMP referred to in Parts 1, 2 and 3 of Chapter 6 of the ICM Act;
c) If applicable, ensure that relevant legislation is enacted to implement the EMP; and
d) Submit an annual report to the Minister on the implementation of the EMP, the legislation and any other matter.

Chapter 8 of the ICM Act establishes integrated procedures and other requirements for regulating the disposal of effluent (polluted water) and waste (any substance disposed of in the coastal environment) into estuaries and the sea. These procedures and requirements relate to both the discharge of effluent from specific sources and the dumping and incineration of waste. The ICM Act provides for the authorisation of discharge of effluent into coastal waters via a Coastal Waters Discharge Permit and for consultation with the Minister of Water and Sanitation in situations related to estuarine discharges. The ICM Act also provides for the establishment of Special Management Areas that are wholly or partially in the coastal zone. These areas may only be declared by the Minister and such declaration may prohibit certain activities from taking place within such a management area. The ICM Act also includes the Public Launch Site Regulations (2014), which control public launch sites that are listed by the authority and managed by a management body appointed for such purposes.

7.1.4 National Water Act

Water quality and quantity are mainly controlled under the NWA (Act No. 36 of 1998), which is implemented and controlled by the Department of Water and Sanitation (DWS). The White Paper on National Water Policy for SA (1997) promotes efficiency, equity and sustainability in the use of water resources through its slogan "*some, for all, forever*". The policy explicitly recognises the environment as a legitimate user of water and makes provision to protect the environment from overexploitation of water resources. The NWA provides the legal framework for this policy. The NWA makes provision for a water "Reserve" which provides the quantity and quality of water flow required in aquatic ecosystems to meet basic human needs and to protect the natural functioning of a water resource. The latter portion of the reserve is known as the ecological Reserve, a determination which is currently in progress via a separate study (Biggs, 2022[10]; *pers. comm.*).

The Classification Process

The extent to which an estuary's functioning is catered for is determined by the designated "class" (future state of health) of that estuary, with some estuaries being assigned a low class to allow maximal water provision and others being assigned a high class in order to meet conservation needs. The decision as to the designated class of the estuary is thus a critical one. This will take place using a gazetted classification process which entails consideration of the trade-offs in value generated by allocating water (or pollution rights) to off-stream users (e.g. irrigation agriculture), flow-reducing activities (e.g. plantation forestry) and polluters (e.g. municipalities or industries) versus allocating water to the environment for the provision of ecosystem services (e.g. fishing, tourism etc.). The Catchment Management Agencies are proposed to play the key role in this decision-making process.

The Reserve Determination Process

For systems that have yet to be classified, the ecological Reserve is determined on the basis of recommendations emanating from a reserve determination study using the Resource Directed Measures (RDM) methodology in conjunction with considerations of the demand for water in the catchment (the classification process described above will effectively standardise the way this is done). In the absence of reserve determination studies for individual estuaries, the ecological state of South Africa's estuaries was predicted at a desktop level as part of the estuary component of the 2011 National Biodiversity Assessment. In this assessment, the PES is provisionally established (unless more detailed studies have been undertaken) for all estuarine systems, to guide planning decisions.

7.1.5 Marine Living Resources Act

The exploitation of marine living resources in South Africa (which includes estuarine resources) is governed by the Marine Fisheries Policy for South Africa (1997) and the Marine Living Resources Act (Act No. 18 of 1998, as amended). Objectives of the policy and Act are as follows:

- To achieve optimum utilisation and sustainable development of marine living resources;
- To conserve marine living resources for present and future generations, to use marine living resources;
- To achieve economic growth, human resource development, capacity building within fisheries and mariculture branches, employment creation and a sound ecological balance consistent with the development objectives of national governments;
- To protect the ecosystem as a whole, including species which area not targeted for exploitation; and
- To preserve marine biodiversity.

[10] Mr H. Biggs, Port Alfred Resident.

The Marine Living Resources Act defines the species that can be exploited, and protection measures for those species, such as closed areas, closed seasons and size and bag limits. Various types of resource-use permit systems are also defined under this Act.

7.1.6 Spatial Planning and Land Use Management Act

The primary aim of the Spatial Planning and Land Use Management Act (SPLUMA) (Act No. 16 of 2013), insofar as it relates to estuarine management, is for the provision of a framework for spatial planning and land use management. Section 7 of SPLUMA sets out five development principles that are applicable to spatial planning, land development and land use management and includes the following three principles that pertain to environmental management:

i. Spatial sustainability refers to, *inter alia*, the need for spatial planning and land use management systems to promote land development that is viable and feasible within a South African context, to ensure protection of agricultural land and maintain environmental management mechanisms;
ii. Efficiency relates to the need for optimal use of existing resources and infrastructure, decision-making that minimises negative financial, social, economic or environmental impacts and development application procedures that are efficient and streamlined; and
iii. Spatial resilience refers to the extent to which spatial plans, policies and land use management systems are flexible and accommodating to ensure sustainable livelihoods in communities most likely to suffer the impacts of economic and environmental shocks.

Furthermore, Section 42 of SPLUMA refers to the factors that must be considered by a municipal tribunal when adjudicating a land use planning application, which includes compliance with environmental legislation.

7.1.7 Protected Areas Act

The National Environment Management: Protected Areas Act (NEMPAA) (Act No. 57 of 2003) provides for the declaration and management of protected areas, and can also provide for co-operative governance, the sustainable utilisation of protected areas that preserves their ecological character, and the participation of local communities in the management of protected areas, where appropriate. A consultation and public participation process is outlined in NEMPAA and it also contains the requirement that marine and terrestrial protected areas with common boundaries must be managed as an integrated protected area by a single management authority. It is also important to note that under the NEMPAA, commercial prospecting or mining is prohibited in any nature reserve.

7.1.8 Biodiversity Act

The National Environment Management: Biodiversity Act (NEM:BA) (Act No. 10 of 2004) provides for the conservation of biological diversity. It requires identification of important landscapes, ecosystems, ecological process and species for biodiversity conservation, as well as monitoring of these areas. It also provides for the proclamation of protected areas, recognising South Africa's obligations to international conventions, such as the Convention on Biological Diversity, the Convention on Wetlands of International Importance, especially Waterfowl Habitat (Ramsar Convention) and the Convention on Migratory Species (Bonn Convention).

7.1.9 Conservation of Agricultural Resources Act

The Department of Agriculture, Land Reform and Rural Development (DALRRD) is the lead agent for the Conservation of Agricultural Resources Act (CARA) (Act No. 43 of 1983). The objective of the CARA is to provide for the conservation of the natural agricultural resources of South Africa by:

- The maintenance of the production potential of land;

- The combating and prevention of erosion and weakening or destruction of the water sources (including estuaries); and
- The protection of the vegetation and the combating of weeds and invader plants.

7.1.10 National Environmental Management: Waste Act

The National Environmental Management: Waste Act (NEM:WA) gives legal effect to the policies and principles relating to waste management in South Africa, as reflected in the National Waste Management Strategy (NWMS). Chapter 4, Part 4 deals with waste management activities, Part 5 covers storage, collection and transportation of waste, Part 6 deals with treatment, processing and disposal of wastes, Part 7 covers industry waste management plans and Part 8 deals with contaminated land. The NEM:WA categorises waste into hazardous waste (waste that may have a detrimental impact on health and the environmental and includes hazardous substances) and general waste (waste that does not pose an immediate hazard or threat to health or to the environment). There are various subcategories of hazardous and general waste and include waste from agriculture, construction wastes and inert waste (e.g. discarded concrete, soil and stones). The NEM:WA, similar to the NEMA, has a list of waste management activities that would require a waste management licence and includes certain thresholds relating to storage of waste, recycling of waste, treatment of waste and disposal of waste.

7.1.11 National Health Act

While the Department of Health is the lead agent for the National Health Act (NHA) (Act No. 61 of 2004), the implementation of this act is delegated to the municipal and provincial authorities. The responsibility for rendering environmental health services under the NHA has been delegated to metropolitan and district councils as of 1 July 2004. Every district municipality must ensure that appropriate municipal health services are effectively and equitably provided in their respective areas. These include (insofar as it influences human health, except in ports):

- Water quality monitoring;
- Waste management; and
- Environmental pollution control.

7.1.12 National Heritage Resources Act

The South African Heritage Resources Agency (SAHRA) is the lead agent for the National Heritage Resources Act (NHRA) (Act No. 25 of 1999). The NHRA provides an integrated and interactive system for the management of national heritage resources (which include landscapes and natural features of cultural significance). One of the important elements of the NHRA is that it provides the opportunity for communities to participate in the identification, conservation and management of cultural resources.

The Act also requires that, in areas where there has not yet been a systematic survey to identify conservation-worthy places, a permit is required to alter or demolish any structure older than 60 years. This will apply until a survey has been done and identified heritage resources are formally protected. Anyone who intends to undertake a development must notify the SAHRA or the provincial branch (in this case the Eastern Cape and if there is reason to believe that heritage resources will be affected, an impact assessment report must be compiled at the developer’s cost. Development must cease if a heritage resource is discovered.

The Kowie Estuary contains what are referred to as Maritime and Underwater Cultural Heritage (MUCH) resources, which SAHRA is mandated to protect. If any listed activity is to be undertaken below the high-water mark of the estuary, an application must be lodged with SAHRA, as SAHRA must comment on potential impacts on MUCH resources. Shipwrecks older than 60 years are defined as archaeological resources in terms of the NHRA. There are other aspects of heritage surrounding the Kowie Estuary that might fall within the remit of a provincial or municipal heritage resources authority, such as the old stone mill and old stone jetty, together with numerous old structures and buildings older than 60 years.

7.1.13 Local Government: Municipal Systems Act

The Department of Provincial and Local Government is the lead agent for the Municipal Systems Act (Act No. 32 of 2000). The Municipal Systems Act (Chapter 5) deals with the Integrated Development Plan (IDP), which all municipalities are obliged to prepare and update on a regular basis. An IDP is intended to encompass and harmonise planning over a range of sectors such as water, transport, land use and environmental management.
It requires each local authority to adopt a single, inclusive plan for the development of the municipality which:

- Links, integrates and coordinates plans and take into account proposals for the development of the municipality;
- Aligns the resources and capacity of the municipality with the implementation of the plan;
- Forms the policy framework and general basis on which annual budgets must be based; and
- Is compatible with national and provincial development plans and planning requirements that are binding on the municipality in terms of legislation.

Chapter 5 of the Municipal Systems Act deals with integrated development planning that sets the social and economic objectives for a particular area. The Municipal Planning and Performance Management Regulations promulgated in terms of this Act describe the content requirements of IDPs. The regulations, for example state that the Spatial Development Framework (SDF), reflected in the municipality's IDP, must 'contain a strategic assessment of the environmental impact of the spatial development framework'.

7.1.14 Other Relevant National Policies and Guidelines

In addition to the abovementioned legislation, the following policies and guideline documents, established at national level, are relevant to the management of the Kowie Estuary:

- National Coastal Management Programme;
- National Estuarine Management Protocol;
- White Paper for Sustainable Coastal Development;
- Department of Water Affairs River Health Programme;
- National Waste Management Strategy;
- National Biodiversity Strategy and Action Plan;
- National Protected Area Expansion Strategy for South Africa;
- National Climate Change Response White Paper;
- South African Risk and Vulnerability Atlas (SRVA); and
- National Climate Change Coastal Vulnerability Assessment and Decision Support Tool.

7.2 Provincial Legislation and Policies

Although specific legislative acts are handled at the national level, the provincial legislature provides for a number of policies relating to environmental management, including that pertaining to estuaries. The following provincial policies are relevant to the development of an EMP for the Kowie Estuary:

- Eastern Cape State of Environment Report (2010);
- Eastern Cape Climate Change Response Strategy (2011);
- Eastern Cape Biodiversity Conservation Plan (ECBCP) (2019);
- Eastern Cape Coastal Management Programme (2013);

- DEDEAT Coastal Environmental Management Framework (Kei Mouth to Cannon Rocks) (2012);
- Eastern Cape Air Quality Management Plan (2013);
- Eastern Cape Provincial Integrated Waste Management Plan (PIWMP) (2010); and
- Eastern Cape Parks and Tourism Conserved Area Expansion Programme (2012).

The Eastern Cape State of Environment Report (DEDEAT, 2010) provides a general summary of estuaries within the province and notes that "*waste-water and pollution are impacting on water quality of estuarine systems and the in shore coastal waters*." The Eastern Cape Climate Change Response Strategy (2011) identifies agricultural activities and urban demands as threats to the provision of freshwater influx into estuaries.

In the ECBCP (2019), estuaries throughout the province are classified as either a Critical Biodiversity Area (CBA) or an Ecological Support Area (ESA) and have specific land use planning guidelines, while the DEDEAT Coastal Environmental Management Framework facilitates conservation of important natural resources and rapid development within the coastal zone between the Great Kei River and Cannon Rocks (DEDEAT, 2021). Estuaries are identified as one of the nine priority areas in the 2013 Eastern Cape Coastal Management Programme.

7.3 Local Legislation and Policies

Local legislation includes municipal by-laws that are specific to a particular area within a province. The local municipality, in this case the Ndlambe Local Municipality, is responsible for implementing and policing these by-laws. Furthermore, there are a number of local and regional policies, guidelines and plans that are relevant to the management of coastal areas including estuaries:

- Sarah Baartman District Municipality IDP;
- Sarah Baartman District Municipality SDF;
- Ndlambe Local Municipality IDP;
- Ndlambe Local Municipality SDF;
- Sarah Baartman District Municipality CMP;
- Ndlambe Local Municipality CMP; and
- Ndlambe Municipality Bylaws for the Control of Boats and Other Activities on Rivers.

The district IDP identifies the Kowie Estuary as an important resource for supply of sea-water, via an RO process, to supply bulk water to the Ndlambe Municipality. The Ndlambe Local Municipality IDP states that "*all boats that operate on the Ndlambe estuaries may not do so unless compliant with SAMSA*[11] *regulations and can produce the necessary Skippers, Certificate of Fitness, and buoyancy certificates. Then only can they register with Ndlambe municipality to obtain river usage periods to operate on estuaries within the Ndlambe area of jurisdiction*." Both the district and local SDFs make provision for existing development surrounding the Kowie Estuary, but identify the risk to infrastructure due to its location within the floodplain. The district CMP provides an overall assessment of the coastal zone and estuaries within the wider Sarah Baartman region, while the Ndlambe Local Municipality CMP details specific issues relating to the Kowie Estuary. The municipal bylaws are the primary instrument utilised by the Ndlambe environmental officers for the protection and management of the local estuarine systems, including the Kowie Estuary.

[11] The South African Maritime Safety Authority (SAMSA) who, together with the Ndlambe Municipality, decided on these requirements in February 2020.

8. Opportunities and Constraints

8.1 SWOT Analysis

The following section provides a summary of the strengths, weaknesses, opportunities and threats (SWOT) associated with the Kowie Estuary and its current situation and management:

Strengths

- Long meandering system with variety of estuarine habitats (e.g. saltmarsh, *Zostera* beds etc.)
- Upper reaches are steeply sided and prevent development encroachment
- Little change to the MAR
- Small boat harbour
- Open mouth – continuous flushing and exchange of seawater
- High fish diversity
- Important nursery functions
- Considerable amount of research undertaken by tertiary institutions

Weaknesses

- Lower reaches largely and irreversibly transformed
- Densely urbanised space
- More than 50 % of original saltmarsh area has been lost
- Altered flow patterns as a result of marina development
- Persistent sedimentation in lower reaches
- Marine ingress of sediment, making safe maritime navigation difficult
- Loss and disturbance to estuarine habitat (e.g. *Zostera* beds and bird feeding areas) by boats and recreational activities
- Pollution and eutrophication of marginal habitats, leading to algal blooms
- Retaining walls and rock revetments damaged in places (existing EA and MMP for repairs and maintenance does not specify these repairs as part of the scope)
- Uncontrolled launch sites (private slipways) that do not fall within the ambit of the Public Launch Sites regulations.
- Dangers of strong tidal currents
- Entire estuary is not accessible to the public and some areas are declared as private access
- Low institutional capacity (control officers are not sufficiently equipped to conduct enforcement on the estuary)
- Old and failing infrastructure together with inadequate maintenance services within the municipality

Opportunities

- Regulated saline water abstraction - RO plant(s)
- Continued controlled use of the system both recreationally and for resource use
- Protection of *Zostera* beds
- Creation and restoration of marginal habitats
- Improved dredging practices

Threats

- Large catchment imposing water quality issues through poor catchment land-uses and activities
- Drought
- Sea-level rise as a result of global climate change
- Sedimentation of estuary channels if dredging is not maintained
- Discharge of poorly treated / untreated sewage
- Leachate from the landfill site entering the estuary
- Ongoing urban pollution inputs (contaminated stormwater, solid waste, vessel pollution, etc.)
- Ongoing high nutrient inputs
- Reduction in indigenous fish species through predation by alien fish species
- Unsustainable resource use / over exploitation of fish and bait species, leading to collapse of important species
- Failure of bulk services (e.g. bulk water pipeline through estuary, sewage pumpstations and infrastructure on the estuary banks)
- Failure of proposed new sewerage reticulation network
- Crime in public open spaces (e.g. Centenary Park)
- Grazing and trampling pressures could lead to fragmentation of salt marshes
- Removal of reeds/habitat for legal and illegal jetties
- Boat use and impact of noise from propellors
- Current bylaws do not cover refuelling of boats or storage of hazardous substances associated with boating
- Potential discharge from hospital and other facilities

8.2 Potential for Protected Area Status

The Kowie Estuary was not identified as a core system on the list of national priority estuaries. Protection of this system is therefore not of national importance. Notwithstanding, the Kowie Estuary was ranked as the 33rd most important in South Africa in terms of its biodiversity importance (Turpie, and Clark, 2007), and was rated as 'Important to Very Important'. The system is considered a very important nursery area, particularly for juvenile Dusky Kob species and Spotted Grunter, and it displays overall high fish diversity (Van Niekerk *et al*., 2015). In addition, the estuary is also located in the Algoa to Amathole Ecologically and Biologically Significant Marine Area (EBSA), and is in close proximity to the Addo Elephant National Park Marine Protected Area (MPA), which emphasises the value of the estuary as a nursery area for supporting these areas of conservation importance. Although it is no longer formally implemented, the Subtropical Thicket Ecosystem Planning (STEP) project included six priority areas. The Kowie River and its estuary fall within the Great Fish/Kowie "Mega-conservancy Network" priority area (Nel *et al*., 2006). Results from STEP (2006) have been taken up into other conservation planning and implementation initiatives.

There are also numerous conservation areas along the estuary, including private and municipal nature reserves, as well as provincial protected areas (Waters Meeting Nature Reserve). Inclusion of parts of the estuary into one (or some) of the existing protected areas would be advantageous, but strict control would be required to establish and maintain conservation objectives in light of the current recreational and extractive use.

8.3 Priority Restoration Actions

Comments from Interested and Affected Parties (I&APs) have suggested that, in order to prevent further habitat loss and reduce cumulative impacts, any development within the EFZ (outside of the existing urban edge) should be severely restricted. The 'Duck Pond' saltmarsh on the west bank is a closed area for fishing and bait collection and would be worthwhile protecting and formalised as such. The ski-zone in Bay of Biscay poses a safety risk to other users and is a source of noise pollution to residents. There is also damage, caused by propellor wash, to the large mudbank and extensive *Zostera* beds at high tide when speeding boats traverse the area. Consideration should be given to removing this ski-zone and making it a wake-free zone to reduce damage to habitat and for safety to other users.

From an infrastructure point of view, stakeholders have indicated that the priority should be the maintenance and reconstruction of the collapsing stone wall banks between the Nico Malan Bridge and the river mouth as this will become a navigational problem and will be unsightly. Other restoration measures should include the cleaning of the salt marsh areas especially on the eastern bank adjacent to the Nico Malan Bridge. There is also room to rehabilitate the margins of the marina to recreate shallow water refuge by getting the local quarry to donate rock rubble to be dumped along margins.

According to the regional EcoClassification Study for temperate estuaries and the 2018 NBA (Van Niekerk *et al*., 2015; 2019), the following flow and non-flow interventions are required to maintain the Kowie Estuary in a Category C condition:

- Maintain/protect base flows – maintain the present flow regime (pMAR = 30.3 million m^3) and protect the current baseflow by preventing illegal abstractions, and reducing run-of-river abstraction (e.g. to the Sarel Hayward Dam) during the low flow season;
- Improve water quality through managed land-use, strictly controlled effluent discharge, well maintained and managed sewage infrastructure, improved stormwater management within the catchment. Any relevant authorisations required from the DEDEAT and/or DWS must be obtained for these discharges;
- The status of the preventive measures around the landfill site (e.g. perimeter monitoring boreholes if available) and the status of runoff and leachate monitoring should be reviewed and corrected if found deficient.
- Rehabilitate riparian and wetlands area, particularly reconnecting intertidal habitat;
- Remove terrestrial alien vegetation that would reduce freshwater run-off to the estuary;
- Control recreational activities impacting on birds by reducing noise and wake causing activities, particularly in the vicinity of major wetland feeding areas;
- Reduce fishing pressure and bait collection through improved compliance monitoring of fishing and bait harvesting activities; and
- Investigate eradication of alien fish (e.g. alien fish control programme including species-specific angling).

Additional actions should include:

- Rehabilitation of marginal areas in the lower estuary (e.g. Duck Pond and remnant Eastern lagoon) and marina to improve the nursery function of the system (Kruger, 2010). Use of innovative ways to improve the habitat value in this area;
- Urgent repair and maintenance of defence structures that are in a degraded state and leading to bank erosion, undermining and/or damage to infrastructure, and posing a risk to safe navigation of the estuary channel. It will need to be determined if the existing EA and MMP held by the Ndlambe Local Municipality may be extended to include these repairs or if a separate application is necessary;
- Review of marina dredging activities – Environmental best practise (Nadine Strydom comment);
- Potential amendment to boating bylaws to include management of refuelling; and
- Implementation of a long-term monitoring programme to test for compliance with the soon to be developed Resource Quality Objectives, existing water quality guideline, and to continuously improve understanding of ecosystem function, as well as monitor pollution sources and loads.

9. Information Gaps and Recommendations

The Kowie Estuary has a significant amount of research and information available from historic and more recent studies. Understanding the nature and bathymetry of the system would result in a greater knowledge of the habitats provided for estuarine fauna. This would help to regulate fishing and protect fish habitats. Freshwater input remains valuable and, given the impoundments which remove water, abstraction should not be to the detriment of the estuary. The water quality results show that the estuary is not entirely characteristic of seawater, thus contributing to habitat diversity.

Therefore, recommendations regarding future studies include the following:

- Bathymetry studies of the whole system (as opposed to limited studies for the marina);
- Additional benthos studies (apart from the mudprawn resource use);
- Studies on marine megafauna (mammals and, potentially, turtles) that make use of the estuary;
- Determine the ecological reserve (currently in progress);
- Long-term monitoring of invertebrates;
- Monitoring of catch and effort data for recreational and small-scale fisheries; and
- Study on the extent and importance of the REI.

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