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RESERVE DETERMINATION STUDIES FOR THE SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE GOURITZ WATER MANAGEMENT AREA

PROJECT TECHNICAL REPORT 6, VOLUME 1

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Report Number 02	RDM/WMA16/00/CON/0213	Desktop EcoClassification Report
Report Number 03, Volume 1	RDM/WMA16/00/CON/0313, Volume 1	Delineation Report, Volume 1 (Groundwater, Estuaries and Wetlands)
Report Number 03, Volume 2	RDM/WMA16/00/CON/0313, Volume 2	Delineation Report, Volume 2 (Rivers)
Report Number 04	RDM/WMA16/02/CON/0413	Groundwater Report
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EXECUTIVE SUMMARY

This study presents the preliminary Reserve determination on the Hartenbos, Blinde, Piesang, Groot (Wes) and Bloukrans estuaries conducted at Desktop levels. For the Gouritz Water Management Area (WMA) a "best attainable" approach was adopted to assess as many estuaries as possible within the available budgetary framework. In selecting the level of Reserve (i.e. Intermediate, Rapid or Desktop) for various estuaries, systems were prioritised in terms of the degree to which they were already water stressed or had major future abstraction pressures. Their protected status or desired protected status as set out in the National Biodiversity Assessment 2011 (NBA 2011) (Van Niekerk and Turpie, 2012) was also taken into account. Using this rating system, the Goukou, Gouritz and Duiwenhoks estuaries showed highest priority (best attainable: Intermediate level) followed by the Klein Brak and Wilderness estuaries (best attainable: Rapid level). The Hartenbos, Blinde, Piesang, Groot (Wes) and Bloukrans estuaries clustered as the lowest rated systems (best attainable: Desktop assessment). The preliminary Reserve determination on the Hartenbos, Blinde, Piesang, Groot (Wes) and Bloukrans estuaries study is summarised below:

ESTUARY	ECOCLASSIFICATION				RECOMMENDED MITIGATION MEASURES											
					Water			Land-use and development						Fisheries		
	Present Ecological Status	Importance	Protection Status	Recommended Ecological Category	Restore base flows	Restore Floods	Improve Water Quality	Restore connectivity/ hydrological functioning	Improve mouth management	Rehabilitate riparian areas/ wetlands	Remove alien vegetation	Implement cattle exclusion zone	Control human disturbance of birds	Important nurseries	Remove/reduce fishing pressure/ bait collection	Remove alien fish
Blinde	C	3	1	C	●		●									
Hartenbos	D	4	1	C	●	●	●			●						
Piesang	D	4	5	B/C	●		●		●		●			●		
Groot (Wes)	B	4	5	A	●										●	
Bloukrans	A	3	5	A												

Preliminary Reserve determination studies have been conducted previously on a number of other estuaries in the Gouritz WMA, done as either a Rapid or Desktop level assessment. These were:

- *Maalgate*
- *Gwaing*
- *Kaaimans*
- *Goukamma*
- *Noetsie*
- *Keurbooms*
- *Matjies*

Being Rapid or Desktop assessments, Ecological Specifications (EcoSpecs) and monitoring programmes were not provided for those systems as it was not a requirement at the time. This study therefore also provides a preliminary list of EcoSpecs for these systems.

Finally, a generic baseline and long-term monitoring programme is provided that can be applied in all the estuaries assessed as part of this Desktop assessment, as well as those for which baseline and long-term monitoring programmes have not been provided previously. These need to be conducted to improve the confidence of the Ecological Water Requirement (EWR) in future studies, as well as to assess compliance with EcoSpecs. The recommended execution of these monitoring programmes should be undertaken in collaboration with various responsible departments in Department of Water and Sanitation (DWS), as well as other national and provincial departments and institutions responsible for estuarine resource management such as Department of Agriculture, Forestry and Fisheries (DAFF), Department of Environmental Affairs (DEA: Oceans and Coasts), South African National Biodiversity Institute (SANBI), CapeNature, SANParks, as well as relevant municipal authorities. It is recommended that the estuarine management planning process and the associated institutional structures (as required under the Integrated Coastal Management Act of 2008) be used as mechanisms through which to facilitate the implementation these interventions.

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ACRONYMS AND ABBREVIATIONS

BAS	Best Attainable State
CSIR	Centre of Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphate
DO	Dissolved Oxygen
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category / Electrical Conductivity
EcoSpecs	Ecological Specifications
EFZ	Estuary Functional Zone
EHI	Estuarine Health Index
EIS	Estuarine Importance Score
EWR	Ecological Water Requirement
GRDS	Gouritz Reserve Determination Study
MAR	Mean Annual Runoff
MSL	Mean Sea Level
NMMU	Nelson Mandela Metropolitan University
NBA	National Biodiversity Assessment
NBA 2011	National Biodiversity Assessment 2011
NTU	Nephelometric Turbidity Units
NWA	National Water Act (1998)
ORDS	Outeniqua Reserve Determination Study
PES	Present Ecological Status
RDM	Resource Directed Measures
REC	Recommended Ecological Category
REI	River Estuary Interface
SANBI	South African National Biodiversity Institute
SC&A	Scherman Colloty & Associates cc
TPCs	Thresholds of Potential Concern
UNEP	United Nations Environmental Programme
WIO	Western Indian Ocean
WMA	Water Management Area
WRC	Water Research Commission
WWTW	Waste Water Treatment Works

1 INTRODUCTION

1.1 ECOLOGICAL WATER REQUIREMENT METHOD FOR ESTUARIES

Methods to determine the Environmental Water Requirement (EWR) of estuaries were established soon after the promulgation of the National Water Act (No. 36 of 1998) (NWA). The so-called "Preliminary Reserve Method" involves setting a Recommended Ecological Category (REC) (i.e. desired state), recommended Ecological Reserve (i.e. flow allocation to achieve the desired state) and Ecological Specifications (EcoSpecs) for a resource on the basis of its present health status and its ecological importance. The method follows a generic methodology which can be carried out at different levels (e.g. Rapid, Intermediate or Comprehensive). The official method for estuaries (Version 2) is documented in DWAF (2008). Currently a Version 3 of the method is in preparation as part of a Water Research Commission (WRC) study (Turpie *et al*., in prep.). Pending the official approval of Version 3 by the Department of Water and Sanitation (DWS), Version 2 is still applied in this study (DWAF, 2008), but considers obvious improvements proposed in Version 3. Currently, the official suite of "Preliminary Reserve Methods" for estuaries does not include a Desktop assessment method. However, a Desktop approach for assessing estuary health in data-poor environments was recently applied successfully in the National Biodiversity Assessment 2011 (NBA 2011) (Van Niekerk and Turpie, 2012). This method has since been refined in a WRC study (Van Niekerk *et al.*, 2014) and was also applied in this Gouritz Reserve Determination Study (GRDS), where considered appropriate.

For management and improved governance reasons, South Africa's 19 water management areas have been consolidated into nine (9) WMAs. The Gouritz WMA (previously WMA16) now forms part of the Breede WMA (WMA8) and is known as the Breede-Gouritz WMA. It will be governed by the Breede-Gouritz Catchment Management Agency (CMA).

Within the time and budgetary constraints it was not possible to conduct the preliminary reserve determination studies on the estuaries of the Gouritz Water Management Area (WMA) at a high confidence. Instead a "best attainable" approach was adopted to assess as many estuaries as possible within the available budgetary framework. In selecting the level of Reserve (i.e. Intermediate, Rapid or Desktop) for various estuaries, systems were prioritised in terms of the degree to which they were already water stressed or had major future abstraction pressures. Also, their protected status or desired protected status (NBA 2011) was taken into account. Using this rating system, the Goukou, Gouritz and Duiwenhoks estuaries showed highest priority (best attainable: Intermediate level) followed by the Klein Brak and Wilderness estuaries (best attainable: Rapid level). The Hartenbos, Blinde, Piesang, Groot (Wes) and Bloukrans estuaries clustered as the lowest rated systems (best attainable: Desktop assessment). The **Hartenbos, Blinde, Piesang, Groot (Wes) and Bloukrans** estuaries clustered as the lowest rated systems (best attainable: Desktop assessment). This report presents the Desktop assessment studies.

The official EWR methods for estuaries do not provide for a Desktop assessment of the preliminary reserve. However, a Desktop assessment method for South African estuaries was recently developed as part of a WRC project (Van Niekerk *et al.*, 2014) which was applied in this study. The

Desktop approach (simplified version of the official "Ecological Reserve Method" for estuaries) was applied as follows for each estuary:

Step 1: Initiate study by defining the study area, project team and level of study (confirmed in the GRDS **Inception Report** of this study; DWA, 2013).

Step 2: Delineate the geographical boundaries of the resource units (confirmed in the GRDS **Delineation Report** of this study; DWA, 2014).

Step 3a: Determine the **Present Ecological Status (PES)** of resource health (water quantity, water quality, habitat and biota) assessed in terms of the degree of similarity to the reference condition (referring to natural, un-impacted characteristics of a water resource, and must represent a stable baseline based on expert judgement in conjunction with local knowledge and historical data). An Estuarine Health Index (EHI) is used (**Table 1.1**).

Table 1.1 Estuarine Health Index (EHI) scoring system

Variable	Score	Weight	Weighted score
Hydrology	…	25	…
Hydrodynamics and mouth condition	…	25	…
Water quality	…	25	…
Physical habitat alteration	…	25	…
Habitat health score			**…**
Microalgae	…	20	…
Macrophytes	…	20	…
Invertebrates	…	20	…
Fish	…	20	…
Birds	…	20	…
Biotic health score			**…**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)			**…**

In the case of Desktop assessment studies (selected as best attainable option in data-poor environments) the EHI scoring of the various variables is based on selected "proxy data" and/or expert judgement.

The EHI score, in turn, corresponds to an Ecological Category that describes the health using six categories, ranging from natural (A) to critically modified (F) (**Table 1.2**). The A to F scale represents a continuum, where the boundaries between categories are conceptual points along the continuum. To reflect this, straddling categories (+/- 3 from the category scoring range) were therefore introduced in this study, denoted by A/B, B/C, C/D, and so on.

Table 1.2 Translation of EHI scores into ecological categories

EHI score	PES	General description
91 – 100	A	**Unmodified,** or approximates natural condition; the natural abiotic template should not be modified. The characteristics of the resource should be determined by unmodified natural disturbance regimes. There should be no human induced risks to the abiotic and biotic maintenance of the resource. The supply capacity of the resource will not be used
76 – 90	B	**Largely natural with few modifications**. A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged. Only a small risk of modifying the natural abiotic template and exceeding the resource base should not be allowed. Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities may be slightly higher than expected under natural conditions, the resilience and adaptability of biota must not be compromised. The impact of acute disturbances must be totally mitigated by the presence of sufficient refuge areas.
61 – 75	C	**Moderately modified**. A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. A moderate risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the wellbeing and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. However, the impact of local and acute disturbances must at least be partly mitigated by the presence of sufficient refuge areas.
41 – 60	D	**Largely modified**. A large loss of natural habitat, biota and basic ecosystem functions has occurred. Large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risk to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assume pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by refuge areas.
21 – 40	E	**Seriously modified**. The loss of natural habitat, biota and basic ecosystem functions is extensive.
0 – 20	F	**Critically modified**. Modifications have reached a critical level and the biotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible

Step 3b: Determine the **Estuary Importance Score (EIS)** that takes into account the size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary. The EIS takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account (**Table 1.3**). Biodiversity importance is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. These importance scores ideally refer to the system in its present state. The scores have been determined for all South African estuaries (Turpie and Clark, 2007). The Estuary Importance Scores are then translated into an importance rating (**Table 1.4**).

Table 1.3 Estuary Importance scoring system

Criterion	Score	Weight	Weighted score
Estuary size	…	15	…
Zonal rarity type	…	10	…
Habitat diversity	…	25	…
Biodiversity importance	…	25	…
Functional importance	…	25	…
Weighted Estuary Importance Score			**…**

Table 1.4 Estuarine Importance rating system

EIS	Importance rating
81 – 100	Highly important
61 – 80	Important
0 – 60	Of low to average importance

Step 3b: Set the **Recommended Ecological Category (REC)** which is derived from the PES and EIS (or the protection status allocated to a specific estuary) (**Table 1.5**).

Table 1.5 Guidelines to assign REC based on protection status and importance, as well as PES of estuary

Protection status and importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to, and maintained, in the best possible state of health.
Desired protected area (based on complementarity)		
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B category.
Important	PES + 1, min C	Important estuaries should be in an A, B or C category.
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D category.

* BAS = Best Attainable State

An estuary cannot be allocated an REC below a category “D”. Therefore systems with a PES in categories ‘E’ or ‘F’ needs to be managed towards achieving at least a REC of “D”.

Step 4: Estimate (% of Mean Annual Runoff [MAR]) the recommended **Ecological Water Requirements** by providing an approximate estimate of water that would still be available from this catchment without detrimentally impacting on the REC (where appropriate).

Step 5: Recommend **Ecological Specifications (EcoSpecs)** for the REC.

Preliminary EWR studies have been conducted previously on a number of other estuaries in the Gouritz WMA, done as either a Rapid or Desktop level assessment. These were:

- Maalgate
- Gwaing
- Kaaimans
- Goukamma
- Noetsie
- Keurbooms
- Matjies

Being Rapid or Desktop assessments, EcoSpecs and monitoring programmes were not provided for these systems. This study therefore also provides a preliminary list of EcoSpecs for these systems.

Finally, a **generic baseline and long-term monitoring programme** is provided that can be applied in all the estuaries assessed as part of this Desktop assessment, as well as those for which baseline and long-term monitoring programmes have not been previously provided. These need to be conducted to improve the confidence of the EWR in future studies, as well as to assess compliance with EcoSpecs.

1.2 DEFINITION OF CONFIDENCE LEVELS

The level of available historical data in combination with the level of effort expended during the assessment, determines the level of confidence of the study. Criteria for the confidence levels attached to statements in this study are:

Confidence level	Situation	Expressed as percentage
Very low	No data available for the estuary or similar estuaries	(i.e. < 40% certain)
Low	Limited data available	40 – 60% certainty
Medium	Reasonable data available	60 – 80% certainty
High	Good data available	> 80% certainty

In the case of this Desktop assessment, confidence levels fall in the “very low” to “low” categories.

1.3 SPECIALIST TEAM

The following specialists comprised the core team for this study:

Specialist	Affiliation	Area of responsibility
Dr S Taljaard	CSIR, Stellenbosch	Project co-ordinator/Water quality
Ms L van Niekerk	CSIR, Stellenbosch	Hydrodynamics
Mr A K Theron	CSIR, Stellenbosch	Sediment dynamics, abiotic morphology
Mr P Huizinga	Private Consultant	Hydrodynamics (advisory role)
Dr G Snow	Nelson Mandela Metropolitan University	Microalgae

Specialist	Affiliation	Area of responsibility
Prof J Adams	Nelson Mandela Metropolitan University	Macrophytes
Prof T Wooldridge	Nelson Mandela Metropolitan University	Invertebrates
Dr S Lamberth	DAFF	Fish
Dr J Turpie	Anchor Environmental Consultants	Birds

1.4 ASSUMPTIONS AND LIMITATIONS FOR THIS STUDY

The following assumptions and limitations should be taken into account:

- The accuracy and confidence of an Estuarine Ecological Water Requirements study is strongly dependant on the **quality of the simulated hydrology**. The overall confidence in the hydrology supplied for the Desktop assessment is very low (< 40).
- The official EWR methods for estuaries do not provide for a Desktop assessment of the preliminary reserve. However, a Desktop assessment method for South African estuaries was recently developed as part of a WRC project (Van Niekerk *et al.,* 2014) which was applied in this study.
- This Desktop assessment cannot be used for individual licensing. At least a Rapid level assessment is required for individual licensing for small impacts in unstressed catchments of low importance and sensitivity. For individual licensing in important, unstressed systems an Intermediate level assessment is required, while a comprehensive level assessment is required for individual licensing for large impacts in any catchment (e.g. dams), as well as small or large impacts in very important and/or sensitive catchments (DWAF, 2008).

1.5 OUTLINE OF THIS REPORT

This section (**Section 1**) provides an overview of EWR methods applied in this study, confidence of the study, study team, as well as a summary of the content of this report. **Sections 2** to **6** present the Desktop assessment for the Blinde, Hartenbos, Piesang, Groot (Wes) and Bloukrans estuaries, respectively. Each section includes:

- Catchment characteristics;
- Geographical boundaries of the estuary;
- Estuary characteristics;
- Assessment of PES, using the EHI;
- Estuary importance and conservation status; and
- REC, discussion on ecological flow requirements and the EcoSpecs.

Section 7 presents a generic baseline and long-term monitoring programme for all the estuaries discussed in this report, as well as systems that were assessed previously but for which such programmes were not provided. References are listed in **Section 8**.

Appendix A presents an overview on the estuarine habitat of the systems included in this Desktop assessment study, while **Appendix B** lists the EcoSpecs for the other estuaries that were assessed previously (as part of previous Outeniqua Reserve Determination Study (ORDS)) but for which EcoSpecs were not provided. Finally, **Appendix C** presents the Comments and Response Register.

2 BLINDE ESTUARY

2.1 CATCHMENT CHARACTERISTICS

The dominant land-use types in the catchment are (**Figure 2.1**):

- 40% (green) cultivated, temporary, commercial dryland;
- 19% (yellow-green) planted grassland;
- 16% (light brown) thicket, bushland, bush clumps and high fynbos;
- 11% (grey) urban area; and
- 11% (orange brown) shrubland and low fynbos.

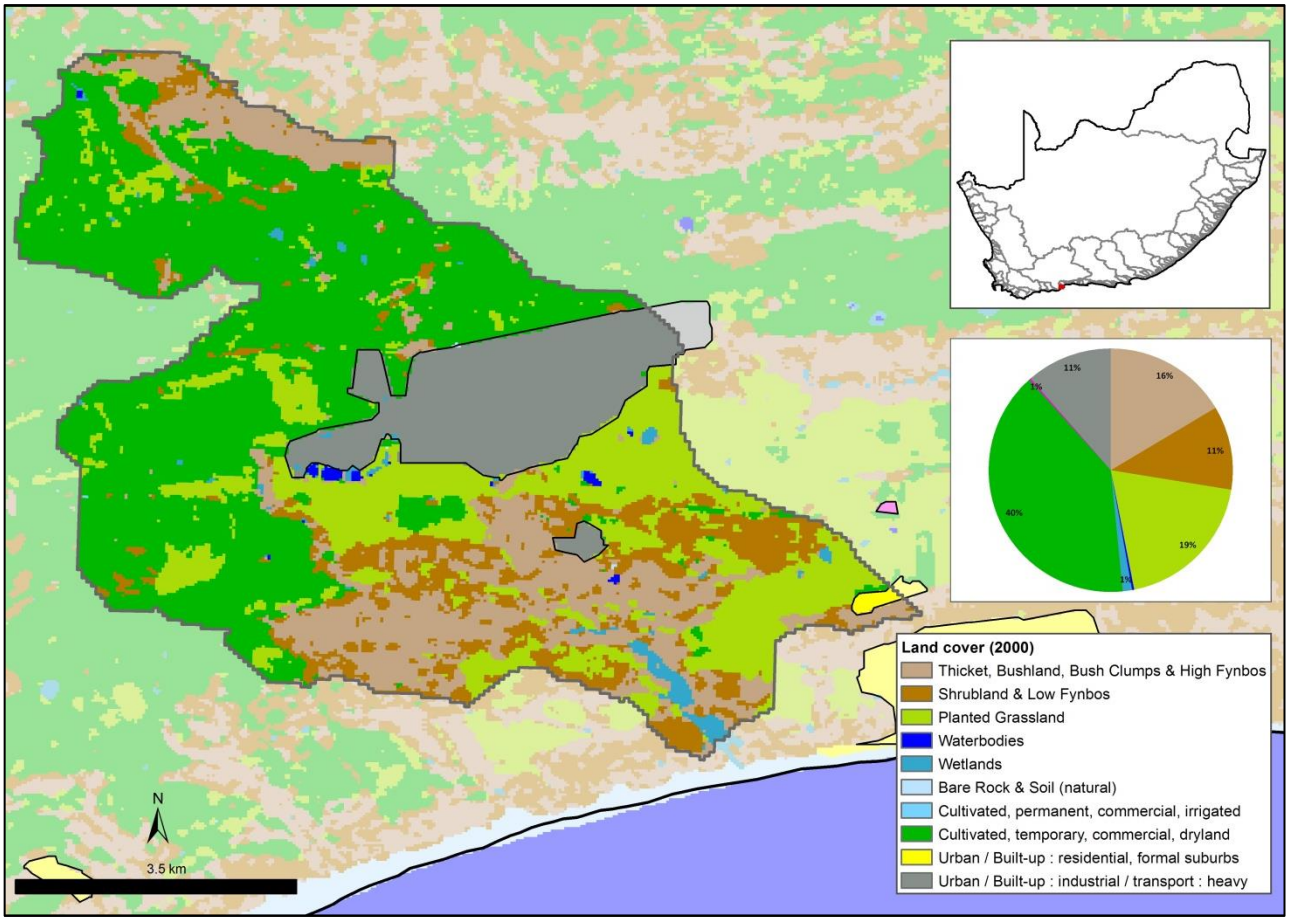

Figure 2.1 Catchment of the Blinde Estuary, as well as dominant land-use distribution

The Blinde catchment receives rainfall throughout the year, with peaks in autumn and spring. The MAR to the Blinde Estuary was 1.3 million m^3 under the Reference Condition (**Table 2.1**). This has been reduced by 30% to 0.9 million m^3 under the Present State. A broad assessment of the changes in runoff to the estuary shows both a reduction in low and high flow months with a related increase in the low flow period.

Table 2.1 Summary of hydrological parameters relevant to inflow to the Blinde Estuary

Parameter	Summary of change in flow parameters
Reference MAR (million m^3/a)	1.3
Present MAR (million m^3/a)	0.9
% MAR similarity	70
% Base flow similarity	0
% Median flow similarity	0
Change in high flow duration	Yes
Change in base flow variance	
Change in low flow duration	Yes
Shift in high flow onset month	

2.2 ESTUARY CHARACTERISTICS

The Blinde Estuary is a relatively small (1.75 ha), perched system that drains a steep-sided incised valley leading to a predominantly closed mouth (**Table 2.2**, for more details refer to **Appendix A**). The estuary remains closed for most of the year except during a flood, but wash-over from the sea can occur during high tides or storm events.

Table 2.2 Summary of the Blinde Estuary habitat features

Habitat type	Area (ha)
Supratidal salt marsh	0
Intertidal salt marsh	0
Reeds and sedges	0.04
Swamp forest	0
Mangroves	0
Sand/mud banks	0.05
Submerged macrophytes	0
Channel	1.66
Rocks	0
TOTAL	1.75

2.3 GEOGRAPHICAL BOUNDARIES

The geographical boundaries for the Blinde Estuary (**Figure 2.2**) are defined as follows:

Downstream boundary:	Estuary mouth 34°12'37.65"S, 22° 0'46.11"
Upstream boundary:	34°12'20.27"S, 22° 0'32.43"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

Figure 2.2 Geographical boundaries of the Blinde Estuary

2.4 PRESENT ECOLOGICAL STATUS

The individual present health scores for the various abiotic and biotic components are used to determine the PES of the Blinde Estuary, in accordance with the EHI as presented in **Table 2.3**.

Table 2.3 Blinde Estuary: Present Ecological Status

Variable	Weight	Score
Hydrology	25	60
Hydrodynamics and mouth condition	25	80
Water quality	25	62
Physical habitat alteration	25	90
Habitat health score		**73**
Microalgae	20	64
Macrophytes	20	85
Invertebrates	20	60
Fish	20	35
Birds	20	90
Biotic health score		**67**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**70**
PRESENT ECOLOGICAL STATUS (PES)		**C**
OVERALL CONFIDENCE		**Very Low**

The EHI score for the Blinde Estuary is 73 thus a **PES of Category C** (**Table 1.2**). However, the system is on a negative trajectory of change related to key pressures in the catchment, including:

- Reduced water quality as a result of industrial activities in the catchment;
- Flow modification (high and low flows reduced), with a related shift in the onset of the high flow period and increase in the duration of the low flow period; and
- Limited bait collection and fishing.

2.5 ESTUARY IMPORTANCE AND CONSERVATION STATUS

Referring to the estuarine importance rating system (DWAF, 2008; Turpie and Clark, 2007), the importance score of the Blinde Estuary – a score of 27 – indicates that the estuary is of **"Average Importance"** (**Table 2.4**).

Table 2.4 Blinde Estuary: Estuary importance scores and protection status

ESTUARY IMPORTANCE	
Size	10
Habitat importance	10
Zonal type rarity	10
Biodiversity importance	77.5
ESTUARY IMPORTANCE SCORE	**27**
RATING	**Average Importance**

PROTECTION STATUS	
National Estuary Biodiversity Plan	Not included

The system does not form part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan for the National Biodiversity Assessment (Turpie *et al.*, 2012). Loggerhead turtles, which are associated with freshwater seeps on beaches, are known to nest at Blinde Estuary, indicating the importance of freshwater input to this system.

2.6 RECOMMENDATIONS

2.6.1 Recommended Ecological Category

Applying the guidelines for the determination of the REC (**Table 1.5**), the Blinde Estuary should be maintained in a **Category C** (maintain PES). To mitigate the negative trajectory of change, the deterioration of water quality as a result of industrial activities in the catchment should be investigated, as well as the degree to which base flow can be returned to the system.

2.6.2 Recommendation on Ecological Flow

Flow modification has already resulted in a shift in the onset of the high flow period and an increase in the duration of the low flow period. The present flow distribution (MAR_P = 0.9 million m^3) should therefore be maintained with no additional base flow abstraction occurring. Effort to increase base flow should be investigated as a contributing mitigating measure to reverse the negative trajectory of change.

2.6.3 Ecological Specifications

The EcoSpecs and associated TPCs representative of a Category C for the Blinde Estuary are presented in **Table 2.5**.

Table 2.5 EcoSpecs and Thresholds of Potential Concern for the Blinde Estuary (Category C)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain flow regime (small system needs most flows)	▪ MAR does not vary by more than 10% from present ▪ Floods (indicated by 1:10 year event) do not reduce by more than 5% from present ▪ Base flows do not differ by more than 5% from present
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state increase/decrease by 10% from present ▪ Presence of semi-closed mouth state with continuous outflow to sea. ▪ Average water depth < 0.5 m (to be confirmed by monitoring) ▪ Rate of change in water level > 30% from present
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ Dissolved inorganic (DIN)/dissolved inorganic phosphate (DIP) concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Salinity > 20 (expected range 5-15) ▪ Dissolved oxygen (DO) < 5 mg/ℓ in estuary ▪ Turbidity > 10 NTU in low flow ▪ Secchi depth: to bottom ▪ DIN > 100 µg/ℓ (average) ▪ DIP > 20 µg/ℓ (average) ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per Western Indian Ocean (WIO) Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel change from 30% of baseline (to be determined) (system expected to experience significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain low/median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton> 3.5 µg/ℓ (median) ▪ Benthic microalgae > 23 mg/m^2 (median) ▪ Phytoplankton > 20 µg/ℓ and/or cell density >10 000 cells/ml (once-off)
Macrophytes	▪ Maintain distribution of macrophyte habitats ▪ Prevent the spread of reeds into open water ▪ Prevent an increase in nutrients and macroalgal blooms ▪ Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone	▪ 20% change in the macrophyte area. (Reeds currently cover 0.04 ha.) ▪ Reeds occupy > 0.5 ha ▪ Macroalgal blooms cover > 50% of the open water area ▪ Presence of invasive aquatic macrophytes e.g. *Azolla*, water hyacinth ▪ Invasive trees cover > 50% of riparian zone
Invertebrates	▪ Establish presence/absence of sand prawn *Callichirus kraus*si on sand banks in lower estuary ▪ Establish presence/absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%

Ecological component	EcoSpecs	Thresholds of Potential Concern
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically, assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (5-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least two species (e.g. *G.aestuaria, & Hyporamphus capensis).* Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus, Lichia amia*). REI (River Estuary Interface) species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 10% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species <1%
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

3 HARTENBOS ESTUARY

3.1 CATCHMENT CHARACTERISTICS

The dominant land-use types in the catchment are (**Figure 3.1**):

- 51% (green) cultivated, temporary, commercial, irrigated land;
- 22% (light brown) thicket, bushland, bush clumps and high fynbos;
- 16% (light orange-brown) shrubland and low fynbos;
- 5% (light green) planted grassland; and
- 1% (pink) urban.

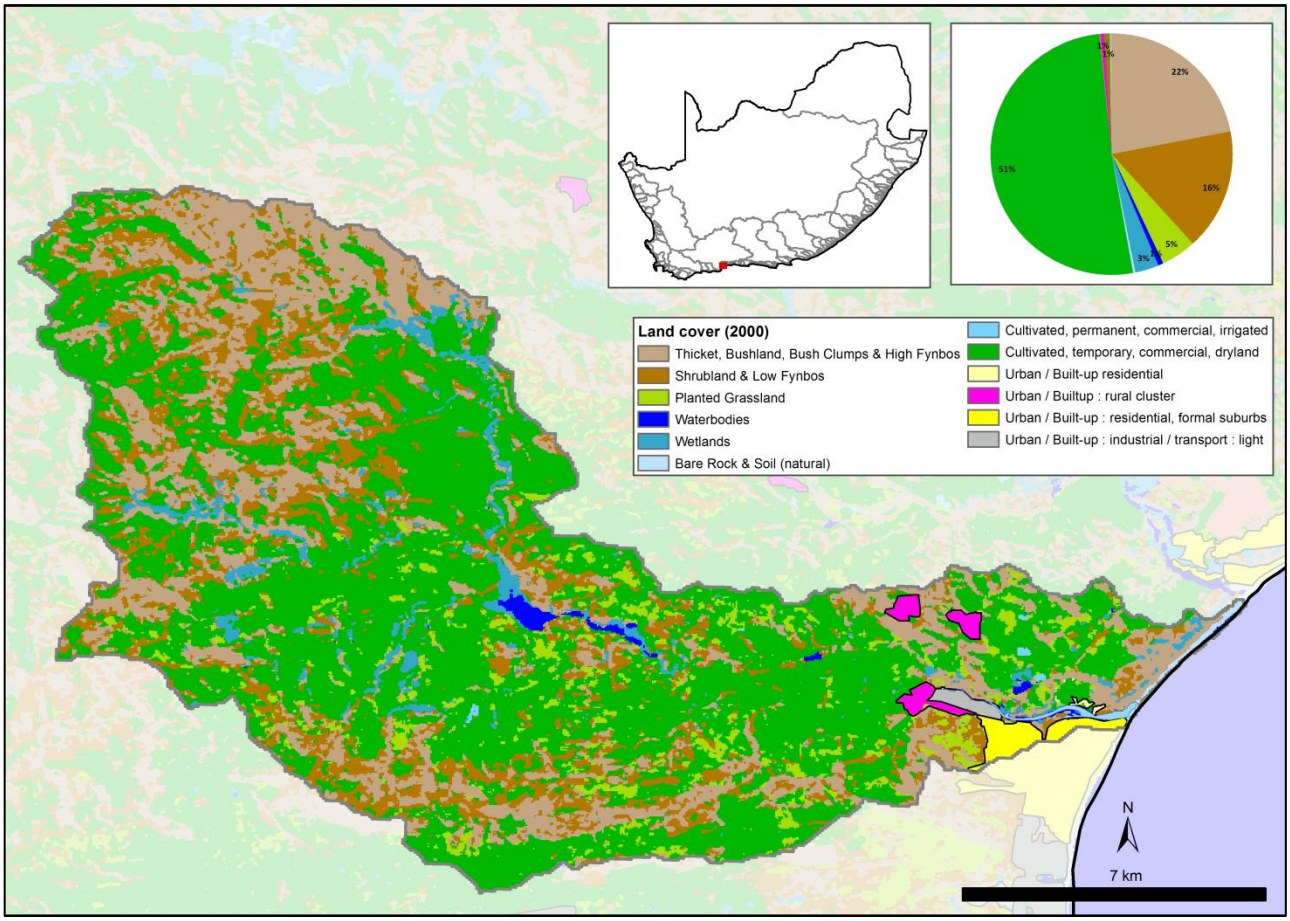

Figure 3.1 Catchment of the Hartenbos Estuary, as well as dominant land-use distribution

The Hartenbos catchment receives rainfall throughout the year, with peaks in autumn and spring. The MAR to the Hartenbos Estuary was 4.6 million m^3 under the Reference Condition. This has been reduced by 39% to 2.8 million m^3 under the Present State (**Table 3.1**). The major obstruction in the catchment is the Hartebeeskuil Dam constructed in 1970. Its capacity is 15.53 million m^3 and is situated about 12 km upstream of the estuary. The dam totally impounds water from the upper reaches.

A broad assessment of the changes in runoff to the estuary shows both a reduction in low and high flow months with a related increase in the low flow period.

Table 3.1 Summary of hydrological parameters relevant to inflow to the Hartenbos Estuary

Parameter	Summary of change in flow parameters
Reference MAR (million m^3/a)	4.6
Present MAR (million m^3/a)	2.8
% MAR similarity	61
% Base flow similarity	63
% Median flow similarity	50
Change in high flow duration	Yes
Change in base flow variance	
Change in low flow duration	Yes
Shift in high flow onset month	

3.2 ESTUARY CHARACTERISTICS

The Hartenbos Estuary is a small- to medium-sized (40 ha open water) temporarily open/closed estuary (**Table 3.2**, refer to **Appendix A** for more details). Since the construction of the Hartebeeskuil Dam, the estuary mouth has remained closed for extended periods of time. Further, the related reduction in floods have reduced the scouring forces necessary to keep the main channels and mouth area free of sand and silt, leading to infilling and loss of habitat.

Table 3.2 Summary of the Hartenbos Estuary habitat features

Habitat	Area (ha) in 1942	Area (ha) in 2013
Floodplain agriculture	96	91
Floodplain undisturbed	66	73
Supratidal salt marsh	29	35
Intertidal salt marsh	-	-
Submerged macrophytes	-	-
Reeds & sedges	2	1
Mud and sandbanks	10	1
Open water surface area	26	38
Total area	**229**	**239**

3.3 GEOGRAPHICAL BOUNDARIES

The geographical boundaries for the Hartenbos Estuary (**Figure 3.2**) are defined as follows:

Downstream boundary:	Estuary mouth 34° 7'0.66"S, 22° 7'27.20"E
Upstream boundary:	34° 6'42.45"S, 22° 5'3.95"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

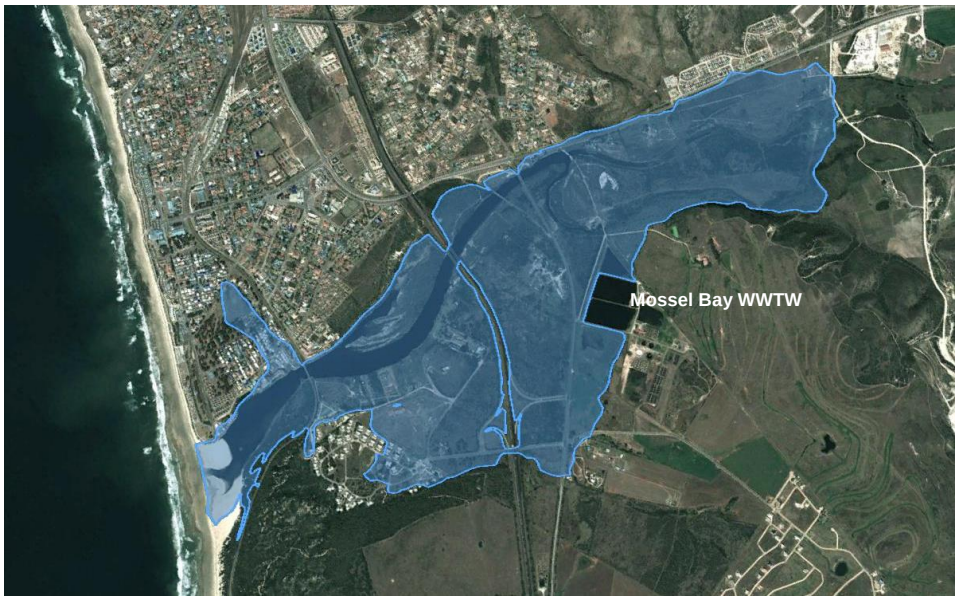

Figure 3.2 Geographical boundaries of the Hartenbos Estuary

3.4 PRESENT ECOLOGICAL STATUS

The individual present health scores for the various abiotic and biotic components are used to determine the PES of the Hartenbos Estuary, in accordance with the EHI as presented in **Table 3.3**.

Table 3.3 Hartenbos Estuary: Present Ecological Status

Variable	Weight	Score
Hydrology	25	62
Hydrodynamics and mouth condition	25	50
Water quality	25	42
Physical habitat alteration	25	40
Habitat health score		**49**
Microalgae	20	46
Macrophytes	20	55
Invertebrates	20	50
Fish	20	55
Birds	20	60

Variable	Weight	Score
Biotic health score		**53**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**51**
PRESENT ECOLOGICAL STATUS (PES)		**D**
OVERALL CONFIDENCE		**Very Low**

The EHI score for the Hartenbos Estuary is 51, thus a **PES of Category D** (**Table 1.2**), but the system is on a **negative trajectory of change** as a result of various pressures including:

- Dam construction has resulted in a reduction in base flow and floods to the system, with a shift in the onset of the high flow period and an increase in the duration of the low flow period;
- Artificial breaching;
- Loss of tidal flows and habitat as result of bridge construction (e.g. old N2, railway bridge);
- Infilling of estuary channel and mouth area as a result of loss of floods and artificial breaching;
- A significant reduction in water quality as a result of the Mossel Bay WWTW discharge and urban runoff;
- Development in the EFZ;
- Alien vegetation;
- Limited bait collection and fishing effort; and
- Human disturbance (which influences bird abundance).

3.5 ESTUARY IMPORTANCE AND CONSERVATION STATUS

Referring to the estuarine importance rating system (DWAF, 2008; Turpie and Clark, 2007), the importance score of the Hartenbos Estuary – a score of 66 – indicates that the estuary is of **"Average Importance"** (**Table 3.4**).

The system does not form part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan for the National Biodiversity Assessment (Turpie *et al.*, 2013).

Table 3.4 Estuarine Importance scores and protection status for the Hartenbos Estuary

ESTUARY IMPORTANCE	
Size	70
Habitat importance	60
Zonal type rarity	10
Biodiversity importance	86.5
ESTUARY IMPORTANCE SCORE	**66**
RATING	**Important**

PROTECTION STATUS	
National Estuary Biodiversity Plan	Not included

3.6 RECOMMENDATIONS

3.6.1 Recommended Ecological Category

Applying the guidelines for the determination of the REC (**Table 1.5**), the Hartenbos Estuary – as an "Important" system should at least be managed in a **Category C.** To mitigate the negative trajectory of change, significant improvement in the water quality of the system is required (linked to the Mossel Bay WWTW discharge). Also ways in which to increase base flow to the estuary should be investigated to restore connectivity with the marine environment. Improved mouth management and rehabilitation of riparian areas/wetlands will contribute to reversing the negative trajectory of change.

3.6.2 Recommendations on Ecological Flow

Dam construction has already resulted in a reduction in base flow and floods to the system, with a shift in the onset of the high flow period and an increase in the duration of the low flow period. The present flow regime (MAR_P = 2.8 million m^3) should therefore be maintained, as a minimum, but to reverse the negative trajectory of change in future, it is estimated that a significant quantity of the base flow will need to be returned to maintain a longer open mouth state during low flow periods.

3.6.3 Ecological Specifications

The EcoSpecs and associated TPCs representative of a Category C for the Hartenbos Estuary are presented in **Table 3.5**.

Table 3.5 EcoSpecs and Thresholds of Potential Concern for the Hartenbos Estuary (Category C)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain at least present day base flows (to be confirmed)	▪ MAR does not vary by more than 10% ▪ Floods (indicated by 1:10 year event) do not reduce by more than 5% from present ▪ Base flows do not increase by more than 50% from present
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state does not decrease by 10% from present ▪ Average water level in system > 10% from present ▪ Tidal amplitude (when open) < 20%
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause	▪ Average salinity along estuary decreases by 5 below baseline average (to be determined) ▪ DO < 5 mg/ℓ in estuary ▪ Turbidity > 20 NTU in low flow ▪ Secchi in fresher part: < 0.5 m ▪ DIN > 200 µg/ℓ average (to be confirmed) ▪ DIP > 50 µg/ℓ average (to be confirmed) ▪ Concentrations in water column exceed

Ecological component	EcoSpecs	Thresholds of Potential Concern
	exceedance of TPCs for biota	target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel changes from 30% of baseline (to be determined) (system expected to experience significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton > 8 µg/ℓ (median) ▪ Benthic microalgae > 42 mg/m^2 (median) ▪ Phytoplankton > 20 µg/ℓ and/or cell density > 10 000 cells/ml (once-off) ▪ Dinoflagellates, chlorophytes and/or cyanobacteria > 10% of relative abundance
Macrophytes	▪ Maintain distribution of macrophyte habitats ▪ Prevent the spread of reeds into open water ▪ Prevent an increase in nutrients and macroalgal blooms ▪ Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone. ▪ Maintain integrity of salt marsh	▪ 20% change in macrophyte area (Reeds currently cover 9 ha, saltmarsh 47 ha.) ▪ Macroalgal blooms cover > 50% of the open water area ▪ Presence of invasive aquatic macrophytes e.g. *Azolla*, water hyacinth ▪ Invasive plants cover > 10% of flood plain ▪ Increase in bare areas in salt marsh because of decrease in moisture and increase in salinity > 30% of salt marsh
Invertebrates	▪ Establish presence/absence of sand prawn *Callichirus kraus*si on sand banks in lower estuary ▪ Establish abundance of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%

Ecological component	EcoSpecs	Thresholds of Potential Concern
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically, assemblage should comprise: ▪ Ia estuarine residents (20-60%) ▪ Ib marine and estuarine breeders (10-30%) ▪ IIa obligate estuarine-dependent (20-40%) ▪ IIb estuarine associated species (5-20%) ▪ IIc marine opportunists (20-80%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least two species (e.g. *G.aestuaria, Hyporamphus capensis, Omobranchus woodii*). Category IIa obligate dependents should be well represented by large exploited species (i.e. *A. japonicus, L. lithognathus, P. commersonnii, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 20% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 20% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ IV indigenous fish < 1% ▪ V catadromous species < 1% ▪ Ia represented only by *G. aestuaria*. ▪ IIa exploited species in very low numbers or absent ▪ REI species represented only by *G. aestuaria*, *Myxus capensis* absent
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

4 PIESANG ESTUARY

4.1 CATCHMENT CHARACTERISTICS

The dominant land-use types in the catchment are (**Figure 4.1**):

- 28% (light brown) thicket, bushland, bush clumps and high fynbos;
- 26% (green) indigenous forest;
- 20% (light orange-brown) shrubland and low fynbos;
- 15% (light green) planted grassland; and
- 8% (pink, yellow) urban.

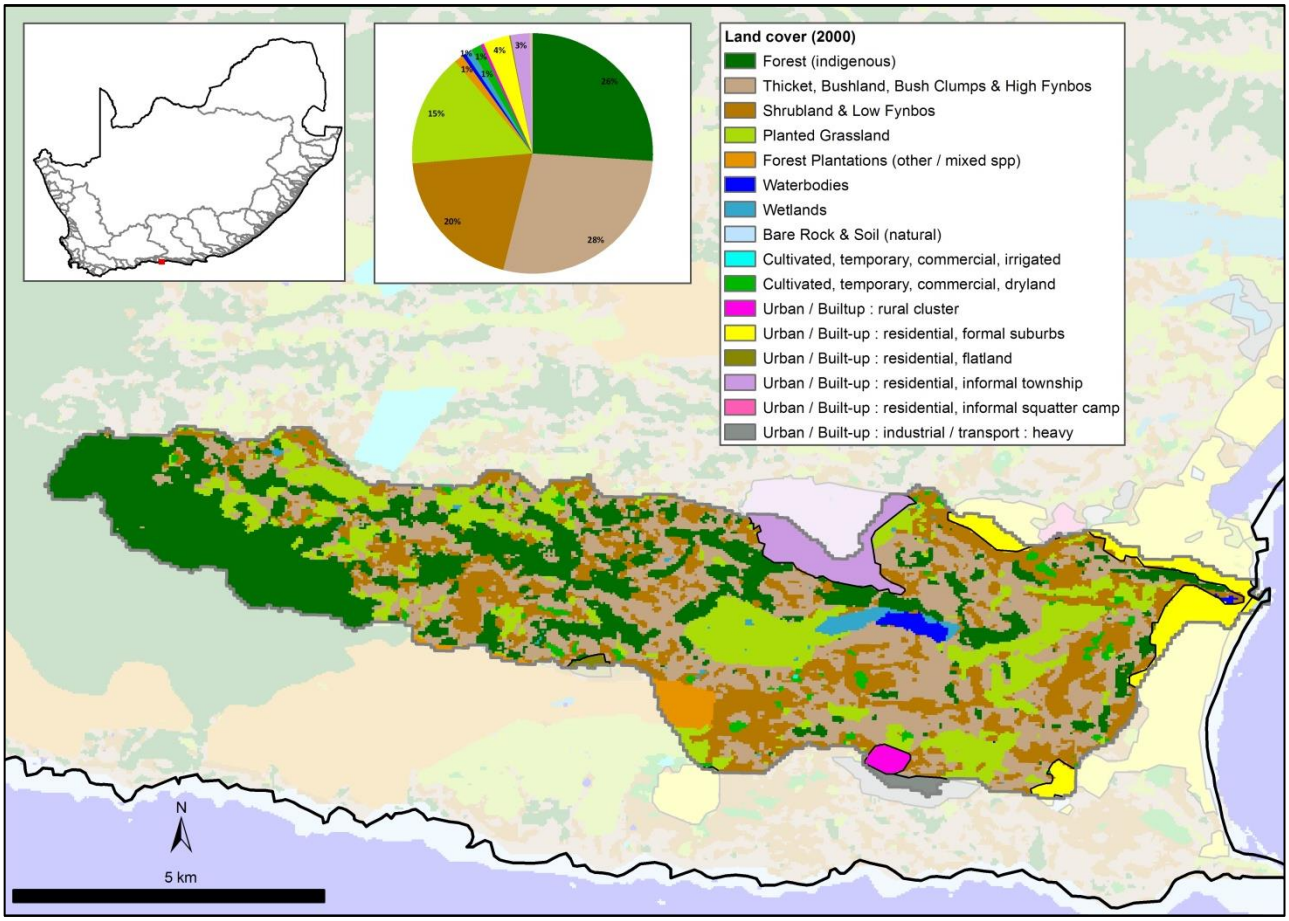

Figure 4.1 Catchment of the Piesang Estuary, as well as dominant land-use distribution

The Piesang catchment receives rainfall throughout the year, with peaks in autumn and spring. The MAR to the Piesang Estuary was 5.2 million m^3 under the Reference Condition (**Table 4.1**). This has been reduced by 34% to 3.4 million m^3 under the Present State due to abstractions in the catchment. A broad assessment of the changes in runoff to the estuary shows both a reduction in low and high flow months resulting in an increase in the low flow period.

Table 4.1 Summary of the hydrological change to the Piesang Estuary

Parameter	Summary of change in flow parameters
Reference MAR (million m^3/a)	5.2
Present MAR (million m^3/a)	3.4
% MAR similarity	66
% Base flow similarity	36
% Median flow similarity	55
Change in high flow duration	Yes
Change in base flow variance	
Change in low flow duration	Yes
Shift in high flow onset month	Yes

4.2 ESTUARY CHARACTERISTICS

The Piesang Estuary is a small- to medium-sized (92 ha) temporarily open/closed estuary (**Table 4.2**, see **Appendix A** for more detail). Extensive development occurs within the EFZ of the Piesang Estuary. More recently a reverse osmosis plant has started taking water directly from the Piesang Estuary leading to significant increases in its closed mouth state and a decline in water levels under the closed mouth state.

Table 4.2 Summary of the Piesang Estuary habitat features

Habitat type	Area (ha)
Supratidal salt marsh	0
Intertidal salt marsh	0
Reeds and sedges	3.14
Swamp forest	0
Mangroves	0
Sand/mud banks	80.6
Submerged macrophytes	0
Channel	8.5
Rocks	0
TOTAL	92.24

4.3 GEOGRAPHICAL BOUNDARIES

The geographical boundaries for the Piesang Estuary (**Figure 4.2**) are defined as follows:

Downstream boundary:	Estuary mouth 34° 3'37.62"S 23°22'43.85"E
Upstream boundary:	34° 3'44.46"S 23°21'21.04"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

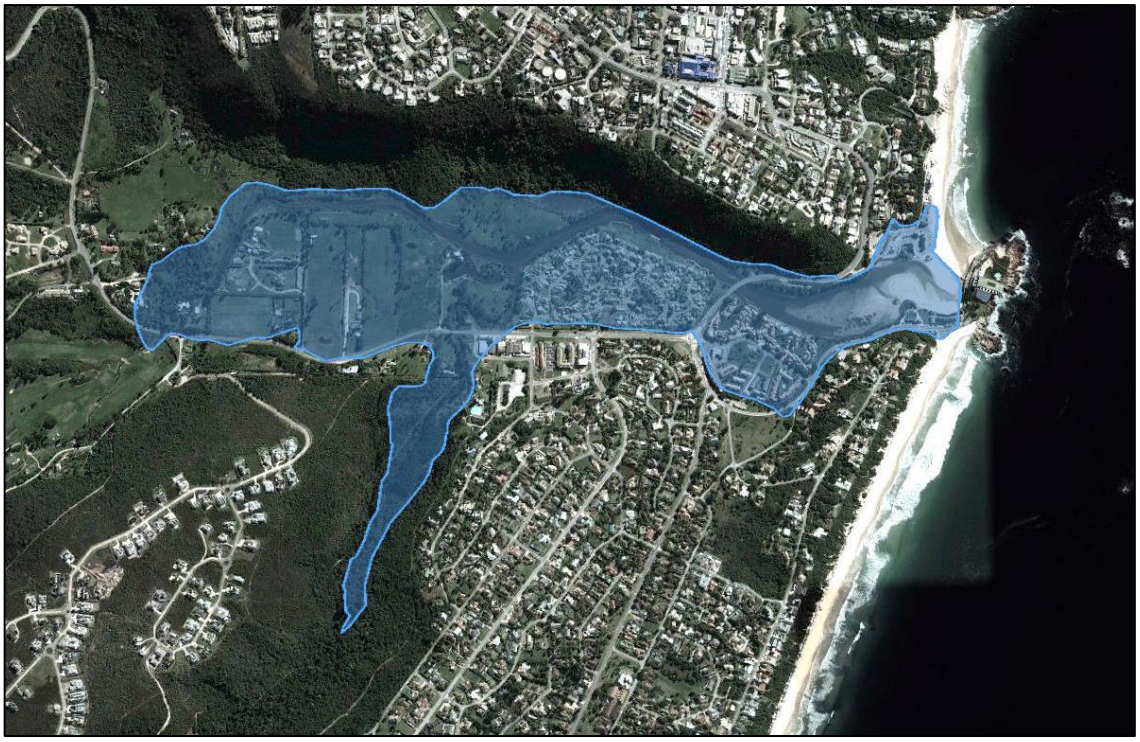

Figure 4.2 Geographical boundaries of the Piesang Estuary

4.4 PRESENT ECOLOGICAL STATUS

The individual present health scores for the various abiotic and biotic components are used to determine the PES of the Piesang Estuary, in accordance with the EHI as presented in **Table 4.3**.

Table 4.3 Piesang Estuary: Present Ecological Status

Variable	Weight	Score
Hydrology	25	48
Hydrodynamics and mouth condition	25	40
Water quality	25	59
Physical habitat alteration	25	50
Habitat health score		**49**
Microalgae	20	53
Macrophytes	20	50
Invertebrates	20	50
Fish	20	65
Birds	20	50
Biotic health score		**54**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**51**
PRESENT ECOLOGICAL STATUS (PES)		**D**
OVERALL CONFIDENCE		**Very Low**

The EHI score for the Piesang Estuary is 51 thus a **PES of Category D** (**Table 1.2**). The following key pressures are contributing factors to PES:

- A reduction in base flows and floods to the system, with a shift in the onset of the high flow period;
- Direct abstraction of water from the mouth region for the reverse osmosis plant causing increased mouth closure and low water levels;
- Loss of tidal flows and habitat as a result of bridge construction (e.g. old and new N2 bridge, railway bridge);
- A decline in water quality as a result of urban runoff;
- Significant development in the EFZ and related loss of habitat;
- Limited fishing effort; and
- Human disturbance (which influences bird abundance).

4.5 ESTUARY IMPORTANCE AND CONSERVATION STATUS

Referring to the estuarine importance rating system (DWAF, 2008; Turpie and Clark, 2007), the importance score of the Piesang Estuary – a score of 71 – indicates that the estuary is **"Important"** (**Table 4.4**). The estuary shows a very high diversity of fish for such a relatively small system and is considered an important supporting nursery area for surrounding estuaries, e.g. Keurbooms Estuary. The system also forms part of the core set of priority estuaries (i.e. desired protected area) in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan for the National Biodiversity Assessment (Turpie *et al*., 2013). The NBA 2011 (Van Niekerk and Turpie, 2012) recommends that the minimum Category for the Piesang Estuary be **partially protected**, and **that 50% of the estuary margin be undeveloped**.

Table 4.4 Estuarine Importance scores and protection status for the Piesang Estuary

ESTUARY IMPORTANCE	
Size	80
Habitat importance	80
Zonal type rarity	10
Biodiversity importance	72.5
ESTUARY IMPORTANCE SCORE	**71**
RATING	**Important**

PROTECTION STATUS	
National Estuary Biodiversity Plan	Partial protection

4.6 RECOMMENDATIONS

4.6.1 Recommended Ecological Category

Applying the guidelines for the determination of the REC (**Table 1.5**), the Piesang Estuary should be managed in a Category A or Best Attainable State (BAS) based on its protection status. However, due to its transformed state, a realistic BAS was set as REC, namely a **Category B/C.**

For the PES, the assessment of mouth state and water level was based on data gathered from the Piesang Estuary (2011-2012) when the desalination plant is in full operation (P Huizinga, *pers. comm*.). This data indicated that at full capacity the desalination plant withdraws water from the lower estuary to such low levels that the mouth of the estuary closes more frequently. This high level of abstraction contributes significantly to the PES of Category D. However, should direct abstraction from the estuary be reduced, it will contribute significantly towards improving the estuary to the REC. Further, improvement in water quality from adjacent urban areas should also be investigated, as well as the degree to which base flow can be returned to the system in low flow periods.

4.6.2 Recommendations of Ecological Flow

Reduced base flow into the Piesang Estuary is already contributing significantly to its modified health state. Therefore the present flow regime (MAR_P = 3.4 million m^3) should be maintained as a minimum. To improve the health of the system from the PES to the REC, additional base flow will be required in order to keep the mouth open for longer periods during the low flow season. This can be achieved, for example, by reduced abstraction for the reverse osmosis plant.

4.6.3 Ecological Specifications

The EcoSpecs and associated TPCs representative of a Category B/C for the Piesang Estuary are presented in **Table 5.2**.

Table 4.5 EcoSpecs and Thresholds of Potential Concern for the Piesang Estuary (Category B/C)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain present day base flow as a minimum (to be confirmed)	▪ MAR does not vary by more than 10% ▪ Floods (indicated by 1:10 year event) do not reduce by more than 5% from present. ▪ Base flows do not increase by more than 50% from present
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state increase by 10% from present ▪ Average water level in system > 10% from present ▪ Tidal amplitude (when open) < 20%

Ecological component	EcoSpecs	Thresholds of Potential Concern
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Salinity > 20 (expected range 10-20) ▪ Salinity < 5 (expected range 10-20) ▪ DO < 5 mg/ℓ in estuary ▪ Turbidity > 10 NTU in low flow ▪ Secchi: to bottom ▪ DIN > 100 µg/ℓ once-off ▪ DIP > 20 µg/ℓ once-off ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary changes from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel changes from 30% of baseline (to be determine) (system expected to experience significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton > 3.5 µg/ℓ (median) ▪ Benthic microalgae > 11 mg/m^2 (median) ▪ Phytoplankton > 20 µg/ℓ and/or cell density > 10 000 cells/ml (once-off)
Macrophytes	▪ Maintain distribution of macrophyte habitats ▪ Prevent an increase in nutrient input leading to macroalgal blooms ▪ Control the spread of invasive plants in the riparian zone	▪ Greater than 20 % change in the area covered by macrophytes (reeds and sedges currently cover 3.14 ha, submerged macrophytes and salt marsh present) ▪ Macroalgal blooms cover > 50% of the open water area during closed mouth conditions ▪ Invasive plants cover > 5% of total habitat
Invertebrates	▪ Maintain presence of sand prawn *Callichirus krauss*i on sand banks in lower estuary ▪ Maintain presence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ Populations deviate from average baselines (as determined in first three visits) by more 30%

Ecological component	EcoSpecs	Thresholds of Potential Concern
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically, assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (5-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least two species (e.g. *G.aestuaria, & Hyporamphus capensis.* Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 10% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species < 1%
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

5 GROOT (WES) ESTUARY

5.1 CATCHMENT CHARACTERISTICS

The dominant land-use types in the catchment are (**Figure 5.1**):

- 39% (light brown) thicket, bushland, bush clumps and high fynbos;
- 29% (green) indigenous forest;
- 19% (light orange-brown) shrubland and low fynbos; and
- 10% (orange) forest plantation.

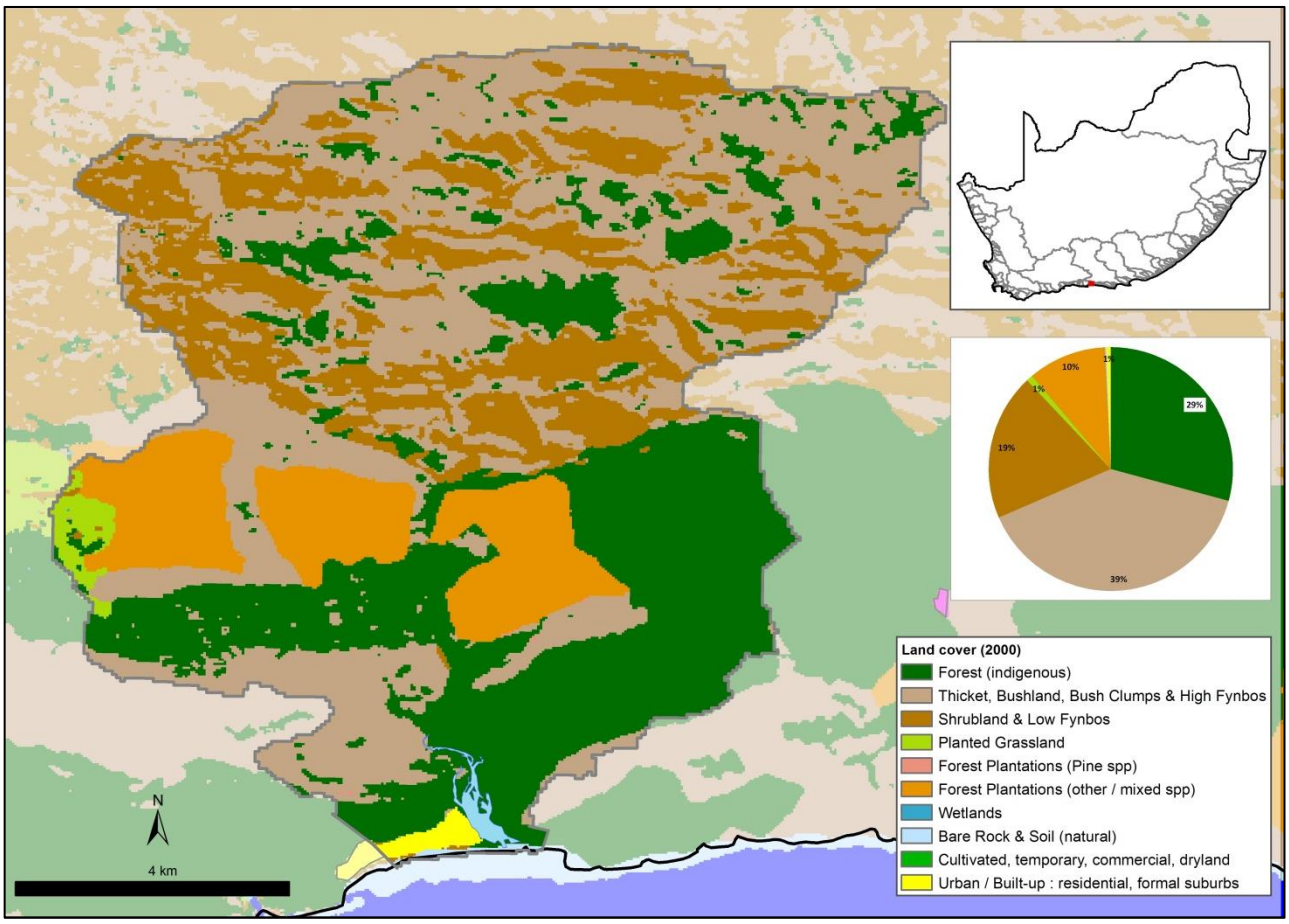

Figure 5.1 Catchment of the Groot (Wes) Estuary, as well as dominant land-use distribution

The Groot (Wes) catchment receives rainfall throughout the year, with peaks in autumn and spring. The MAR to the Groot (Wes) Estuary was 12.8 million m^3 under the Reference Condition. This has been reduced by 13% to 11.1 million m^3 under the Present State (**Table 5.1**). A broad assessment of the changes in runoff to the estuary shows both a reduction in low and high flow months with a related shift in the onset of the high flow period.

Table 5.1 Summary of the hydrological change to the Groot (Wes) Estuary

Parameter	Summary of change in flow parameters
Reference MAR (million m^3/a)	12.8
Present MAR (million m^3/a)	11.1
% MAR similarity	87
% Base flow similarity	61
% Median flow similarity	85
Change in high flow duration	
Change in base flow variance	
Change in low flow duration	
Shift in high flow onset month	Yes

5.2 ESTUARY CHARACTERISTICS

The Groot (Wes) Estuary is a small- to medium-sized (39 ha) temporarily open/closed estuary, entering the sea at Nature's Valley (**Table 5.2**, see **Appendix A** for more detail). Some development occurs within the EFZ and the system is breached artificially when low-lying developments are inundated. High water levels, as a result of back flooding under closed conditions, also pose a threat of contamination of the freshwater supply to Nature's Valley from the weir constructed near the head of the estuary.

Table 5.2 Summary of the Groot (Wes) Estuary habitat features

Habitat type	1983 area (ha)	2011 area (ha)
Supratidal salt marsh	6.38	0.76
Intertidal salt marsh	0	0
Reeds and sedges	2.54	2.54
Swamp forest	0	0
Mangroves	0	0
Sand/mud banks	8.12	8.12
Submerged macrophytes	0	0
Channel	27.86	27.86
Rocks	0	0
Floodplain	39.25 (13.75)	-
TOTAL	**97.9**	**39.28**

5.3 GEOGRAPHICAL BOUNDARIES

The geographical boundaries for the Groot (Wes) Estuary (**Figure 5.2**) are defined as follows:

Downstream boundary:	Estuary mouth 33°58'53.41"S 23°34'8.32"E
Upstream boundary:	33°57'49.27"S 23°33'23.77"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

Figure 5.2 Geographical boundaries of the Groot (Wes) Estuary

5.4 PRESENT ECOLOGICAL STATUS

The individual present health scores for the various abiotic and biotic components are used to determine the PES of the Groot (Wes) Estuary, in accordance with the EHI as presented in **Table 5.3**.

Table 5.3 Groot (Wes) Estuary: Present Ecological Status

Variable	Weight	Score
Hydrology	25	77
Hydrodynamics and mouth condition	25	91
Water quality	25	95
Physical habitat alteration	25	90
Habitat health score		**88**
Microalgae	20	88
Macrophytes	20	80

Invertebrates	20	85
Fish	20	80
Birds	20	90
Biotic health score		**85**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**86**
PRESENT ECOLOGICAL STATUS (PES)		**B**
OVERALL CONFIDENCE		**Very Low**

The EHI score for the Groot (Wes) Estuary is 86 thus a **PES of Category B** (**Table 1.2**). The following key pressures have contributed to the slight modification in ecological health in this system:

- Some reduction in base flow and floods to the system as a result of forestry in the catchment and abstraction by the adjacent town (Natures Valley), with a shift in the onset of the high flow period;
- Loss of tidal flows and habitat as a result of bridge construction;
- Some development in the EFZ and related loss of habitat; and
- Limited bait collection and fishing.

5.5 ESTUARY IMPORTANCE AND CONSERVATION STATUS

Referring to the estuarine importance rating system (DWAF, 2008; Turpie and Clark, 2007), the importance score of the Groot (Wes) Estuary – a score of 62 – indicates that the estuary is **"Important"** (**Table 5.4**). However, the Groot (Wes) Estuary is situated in the Tsitsikamma National Park. The system therefore forms part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan for the National Biodiversity Assessment (Turpie *et al.*, 2013). The NBA 2011 (Van Niekerk and Turpie, 2012) recommends that the estuary be **fully protected**, and that **50% of the estuary margin be undeveloped**.

Table 5.4 Estuarine Importance scores and protection status for the Groot (Wes) Estuary

ESTUARY IMPORTANCE	
Size	70
Habitat importance	50
Zonal type rarity	10
Biodiversity importance	83.5
ESTUARY IMPORTANCE SCORE	62
RATING	**Important**

PROTECTION STATUS	
National Estuary Biodiversity Plan	Tsitsikamma National Park

5.6 RECOMMENDATIONS

5.6.1 Recommended Ecological Category

Applying the guidelines for the determination of the REC (**Table 1.5**), the Groot (Wes) Estuary should be managed in a Category A or BAS based on its protected status. The REC was set as a **Category A**, as key pressures were considered reversible. This can be achieved by improved mouth management practices, as well as returning base flow during low flow periods. The latter can, for example, be achieved through investigating alternative practices to supply water to the adjacent town, Natures Valley (i.e. not drawing from the river during low flow periods). Reducing fishing effort and bait collection will also contribute towards achieving the REC of Category A.

5.6.2 Recommendations on Ecological Flow

Flow to the estuary has already been reduced as a result of increased forestation and abstraction of water for the adjacent town creating conditions that have already contributed to changes in ecological health in this small system. As a minimum, the present flow regime (MAR_P = 11.1 million m^3) should be maintained, but the extent to which base flows can be returned to this system needs to be investigated.

5.6.3 Ecological Specifications

The EcoSpecs and associated TPCs representative of a Category A for the Groot (Wes) Estuary are presented in **Table 5.5**.

Table 5.5 EcoSpecs for the Groot (Wes) Estuary (Category A)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain present day base flow as a mimimum (to be confirmed)	▪ MAR does not vary by more than 10% ▪ Floods (indicated by 1:10 year event) do not reduce by more than 5% from present. ▪ Base flows do not increase by more than 50% from present
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state increases by 10% from present ▪ Average water level in system > 10% from present ▪ Tidal amplitude (when open) < 20%

Ecological component	EcoSpecs	Thresholds of Potential Concern
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Average salinity along estuary decreases by 5 below baseline average (to be determined) ▪ Average salinity < 10 at the head of the estuary (expected average range 5-10 for most of the system) ▪ DO < 5 mg/ℓ in estuary ▪ Turbidity > 10 NTU in low flow ▪ Secchi: to bottom ▪ DIN >100 µg/ℓ once-off ▪ DIP > 20 µg/ℓ once-off ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary changes from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel changes from 30% of baseline (to be determined) (system expected to experience significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton > 3.5 µg/ℓ (median) ▪ Benthic microalgae > 11 mg/m^2 (median) ▪ Phytoplankton > 20 ug/ℓ and/or cell density > 10 000 cells/ml (once-off)
Macrophytes	▪ Maintain distribution of macrophyte habitats. ▪ Prevent an increase in nutrient input leading to macroalgal blooms. ▪ Control the spread of invasive plants in the riparian zone	▪ Greater than 20 % change in the area covered by macrophytes (reeds and sedges currently cover 2.54 ha salt marsh 0.76 ha) ▪ Macroalgal blooms cover > 50% of the open water area during closed mouth conditions. ▪ Invasive plants cover > 5% of total habitat
Invertebrates	▪ Establish presence/absence of sand prawn *Callichirus kraus*si on sand banks in lower estuary ▪ Establish presence/absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%

Ecological component	EcoSpecs	Thresholds of Potential Concern
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically, assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (5-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least two species (e.g. *G.aestuaria, & Hyporamphus capensis).* Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 10% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species <1%
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

6 BLOUKRANS ESTUARY

6.1 CATCHMENT CHARACTERISTICS

The dominant land-use types in the catchment are (**Figure 6.1**):

- 42% (light brown) thicket, bushland, bush clumps and high fynbos;
- 33% (green) indigenous forest;
- 22% (light orange-brown) shrubland and low fynbos; and
- 3% (orange) forest plantation.

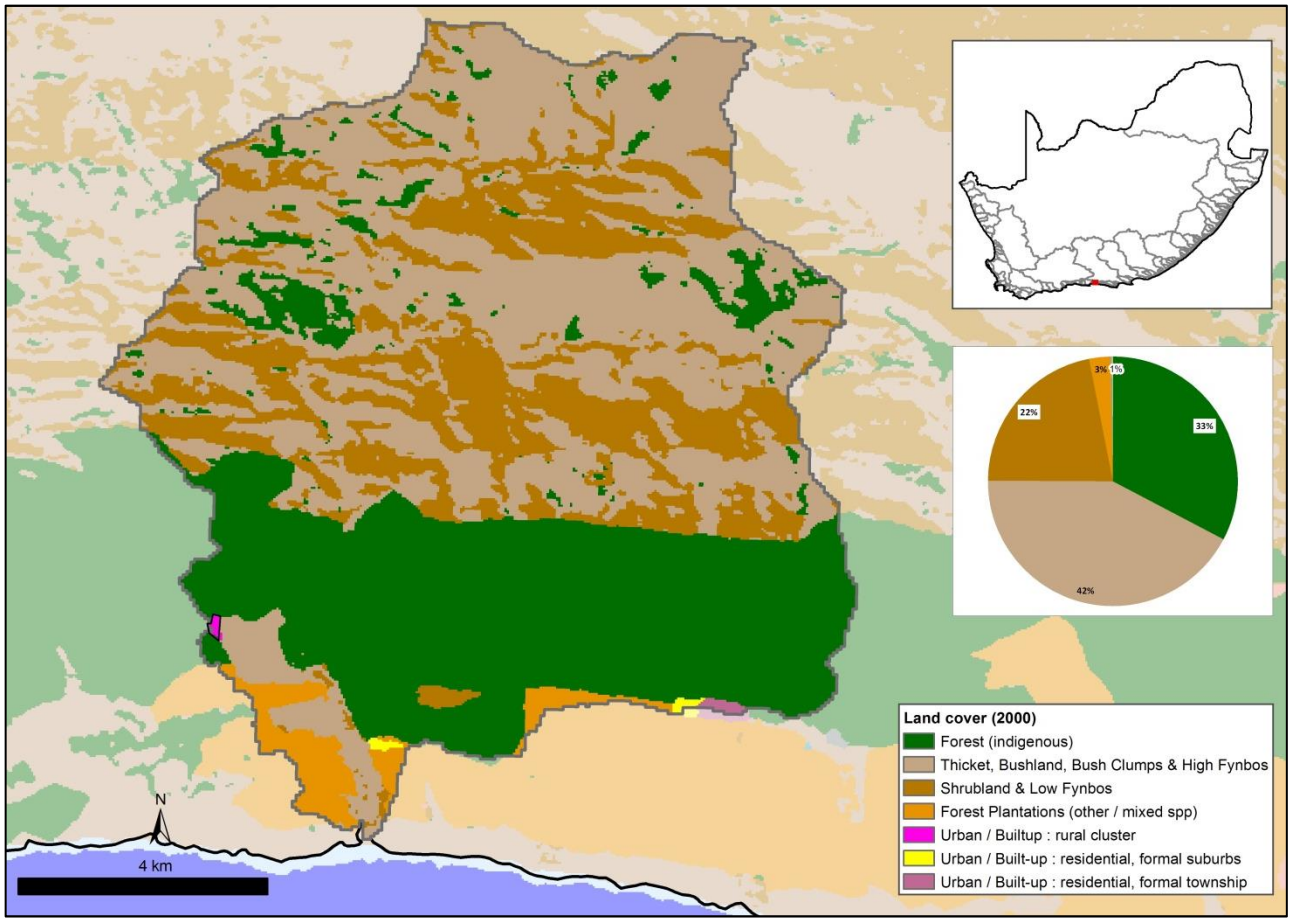

Figure 6.1 Catchment of the Bloukrans Estuary, as well as dominant land-use distribution

The Bloukrans catchment receives rainfall throughout the year, with peaks in autumn and spring. The MAR to the Bloukrans Estuary was 40.1 million m^3 under the Reference Condition (**Table 6.1**). This has been reduced by 2% to 39.3 million m^3 under the Present State. A broad assessment of the changes in runoff to the estuary shows both a slight reduction in base flow to the system and a related increase in the low flow duration.

Table 6.1 Summary of the hydrological change to the Groot (Wes) Estuary

Parameter	Summary of change in flow parameters
Reference MAR (million m^3/a)	40.1
Present MAR (million m^3/a)	39.3
% MAR similarity	98
% Base flow similarity	96
% Median flow similarity	98
Change in high flow duration	
Change in base flow variance	
Change in low flow duration	Yes
Shift in high flow onset month	

6.2 ESTUARY CHARACTERISTICS

The Bloukrans Estuary is a small (4 ha) permanently open estuary (**Table 6.2**). The estuary has a strongly tidal mouth that opens to the sea between steep valley sides.

Table 6.2 Summary of the Bloukrans Estuary habitat features

Habitat type	Area (ha)
Supratidal salt marsh	0
Intertidal salt marsh	0
Reeds and sedges	0
Swamp forest	0
Mangroves	0
Sand/mud banks	0.63
Submerged macrophytes	0
Channel	2.88
Rocks	0
TOTAL	**3.51**

6.3 GEOGRAPHICAL BOUNDARIES

The geographical boundaries for the Bloukrans Estuary (**Figure 6.2**) are defined as follows:

Downstream boundary:	Estuary mouth 33°58'47.08"S 23°38'51.29"E
Upstream boundary:	33°58'33.85"S2 23°38'44.31"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

Figure 6.2 Geographical boundaries of the Bloukrans Estuary

6.4 PRESENT ECOLOGICAL STATUS

The individual present health scores for the various abiotic and biotic components are used to determine the PES of the Bloukrans Estuary, in accordance with the EHI as presented in **Table 6.3**.

Table 6.3 Bloukrans Estuary: Present Ecological Status

Variable	Weight	Score
Hydrology	25	97
Hydrodynamics and mouth condition	25	100
Water quality	25	97
Physical habitat alteration	25	95
Habitat health score		**97**
Microalgae	20	97
Macrophytes	20	100
Invertebrates	20	95
Fish	20	90
Birds	20	95
Biotic health score		**96**
ESTUARY HEALTH SCORE Mean (Habitat health, Biological health)		**96**
PRESENT ECOLOGICAL STATUS (PES)		**A**
OVERALL CONFIDENCE		**Very Low**

The EHI score for the Bloukrans Estuary is 96 thus a **PES of Category A** (**Table 1.2**), although there has been a very slight reduction in base flow to the system and limited fishing does occur in the system

6.5 ESTUARY IMPORTANCE AND CONSERVATION STATUS

Referring to the national estuarine importance rating (DWAF, 2008; Turpie and Clark, 2007), the importance score of the Bloukrans Estuary – a score of 51 – indicates that the estuary is of **"Average Importance"** (**Table 6.4**). However, the Bloukrans Estuary is situated in the Tsitsikamma National Park. The system therefore forms part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan for the National Biodiversity Assessment (Turpie *et al.*, 2013). The NBA 2011 (Van Niekerk and Turpie 2012) recommends that the estuary be **fully protected**, and that **100% of the estuary margin be undeveloped**.

Table 6.4 Estuarine Importance scores and protection status for the Bloukrans Estuary

ESTUARY IMPORTANCE	
Size	70
Habitat importance	10
Zonal type rarity	50
Biodiversity importance	63.5
ESTUARY IMPORTANCE SCORE	**51**
RATING	**Average Importance**

PROTECTION STATUS	
National Estuary Biodiversity Plan	Tsitsikamma National Park

6.6 RECOMMENDATIONS

6.6.1 Recommended Ecological Category

Applying the guidelines for the determination of the REC (**Table 1.5**), the Bloukrans Estuary should be maintained in a **Category A.** Presently, no management interventions are required to meet the REC:

6.6.2 Recommendations on Ecological Flow

The Bloukrans Estuary is relatively resilient to flow reduction. About 1-5% of the MAR_P may therefore still be available for abstraction. However, until more detailed studies have been undertaken to confirm, the present flow regime (MAR_P = 39.3 million m^3) must be maintained.

6.6.3 Ecological Specifications

The EcoSpecs and associated TPCs representative of a Category C for the Bloukrans Estuary are presented in **Table 6.5**.

Table 6.5 EcoSpecs and Thresholds of Potential Concern for the Bloukrans Estuary (Category A)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain present flow regime	▪ Varies more than 10% of MAR
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Estuary mouth closes
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Average salinity < 10 at the head of the estuary (expected average range > 30 for most of the system) ▪ DO < 5 mg/ℓ in estuary ▪ Turbidity > 10 NTU in low flow ▪ Secchi: to bottom ▪ DIN > 100 µg/ℓ once-off ▪ DIP > 20 µg/ℓ once-off ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton > 1.0 µg/ℓ (median) ▪ Benthic microalgae > 11 mg/m^2 (median) ▪ Phytoplankton > 20 µg/ℓ and/or cell density > 10 000 cells/ml (once-off)
Macrophytes	▪ The estuary habitats only consists of sand/mud banks (0.63 ha) and channel (2.88 ha), no macrophytes	▪ N/A

Ecological component	EcoSpecs	Thresholds of Potential Concern
Invertebrates	▪ Establish presence/absence of sand prawn *Callichirus kraus*si on sand banks in lower estuary ▪ Establish presence/absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically, assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (10-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least 4 species (*G.aestuaria, Hyporamphus capensis, Omobranchus woodii*). Category IIa obligate dependents should be well represented by large exploited species (*A. japonicus, L. lithognathus, P. commersonii, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 10% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species < 1%
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

7 GENERIC BASELINE AND LONG-TERM MONITORING PROGRAMME

A generic baseline and long-term monitoring programme to improve the confidence of the preliminary reserve determination in the estuaries assessed as part of this Desktop assessment, as well as other estuaries in the WMA for which such programmes have not been provided previously, is presented in **Tables 8.1** and **8.2** respectively (priority components are highlighted).

Table 7.1 Generic baseline surveys to improve confidence in the preliminary reserve determination of estuaries in the Gouritz WMA (highest priorities are highlighted)

Ecological component	Monitoring action	Temporal scale	Spatial scale
Hydrology	For larger systems record river inflow at head of estuary (smaller systems hydrology to be simulated every 10 years).	Continuous	Install recorder near head of estuaries
Hydrodynamics	Record water levels. Large system (permanent recorder DWS levelled to MSL). Smaller systems (small in situ probe).	Continuous	Near mouth
	Aerial photography (or using high resolution satellite imagery i.e. 5x5 m pixel size, e.g. Google Pro or BirdEye).	Once-off	Entire estuary
Sediment dynamics	Monitoring berm height using appropriate technologies.	Quarterly	Mouth
	Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed (e.g. 300-500m) intervals but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm.	Once-off	Entire estuary
	Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (and ideally origin, i.e. microscopic observations).	Once-off	Entire estuary
Water quality	Electrical conductivity, pH, inorganic nutrients and organic content (e.g. TP and Kjeldahl N) in river inflow *(preferably also suspended solids and temperature).*	Monthly (as in DWS monitoring programme)	Include monitoring station near head of estuary
	Salinity and temperature profiles (and any other in situ measurements possible e.g. pH, DO, turbidity).	Quarterly, preferably for two years	Along entire length of estuary (at least 3 stations covering all zones)
	Inorganic nutrient concentrations (together with above).	Quarterly, preferably for two years	Along entire length of estuary (at least 3 stations covering all zones)
	Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – see Newman and Watling, 2007).	Once-off	Entire estuary, including depositional areas (i.e. muddy areas)

Ecological component	Monitoring action	Temporal scale	Spatial scale
Microalgae	Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC, fluoroprobe. Intertidal and subtidal benthic chlorophyll-a measurements(4 replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly, preferably for two years	Along length of estuary, minimum five stations
Macrophytes	Map area covered by different macrophyte habitats using recent imagery. Conduct field survey to record total number of macrophytes habitats, identification and total number of macrophytes species, number of rare or endangered species, or those with limited populations. Assess extent of invasive species in EFZ. Where there are salt marsh areas greater than 1 ha, measure percentage plant cover along elevation gradient. Sediment samples collected along the transect and analysed in the laboratory for sediment moisture, organic content, EC, pH and redox potential. In the field, measure depth to water table and ground water salinity.	Once-off in summer	Entire estuary (mapping) Where there is salt marsh (minimum three transect sites)
Invertebrates	Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 um mesh) along estuary. Collect sled samples (day) at same zooplankton sites for hyper benthos (190 um). Collect grab samples (5 replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 um). Intertidal invertebrate hole counts using 0.25 m^2 grid (5 replicates per site). Establish the species concerned *(Callichirus kraussi* or *Upogebia Africana*) using a prawn pump. Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton) (*preferably link with sediment dynamics*)	Quarterly, preferably for two years	Minimum of three sites along length of entire estuary For hole counts – three sites in each of muddy or sandy areas,

Ecological component	Monitoring action	Temporal scale	Spatial scale
Fish	Record species and abundance of fish, based on seine net and gill net sampling. Sampling with a small beam trawl for channel fish should also be considered. Seine net specifications: 30 m x 2m, 15 mm bar mesh seine with a 5 mm bar mesh with a 5mm bar mesh 5 m either side and including the cod-end. Gill nets specifications: Set of gill nets each panel 30 m long by 2 m deep with mesh sizes of 44 mm, 48 mm, 51 mm, 54 mm, 75 mm, 100 mm and 145 mm Gill net sampling can be replaced by a large mesh seine (44 mm stretch mesh, 100 m x 2 m). Trawl specification: 2 m wide by 3 m long, 10 mm bar nylon mesh in the main net body and a 5 mm bar in the cod-end	Once-off in spring/ summer and autumn/ winter	Larger system (> 5 km): 10-15 stations along length of estuary) (~ length/10) Small systems (< 5 km): 3-5 stations (mouth, mid, top)
Birds	Undertake count of all water birds	Once-off Hartenbos, and Groot (Wes): Annual, and divide estuary into upper middle lower). Must be sensible divisions	Entire estuary Hartenbos and Groot (Wes): Divide estuary into upper middle lower sections

Table 7.2 Generic long-term monitoring programme for estuaries in the Gouritz WMA (highest priorities are highlighted)

Ecological component	Monitoring action	Temporal scale	Spatial scale
Hydrology	For larger systems, record river inflow at head of estuary (smaller systems, hydrology to be simulated every 10 years).	Continuous	At station near head of estuary
Hydrodynamics	Record water levels. Large system (permanent recorder DWS levelled to MSL). Smaller systems (small in situ probe).	Continuous	Near mouth
	Aerial photography (or using high resolution satellite imagery i.e. 5x5 m pixel size, e.g. Google Pro or BirdEye)	Every three years	Entire estuary
Sediment dynamics	Monitoring berm height using appropriate technologies	Quarterly	Mouth
	Bathymetric surveys: series of cross section profiles and a longitudinal profile collected at fixed (e.g. 300-500 m intervals) but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm.	Every three years (and after large resetting event)	Entire estuary
	Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (and ideally origin, i.e. microscopic observations).	Every three years	Entire estuary

Ecological component	Monitoring action	Temporal scale	Spatial scale
Water quality	Electrical conductivity, pH, inorganic nutrients and organic content (e.g. TP and Kjeldahl N) in river inflow *(preferably also suspended solids and temperature)*	Monthly	At station near head of estuary
	Salinity and temperature profiles (and any other in situ measurements possible e.g. pH, DO, turbidity).	Seasonally, annually	Along entire length of estuary (at least 3 stations covering all zones)
	Inorganic nutrient concentrations (together with above).	Every three years (high flow and low flow) or when significant change in water quality expected	Along entire length of estuary (at least 3 station covering all zones)
	Measure pesticides/herbicides and metal accumulation in sediments.	Every 3-6 years, if results show contamination	Entire estuary, including depositional areas (i.e. muddy areas)
Microalgae	Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC, fluoroprobe. Intertidal and subtidal benthic chlorophyll-a measurements (4 replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Every three years	Along length of estuary, minimum 5 stations
Macrophytes	Map area covered by different macrophyte habitats using recent imagery. Conduct field survey to record total number of macrophyte habitats, identification and total number of macrophyte species, number of rare or endangered species, or those with limited populations. Assess extent of invasive species in EFZ. Where there are salt marsh areas greater than 1 ha, measure percentage plant cover along elevation gradient. Sediment samples collected along the transect and analysed in the laboratory for sediment moisture, organic content, EC, pH and redox potential. In the field measure depth to water table and ground water salinity.	Every three years in summer	Entire estuary (mapping) Where there is salt marsh (minimum 3 transect sites)

Ecological component	Monitoring action	Temporal scale	Spatial scale
Invertebrates	Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 um mesh) along estuary. Collect sled samples (day) at same zooplankton sites for hyper benthos (190 um). Collect grab samples (5 replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 um). Intertidal invertebrate hole counts using 0.25 m^2 grid (5 replicates per site). Establish the species concerned *(Callichirus kraussi* or *Upogebia Africana*) using a prawn pump. Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton) (*preferably link with sediment dynamics*)	Every two years in mid-summer	Minimum of three sites along length of entire estuary For hole counts – three sites in each of muddy or sandy areas,
Fish	Record species and abundance of fish, based on seine net and gill net sampling. Sampling with a small beam trawl for channel fish should also be considered. Seine net specifications: 30 m x 2m, 15 mm bar mesh seine with a 5 mm bar mesh with a 5mm bar mesh 5 m either side and including the cod-end. Gill nets specifications: Set of gill nets each panel 30 m long by 2 m deep with mesh sizes of 44 mm, 48 mm, 51 mm, 54 mm, 75 mm, 100 mm and 145 mm. Gill net sampling can be replaced by a large mesh seine (44 mm stretch mesh, 100 m x 2 m). Trawl specification: 2 m wide by 3 m long, 10 mm bar nylon mesh in the main net body and a 5 mm bar in the cod-end.	Twice annually, spring/ summer and autumn/ winter	Larger system (> 5 km): 10-15 stations along length of estuary) (~ length/10) Small systems (< 5 km): 3-5 stations (mouth, mid, top)
Birds	Undertake count of all water birds	Every two years mid-summer Hartenbos, and Groot (Wes): Annual and divide estuary into upper middle lower) must be sensible divisions	Entire estuary Hartenbos and Groot (Wes): Divide estuary into upper middle lower sections

The implementation of the monitoring programme should be undertaken in collaboration with various responsible departments in DWS, as well as other national and provincial departments and institutions responsible for estuarine resource management such as DAFF, DEA: Oceans and Coasts, SANBI, CapeNature, as well as relevant municipal authorities. It is recommended that the estuarine management planning process and the associated institutional structures (as required under the Integrated Coastal Management Act 2008) be used as a mechanisms through which to facilitate the implementation these interventions.

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APPENDIX A: OVERVIEW OF AVAILABLE INFORMATION ON ESTUARINE HABITAT IN THE HARTENBOS, BLINDE, PIESANG, GROOT (WES) AND BLOUKRANS ESTUARIES

Prepared by JB Adams and N Gordon, Nelson Mandela Metropolitan University

Information from various sources was collated for each of the above-mentioned estuary. These included the CSIR's Green Series reports, previous research projects (Nelson Mandela Metropolitan University [NMMU], Botany Department) and consultancy reports. The estuarine functional zone (estuarine ecosystem area) as determined by the Council for Scientific and Industrial Research (CSIR) for the NBA 2011 (Van Niekerk and Turpie, 2012) was used to delineate the total surface area for each estuary. The estuarine functional zone falls within the 5 m contour for each estuary and the different estuarine macrophyte habitats were mapped within this area. For each estuary the estuarine functional zone (estuarine ecosystem area) and open water areas were digitised using the most recent (2013) Spot 5 imagery combined with (2013) Google Earth images. Earliest aerial photographs (1940) were checked to assess changes in the macrophytes over time.

A.1 BLINDE ESTUARY

The Blinde Estuary is a temporarily open/closed estuary in good condition on the warm temperate south Cape coast near Dana Bay (34º12'35"S; 22º00'47"E). The estuary is surrounded by dense stands of exotic vegetation (*Acacia cyclops* in particular). The system surveyed in 2009 as part of the NBA study (Adams *et al*., 2010), during which time the mouth was again closed, with some evidence of overtopping during the high tide.

This overtopping resulted in salinity levels of ~13 ppt in the estuary and temperatures of approximately 13ºC. Some isolated patches of filamentous macroalgae were observed and a dense stand of *Phragmites australis* 600 m from the mouth (0.04 ha; **Table A.1**, Adams *et al*., 2010). A large sandbank (~0.05 ha) occurred in the middle reaches, while the total area of exposed water was estimated at 1.66 ha. The estuary is situated in a deeply incised valley and is 0.73 km long from the mouth to the 5 m contour in the upper reaches.

Past aerial photography could not be utilised to estimate macrophyte habitat areas for the Blinde Estuary as no 1936/1940 photographs were available. Aerial photographs that could indicate habitat areas included 1976 and 1979, and clearly showed no change in the *Phragmites australis* stands in the upper reaches nor the sandbank in the middle reaches on the eastern shore (**Figure A.1** to **A.3, Table A.1)**.

Figure A.1 **Blinde Estuary with a clear view of the large *Phragmites australis* stands in the upper reaches (CapeNature, 2006)**

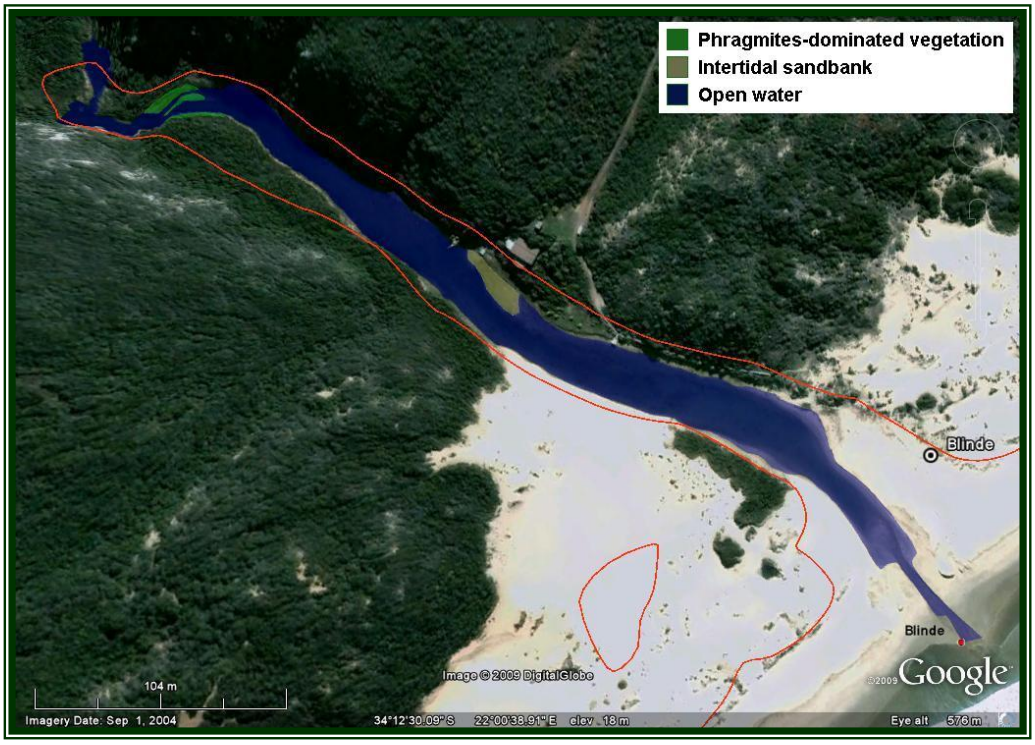


Figure A.2 **Blinde Estuary with polygons marking the areas covered by water, *Phragmites*-dominated vegetation and intertidal sandbank. The 5 m contours are presented as red lines (Source: Google Earth)**

Table A.1 Estuarine habitat in the Blinde Estuary

Habitat type	Defining features, typical/dominant species	2009 area (ha)
Open surface water area	Serves as a possible habitat for phytoplankton.	1.66
Sand and mud banks	Intertidal zone consists of sand/mud that provides a possible area for microphytobenthos to inhabit.	0.05
Reeds and sedges	Mainly *Phragmites australis* that occurs in the middle reaches.	0.04
Total estuarine area		1.75

Figure A.3 Past aerial photographs (1976 and 1979) of the Blinde Estuary indicating the location of the *Phragmites* stands (circles) and sandbank (arrows) within the upper and middle reaches respectively.

Very few changes could be observed from aerial photographs, mainly due to the lack of good quality past images, but also due to the unique topography of this system. As the Blinde Estuary is a deeply incised river valley, there is very limited space on either side of the water channel for macrophytes to colonize. Competition with invasive species such as *Acacia* spp. within the fringe zone could have a negative influence on the natural vegetation. Strong freshwater inflow probably maintains the dominance of emergent reeds and sedges, especially *Phragmites australis* in the upper reaches. Flow reduction and nutrient input would lead to an increase in the area covered by reeds. Marine overtopping appears to be sufficient to limit the distribution of this species further down the estuary as salinity measured in 2009 was 13 for the estuary. Overall there appears to be very little change in the macrophytes and they were assigned an Estuarine Health Index score of 85.

A.2 HARTENBOS ESTUARY

The Hartenbos Estuary is a temporarily open/closed estuary situated in the warm temperate region of the southern Cape (34°07'07"S; 22°07'27"E). According Turpie and Clark (2007), the system is in poor health and a high priority for conservation and rehabilitation in terms of water quantity and quality, and inappropriate bank stabilisation. The system has been severely impacted by road infrastructure development, especially in the lower reaches and at the mouth of the estuary. The national road and bridge were constructed 1.6 km from the mouth and large embankments were constructed within the salt marsh areas (i.e. rubble was dumped onto the salt marsh area). In addition the national railway linking Port Elizabeth and Cape Town, together with its bridge, was constructed in 1956 only 800 m from the mouth, with its accompanying embankments in the salt marsh area. Substantial housing development has also occurred within the floodplain on both the northern and southern banks of the system (Heydorn and Grindley, 1982), resulting in a loss of floodplain habitat and obstruction to floodwaters and water flow.

Previous estimates of the total estuarine open water area ranged between 18 ha (Heydorn and Grindley, 1982) and 15.72 ha (Harrison *et al*., 2001). Total estuarine area estimates for 1982 were 31 ha, with 13 ha of salt marsh (Heydorn and Grindley, 1982). **Figure A.4** provides a map of the lower reaches of the Hartenbos and clearly indicates the effects of development in this region. Present estimates of the total estuarine functional (i.e. within the 5 m contour line) are between 268.185 ha (NBA 2011) (Van Niekerk and Turpie, 2012) and 361 ha based on GIS mapping for 2013. Open water area is estimated at 42 ha, salt marsh at 47 ha and degraded floodplain area at 55 ha (**Table A.2**).

Table A.2 Estuarine habitat in the Hartenbos Estuary

Habitat type	Defining features, typical/dominant species	2013 area (ha)
Open surface water area	Serves as a possible habitat for phytoplankton.	42
Sand and mud banks	Intertidal zone consists of sand/mud banks that are a habitat for microphytobenthos.	1
Submerged macrophytes	Plants that are rooted in the substrata and whose leaves and stems are completely submerged for most states of the tide. Species previously recorded for the Hartenbos were *Ruppia cirrhosa*, *Potamogeton pectinatus* and *Zostera capensis.*	0
Salt marsh	A number of intertidal and supratidal species have been recorded.	47
Reeds and sedges	The following species have been recorded, and belong to the families Cyperaceae, Juncaceae & Poaceae: *Juncus* spp., *Cyperus* spp. and *Phragmites australis*.	9
Floodplain	This is a mostly grassy area which occurs within the 5 m contour line. Also includes dune vegetation at the mouth, and floodplain shrubs and riparian vegetation along the middle and upper reaches of the estuary. Approximately 140 ha included degraded floodplain vegetation with many invasive species.	55 67 140
Total estuarine area		**361**

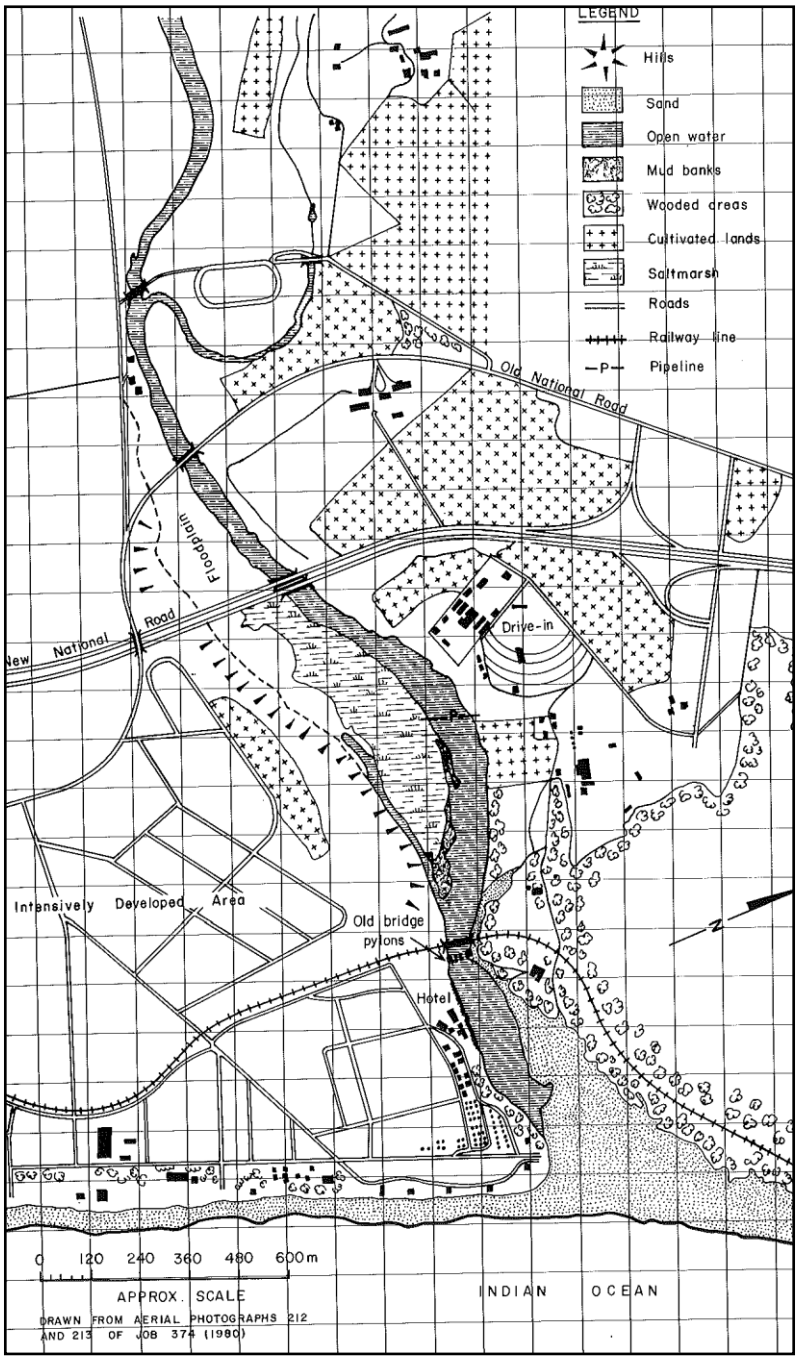


Figure A.4 Map of the lower reaches and mouth of the Hartenbos Estuary (from Heydorn and Grindley, 1982)

The previous survey of the Hartenbos Estuary in 1980/1982 found submerged macrophytes, *Ruppia cirrhosa* and *Potamogeton pectinatus* occurring in the lower and upper reaches, respectively (Heydorn and Grindley, 1982), with some floating *Zostera capensis* at the mouth of the estuary. Salt marsh species included: *Bassia diffusa*, *Eragrostis* sp., *Sarcocornia pillansii*, *S*. cf. *capensis*, *Salicornia meyeriana* and *Spergularia marginata*. In areas with high levels of disturbance *Bromus* sp., *Ehrharta delicatula* and *Plantago lanceolata* were observed (Heydorn and Grindley, 1982).

Present vegetation assessments are limited to the upper intertidal/supratidal and fringe area of the Hartenbos Estuary as assessed by Padayachy (2013). The following species were recorded within the upper intertidal area; *Atriplex vestita*, *Aizoon rigidum, Bassia diffusa, Bolboschoenus maritimus, Chenopodium alblum, Cotula filifolia, Delosperma crissum, Dispyhma crassifolium, Salicornia meyeriana, Sarcocornia pillansii, S. decumbens, Sporobolus virginicus, Stenotaphrum secundatum* and *Triglochin bulbosa*. Reeds and sedges were *Juncus* sp., *Cyperus* sp. and *Phragmites australis*. Padayachy's (2013) study focused on the distribution of invasive species within the supratidal, fringe and terrestrial environment adjacent to the estuary. Species and environmental data were restricted to these areas and do not extend to the water's edge. Environmental data indicated that sediment and groundwater salinity ($r = 0.69$ and $r = 0.89$, $p < 0.05$, respectively) influenced the distribution of species across the salt marsh/terrestrial boundary. High sediment moisture, sediment and groundwater salinity were associated with the salt marsh species (**Figure A.5**).

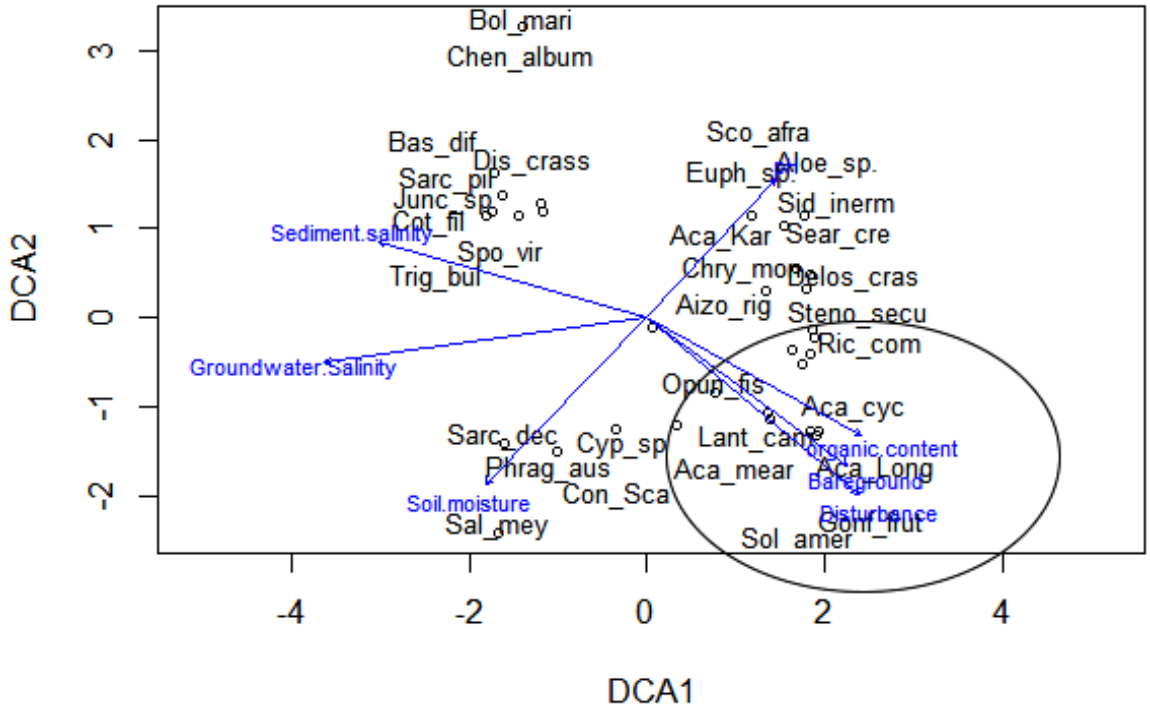


Figure A.5 A combined Detrended Correspondence Analysis of species cover, together with environmental variables, measured from disturbed and pristine sites in the Hartenbos Estuary. Each site represents two replicate transects (from Padayachy, 2013)

Environmental data for the salt marsh habitat of the Hartenbos Estuary is restricted to the upper intertidal and supratidal areas (Padayachy, 2013). Nevertheless, sediment analyses and groundwater measurements indicate that groundwater and sediment salinity were low in the fringe and terrestrial zones (> 5) compared to the supratidal zones (~15), i.e. salinity gradient along the intertidal zone towards the terrestrial environment. Sediment moisture was higher in the salt marsh (~15%) than the fringe and terrestrial environment (~5%), while organic matter accumulated in these zones (i.e. terrestrial biomass and debris) (**Figure A.6**).

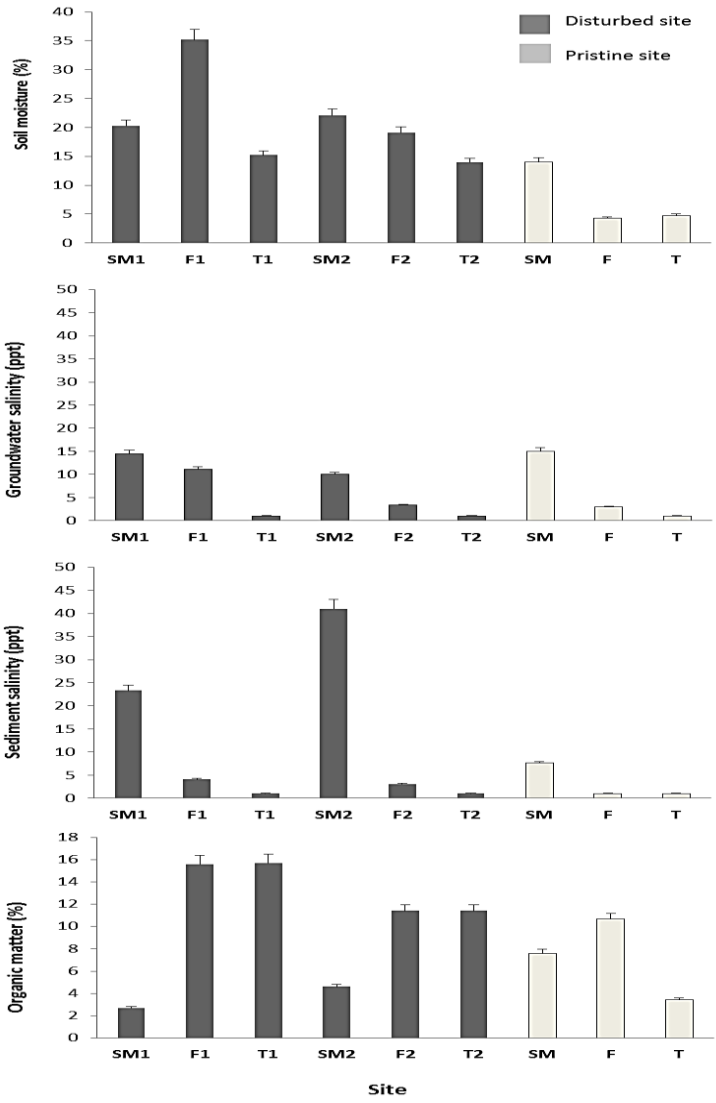


Figure A.6 Sediment and groundwater analyses for disturbed and pristine sites within the supratidal, fringe and terrestrial zones of the Hartenbos Estuary (from Padayachy, 2013)

Prior to the 1940s, agricultural practices within the floodplain already destroyed large areas of salt marsh, with nearly 96 ha already degraded (**Table A.3**) and only 29 ha remaining intact. The railway, road bridges and embankments removed salt marsh areas in the lower reaches of the estuary (**Plate A.1 a, b**). There has been an increase in salt marsh in the middle to lower reaches to 35 ha. Most of this area on the southern bank below the national road bridge was sand bank in 1940.

Table A.3 Area covered by different habitats in the Hartenbos Estuary in 2013 compared with 1942

Habitat	Area 1942 (ha)	Area 2013 (ha)
Floodplain agriculture	96	91
Floodplain developed	-	-
Floodplain undisturbed	66	73
Supratidal salt marsh	29	35
Intertidal salt marsh	-	-
Submerged macrophytes	-	-
Reeds and sedges	2	1
Mud and sandbanks	10	1
Open water surface area	26	38
Total area	**229**	**239**

Phragmites australis occurs within the upper reaches of the estuary, where salinity levels are low enough for the establishment of dense stands on either side of the estuary channel. Prior to the 1940s, large reed beds were encountered along the main channel of the estuary as far as the middle reaches of the estuary and in areas of freshwater inflow. With the flooding and removal of the low-water bridge in 1981, full tidal exchange was established into the middle and upper reaches and increased salinity levels restricting the distribution of *P. australis*. Reeds beds have receded upstream and decreased in overall area to 1 ha.

There are large areas of floodplain shrub and riparian vegetation (73 ha) within the functional estuarine zone (i.e. 5 m contour). These areas have increased by approximately 11% since 1940 (66 ha) as agricultural practices have decreased (most probably as a result of salinisation of the sediment and groundwater, making it unsuitable for cultivation, **Table A.2**). Padayachy (2013) noted that at the fringe area between the salt marsh and terrestrial habitat, a large number of invasive species occur that include; *Acacia cyclops, Acacia longifolia, Acacia mearnsii, Gonforcarpus fruticosus, Lantana camara, Opuntia ficus-indica, Ricinus communis* and *Solanum americanum (***Figure A.7**).

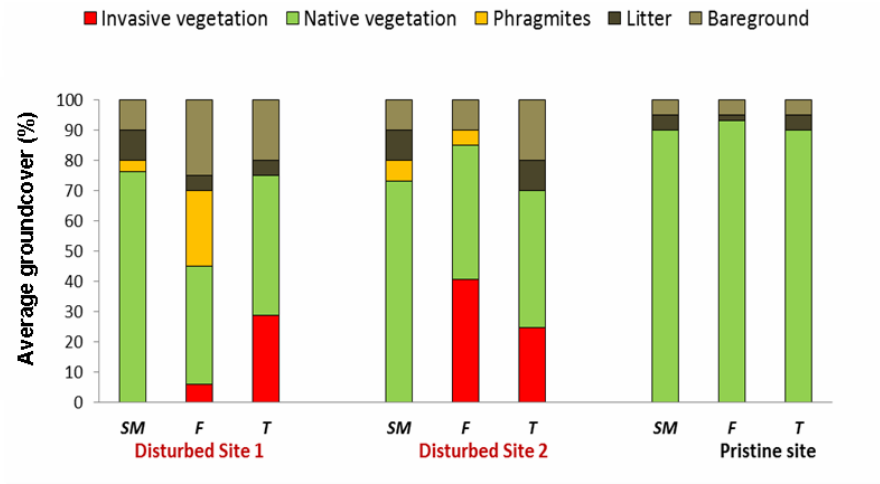


Figure A.7 Percentage groundcover in the major zones (SM=salt marsh, F=Fringe, T=Terrestrial) along transects in disturbed and pristine sites at Hartenbos Estuary (from Padayachy, 2013)

Although no quantitative data are available for the area cover of macroalgae in the Hartenbos Estuary for both past and present conditions, Heydorn and Grindley (1982) note the presence of large algal mats in the lower reaches and mouth areas of the system, especially during periods of mouth closure and increased nutrient input. Some algae present on the rocks near the mouth included; *Zonaria subreticulata*, *Pterosiphonia cloiophylla*, *Corallina* sp., *Lithothamnium* sp., *Plocamium cornatum*, *Ulva* sp. and *Arthrocaria* sp. (Heydorn and Grindley, 1982).

There has been a considerable loss in surface area of sand and mud banks within the Hartenbos Estuary from 10 ha in 1940 to approximately 1 ha in 2013. This is mainly observed at the mouth area of the estuary, where salt marsh vegetation has established on previous exposed sandbanks on the southern shore (**Figure A.8**). This establishment is most likely due to the stabilisation of the sandbanks and a reduced river flow.

Figure A.9 shows a number of historical aerial photographs (1940, 1977, 1979 and 1981) indicating the changes that have occurred especially in the mouth and lower reaches of the estuary. The reduction in sandbanks on the southern shore (1940) compared with more recent aerial photographs (1979, 1981), where salt marsh has become established, is visible.

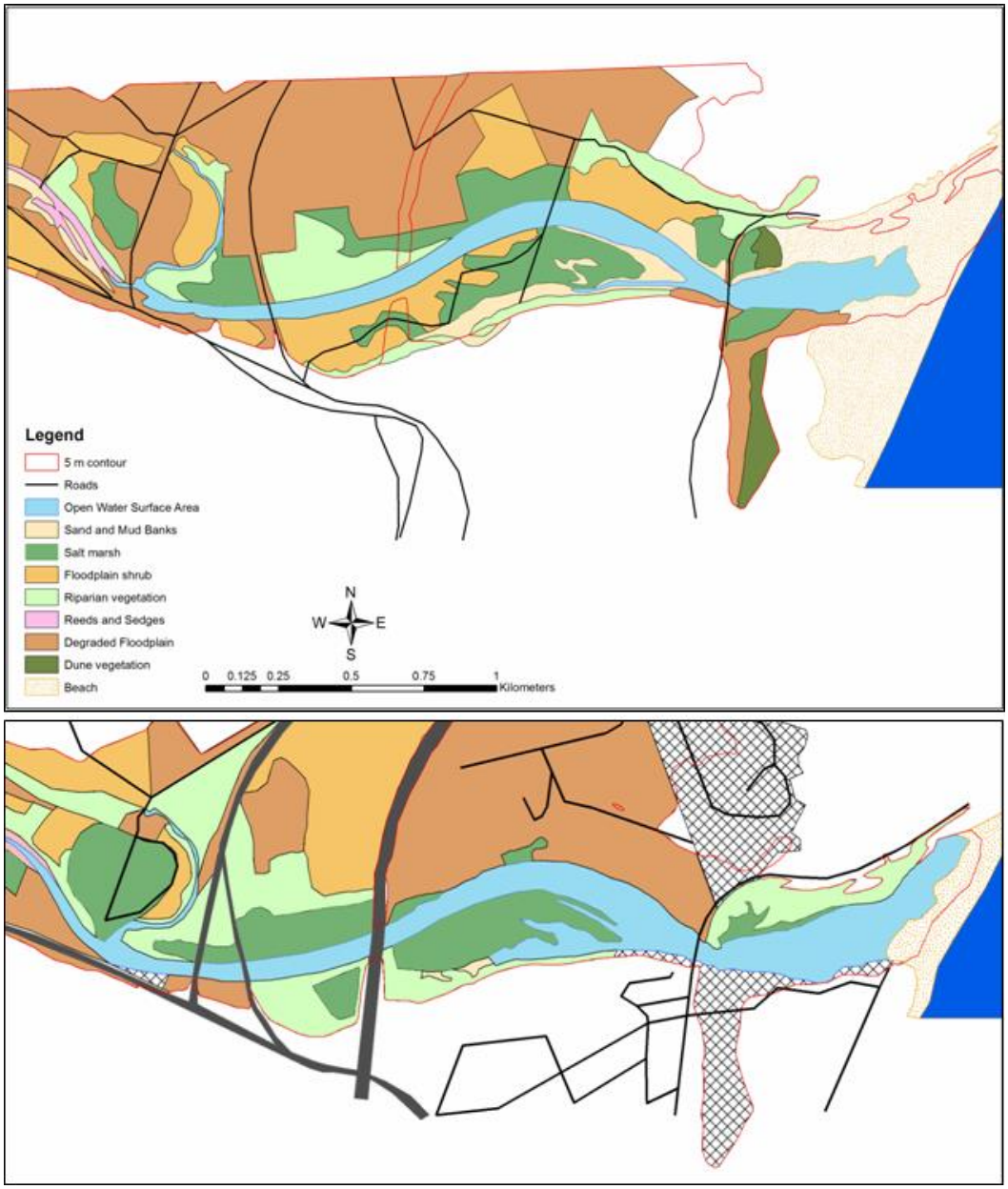


Figure A.8 Past (1940) and present (2013) vegetation map of the middle to lower reaches of the Hartenbos Estuary

1940

1977

1979

1981

Figure A.9 Changes over time for the lower to middle reaches of the Hartenbos Estuary

Plate A.1a Mouth and lower reaches of the Hartenbos Estuary (CapeNature, 2006)

Plate A.1b Lower reaches above the national railway bridge of the Hartenbos Estuary (CapeNature, 2006)

A.3 PIESANG ESTUARY

The Piesang Estuary is a temporarily open/closed estuary situated in the warm temperate Southern Cape and falls within the Plettenberg Bay municipal area (34°03'37"S; 23°22'46"E). The system is in fair condition with moderate anthropogenic impacts that includes some water quality issues and invasive species in the floodplain (Turpie and Clark, 2007). High agriculture pressure is evident in the upper reaches of the system. Due to weak tidal exchange the system closes on a regular basis, especially during period of low freshwater inflow (i.e. dry summer periods). In order to flush the estuary and prevent backflooding the mouth is artificially breached. The system is characterised by clear water with a transparency of 0.8 to 1 m, it is well oxygenated and no signs of eutrophication were observed in the past (Duvenage and Morant, 1984). This situation may have changed with an increase in development and stormwater run-off over the last few years. Most of the floodplain vegetation has been destroyed by the reclamation and inappropriate stabilisation of banks, farming too close to the water channel, and by recreational, residential and industrial development (Duvenage and Morant, 1984). At present a small area of reed and salt marsh is present in the middle reaches of the estuary and a large area of riparian shrub forest on the eastern shore. Salt marsh species that were observed in 1984 were *Triglochin* sp., *Juncus kraussii* and *Paspalum vaginatum*. No macroalgae or submerged macrophytes were observed at that time. The areas covered by the different habitats are a total estuarine area of 92.24 ha, with 8.5 ha of open water area, 80.6 ha of sand and mud banks, and 3.14 ha of reeds and sedges(**Figures A.10** and **A.11**).

Figure A.10 Piesang Estuary at Plettenberg Bay with clearly visible residential development (CapeNature, 2006)

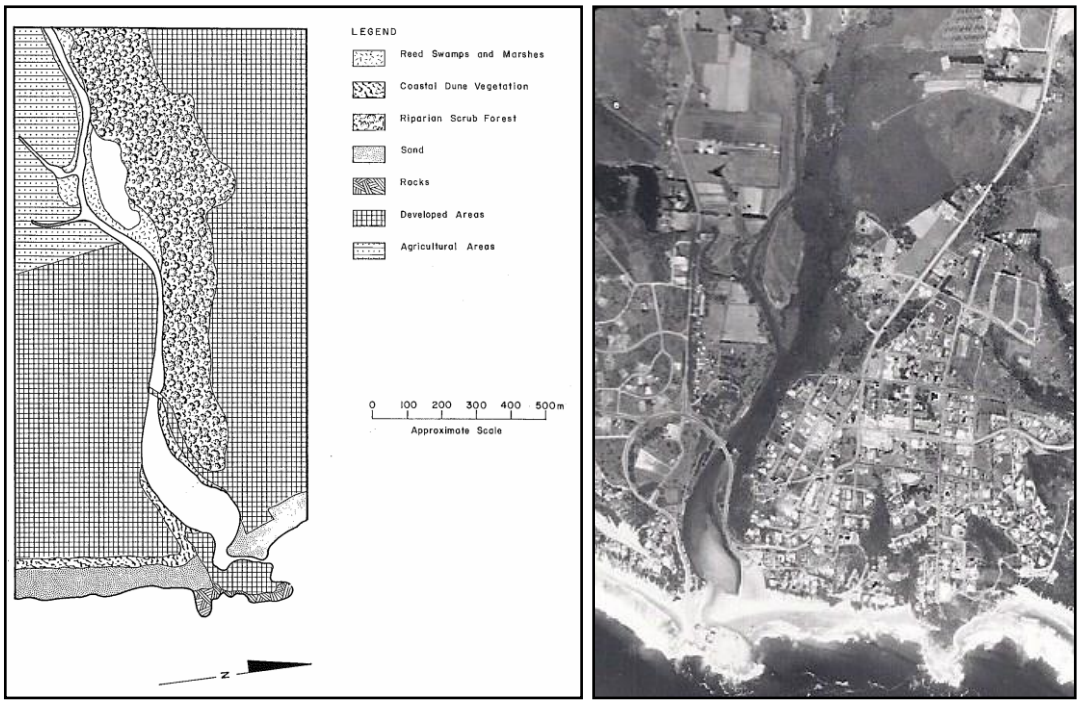


Figure A.11 The 1984 vegetation map (Duvenage and Morant, 1984) and 1973 aerial photograph of the Piesang Estuary with agricultural and residential development observed on the floodplain and up to the water channel in the lower and middle reaches

Due to anthropogenic impacts most of the floodplain vegetation has been lost to residential, industrial and agricultural developments. Competition with invasive species such as *Acacia* sp. within the fringe zone, will also negatively impact on the natural supratidal vegetation that could have occurred in these areas. The score for macrophytes used in the Estuarine Health Index score was 55. The high levels of development within the floodplain pose a severe risk to the remaining salt marsh. Higher sea levels also pose a problem to these developments as an increase in flooding and storm events are expected.

A.4 GROOT (WES) ESTUARY

The Groot (Wes) Estuary is a temporarily open/closed estuary situated in the warm temperate region near the Nature's Valley Village of the Southern Cape and forms the western boundary of the Tsitsikamma National Park. The system is characterised by little anthropogenic impact and is in a good condition. It is a black-water (peat-stained) system, being well oxygenated and stratified on most occasions (Morant and Bickerton, 1983). Backflooding of low-lying areas on the western shores in the lower reaches occurs when the mouth closes as a result of low freshwater inflow and sediment deposition at the mouth brought in by longshore currents (Morant and Bickerton, 1983). Overall nutrient input into the system is low as most of the catchment has been undisturbed by human activities, but sewage seepage from the village at the mouth does at times result in elevated levels, including higher *E. coli* counts (Morant and Bickerton, 1983). During these periods, filamentous macroalgae such as *Entermorpha* and/or *Cladophora* is found on the western bank

(Morant and Bickerton, 1983). Turbidity is low in the system, although the peat-stained water does limit light penetration to 1.6–1.8 m depths. Tidal exchange is weak within the system, with very little marine intrusion during normal open mouth conditions. During periods of mouth closure, stratification has been observed, with marine overtopping being responsible for increased salinity levels in the bottom water of the lower reaches. Once the mouth breaches and the system drains, marine inflow can be large and water column mixing occurs throughout the system for a brief period (Morant and Bickerton, 1983). **Table A.4** provides a breakdown of the macrophyte habitat types and their area cover.

Table A.4 Estuarine habitat in the Groot (Wes) Estuary

Habitat type	Defining features, typical/dominant species	1983 area (ha)	2011 area (ha)
Open surface water area	Serves as a possible habitat for phytoplankton.	27.86	27.86
Sand and mud banks	Intertidal zone consists of sand/mud banks that provide a possible area for microphytobenthos to inhabit.	8.12	8.12
Macroalgae	Some was observed, but too little to quantify. Species include *Chaetomorpha* sp. and *Enteromorpha* spp.	-	-
Submerged macrophytes	Plants that are rooted in both soft subtidal and low intertidal substrata and whose leaves and stems are completely submerged for most states of the tide. Species include: *Ruppia maritima* and *R. cirrhosa.*	-	-
Salt marsh	Halophytic species that can tolerate periods of inundation with saline water. Species include: *Cenia sericea, Chenopodium album, Cotula coronopifolia, Paspalum vaginatum, Psoralea fruticans, Samolus porosus, Sporobolus virginicus* and *Triglochin bulbosa*.	6.38	0.76
Reeds and sedges	The following species have been recorded, and belong to the families Cyperaceae, Juncaceae & Poaceae: *Mariscus thunbergii, Scirpus nodosus, Juncus kraussii* and *Phragmites australis*.	2.54	2.54
Floodplain	This is a mostly grassy area which occurs within the 5 m contour line, i.e. *Stenotraphrum secundatum*. Also includes dune vegetation at the mouth, and floodplain shrubs and riparian vegetation along the middle and upper reaches of the estuary. (Also degraded floodplain vegetation with high levels of invasive species and residential development)	39.25 (13.75)	-
Total estuarine area		**97.9**	**39.28**

** 1983 – Morant and Bickerton, 1983; 2011 – National Biodiversity Assessment*

According to Morant and Bickerton (1983) the Groot (Wes) supports a high number of estuarine plant species (**Figure A.12**). Macroalgae are restricted to the rocky shores near the mouth of the estuary and includes mainly filamentous species such as *Stilophera* sp., *Chaetomorpha* sp. and *Enteromorphora* sp. These algae may also be present on the western shore when seepage from septic tanks is high. Submerged macrophyte species includes mainly *Ruppia maritima* which occurred in dense bends throughout the system, with some *R. cirrhosa* occurring in the creeks. Reeds and sedges were observed mainly on the western shore and included *Mariscus thunbergii*, *Phragmites australis*, *Scirpus nodosus* and *Juncus kraussii*. Salt marsh species were restricted to the supratidal shores and included a variety of species as indicated in **Table A.4**.

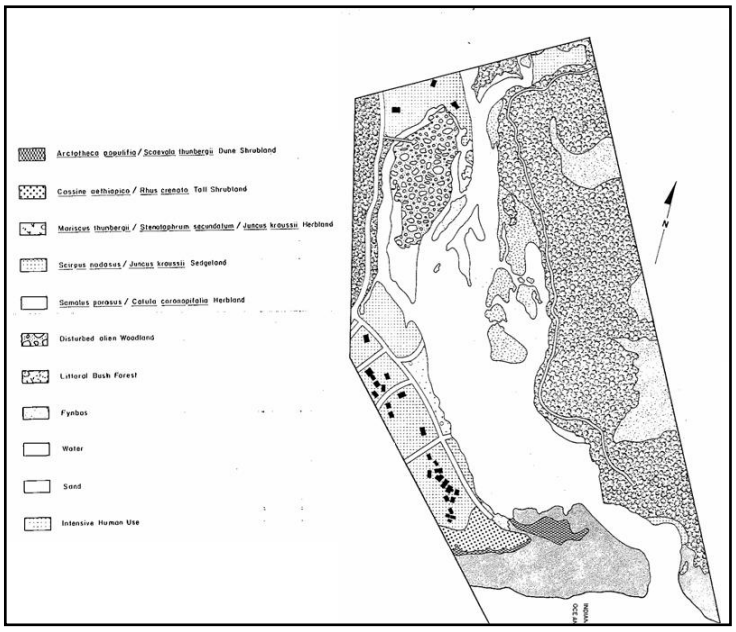


Figure A.12 Vegetation map of the Groot (Wes) Estuary indicating the extent of open water surface areas, residential development on the western shore and riparian forest vegetation on the eastern shore (from Morant and Bickterton, 1983)

Very few changes could be observed from aerial photographs, mainly due to the lack of good quality images. The most observable change that has occurred at the Groot (Wes) Estuary is the residential development on the western shore at the mouth of the system (**Figure A.13**). Some invasive species are noted in the area, e.g. *Acacia* sp. within the fringe zone and these may also negatively impact on the natural supratidal vegetation that could have occurred in these areas. A score of 80 was assigned for macrophytes in the Estuarine Health Index.

Figure A.13 Past (1942) and recent (1980) aerial photography of the Groot (Wes) Estuary. Very little change in vegetation can be observed, with the exception of the residential development on the western shore at the mouth of the estuary

A.5 BLOUKRANS ESTUARY

The Bloukrans is classified as a river mouth situated within the Tsitsikamma National Park (33°58'45"S; 23°38'52"E) and protected in its entirety (**Figure A.14** to **A.16**). The system is in excellent condition with negligible anthropogenic impacts (Whitfield, 2000). It drains a catchment area of 93 km^2, and has a river length of 21.9 km. As the system is situated in a steep-sided valley, flooding occurs frequently and the system has a strong freshwater base flow throughout the year. Consequently the total area that can be classified as estuarine, i.e. salinity exchange between freshwater and marine, is very small at 3.51 ha (Van Niekerk and Turpie, 2012) of which the open water surface area is 2.88 ha. Two large sandbanks are located near the mouth, with a third in the upper reaches, totally an area of 0.63 ha. The Bloukrans is a black-water system (peat-stained), slightly alkaline (7.4 8.1 pH), well oxygenated (7.3–9.3 mg/ℓ), clear water (0 NTU), with a salinity that ranges between 20 to 35 (Harrison et al., 1994). Due to the high freshwater input into the system, nutrient levels are elevated (i.e. nitrate = 0 to 500 ug/ℓ; phosphate = 0 to 30 ug/ℓ), but short retention times ensures that all nutrients are transported into the marine environment fairly quickly, thus posing no threat to the system.

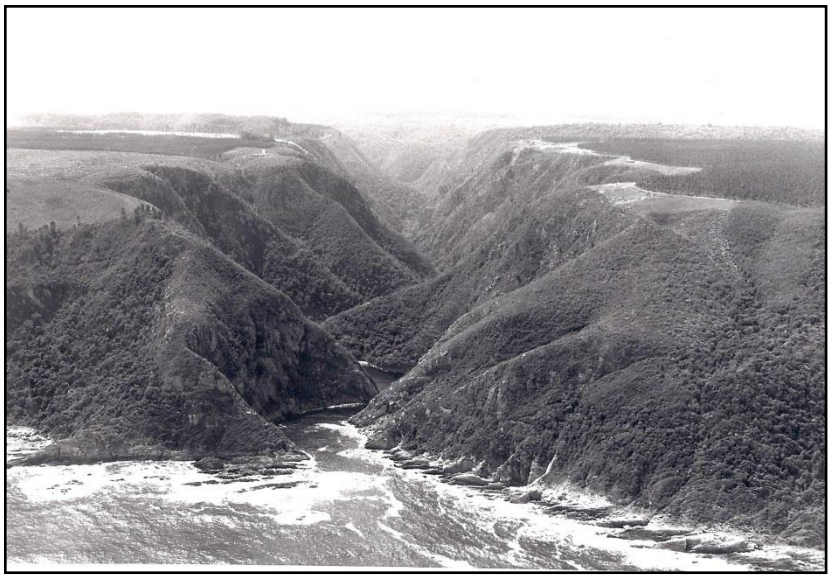
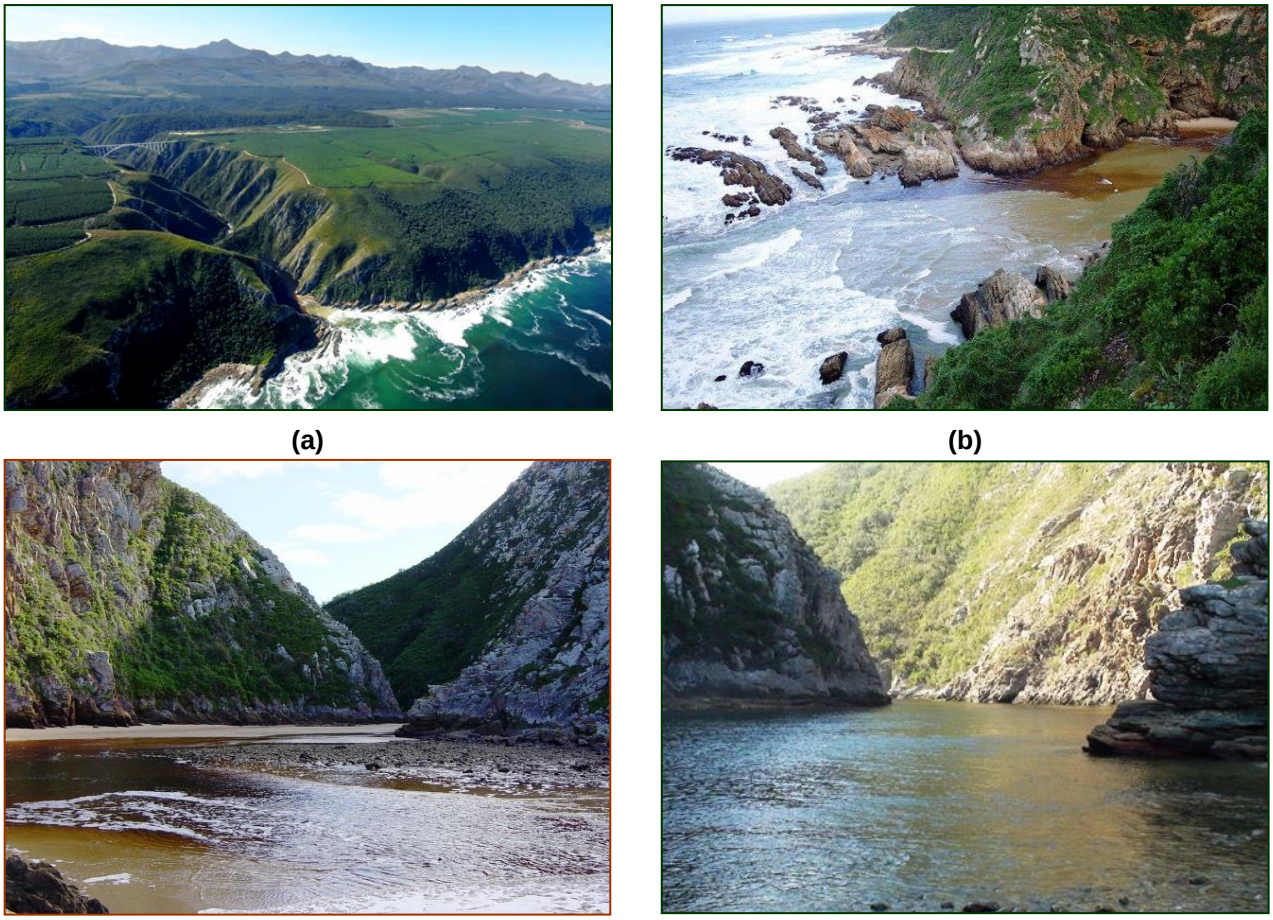


Figure A.14 The deeply incised Bloukrans Estuary within the Tsitsikamma National Park (1979)

Very little changes could be observed from aerial photographs, mainly due to the lack of good quality past images as well as the unique topography that limits the estuarine area to the mouth of the system and the very steep valley within which the system is located. The position of the two larger sandbanks within the upper reaches also appears to have changed very little (both in location and size) over time as observed in **Figure A.16.**



(a) (b)

(c) (d)

Figure A.15 Images of the Bloukrans Estuary; (a) Bloukrans Gorge (www.panoramio.com), (b) the estuary mouth (Dr Wim Richter, http://www.wim.co.za), (c) lower reaches of the Bloukrans Estuary and (d) middle reaches (photo by scuba Chris, www.panoramio.com).

Figure A.16 **Past (1942) and more recent (1979, 1980) aerial photographs of the Bloukrans Estuary indicating the position of the larger two sandbanks in the upper reaches (circled)**

APPENDIX B: ECOLOGICAL SPECIFICATION FOR THE ESTUARIES

B.1 MAALGATE ESTUARY

The EcoSpecs and associated Thresholds of Potential Concern (TPCs) representative of a Category B/C for the Maalgate Estuary are presented in **Table B.1**.

Table B.1 EcoSpecs and Thresholds of Potential Concern for the Maalgate Estuary (Category B/C)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain flow regime (small system needs most flows)	▪ Varies more than 10% of MAR
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state varies by > 20% from present ▪ Average water depth < 1.0 m (to be confirmed by monitoring) ▪ Average water level changes by more than 20% from present
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Average salinity < 10 (expected average range 10-30) ▪ DO < 5 mg/ℓ in estuary ▪ Turbidity > 10 NTU in low flow ▪ Secchi: to bottom ▪ DIN > 100 µg/ℓ once-off ▪ DIP > 20 µg/ℓ once-off ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary changes from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel changes from 30% of baseline (to be determine) (system expected to experience significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton > 3.5 µg/ℓ (median) ▪ Benthic microalgae > 23 mg/m^2 (median) ▪ Phytoplankton > 20 µg/ℓ and/or cell density > 10 000 cells/ml (once-off) ▪ Dinoflagellates, chlorophytes and/or cyanobacteria > 10% of relative abundance

Ecological component	EcoSpecs	Thresholds of Potential Concern
Macrophytes	▪ Prevent an increase in macroalgal blooms ▪ Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone	▪ Macroalgal blooms cover > 20% of the open water area ▪ Invasive trees cover > 20% of riparian zone
Invertebrates	▪ Establish presence/absence of sand prawn *Callichirus kraus*si on sand banks in lower estuary ▪ Establish presence/absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the present. Numerically, assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (5-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least two species (e.g. *G.aestuaria, & Hyporamphus capensis).* Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 10% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species < 1% Species composition > 50% similar to last three sampling trips (system naturally highly unstable due to resetting events)
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

B.2 GWAING ESTUARY

The EcoSpecs and associated TPCs representative of a Category B/C for the Gwaing Estuary are presented in **Table B.2.**

Table B.2 EcoSpecs and Thresholds of Potential Concern for the Gwaing Estuary (Category B/C)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain flow regime	▪ Varies more than 10% of MAR
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state varies by > 20% from present ▪ Average water depth < 1.0 m (to be confirmed by monitoring) ▪ Average water level change by more than 20% from present
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Average salinity < 15 (expected average range 10-30, but to be verified by baseline studies ▪ DO < 5 mg/ℓ in estuary (surface water especially) ▪ Turbidity > 10 NTU in low flow ▪ Secchi: to bottom ▪ DIN > 150 µg/ℓ once-off ▪ DIP > 30 µg/ℓ once-off ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel change from 30% of baseline (to be determined) (system expected to experience significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton > 8 µg/ℓ (median) ▪ Benthic microalgae > 42 mg/m^2 (median) ▪ Phytoplankton > 20 µg/ℓ and/or cell density > 10 000 cells/ml (once-off) ▪ Dinoflagellates, chlorophytes and/or cyanobacteria > 10% of relative abundance.

Ecological component	EcoSpecs	Thresholds of Potential Concern
Macrophytes	▪ Maintain distribution of macrophyte habitats ▪ Prevent the spread of reeds into open water ▪ Prevent an increase in nutrients, macroalgal blooms and aquatic invasive plants ▪ Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone	▪ 20% change in the macrophyte area. (Reeds currently cover 0.14 ha. And salt marsh 1.58 ha) ▪ Reeds occupy > 0.5 ha ▪ Macroalgal blooms cover > 50% of the open water area ▪ Presence of invasive aquatic macrophytes e.g. *Azolla*, water hyacinth ▪ Invasive trees cover > 20% of riparian zone
Invertebrates	▪ Establish presence/absence of sand prawn *Callichirus kraus*si on sand banks in lower estuary ▪ Establish presence/absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the present. Numerically, assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (5-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least two species (e.g. *G.aestuaria, & Hyporamphus capensis).* Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 10% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species < 1% Species composition > 50% similar to last three sampling trips (sytem naturally highly unstable due to resetting events)
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

B.3 KAAIMANS ESTUARY

The EcoSpecsand associated TPCs representative of a Category A/B for the Kaaimans Estuary are presented in **Table B.3**.

Table B.3 EcoSpecs and Thresholds of Potential Concern for the Kaaimans Estuary (Category A/B)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain flow regime	▪ Varies more than 10% of MAR
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state varies by > 10% from present ▪ Average water depth < 0.5 m in the mouth region (to be confirmed by monitoring) ▪ Average water depth < 1.0 m in the middle to upper region, excluding Swart Arm (western arm) which is 5 to 10 m deep (to be confirmed by monitoring). ▪ Average water level change by more than 20% from present
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Average salinity > 30 (expected average range 10-30) ▪ DO < 5 mg/ℓ in estuary ▪ Turbidity > 10 NTU in low flow ▪ Secchi: to bottom ▪ DIN > 100 µg/ℓ once-off ▪ DIP > 20 µg/ℓ once-off ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel change from 30% of baseline (to be determined) (system expected to experience significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton > 3.5 ug/ℓ (median) ▪ Benthic microalgae > 11 mg/m^2 (median) ▪ Phytoplankton > 20 µg/ℓ and/or cell density > 10 000 cells/ml (once-off)
Macrophytes	▪ Maintain distribution of macrophyte habitats	▪ 20% change in the macrophyte area (reeds currently cover 0.6 ha and salt marsh 0.02 ha)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Invertebrates	▪ Establish presence/absence of sand prawn *Callichirus kraussi* on sand banks in lower estuary ▪ Establish presence/absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the present. Numerically, assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (5-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least two species (e.g. *G.aestuaria, & Hyporamphus capensis).* Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 10% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species < 1% Species composition > 50% similar to last three sampling trips (system naturally highly unstable due to resetting events)
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

B.4 GOUKAMMA ESTUARY

The EcoSpecs and associated TPCs representative of a Category A for the Goukamma Estuary are presented in **Table B.4**.

Table B.4 EcoSpecs and Thresholds of Potential Concern for the Goukamma Estuary (Category A)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain flow regime	▪ Varies more than 10% of MAR
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state varies by > 10% from present ▪ Average water depth < 0.5 m in lower reaches (to be confirmed by monitoring) ▪ Average water depth < 2.5 m in middle and upper reaches. Expected range 2.0 to 3.0 m (to be confirmed by monitoring) ▪ Average water level change by more than 20% from present
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Average salinity not between 15 – 35 in lower reaches ▪ Salinity > 10 in upper reaches ▪ DO < 5 mg/ℓ in estuary ▪ Turbidity > 10 NTU in low flow ▪ Secchi: to bottom ▪ DIN > 100 µg/ℓ once-off ▪ DIP > 20 µg/ℓ once-off ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel change from 30% of baseline (to be determined) (system expected to experience significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton > 1.0 µg/ℓ (median) ▪ Benthic microalgae > 11 mg/m^2 (median) ▪ Phytoplankton > 20 µg/ℓ and/or cell density > 10 000 cells/ml (once-off)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Macrophytes	▪ Maintain distribution of macrophyte habitats ▪ Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone	▪ 20% change in the macrophyte area (reeds currently cover 4.1 ha and salt marsh 7.2 ha) ▪ Invasive plants cover > 20% of riparian zone
Invertebrates	▪ Establish presence/absence of sand prawn *Callichirus kraus*si on sand banks in lower estuary ▪ Establish presence/absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the present. Numerically, assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (5-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least two species (*G.aestuaria, & Hyporamphus capensis).* Category IIa obligate dependents should be well represented by at least two large exploited species (*L. lithognathus, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 10% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species <1% Species composition > 50% similar to last three sampling trips (system naturally highly unstable due to resetting events)
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

B.5 NOETSIE ESTUARY

The EcoSpecs and associated TPCs representative of a Category A for the Noetsie Estuary are presented in **Table B.5**.

Table B.5 EcoSpecs and Thresholds of Potential Concern for the Noetsie Estuary (Category A)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain flow regime	▪ Varies more than 10% of MAR
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state varies by > 10% from present ▪ Average water depth < 1.0 m (to be confirmed by monitoring) ▪ Average water level change by more than 20% from present
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Average salinity < 10 (expected average range 10-20) ▪ DO < 5 mg/ℓ in estuary ▪ Turbidity > 10 NTU in low flow ▪ Secchi: to bottom ▪ DIN > 100 µg/ℓ once-off ▪ DIP > 20 µg/ℓ once-off ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton > 1.0 µg/ℓ (median) ▪ Benthic microalgae > 11 mg/m^2 (median) ▪ Phytoplankton > 20 µg/ℓ and/or cell density > 10 000 cells/ml (once-off)
Macrophytes	▪ Maintain distribution of macrophyte habitats. ▪ Prevent an increase in nutrient input leading to macroalgal blooms.	▪ Greater than 20 % change in the area covered by macrophytes (submerged macrophytes currently cover 0.1 ha and reeds and sedges 2.71 ha) ▪ Macroalgal blooms cover > 50% of the open water area.

Ecological component	EcoSpecs	Thresholds of Potential Concern
Invertebrates	▪ Establish presence/absence of sand prawn *Callichirus kraussi* on sand banks in lower estuary ▪ Establish presence/absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically, assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (5-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least two species (e.g. *G.aestuaria, & Hyporamphus capensis).* Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*	▪ Ia estuarine residents < 50% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 10% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species < 1%
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

B.6 MATJIES ESTUARY

The EcoSpecs and associated TPCs representative of a Category B for the Matjies Estuary are presented in **Table B.6**.

Table B.6 EcoSpecs and Thresholds of Potential Concern for the Matjies Estuary (Category B)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain flow regime	▪ Varies more than 10% of MAR ▪ Inflow < 0.03 m^3/s for more than 27% of the time over a 5 year period. ▪ Inflow < 0.1 m^3/s for more than 55% of the time over a 5 year period.
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state varies by > 10% from present ▪ Average water depth < 1.0 m. ▪ Average water level change by more than 20% from present
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Average salinity > 20 for more than 20% of the time (indicative of flow reduction) ▪ Average salinity < 5 for more than 20% of the time (indicative of extended closure) ▪ DO < 5 mg/ℓ in estuary ▪ Turbidity > 10 NTU in low flow ▪ Secchi: to bottom ▪ DIN > 100 µg/ℓ once-off ▪ DIP > 20 µg/ℓ once-off ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain-size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton > 3.5 ug/ℓ (median) ▪ Benthic microalgae > 11 mg/m^2 (median) ▪ Phytoplankton > 20 ug/ℓ and/or cell density > 10 000 cells/ml (once-off)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Macrophytes	▪ Maintain distribution of macrophyte habitats ▪ Prevent an increase in nutrient input leading to macroalgal blooms ▪ Control the spread of invasive plants in the riparian zone	▪ Greater than 20 % change in the area covered by macrophytes (reeds and sedges currently cover 0.2 ha). ▪ Macroalgal blooms cover > 50% of the open water area during closed mouth conditions. ▪ Invasive plants cover > 5% of total habitat
Invertebrates	▪ Establish presence/absence of sand prawn *Callichirus kraussi* on sand banks in lower estuary ▪ Establish presence/absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically, assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (5-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least two species (e.g. *G.aestuaria, & Hyporamphus capensis).* Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50% ▪ Ib marine and estuarine breeders < 10% ▪ IIa obligate estuarine-dependent < 10% ▪ IIb estuarine associated species < 5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species < 1%
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts

B.7 SOUT (OOS) ESTUARY

The EcoSpecs and associated TPCs representative of a Category A for the Sout (Oos) Estuary are presented in **Table B.7**.

Table B.7 EcoSpecs and TPCs for the Sout (Oos) Estuary (Category A)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Hydrology	▪ Maintain present day base flows	▪ MAR do not vary by more than 10% ▪ Floods (indicated by 1:10 year event) do not reduce by more than 5% from present. ▪ Base flows do not increase by more than 50% from present
Hydrodynamics	▪ Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	▪ Closed mouth state increase by 10% from present ▪ Average water level in system > 10% from present ▪ Tidal amplitude (when open) < 20%
Water quality	▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae ▪ Turbidity and Dissolved oxygen not to cause exceedance of TPCs for biota ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae ▪ Toxic substances not to cause exceedance of TPCs for biota	▪ Average salinity along estuary decrease by 5 below baseline average (to be determine) ▪ Average salinity < 10 at the head of the estuary (expected average range 5-10 for most of the system) ▪ DO < 5 mg/ℓ in estuary ▪ Turbidity > 10 NTU in low flow ▪ Secchi: to bottom ▪ DIN >100 µg/ℓ once off ▪ DIP > 20 µg/ℓ once off ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Sediment dynamics	▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey) ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods)
Microalgae	▪ Maintain median phytoplankton/benthic microalgae biomass ▪ Prevent formation of phytoplankton blooms	▪ Phytoplankton >3.5 µg/ℓ (median) ▪ Benthic microalgae >11 mg/m^2 (median) ▪ Phytoplankton >20 ug/ℓ and/or cell density >10 000 cells/ml (once-off)

Ecological component	EcoSpecs	Thresholds of Potential Concern
Macrophytes	▪ Maintain distribution of macrophyte habitats. ▪ Prevent an increase in nutrient input leading to macroalgal blooms ▪ Control the spread of invasive plants in the riparian zone	▪ Greater than 20 % change in the area covered by macrophytes (reeds and sedges currently cover 2.54 ha salt marsh 0.76 ha) ▪ Macroalgal blooms cover > 50% of the open water area during closed mouth conditions ▪ Invasive plants cover >5% of total habitat
Invertebrates	▪ Establish presence absence of sand prawn *Callichirus kraussi* on sand banks in lower estuary ▪ Establish presence absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary	• If present populations deviate from average baselines (as determined in first three visits) by more 30%
Fish	Fish assemblage should comprise the five estuarine association categories in similar proportions (diveristy and abundance) to that under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (50-80% of total abundance) ▪ Ib marine and estuarine breeders (5-20%) ▪ IIa obligate estuarine-dependent (10-20%) ▪ IIb estuarine associated species (5-15%), ▪ IIc marine opportunists (20-80%) ▪ III marine vagrants (not more than 5%) ▪ IV indigenous fish (1-5%) ▪ V catadromous species (1-5%) Category Ia species should contain viable populations of at least 2 species (e.g. *G.aestuaria, & Hyporamphus capensis,* Category IIa obligate dependents should be well represented by at least 2 large exploited species (i.e. *L. lithognathus, Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents <50% ▪ Ib marine and estuarine breeders <10% ▪ IIa obligate estuarine-dependent <10% ▪ IIb estuarine associated species <5% ▪ IIc marine opportunists < 20% ▪ III marine vagrants > 5% ▪ IV indigenous fish <1% ▪ V catadromous species <1%
Birds	▪ Maintain population of original groups of birds present on the estuary	▪ Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

APPENDIX C: COMMENTS AND RESPONSE REGISTER

Section	Report Statement	Comments	Addressed In Report?	Author Comment
Comments: Dr Andrew Gordon (DWS) dated 12 May 2015				
8.2	EcoSpecs	No EWRs and EcoSpecs have been proposed for alternate Ecological Category scenarios	No	In terms of the Estuary methods (DWAF, 2008) and ToR for this preliminary Reserve study, EcoSpecs will only be provided for REC
8.2	EcoSpecs	Phrase “Resource Quality Objective” is used to describe what I think are actually EcoSpecs	Yes	RQOs changed to EcoSpecs throughout report
8.3	Monitoring programme	Recommended monitoring programmes for the estuaries are beyond the current capabilities of the DWS/CMA. Is it possible to suggest a monitoring plan that is phased in over a number of years so that the managing agency has a chance to build capacity	Yes, mostly	Priority components in the monitoring programme have been identified. Also the monitoring was split between baseline surveys and long-term monitoring.
8.2	EcoSpecs: Fish	EcoSpecs for fish need to be more explicit	Yes	Uncertainty in EcoSpecs for fish was changed in all tables
Comments: Dr Angus Paterson (external reviewer, SAIAB) dated May 2015				
Entire report	Entire report	Editorial corrections pointed out in his report	Yes	Editorial corrections were made through out report
9	References	Referencing in the report is not comprehensive. In some instances references in main report are listed in Appendices	Yes	References were checked and consolidated (i.e. removed from individual Appendices) in the Reference section (see Section 9)
1.1	Introduction	The introduction to all the reports should include more detail on the rationale of the RDM analysis level applied to that system.	Yes, this has been included	This has been included (see Section 1.1, paragraph 2). The sections referred to in the Inception report provides the level of EWR studies for those estuaries not included in this study)
1.4	Assumptions and Limitations	The assumptions and limitations of each study must be clearly outlined and should be linked to the Data Availability Tables.	Yes	The Assumptions and Limitation sections have been updated accordingly (see Section 1.4)

Section	Report Statement	Comments	Addressed In Report?	Author Comment
		Specifically any data requirement that is not met in the Data Availability Tables but is prescribed as being required in the 2008 Methods, must be discussed even if it is to indicate that an omission will have negligible bearing on the confidence or outcome of the Reserve		
1.4	Use of study data	The reports must include a more comprehensive guideline on how the different reports should be used by DWS. These guidelines are available in the 2008 methods but should be included in each report and customised to that particular system.	Yes	The Assumptions and Limitation sections has been updated accordingly (see Section 1.4, last bullet)
5.3	Confidence	Low confidences – It is suggested that in Sections which end up having a Low or Very Low confidence, the low confidence be explained in the narrative on that section and/or specifically discussed . If it is data that was limiting or inconclusive this then needs to be linked to the limitations and assumptions section as per comment 5.6 above.	Yes, mostly	Components with low data availability were highlighted in Section 5.3 on confidence. Section 1.2 also explains the different levels of confidence (including low and very low confidence
8.3	Monitoring programme	The resource monitoring programmes should be divided into two discreet sections namely Baseline surveys and Long term compliance monitoring. In terms of long term monitoring a priority system should be included	Yes	The monitoring was split into baseline survey and long-term programmes. Priorities were also defined (see Tables 8.2 and 8.3)
Executive summary	Executive summary	No executive summary. It is suggested that a Table and short narrative is included as an Executive summary	Yes	Executive summary was included
1.4	Assumptions and limitations	Confidence: A section on the confidence and future limitations of the desktops should be included. It should be clearly outlined what the Desktops can and cannot be used for.	Yes	This was included (see Section 1.4)

Section	Report Statement	Comments	Addressed In Report?	Author Comment
Figure 3.2	Blinde Estuary	Very dark	No	Resolution of original picture from Google Earth
All REC sections	REC	In those systems where the REC cannot be met should the reports not clearly indicate that further abstraction should not be allowed, or is this implicit?	Yes	Statements were added (see all section on REC)
Appendix A	Acronym	TOCE – In full	Yes	Amended text
Appendix A	Blinde Estuary	Check 5m contour position in figure	Yes	Figure removed as already correct in main report
Comments: Barbara Weston (DWS) dated September 2015 as presented in Gouritz Report in track changes				
Entire report	Entire report	Editorial corrections made in track changes	Yes	Editorial corrections were made throughout report
Entire report	Salinity	Add units for salinity	No	Salinity is unitless (IS units)
Comments: Dr Aldu le Grange (AECOM) dated 26 October 2015				
Entire report	Entire report	Entire report	Entire report	Entire report