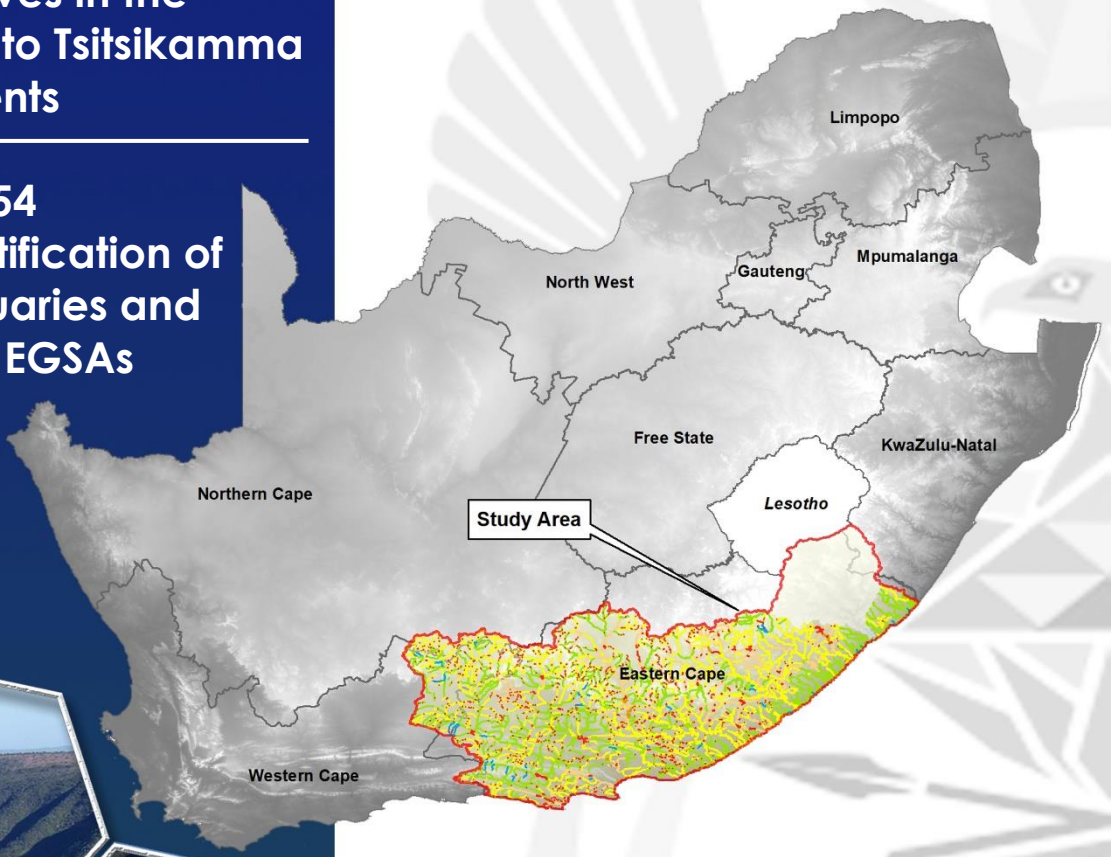
DEPARTMENT OF WATER AND SANITATION

Determination of Water Resource Classes, Reserve and the Resource Quality Objectives in the Keiskamma and Fish to Tsitsikamma Catchments

WP11354
Report on Quantification of the EWR for Estuaries and Changes in EGSAs



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Reports as part of this project:

Bold type indicates this report

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LIST OF ACRONYMS

BAS	Best Attainable State
BHN	Basic Human Needs
CD: WEM	Chief Directorate: Water Ecosystems Management
DFFE	Department of Forestry, Fisheries and the Environment
DIN	Dissolved Inorganic Nitrate
DIP	Dissolved Inorganic Phosphate
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EFR	Environmental flow requirements
EFZ	Estuary Functional Zone
EGSAs	Ecological Goods, Services and Attributes
EHI	Estuarine Health Index
EI	Ecological importance
EIS	Estuary Importance Score
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
GBF	2030 Global Biodiversity Framework
HABs	Harmful algal blooms
ICM	Integrated Coastal Management
IUA	Integrated Unit of Analysis
IWRM	Integrated Water Resource Management
MAR	Mean Annual Runoff
MPA	Marine protection area
MSL	Mean Sea Level
N SWSA	National Strategic Water Source Areas
NWA	National Water Act
NWRCS	National Water Resource Classification System
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQO	Resource Quality Objectives
Snc	Scenario
WRCS	Water Resource Classification System
WWTW	Waste Water Treatment Works

EXECUTIVE SUMMARY

BACKGROUND AND PURPOSE

This Report on Quantification of the Ecological Wate Requirements (EWR) for Estuaries and Changes in Ecological Goods, Services and Attributes (EGSAs) Report forms part of step 4 of the Reserve determination process and aligns with Step 3 of the integrated framework, DWS (2017) as part of the study to Determine the Water Resource Classes, Reserve and Resource Quality Objectives (RQOs) in the Keiskamma and Fish to Tsitsikamma catchment.

The results from this study will guide the Department of Water and Sanitation (DWS) to meet the objectives of maintaining, and if attainable, improving the ecological state of the water resources to facilitate sustainable use of the water resources while maintaining ecological integrity. The primary deliverable will be the preparation of the templates with the final Water Resource Classes and RQOs for gazetting.

This report draws on the results of the eco-categorisation that was undertaken for all selected priority estuaries (see Report No. WEM/WMA7/00/CON/RDM/2024). The focus of this report is the quantification of the EWRs.

STUDY AREA AND LOCATION OF PRIORITY ESTUARIES

Overall, there are 155 estuaries in the study area. Ten of the estuaries in the WMA have been the focus of previous Environmental Flow Requirement or EWR studies, albeit it is of low confidence in some cases. An additional seven estuaries are being assessed in more detail as part of this study to address gaps in the water resources classification process, with selection influenced by identified water resources pressure (current or future), estuary ecological importance, requests from other sectors of government, and available study resources.

The priority estuaries for Rapid/Comprehensive EWR assessments that will be done in more detail include:

- Mngazi
- Mbashe
- Great Kei
- Keiskamma
- Kariega
- Gamtoos
- Kabeljous

See **Figure 1** for the location and relative catchment size of the 7 priority estuaries.

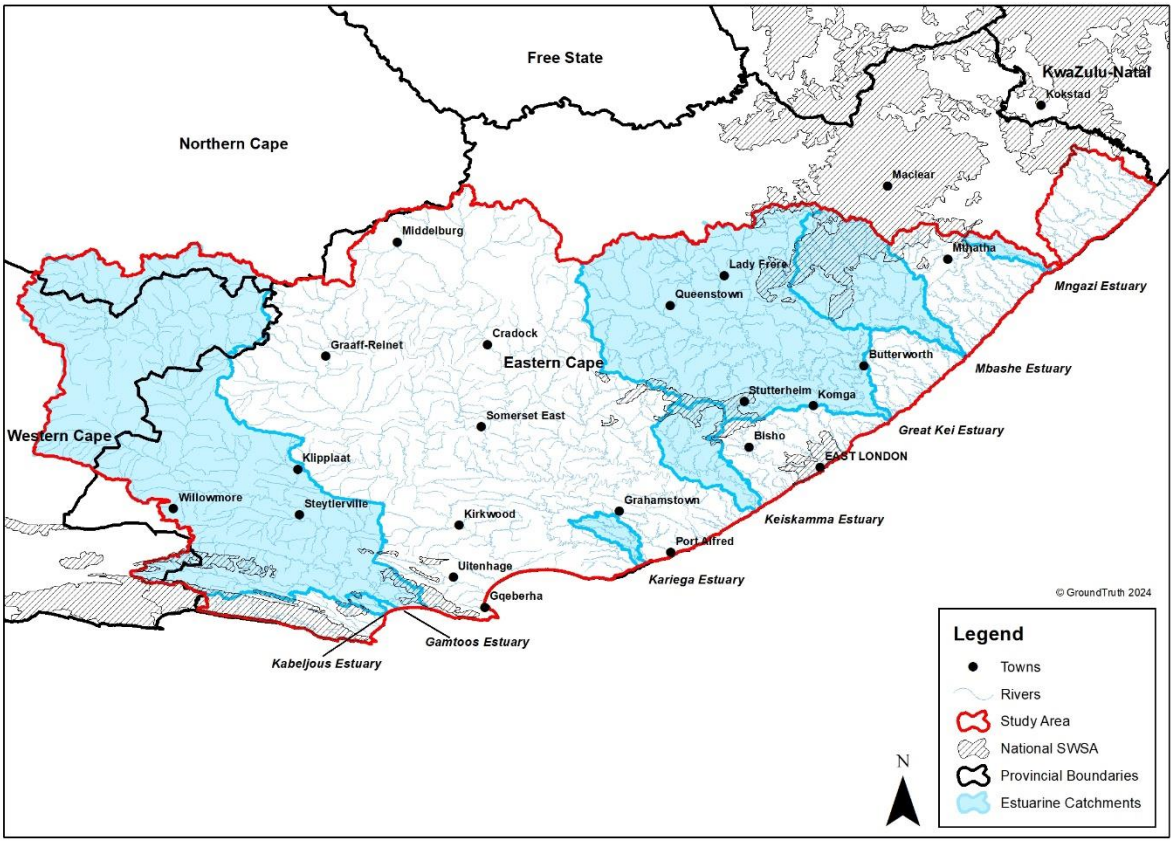

Figure 1: *Overview of the priority estuary catchments.*

Approach and Methodology

Methods to determine the Ecological Water Requirements for estuaries were established soon after the promulgation of the National Water Act (NWA) in 1998. The "Preliminary Reserve Method" involves setting a Recommended Ecological Category (REC) (i.e. desired state), recommended Ecological Reserve (i.e. flow allocation to achieve the REC) and recommended RQOs for a resource based on its present health status and its ecological importance. The official method for estuaries (Version 2), is documented in DWA (2008). In 2013, an unofficial Version 3 of the method was published, as part of a Water Research Commission study (Turpie *et al*., 2012a,b). The study uses Version 2 of the methodology (DWA, 2008), but with consideration of obvious improvements proposed in Version 3 (Turpie *et al*., 2012a,b) and Taljaard *et al*. (2022). The generic steps of the official "Ecological Reserve Method" for estuaries were applied as follows:

- Step 1: Initiate a study defining the study area, project team and level of study (confirmed in the **inception report** of this study).

- Step 2: Delineate the geographical boundaries of the resource units (confirmed in the **delineation report** of this study).

- Step 3a: Determine the **Present Ecological State** (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, unimpacted 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 to evaluate the current condition of the estuary. The EHI scoring of the various variables is based on a review of historical data, as well as data collected during a field monitoring programme in 2023/4. Both abiotic and biotic variables are included as the relationships between the abiotic and biotic variables are often not well understood and because the biotic response to certain abiotic variables can be lagging. The estuarine health score is translated into one of six Ecological Categories (ECs) from A to F.

- 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 into account rating an estuary from low to high importance as below:

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

- Step 3c: Set the **Recommended Ecological Category (REC)** which is derived from the PES and EIS (or the protection status allocated to a specific estuary) following the guidelines listed below:

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.

** Best Attainable State*

An estuary cannot be allocated a REC below a Category “D”. Therefore, systems with a PES in Categories ‘E’ or ‘F’ need to be managed towards achieving at least a REC of “D”.

- Step 4: **Quantify the ecological consequences of various runoff scenarios** (including proposed operational scenarios) where the predicted future condition of the estuary is assessed under each scenario. As with the determination of the PES, the EHI is used to assess the predicted condition in terms of the degree of similarity to the reference condition.

- Step 5: Quantify the (recommended) **Ecological Water Requirements (EWR)**, which represent the lowest flow scenario that will maintain the resource in the REC. Please note the detailed information pertaining to the EGSA will be provided within the Socio-economic Report.

- Step 6: Estimate (recommended) **Resource Quality Objectives (Ecological Specification)** for the REC, as well as future monitoring requirements to improve the confidence of the EWR.

EWR RESULTS SUMMARY

MNGAZI ESTUARY

Description of hydrological scenarios

Table 1 provides a summary of a range of water resource development scenarios that could affect the Mngazi Estuary.

Table 1: Summary of flow scenarios

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity	Category
Reference	Natural (~1750)	87.31	100.0	A
Present	Present (no EWR)	83.52	95.7	B
Scenario 1	Present (with EWR)	83.52	95.7	B
Scenario 2	Mid-term (no EWR)	83.04	95.1	B
Scenario 3	Long-term (no EWR)	82.55	94.6	B
Scenario 4*	Dams (no EWR)	77.87	89.2	B/C

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

The Mngazi Estuary PES is estimated to be 84% similar to natural conditions, which translates into a PES of a B Category. Scenarios 1 to 3 rate the same as the present with no definable change in health condition. Under Scenario 4 the estuary declines a further 7% in condition to a Category B/C.

The PES and REC for the Mngazi Estuary is a B Category as the estuary is not a conservation priority.

Recommendations to maintain or improve/maintain estuary condition

Key interventions required to improve the condition of the Mngazi Estuary (on the edge of a B/C Category) include:

- Develop an Estuary Management Plan for the Mngazi Estuary to identify key actions required to arrest the downward trajectory and coordinate restoration efforts where required (requirement of National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008).
- Ensure maintenance of low-flow conditions to prevent prolonged periods of mouth closure that promote microalgal accumulation and the severity of bottom-water hypoxia.
- Manage nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring riparian vegetation (buffer zones).
- Manage/reduce fishing pressure by managing access, increased compliance and improved community awareness.

- Prevent disturbance of riparian vegetation, including trampling by cattle, fire, and remove alien vegetation from the EFZ.

The Recommended Flow Scenario is Scenario 3 (Long-term development) coupled with the interventions listed above to address further decline. The flow requirements for the estuary are the same as those described for Scenario 3 and are summarised in **Table 2.**

Table 2: Mngazi Estuary: Summary of the monthly flow distribution (in m^3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 3: Long-term development).

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	25.21	25.11	16.08	12.95	16.57	37.41	26.41	10.41	20.09	27.39	9.95	28.95
90	5.50	9.25	7.50	3.72	7.72	13.81	10.43	4.03	3.00	3.29	2.00	3.85
80	2.17	5.94	3.95	2.23	3.97	7.38	5.62	2.15	1.51	1.25	1.16	1.34
70	1.49	2.67	2.44	1.40	1.40	4.69	2.90	1.37	1.23	1.09	0.96	0.98
60	1.03	1.73	1.54	1.04	1.22	3.50	2.15	1.15	0.96	0.90	0.79	0.89
50	0.95	1.14	1.03	0.89	1.06	1.78	1.32	0.99	0.86	0.80	0.72	0.75
40	0.84	1.04	0.88	0.77	0.88	1.19	1.08	0.85	0.73	0.66	0.62	0.68
30	0.70	0.85	0.69	0.69	0.80	1.00	0.98	0.73	0.62	0.58	0.56	0.63
20	0.62	0.75	0.57	0.58	0.72	0.76	0.74	0.63	0.56	0.50	0.49	0.55
10	0.50	0.62	0.49	0.49	0.55	0.58	0.55	0.53	0.43	0.39	0.39	0.43
1	0.30	0.32	0.29	0.26	0.32	0.24	0.29	0.27	0.26	0.28	0.24	0.26

MBASHE ESTUARY

Description of hydrological scenarios

Table 3 provides a summary of a range of water resource development scenarios that could affect the Mbashe Estuary.

Table 3: Mbashe Estuary: Summary of flow scenarios

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity	Category
Reference	Natural	786.88	100.0	A
Present	Present (no River EWR)	861.16	109.4	B/C
Scenario 1	Mid-term (no River EWR)	858.15	109.1	B/C
Scenario 2	Long-term (no River EWR)	853.72	108.5	B/C
Scenario 3*	50 % reduction in the transfer scheme	819.21	104.1	B
Scenario 4*	No transfer scheme input	770.59	97.9	B
Scenario 5*	Dam development (no River EWR)	682.56	86.7	C
Scenario 6*	Scenario 2 Long-term (no River EWR) with additional estuary restoration interventions	853.72	108.5	B

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

The present MAR into the Mbashe Estuary is 861.16 Million m^3. This is an **increase** of 9.4% compared to the natural MAR of 786.88 Million m^3. The Mbashe Estuary in its present state is estimated to be 74% similar to natural conditions, which translates into a PES of a B/C Category.

Scenario 1 and 2 are similar to the present, Category B/C, with Scenario 2 representing a slight improvement. Scenarios 3 and 4 represent an improvement to Category B, but some of the higher trophic levels (e.g. inverts and fish) are still in a degraded state. Scenario 5 represents a decline to Category C. Scenario 6, the flow regime of Scenario 2 with additional restoration interventions, improves the system to a Category B – thus meeting biodiversity requirements and restoring key ecosystem services such as nursery function (food security for the region) for and carbon sequestration (contribute to climate protection).

Recommendations to maintain or improve estuary condition

Given the high degree of land-use change in the Mbashe Catchment, the impact of the interbasin transfer scheme, and the present level of natural resource utilisation (fishing and grazing) the REC is set as a B Category (BAS). Hence, Scenario 6 was selected to stabilise the ecosystem functioning

The Recommended interventions to address the ongoing decline in condition and achieve the REC:

- Develop an Estuary Management Plan to identify key management actions required to achieve the REC and coordinate restoration efforts.
- Significantly reduce fishing pressure by managing access, increased compliance and community interactions to achieve MPA protection objectives and REC.
- Manage nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring riparian vegetation.
- Prevent disturbance of riparian vegetation, including cattle trampling, occurrence of fire, and removal of alien vegetation in the EFZ.
- Limit trampling and browsing of saltmarsh and browsing and harvesting of mangroves. Mangroves are legally protected by two separate pieces of legislation: National Forests Act (84 of 1998) and the Marine Resources Act (18 of 1998). The species *Bruguiera gymnorrhiza* and *Rhizophora mucronata* are further protected by the Protected Tree list (DWAF, 2010). All these would be addressed through an Estuary Management Plan. The sustainable use of mangroves should be encouraged with the harvesting of mangroves.

Ecological flow requirements

The flow requirements for the estuary are the same as those described for Scenario 2 below and are summarised in **Table 4**.

Table 4: Mbashe Estuary: Summary of the monthly flow distribution (in m^3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 6: Scenario 2 - Long-term with no River EWR with estuary restoration measures)

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	159.58	178.78	147.14	166.59	171.52	244.68	147.93	86.02	82.59	96.80	92.24	143.03
90	54.15	106.87	81.31	69.89	87.74	111.56	78.18	30.68	18.78	19.15	25.80	57.10
80	30.53	61.61	58.58	50.33	58.44	69.96	47.09	22.85	13.50	11.44	10.04	22.20
70	22.45	32.51	40.35	34.16	40.08	57.62	28.70	14.48	10.27	9.40	9.26	14.03
60	19.29	22.72	22.76	25.72	32.63	43.32	23.75	10.22	8.51	8.26	7.96	9.28
50	15.71	17.35	15.77	19.41	27.32	32.34	18.26	8.62	7.57	7.44	7.36	8.18

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
40	11.00	14.10	10.50	13.94	19.34	23.01	14.30	7.83	7.15	6.79	6.64	7.27
30	8.57	10.70	8.23	9.49	14.44	16.64	11.75	6.92	6.88	6.43	6.17	6.28
20	7.54	8.71	6.06	7.28	10.66	12.65	8.14	6.50	6.35	5.93	5.93	5.98
10	6.29	7.00	5.52	5.69	7.72	10.13	6.92	6.01	5.67	5.45	5.43	5.57
1	4.36	4.66	3.06	2.89	5.04	3.00	4.77	3.55	3.13	3.08	3.12	3.40

GREAT KEI ESTUARY

Description of hydrological scenarios

Table 5 provides a summary of a range of water resource development scenarios that could affect the Great Kei Estuary.

Table 5: Great Kei Estuary: Summary of flow scenarios.

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity	
Reference	Natural	1040.71	100.0	A
Present	Present (no river EWR)	741.99	71.3	C
1*	Restoration (Present with river EWR + remove Invasive Aliens)	771.03	74.1	B/C
2	Present (with river EWR)	762.06	73.2	B/C
3	Mid-term (no river EWR)	742.24	71.3	C
4	Long-term (with river EWR)	754.82	72.5	B/C
5	Long-term (no river EWR)	734.80	70.6	C
6*	Long-term (no river EWR) and increased baseflow abstraction (3 m^3/s)	651.51	62.6	D
7*	Restoration (Present with river EWR + remove Invasive Aliens) with additional management interventions at the Estuary	771.03	74.1	B/C

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

The present MAR into the Great Kei Estuary is 742 Million m^3. This is a decrease of 29% compared to the natural MAR of 1 041 Million m^3. The Great Kei Estuary in its present state is estimated to be 68% similar to natural conditions, which translates into a PES of a C Category.

Scenarios 1, 2, and 4 (scenarios with River EWR release) improve estuary condition to a B/C Category, but some of the higher trophic levels (e.g. invertebrates, fish and birds) remain degraded and do not contribute optimally to ecosystem services and conservation objectives. Under Scenario 7 (Scenario 1 with additional management measures at the estuary), the estuary health improves to a B/C Category, and critical ecosystem services such as nursery function and carbon sequestration meet biodiversity and conservation objectives. Overall, the estuary showed a ~6% improvement in health in response to the release of a river EWR across present and further development scenarios. Under Scenarios 3 and 5 the estuary health remains similar to the present, i.e. shows little sensitivity to medium and long-term

development scenarios. Under the 'worst-case' Scenario 6 the estuary declines further to a Category D – highlighting the estuary's sensitivity to flow reduction.

Recommendations to maintain or improve estuary condition

The PES for the Great Kei Estuary is a C Category, but as the estuary is of high biodiversity and conservation importance it should be in an A or B Category or BAS. **However, given the level of land use change in the catchment and the high level of resource use in and around the estuary, the REC is a B/C (BAS).**

Key interventions required to improve the condition of the Great Kei Estuary include:

- Develop an Estuary Management Plan for the Great Kei Estuary to identify key actions required to address the ongoing decline in condition and coordinate restoration efforts.
- Reduce fishing and bait collection pressure by managing access, increased compliance and community interactions.
- Ensure maintenance of low-flow conditions to prevent prolonged periods of increased water residency that promote the accumulation of phytoplankton and benthic microalgal communities.
- Manage nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring riparian vegetation.
- Prevent disturbance of riparian vegetation (especially mangroves), including trampling and grazing/browsing by cattle and fire.
- Remove alien vegetation within the EFZ.
- Manage/control recreational activities (e.g. boating) in the lower and middle reaches, particularly along the shoreline on the seaside affecting bird abundance.

Ecological flow requirements

The Recommended Flow Scenario is Scenario 7 – similar in river inflow requirement to Scenario 1 (Present with river EWR release and additional removal of invasive alien plants from catchment) coupled with the estuary management interventions listed above. The flow requirements for the estuary are the same as those described for Scenario 1 and are summarised in Table 6.

Table 6: Great Kei: Summary of the monthly flow distribution (in m3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 7: Restoration (Present with river EWR + remove Invasive Aliens from catchment) with additional management interventions at the Estuary).

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	230.3	328.5	197.0	189.0	318.3	513.5	230.6	146.2	77.6	101.8	160.7	164.8
90	51.1	124.4	87.0	106.6	109.5	135.9	78.9	41.5	20.4	15.6	26.8	46.9
80	28.4	68.4	63.8	65.6	83.8	96.0	49.8	21.7	13.4	13.2	11.5	20.7
70	20.4	28.4	42.6	38.7	62.0	62.3	37.8	14.2	10.3	9.8	9.6	13.8
60	15.9	21.3	25.6	30.6	42.1	37.8	26.7	11.7	9.4	8.2	8.2	11.6
50	13.1	15.3	18.7	20.4	32.6	34.2	19.4	10.1	8.0	7.6	7.2	9.0
40	10.4	13.1	14.1	17.4	23.0	27.4	16.3	9.1	7.2	6.6	6.6	7.2
30	8.9	10.8	9.7	12.6	16.4	24.0	12.8	7.5	6.6	6.2	6.3	6.5
20	6.8	9.0	7.0	7.0	13.0	17.0	10.1	6.6	6.0	5.7	5.7	5.6

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
10	5.2	6.8	5.1	5.2	9.1	11.4	7.9	5.8	5.2	5.1	5.0	5.1
1	3.7	3.7	3.5	2.6	3.4	4.3	4.6	4.7	4.0	3.7	3.6	3.7

KEISKAMMA ESTUARY

Description of hydrological scenarios

Table 7 provides a summary of a range of water resource development scenarios that could affect the Keiskamma Estuary.

Table 7: Keiskamma Estuary: Summary of flow scenarios.

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity	Category
Reference	Natural	128.68	100.0	A
Present	Present (no River EWR)	86.43	67.2	C
1*	Restoration (Present with EWR + removal of invasive alien plants from catchment)	98.85	76.8	B
2	Present (with EWR)	88.48	68.8	B/C
3	Long-term (with EWR)	85.07	66.1	B/C
4	Mid-term (no EWR)	82.85	64.4	C
5	Long-term (no EWR)	82.44	64.1	C
6*	Worse case (Long-term no EWR, increased baseflow abstraction, large dams)	72.58	56.4	C/D
7*	Scenario 1: Restoration (Present with EWR + invasive alien plant eradication) with estuary management interventions	98.85	76.8	B

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

The present MAR into the Keiskamma Estuary is 86.4 Million m^3. This is a decrease of 33% compared to the natural MAR of 128.7 Million m^3. The Keiskamma Estuary in its present state is estimated to be 67% similar to natural conditions, which translates into a PES of a C Category.

Scenario 1 (Present with EWR release and invasive alien plant eradication from catchment) represents an improvement of the Estuary to a Category B, while Scenarios 2 and 3 represent only a half-category overall improvement. However, higher ecology remains stressed under these scenarios as a result of present estuary resource use levels. Scenarios 4 and 5 are similar to the Present with only a slight decline in estuary condition. Scenario 6 represents a significant decline in estuary condition as a result of further flow reduction, amplifying existing nutrient pressure. Scenario 7 (Scenario 1: Present with EWR release and invasive alien plant eradication from catchment) with estuary management interventions listed above) represents the only scenario in which all components of the ecosystem improve with a marked improvement in critical ecosystem services such as nursery function and carbon sequestration.

Recommendations to maintain or improve estuary condition

The PES for the Keiskamma Estuary is a C Category, but as the estuary is degraded and of high biodiversity and conservation importance it should be in an A or B Category or BAS. **Given the land-use change in the Keiskamma Catchment and estuary environs and the present level of natural resource utilisation of the estuary the REC is set at a B Category (BAS).**

Key interventions required to improve the condition of the Keiskamma Estuary include:

- Develop an Estuary Management Plan for the Keiskamma Estuary to identify key actions require to address the ongoing decline in condition and coordinate restoration efforts.
- Reduce fishing and bait collection pressure by managing access, increase compliance and improve community interactions.
- Ensure maintenance of low-flow conditions to prevent prolonged periods of increased water residency that promote the accumulation of microalgal communities.
- Manage nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring riparian vegetation.
- Restore saltmarsh areas that are fallow at present.
- Prevent disturbance of riparian vegetation, including trampling and severe overgrazing by cattle.
- Removal of alien vegetation from EFZ.

Ecological flow requirements

The REC for the Keiskamma Estuary is Category B. The Recommended Flow Scenario is Scenario 1: Restoration (Present with EWR + invasive alien plant eradication) coupled with interventions listed above. The flow requirements for the estuary are the same as those described for Scenario 1 and are summarised in **Table 8**.

Table 8: Keiskamma Estuary: Summary of the monthly flow distribution (in m^3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 1: Present with EWR and invasive alien plant eradication) coupled with management interventions.

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	29.6	60.9	27.5	19.1	20.0	45.2	23.2	19.6	14.4	22.3	54.0	24.2
90	7.7	12.5	11.1	8.9	10.1	13.4	8.7	4.4	3.1	3.1	4.7	8.1
80	5.4	7.0	6.9	5.1	6.6	6.9	5.0	2.5	2.2	2.3	2.2	4.0
70	3.6	4.4	4.5	3.9	4.2	5.3	3.3	2.0	1.7	1.8	1.9	2.6
60	3.0	3.5	3.3	2.7	3.3	4.0	2.8	1.7	1.5	1.6	1.6	1.8
50	2.3	2.7	2.5	2.3	2.3	2.9	2.4	1.5	1.3	1.3	1.4	1.6
40	1.9	2.3	1.9	1.7	1.9	2.2	1.9	1.3	1.3	1.2	1.3	1.4
30	1.7	2.0	1.7	1.4	1.6	1.9	1.6	1.1	1.1	1.1	1.2	1.3
20	1.4	1.7	1.2	1.0	1.5	1.5	1.2	1.0	1.0	1.0	1.0	1.1
10	1.1	1.3	0.9	0.7	0.9	1.2	0.9	0.8	0.9	0.9	0.9	0.9
1	0.8	0.6	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.6	0.7	0.7

KARIEGA ESTUARY

Description of hydrological scenarios

Table 9 provides a summary of a range of water resource development scenarios that could affect the Kariega Estuary.

Table 9: Kariega Estuary: Summary of flow scenarios

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity	Category
Reference	Natural	21.89	100.0	**A**
Present	Present (no river EWR)	13.08	59.8	**C**
1*	Restoration (strategic releases from the Settlers Dam (0.005 m^3/s) in the months in which the estuary does not receive incremental flows from below the dam,33% reduction in irrigation below the dam, and no support to Grahamstown from Settlers)	14.96	68.3	**C**
2	Medium/Long Term (no river EWR)	13.08	59.8	**C**
3*	Worse Case (full demand of Makhanda (Grahamstown) supplied from the Kariega, no Orange-Fish transfer)	9.89	45.2	**D**

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

The present MAR into the Kariega Estuary is 13.1 Million m^3. This is a decrease of 40% compared to the natural MAR of 21.9 Million m^3.

The Kariega Estuary in its present state is estimated to be 68% similar to natural conditions, which translates into a PES of a C Category. Under Scenarios 1 and 2 the estuary is in a Category C, the same as the PES, with Scenario 1 only representing a slight 3% increase in condition with a major impact on water resource allocation in the catchment. Scenario 3 resulted in an additional 15% decline in condition, resulting in a D Category.

Recommendations to maintain or improve estuary condition

The PES for the Kariega Estuary is a C Category, but as the estuary is degraded and of high biodiversity and conservation importance it should be in an A Category or BAS. **However, given the small size of the catchment; the degree of land-use change in the catchment and lower parts of the estuary; and the present level of natural resource utilisation of the Kariega Estuary, the REC is set as a C Category (BAS).**

Key interventions required to assist with species protection and to halt further decline in the condition of the Kariega Estuary include:

- Increase the protection of the estuary to ensure the protection of Estuarine pipefish and seagrass, i.e. stewardship agreements with Private Nature Reserve adjacent to the system.
- Develop an Estuary Management Plan for the Kariega Estuary to identify key actions required to improve/protect the system and coordinate restoration efforts (requirement of National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008) to coordinate management and restoration actions.

- Prevent further loss of low-flow conditions to limit the extent and duration of hypersalinity that leads to a loss of primary productivity. Increase base flows (e.g. through the removal of alien vegetation, unauthorised abstractions and/or forestry) to prevent mouth closure.
- Create interventions within the catchment and institute a buffer zone around the river and EFZ that would improve the nutrient status and help with sedimentation issues.
- Reduce fishing and bait collection pressure by managing access, increase compliance and improve community interactions to restore nursery function.
- Undertake restoration of the estuary floodplain and reduce agriculture impacts in the supratidal area of the system.
- Prevent disturbance of riparian vegetation, including trampling, cattle, fire, and removal of alien vegetation.

Ecological flow requirements

The REC for the Kariega Estuary is Category C. Scenario 2 yields the same scores as the Present, thus the Recommended Flow Scenario is Scenario 2 (Medium Term/Long Term development) coupled with the interventions above. The flow requirements for the estuary are the same as those described for Scenario 2 and are summarised in **Table 10.**

Table 10: Kariega Estuary: Summary of the monthly flow distribution (in m^3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 2: Medium / Long term development)

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	7.767	11.136	4.886	1.388	1.297	8.587	7.097	6.468	9.654	5.122	11.310	10.232
90	0.501	0.494	0.605	0.209	0.160	0.554	0.451	0.386	0.205	0.247	0.662	1.213
80	0.341	0.221	0.167	0.048	0.062	0.285	0.183	0.107	0.090	0.060	0.097	0.296
70	0.206	0.120	0.068	0.027	0.033	0.082	0.117	0.053	0.051	0.045	0.051	0.062
60	0.086	0.054	0.037	0.019	0.021	0.046	0.080	0.037	0.040	0.034	0.034	0.040
50	0.052	0.041	0.026	0.009	0.017	0.034	0.033	0.030	0.031	0.026	0.026	0.027
40	0.032	0.031	0.011	0.004	0.004	0.026	0.023	0.022	0.027	0.022	0.019	0.023
30	0.018	0.014	0.000	0.000	0.000	0.011	0.015	0.015	0.019	0.018	0.015	0.019
20	0.007	0.004	0.000	0.000	0.000	0.004	0.003	0.007	0.015	0.011	0.010	0.011
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.008	0.007	0.004	0.000
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

GAMTOOS ESTUARY

Description of hydrological scenarios

Table 11 provides a summary of a range of water resource development scenarios that could affect the Gamtoos Estuary.

Table 11: Gamtoos Estuary: Summary of flow scenarios

Scenario	Description	MAR ($X\ 10^6\ m^3$)	% Similarity	Category
Reference	Natural	404.23	100.0	A
Present	Present (no River EWR)	194.82	48.2	D
1*	Restoration Scenario (Present with River EWR, irrigation demands 33% decreased on Kouga	219.71	54.4	C

Scenario	Description	MAR (X 10^6 m^3)	% Similarity	Category
	Dam, all alien invasives have been removed - except for the Groot)			
2	Present (with River EWR)	209.19	51.8	**C**
3	Mid-term (no River EWR)	199.86	49.4	**D**
4	Long-term Desalination (no EWR)	199.59	49.4	**D**
5	Long-term Kouga Dam Raised (with River EWR)	198.60	49.1	**D**
6	Long-term Kouga Dam Raised (no River EWR)	192.57	47.6	**D**
7*	Long-term Worst case (Long-term demands, raised Kouga Dam, no EWR, no support from the Fish/ Sundays scheme)	175.04	43.3	**D**
8*	Present (with River EWR) with Estuary Management interventions	209.19	51.8	**C**

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario.*

The present MAR into the Gamtoos Estuary is 195 million m^3. This is a decrease of 52% compared to the natural MAR of 404 million m^3. The Gamtoos Estuary in its present state is estimated to be 54% similar to natural conditions, which translates into a PES of a D Category. Scenarios 1 and 2 (both include River EWR releases) represent a nearly 10% improvement in the health of the Gamtoos Estuary resulting in a Category C. The difference between Scenario 1 and 2 is minimal in benefits to the estuary, even though Scenario 1 represents a 33% decrease in irrigation demand from the Kouga Dam and all invasive alien plants removed from most of the catchment). Indicating that little ecological benefit can be derived at the expense of existing water resource allocation. Scenarios 3 to 6 largely remain similar to the present, with an additional 8 % decline in the condition expected under Scenario 7, but with the system remaining in a D category. Scenario 8 (Present with River EWR releases and additional estuary management interventions) represents the scenario with the best ecological outcomes with important ecosystem services such as nursery function and carbon sequestration optimised even if conservation targets cannot be met overall.

Recommendations to maintain or improve estuary condition

The PES for the Gamtoos Estuary is a D Category, but as the estuary is degraded and of high biodiversity and conservation importance it should be in an A Category or BAS. **However, given the degree of land-use change, specifically agriculture, in the catchment and estuary floodplain; concerns regarding water quality; and the present very high level of natural resource utilisation of the Gamtoos Estuary the REC is a C Category (BAS).**

Key interventions required to improve the condition of the Gamtoos Estuary include:

- Develop an Estuary Management Plan for the Gamtoos Estuary to identify key actions required to halt the ongoing degradation of estuary condition and restore and coordinate restoration efforts (requirement of National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008).
- Increase base flows (e.g. through the removal of alien vegetation, unauthorised abstractions and/or forestry) to prevent mouth closure.
- Maintain a degree of natural hydrodynamic variability and periodic system flushing to prevent persistent eutrophic conditions (i.e., HABs, hypoxia, loss of species diversity).
- Reduce nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring riparian vegetation.

- Institute a buffer zone around the river and EFZ that would improve the nutrient status and help with sedimentation issues.
- Develop and approve an Estuary Mouth/Maintenance Management Plan (required under the Environmental Impact Assessment regulations under the National Environmental Management Act (No. 107 of 1998)) to facilitate artificial breaching if required in future.
- Reduce fishing pressure by managing access, increase compliance and improve community interactions to restore nursery function.
- Prevent further disturbance of estuary riparian vegetation, including reducing trampling and grazing by livestock, the occurrence of fire, and remove alien vegetation from the EFZ.
- Undertake active restoration of the degraded estuary floodplain and reduce agriculture impacts in the supratidal area of the system.

Ecological flow requirements

The REC for the Gamtoos Estuary is Category C. The Recommended Flow Scenario is Scenario 8, which is a similar flow regime to Scenario 2: Present (with River EWR) coupled with estuary restoration interventions listed above. The flow requirements for the estuary are the same as those described for Scenario 2 and are summarised in Table 12.

Table 12: Gamtoos Estuary: Summary of the monthly flow distribution (in m3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 8: Present with River EWR with estuary restoration intervention)

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	32.9	69.9	57.2	68.2	97.8	122.3	57.8	54.2	48.1	37.1	112.3	48.1
90	7.8	8.9	7.2	6.2	20.8	32.4	20.7	5.6	5.1	8.7	26.1	30.4
80	5.1	4.3	3.1	3.0	6.0	12.5	6.6	2.6	2.3	2.4	5.5	9.0
70	3.3	3.4	2.5	2.0	3.1	7.6	3.4	2.1	1.9	2.0	3.6	3.7
60	2.1	2.9	1.9	1.7	2.2	6.6	1.9	1.7	1.7	1.7	3.0	2.7
50	1.7	2.6	1.5	1.2	1.7	4.0	1.5	1.3	1.4	1.5	2.4	2.2
40	1.4	2.2	1.2	0.8	1.3	2.7	1.3	1.1	1.2	1.2	1.9	1.7
30	1.2	1.4	1.0	0.5	1.0	2.0	1.0	1.0	1.0	1.1	1.6	1.2
20	1.0	1.2	0.9	0.4	1.0	1.5	0.9	0.9	0.9	1.0	1.3	1.1
10	0.9	1.0	0.9	0.4	0.8	1.0	0.6	0.7	0.8	0.8	1.1	0.9
1	0.4	0.7	0.7	0.3	0.5	0.8	0.4	0.4	0.4	0.6	0.8	0.8

KABELJOUS ESTUARY

Description of hydrological scenarios

Table 13 provides a summary of a range of water resource development scenarios that could affect the Kabeljous Estuary.

Table 13: Kabeljous Estuary: Summary of flow scenarios

Scenario	Description	MAR	%Similarity	Category
Reference	Natural (with 33 % more groundwater input)	5.27	100.0	A
Present	Present (no EWR)	4.70	89.3	B

Scenario	Description	MAR	%Similarity	Category
1*	Restoration (20% decrease in dams and corresponding irrigation)	4.90	93.0	B
2	Mid-term (no EWR)	4.72	89.6	B/C
3*	Worse case (~30% increase in dams and corresponding irrigation)	3.99	75.8	C
4.*	Present with 33% reduction in groundwater input	4.70	89.3	C

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

The estuary is fed by the Kabeljous and Gheis River, with a total length of approximately 30 km). The total catchment of the area is ~238 km^2 (Bickerton and Pierce, 1988). The Kabeljous Estuary receives a mean annual precipitation of approximately 450 mm. Historical studies have estimated the mean annual runoff of between 15 x 10^6 m^3 and 27 x 10^6 m^3 (Bickerton and Pierce, 1988; Klages, 2005), but this has recently been adjusted downwards in the Algoa Bay study. According to the hydrological data provided for this study, the present MAR into the Kabeljous Estuary is 4.7 Million m^3. This is a decrease of 11% compared to the natural MAR of 5.27 Million m^3. The Kabeljous Estuary in its present state is estimated to be 78% similar to natural conditions, which translates into a PES of a B Category. Scenario 1 (Restoration: 20% decrease in dams and corresponding irrigation) represents only a 2% increase in estuary conditions despite its significant impact on the water allocation in the catchment. Scenario 2 (Medium-term development) represents a decline to a Category B/C, albeit only a 1% decline in overall condition. Scenario 3 (~30% increase in dams) and Scenario 4 (potential further 33% reduction in groundwater) both pose considerable risks to the estuary condition as they increase either the duration of hypersalinity conditions or the intensity of hypersalinity conditions, or both. Groundwater especially in closed shallow estuaries plays an important role in moderating the development of hypersalinity and water levels. The present 33% reduction in groundwater is estimated to already play a role in the development of hypersalinity values of 55 to 60 (seawater = 35).

Recommendations to maintain or improve/maintain estuary condition

The PES for the Kabeljous Estuary is a B Category. **Given the degree of agriculture and development in the catchment and estuary environs; concerns regarding surface water and groundwater abstraction, declining water quality; and the high level of fishing effort the REC is also set at a B Category.**

Key interventions required to improve the condition of the Kabeljous Estuary include:

- Develop an Estuary Management Plan for the Kabeljous Estuary to identify key actions needed to improve the condition and coordinate restoration efforts.
- **Ensure maintenance of low-flow conditions (including groundwater) to prevent prolonged periods of mouth closure and the development of extreme hypersalinity that promotes microalgal and macroalgal accumulations.**
- **Increase base flows (e.g. through the removal of alien vegetation, unauthorised abstractions and/or forestry).**
- Reduce nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and over-irrigation) and restoring riparian vegetation.
- Reduce fishing pressure by managing access, increase compliance and improve community interactions to restore nursery function.

- Prevent disturbance of riparian vegetation, including trampling by humans and cattle, fire, and removal of alien vegetation.
- Prevent artificial breaching of the mouth (currently not a concern).

Ecological flow requirements

The REC for the Kabeljous Estuary is Category B. **The Recommended Flow Scenario is the present day flow regime for surface and groundwater coupled with interventions listed above to halt the further decline in estuary condition.** The flow requirements for the estuary are the same as those described for the present day (PES) and are summarised in Table 14 below.

Table 14: Kabeljous Estuary: Summary of the monthly flow distribution (in m^3/s) for the Recommended Ecological Flow Scenario (i.e. Present)

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	2.862	1.807	0.711	0.164	0.543	0.627	0.311	1.288	1.073	0.534	8.318	8.460
90	0.318	0.202	0.080	0.035	0.027	0.038	0.059	0.132	0.116	0.171	0.254	0.475
80	0.199	0.140	0.065	0.026	0.021	0.028	0.035	0.054	0.081	0.105	0.163	0.204
70	0.164	0.119	0.046	0.024	0.019	0.016	0.027	0.041	0.060	0.080	0.120	0.147
60	0.123	0.092	0.039	0.020	0.014	0.011	0.019	0.029	0.051	0.061	0.095	0.118
50	0.107	0.076	0.032	0.015	0.010	0.009	0.015	0.021	0.033	0.051	0.075	0.104
40	0.092	0.061	0.025	0.014	0.010	0.009	0.011	0.015	0.028	0.044	0.060	0.076
30	0.073	0.054	0.023	0.011	0.007	0.008	0.009	0.014	0.024	0.036	0.051	0.061
20	0.054	0.043	0.017	0.009	0.006	0.006	0.009	0.012	0.016	0.029	0.040	0.051
10	0.041	0.035	0.014	0.006	0.006	0.003	0.006	0.006	0.012	0.021	0.030	0.043
1	0.005	0.018	0.007	0.003	0.003	0.002	0.003	0.002	0.003	0.006	0.007	0.021

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1. INTRODUCTION

1.1 Background

The National Water Act, 1998 (No. 36 of 1998) (NWA) is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public without affecting the functioning of water resource systems. To achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the implementation of Resource Directed Measures (RDM). These measures are protection-based and include Water Resource Classification, determination of the Reserve and setting the associated Resource Quality Objectives (RQOs). These measures collectively aim to ensure that a balance is reached between the need to protect and sustain water resources, while allowing socio-economic development.

The provision of water required for the maintenance of the natural functionality of the ecosystem and the provision of Basic Human Needs (BHN) is the only right to water in the National Water Act (No. 36 of 1998) (NWA). The other water users from a strategic use who are second in line to other water users are subject to formal gazetted General Authorization and water use authorization as per Section 21 of the NWA.

The Department of Water and Sanitation, through the Chief Directorate: Water Ecosystems Management (CD: WEM), has initiated a study for the determination of Water Resource Classes, Reserve and associated Resource Quality Objectives for the identified significant water resources in the Keiskamma and Fish to Tsitsikamma catchments. The water resource components included in this study are rivers, wetlands, groundwater and estuaries. The Reserve determination includes both the water quantity and quality of the Ecological Water Requirements (EWR) and Basic Human Needs (BHN). This will ensure the availability of water required to protect aquatic systems (i.e. the EWR) and that the essential needs of individuals who are directly dependent on these water resources (i.e. BHN) are met.

1.2 Purpose of this study

The Keiskamma and Fish to Tsitsikamma catchments within the Mzimvubu to Tsitsikamma Water Management Area (WMA 7) are amongst many waters stressed catchments in South Africa. These areas are important for conservation and have recognisable protected areas, natural heritage, cultural and historical sites that require protection. However, water use from surface as well as groundwater for agricultural and domestic purposes are high, especially in the more arid catchments, impacting on the availability of water resources for the protection of the aquatic ecosystems. Industrial practices and domestic water use are on the rise in some of these catchments, especially around the major towns and cities. Water transfers into the study area from adjacent WMAs and within the study area and numerous storage dams changes the natural flow patterns, impacting the aquatic biota.

Thus, the main purpose of the study is to determine, appropriate Water Resource Classes, the Reserve and set associated RQOs for all significant water resources in the study area to facilitate sustainable use of the water resources while maintaining ecological integrity.

The aim is to:

- implement the Water Resource Classification System (WRCS) (Regulation 810, 2010) to determine the Water Resource Classes (classes ranging from 1 – 3);
- follow the integrated framework (DWS, 2017);
- undertake the 7-step process to determine and set RQOs; and
- determine the Reserve for the significant water resources in the study area.

This will ultimately assist the DWS in the management of the water resources in the study area and aid in the making of informed decisions regarding the authorisation of future water use and the magnitude of the impacts of proposed developments. It must be noted that the protection and management of water resources should be done in an integrated manner, hence from source to sea. This illustrates the importance of realising that IWRM requires the co-operation and buy-in of stakeholders in the catchment and hence the forming of partnerships is essential i.e. water forums, catchment management agencies (CMA), Integrated Development Management Plans, Estuarine Management plans etc. The IWRM also relies heavily on co-operative governance. Representative participation on the platforms that the Department creates through studies such as this, is in the form of Project Steering Committees, but the latter is but one example, of inviting integrated participation.

1.3 Purpose of this report

The purpose of this report is to document the results of the quantification of the Ecological Water Requirements (EWR) within the study area (Keiskamma and Fish to Tsitsikamma). This forms part of step 4 of the Reserve determination process and aligns with Step 3 of the integrated framework, DWS (2017).

1.4 Ecological Water Requirement Method for Estuaries

Methods to determine the environmental flow requirement of estuaries were established soon after the promulgation of the National Water Act (NWA) in 1998. The “Preliminary Reserve Method” involves setting a REC (i.e. desired state), recommended Ecological Reserve (i.e. flow allocation to achieve the desired state) and recommended RQOs for a resource based on its present health status and its ecological importance.

The approach follows a generic methodology that can be carried out at different levels of effort (e.g. rapid, intermediate or comprehensive). The official method for estuaries (Version 2), is documented in DWA (2008). In 2013, an unofficial Version 3 of the method was published, as part of a Water Research Commission study (Turpie *et al*., 2012a,b). The study uses the official Version 2 of the methodology (DWA, 2008), but with consideration of obvious improvements proposed in Version 3 (Turpie *et al*., 2012a,b) and Taljaard *et al*. (2022).

The generic steps of the official "Ecological Reserve Method" for estuaries were applied as follows:

- Step 1: Initiate study defining the study area, project team and level of study (confirmed in the **inception report** of this study).
- Step 2: Delineate the geographical boundaries of the resource units (confirmed in the **delineation report** of this study).
- Step 3a: Determine the **Present Ecological State** (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, unimpacted 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 to evaluate the current condition of the estuary (**Table 1-1**). The fact that the physical conditions in estuarine systems are more dynamic than those of other aquatic ecosystems means that severe degradation of an estuary may involve a shift from a dynamic to a more stable, or unidirectional, system. This means that the loss of dynamic function *per se* is an important indication of declining estuarine health (DWAF, 2008). Thus, in an estuarine health assessment, measures of these different states need to be sufficiently robust so that different practitioners/disciplines will arrive at the same categorisation.

Table 1-1: Estuarine Health Index 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 this assessment, the EHI scoring of the various variables is based on a review of historical data, as well as data collected during a field monitoring programme in 2023/4. The assessment was undertaken by a multidisciplinary group of estuarine scientists in a workshop setting, based on their collective understanding of the likely impacts affecting each system. Expert knowledge and available information were all used to build up a "picture" of the probable pristine state of each estuary and the changes under current conditions. The

EHI is applied to all levels of ecological water requirement studies (comprehensive, intermediate or rapid), with only the level of information supporting the study and the level of confidence varying. For each variable, the conditions are estimated as a percentage (0 – 100%) of the pristine health. Scores are then weighted and aggregated so that the final score reflects the present health of the estuary as a percentage of the pristine state (**Table 1.1**). Both abiotic and biotic variables are included as the relationships between the abiotic and biotic variables are often not well understood and because the biotic response to certain abiotic variables can be lagging.

For comparative reasons (with previous assessments) the individual health scores were aggregated as illustrated in **Figure 1-1** and **Table 1-2**. In estuaries, unlike in the terrestrial environment, degradation or loss of habitat seldom means a complete loss of an estuary. This can only happen if an estuary becomes completely degraded, e.g. changed into a parking lot or golf course. In most cases, degradation means loss of processes or loss of biological functionality, e.g. the estuarine space is filled with a different salinity condition or different species composition. This loss of functionality happens on a continuum, with estuaries which retain more than 90% of their natural processes and pattern being rated as Excellent and estuaries degraded to less than 40% of natural functionality rated as Poor.

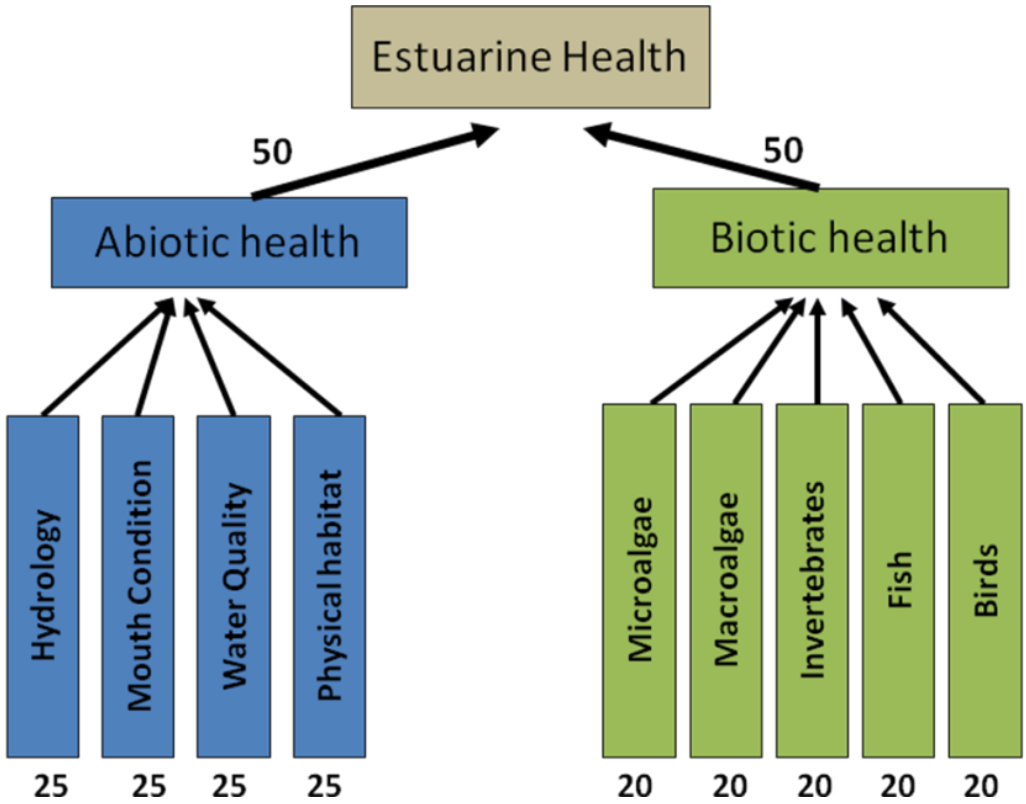

Figure 1-1: Components and weightings of the Estuarine Health Index (DWAF, 2008)

Table 1-2: Schematic illustration of the relationship between loss of ecosystem condition and functionality

Condition	≥91%	90-75	75 - 61	60 - 41	40-21	≤20
Category	A Natural	B Largely natural with few changes	C Moderately modified	D Largely modified	E Highly degraded	F Extremely degraded
State	Excellent	Good	Fair		Poor	
Functionality	Retain Process & Pattern (representation)		Loss of Process or Pattern		No Process & Pattern	

The estuarine health score is translated into one of six Ecological Categories (ECs) provided below in **Table 1-3.**

Table 1-3: Translation of EHI score 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 partly be 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 lotic 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[1])** that takes into account the size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account (**Table 1-4 and Table 1-5**).

Table 1-4: 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 1-5: Estuarine Importance rating system

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

- Step 3c: Set the **Recommended Ecological Category (REC)** which is derived from the PES and EIS (or the protection status allocated to a specific estuary) following the guidelines listed in **Table 1-6**.

Table 1-6: Guidelines to assign REC, based on protection status and importance, and PES of an 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.

* Best Attainable State (BAS)

[1] Note that EIS does not have the same meaning as EIS for rivers, which refer to Ecological Importance and Sensitivity.

An estuary cannot be allocated a REC below a Category “D”. Therefore, systems with a PES in Categories ‘E’ or ‘F’ need to be managed towards achieving at least a REC of “D”.

- Step 4: **Quantify the ecological consequences of various runoff scenarios** (including proposed operational scenarios) where the predicted future condition of the estuary is assessed under each scenario. As with the determination of the PES, the EHI is used to assess the predicted condition in terms of the degree of similarity to the reference condition.

- Step 5: Quantify the (recommended) **Ecological Water Requirements (EWR)**, which represent the lowest flow scenario that will maintain the resource in the REC. Please note the detailed information pertaining to the EGSA will be provided within the Socio-economic Report.

- Step 6: Estimate (recommended) Resource Quality Objectives (Ecological Specification) for the REC, as well as future monitoring requirements to improve the confidence of the EWR.

2. OVERVIEW OF STUDY AREA

2.1 Main catchments and rivers in the study area

The study area forms part of the Mzimvubu to Tsitsikamma WMA7 as indicated in **Table 2-1** and **Figure 2-1**. The water resources of the Mzimvubu River (T31 – T36) are not included as part of the study. Secondary catchments T40 (Mtamvuna) and T50 (Mzimkhulu) form part of WMA 4. A detailed overview and status quo of the study area in terms of the rivers, wetlands, estuaries and groundwater, water resource infrastructure and socio-economics has been presented in the delineation of IUAs Report (Report Number: WEM/WMA7/00/CON/RDM/0322).

Table 2-1: Main catchments and rivers in the study area.

Catchment	Major Rivers
K80	Tsitsikamma and small coastal rivers
K90	Krom, Seekoei rivers and small coastal rivers, also part of Algoa System
L10 - L90	Gamtoos with main tributaries Groot, Baviaanskloof and Kouga
M10 - M30	Koega, Swartkops and small coastal rivers, part of the Algoa System
N10 - N40	Sundays
P10 - P40	Kowie, Kariega, Boesmans and small coastal rivers (or Albany Coast)
Q10 - Q90	Fish River with main tributaries of Little Fish, Koonap and Kat
R10 - R50	Keiskamma, Buffalo, Nahoon and Gqunube Rivers (also known as the Amatole System)
S10 - S70	Great Kei River with main tributaries of Klipplaats, Indwe, White Kei, Black Kei
T10	Mbhashe
T20	Mthatha
T60	Small coastal rivers (Mtentu, Msikaba, Mzintlava), including estuaries of high conservation value
T70	Small coastal rivers (Mtakatye, Mngazi), including estuaries of high conservation value
T80 & T90	Small coastal rivers, including estuaries of high conservation value

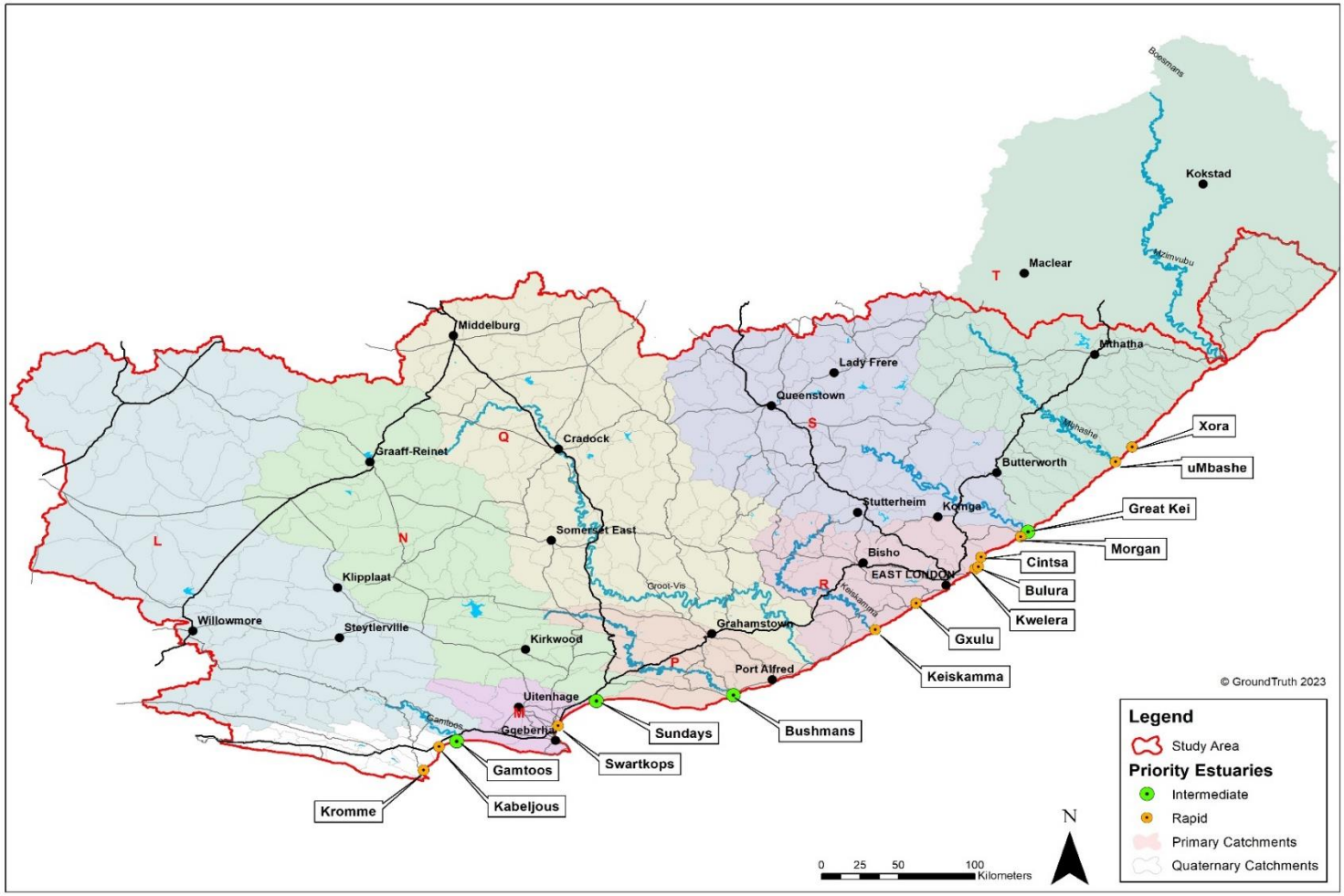

Figure 2-1: Overview of the greater study area (primary catchments)

2.2 Estuaries

Table 2-2 provides a summary of the main estuaries in the sub-catchments within the study area, along with their catchment area size. Overall, there are 155 estuaries in the study area, with ten of these being the focus of previous Environmental Flow Requirement or EWR studies, albeit it is of low confidence in some cases. These are indicated in **Table 2-3.**

Table 2-2: Main estuaries in the sub-catchments within the study area

Primary catchment	Sub-catchment	Main River	Associated Rivers	Main Estuaries	Catchment Area (1) (km²)
K	K80A-F	Tsitsikamma	Elandsbos, Kleinbos, Storms, Elands, Groot, Klasies, Klipdrift	Tsitsikamma, Elandsbos, Storms, Elands, Groot	1 206
	K90A-G	Krom	Seekoei, Kabeljous	Krom, Seekoei, Kabeljous	1 558
L	L11, L12, L21, L22, L23, L30, L40, L50, L60, L70, L81, L82, L90	Gamtoos	Sout, Buffels, Kariga, Plessis, Heuningklip, Groot, Baviaanskloof, Kouga	Gamtoos, Buffels, Groot	34 816
M	M10, M20, M30	Swartkops	Van Stadens, Maitland, Bakens, Papkuils, Coega	Swartkops, Van Stadens, Maitland, Coega	2 630
N	N11, N12, N13, N14, N21, N22, N23, N24, N30, N40	Sundays	Kamdeboo, Gats, Melk, Bul, Voel, Kariega	Sundays	21 248
P	P10, P20, P30, P40	Boesmans	Diepkloof, Boknes, Kariega, Kowie, Kasouga, Riet, Wes-Kleinemonde, Oos-Kleinemonde	Boesmans, Boknes, Kariega, Kowie, Kasouga, Riet, Wes-Kleinemonde, Oos-Kleinemonde	5 322
Q	Q11, Q12, Q13, Q14, Q21, Q22, Q30, Q41, Q42, Q43, Q44, Q50, Q60, Q70, Q80, Q91, Q92, Q93, Q94	Great Fish	Groot-Brak, Pauls, Tarka, Baviaans, Koonap, Little Fish, Kat	Great Fish	30 243
R	R10, R20, R30, R40, R50	Keiskamma	Tyume, Buffalo, Nahoon, Qinira, Gqunube, Kwelera, Kwenxura, Quko, Tyolomnqa, Gxulu, Bhirha, Mgwalana	Keiskamma, Buffalo, Nahoon, Qinira, Gqunube, Kwelera, Kwenxura, Quko, Tyolomnqa, Gxulu, Bhirha, Mgwalana	7 936
S	S10, S20, S31, S32, S40, S50, S60, S70	Great Kei	White-Kei, Indwe, Klipplaat, Klaas Smit, Black-Kei, Tsomo, Kubusi, Gcuwa	Great Kei	20 485
T	T11, T12, T13, T20, T60, T70, T80, T90	Mbashe	Xuka, Mgwali, Mthatha, Mzamba, Mtentu, Msikaba, Mzintlava,	Mbashe, Mgwali, Mthatha, Mzamba, Mtentu, Msikaba,	17 938

Primary catchment	Sub-catchment	Main River	Associated Rivers	Main Estuaries	Catchment Area [1] (km^2)
			Mntafufu, Mngazi, Mngazana, Mtakatye, Mdumbi, Nenga, Mncwasa, Xora, Nqabarha, Shixini, Qhorha, Kobonqaba	Mzintlava, Mntafufu, Mngazi, Mngazana, Mtakatye, Mdumbi, Nenga, Mncwasa, Xora, Nqabarha, Shixini, Qhorha, Kobonqaba	
			Total catchment area		**143 382**

[1]*WR2012 Data*

Table 2-3: Main estuaries in the sub-catchments within the study area

NAME	Historical Studies	Biodiversity Importance Rating
Tsitsikamma	Rapid 2003	**Low to Average Importance**
Kromme	Comprehensive 2006	**High Importance**
Seekoei	Rapid 2006	**Important**
Swartkops	Comprehensive 2021	**High Importance**
Sundays	Comprehensive 2008	**Important***
Bushmans	Intermediate 2003	**Important**
East Kleinemonde	Intermediate 2008	**Important**
Great Fish	Rapid 2013	**High Importance**
Nahoon	EFR/Intermediate 2001	**Important**
Mtata	Rapid 2002	**Important**

An additional seven estuaries are being assessed in more detail as part of this study to address gaps in the water resources classification process, with selection influenced by identified water resources pressure (current or future), estuary ecological importance, requests from other sectors of government, and available study resources.

The priority estuaries for rapid/comprehensive EWR assessments that will be done in more detail include:

- Mngazi Estuary;
- Mbashe Estuary;
- Great Kei Estuary;
- Keiskamma Estuary;
- Kariega Estuary;
- Gamtoos Estuary; and
- Kabeljous Estuary

See **Figure 2-2** for the location and relative catchment size of the 7 priority estuaries.

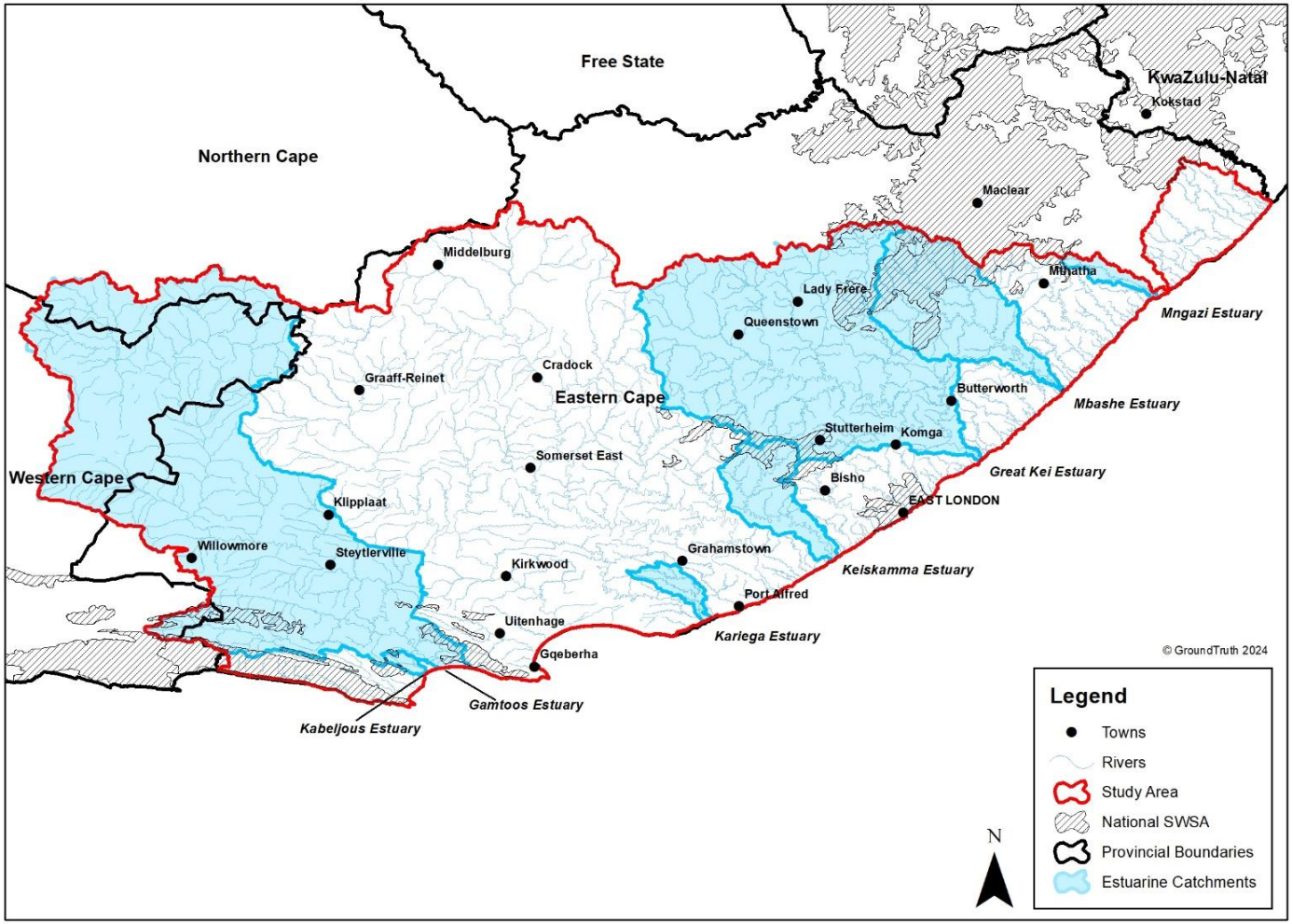

Figure 2-2: Overview of the priority estuary catchments.

3. MNGAZI ESTUARY

3.1 Geographical boundaries

The temporarily open Mngazi Estuary lies just south of the coastal town of Port St Johns on the Wild Coast of the Eastern Cape. The upper reaches of the estuary are muddy with flat marshy banks. Lower down near the Mngazi Bungalows, approximately 800 m from the mouth, the banks are steeper and the bed of the estuary is a firm mixture of sand and mud. From there the estuary broadens to form a shallow lagoon behind the berm. The geographical boundaries of the Mngazi Estuary are defined as follows (**Figure 3.1**):

Downstream boundary:	31°40'34.12"S, 29°27'40.15"E(estuary mouth)
Upstream boundary:	31°37'27.80"S; 29°24'52.96"E
Lateral boundaries:	Estuary functional zone along each bank (~5 m MSL contour)

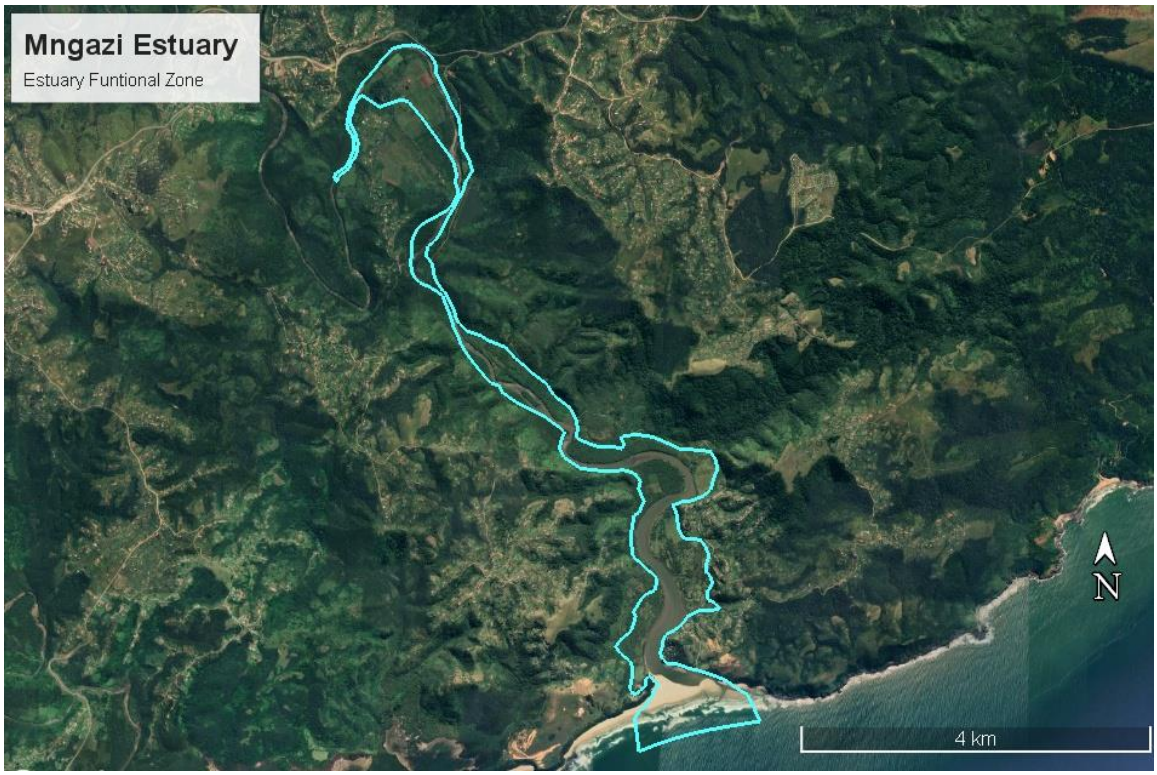

Figure 3-1: Geographical boundaries of the Mngazi Estuary based on the Estuary Functional Zone.

3.2 Description of hydrological scenarios

Table 3-1 provides a summary of a range of water resource development scenarios that could affect the Mngazi Estuary.

Table 3-1: Summary of flow scenarios

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity
Reference	Natural (~1750)	87.31	100.0
Present	Present (no EWR)	83.52	95.7
Scenario 1	Present (with EWR)	83.52	95.7
Scenario 2	Mid-term (no EWR)	83.04	95.1
Scenario 3	Long-term (no EWR)	82.55	94.6
Scenario 4*	Dams (no EWR)	77.87	89.2

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

According to the hydrological data provided for this study, the present MAR into the Mngazi Estuary is 83.52 Million m^3. This is a decrease of 4.3% compared to the natural MAR of 87.31 Million m^3.

3.3 Present Ecological Status

The Mngazi Estuary in its present state is estimated to be 84% similar to natural conditions, which translates into a PES of a B Category. This is mostly attributed to the following factors:

- Flow reduction with a focus on baseflow reduction in the low flow period increasing mouth closure;
- A decline in water quality due to agricultural activities;
- Over-exploitation of living resources (e.g. recreational fishing, small-scale fishing and illegal gill netting);
- Overgrazing of saltmarsh by cattle.
- Agricultural activities in the EFZ cause loss of estuarine habitat; and
- Recreational activities in the lower reaches affect bird abundance.

The overall current Estuarine Health Index (EHI) score as well as the percentage attributed to non-flow related pressures is given in **Table 3-2** below.

Table 3-2: Mngazi: Present Ecological State scores

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence**
Hydrology	92	-*	M
Hydrodynamics and mouth condition	94	0%	M
Water quality	80	90%	M
Physical habitat alteration	85	95%	L - M
Habitat health score	88		
Microalgae	82	50%	L - M
Macrophytes	87	80%	M
Invertebrates	80	10%	L

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence**
Fish	75	15%	M
Birds	81	11%	L
Biotic health score	81		
ESTUARY HEALTH SCORE	84		**L/M**
PRESENT ECOLOGICAL STATUS (PES)	**B**		

*- *Not applicable*
** *Confidence levels: Very Low (VL), Low (L), Medium (M), High (H)*

3.4 Ecological consequences of future scenarios

The individual EHI scores, as well as the corresponding ecological category under different scenarios, are provided below in **Table 3-3**.

Scenarios 1 to 3 rate the same as the present with no definable change in health condition. Under Scenario 4 the estuary declines a further 7% in condition to a Category B/C.

Table 3-3: Mngazi: Summary of ecological health scores under various scenarios

Component	Present	Scenario			
		1	2	3	4
Hydrology	92	92	91	90	80
Hydrodynamics and mouth condition	94	94	94	94	85
Water quality	80	80	80	79	78
Physical habitat alteration	85	85	84	83	75
Habitat health score	**88**	**88**	**87**	**87**	**80**
Microalgae	82	82	82	82	75
Macrophytes	87	86	86	86	80
Combined Inverts	80	80	80	80	73
Fish	75	75	75	75	70
Birds	81	81	81	81	77
Biotic health score	**81**	**81**	**81**	**81**	**75**
ESTUARINE HEALTH SCORE	**84**	**84**	**84**	**84**	**77**
PRESENT ECOLOGICAL STATUS	**B**	**B**	**B**	**B**	**B/C**

3.5 Recommendations to maintain or improve estuary condition

The PES and REC for the Mngazi Estuary is a B Category as it is not a conservation priority.

Key interventions required to improve the condition of the Mngazi Estuary (on the edge of a B/C Category) include:

- Develop an Estuary Management Plan for the Mngazi Estuary to identify key actions required to arrest the downward trajectory and coordinate restoration efforts if required (requirement of National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008).

- Ensure maintenance of low-flow conditions to prevent prolonged periods of mouth closure that promote microalgal accumulation and the severity of bottom-water hypoxia.
- Manage nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring riparian vegetation (buffer zones).
- Manage/reduce fishing pressure by managing access, increased compliance and improved community awareness.
- Prevent disturbance of riparian vegetation, including trampling by cattle, fire, and remove alien vegetation from the EFZ.

3.6 Ecological flow requirements

The 'recommended Ecological Flow Requirement' scenario, is defined as the flow scenario (or a slight modification thereof to address low-scoring components) that represents the highest change in river inflow that will still maintain the estuary in the REC. Where any component of the health score is less than 40, then modifications to flow and measures to address anthropogenic impacts must be found that will rectify this.

The REC for the Mngazi Estuary is Category B. The Recommended Flow Scenario is Scenario 3 (Long-term development) coupled with the interventions listed above to address further decline. The flow requirements for the estuary are the same as those described for Scenario 3 and are summarised in **Table 3-4.**

Table 3-4: Mngazi: Summary of the monthly flow distribution (in m^3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 3: Long-term development).

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	25.21	25.11	16.08	12.95	16.57	37.41	26.41	10.41	20.09	27.39	9.95	28.95
90	5.50	9.25	7.50	3.72	7.72	13.81	10.43	4.03	3.00	3.29	2.00	3.85
80	2.17	5.94	3.95	2.23	3.97	7.38	5.62	2.15	1.51	1.25	1.16	1.34
70	1.49	2.67	2.44	1.40	1.40	4.69	2.90	1.37	1.23	1.09	0.96	0.98
60	1.03	1.73	1.54	1.04	1.22	3.50	2.15	1.15	0.96	0.90	0.79	0.89
50	0.95	1.14	1.03	0.89	1.06	1.78	1.32	0.99	0.86	0.80	0.72	0.75
40	0.84	1.04	0.88	0.77	0.88	1.19	1.08	0.85	0.73	0.66	0.62	0.68
30	0.70	0.85	0.69	0.69	0.80	1.00	0.98	0.73	0.62	0.58	0.56	0.63
20	0.62	0.75	0.57	0.58	0.72	0.76	0.74	0.63	0.56	0.50	0.49	0.55
10	0.50	0.62	0.49	0.49	0.55	0.58	0.55	0.53	0.43	0.39	0.39	0.43
1	0.30	0.32	0.29	0.26	0.32	0.24	0.29	0.27	0.26	0.28	0.24	0.26

4. MBASHE ESTUARY

4.1 Geographical boundaries

The 8 km long Mbhashe Estuary is a permanently open, turbid and channel-like estuary located approximately 70 km north of the Kei Estuary, the nearest estuary of similar size and configuration. The geographical boundaries of the Mbashe Estuary are defined as follows (**Figure 4.1**):

Downstream boundary:	31°40'34.12"S, 29°27'40.15"E(estuary mouth)
Upstream boundary	31°37'27.80"S; 29°24'52.96"E
Lateral boundaries:	Estuary functional zone along each bank (~5 m MSL contour)

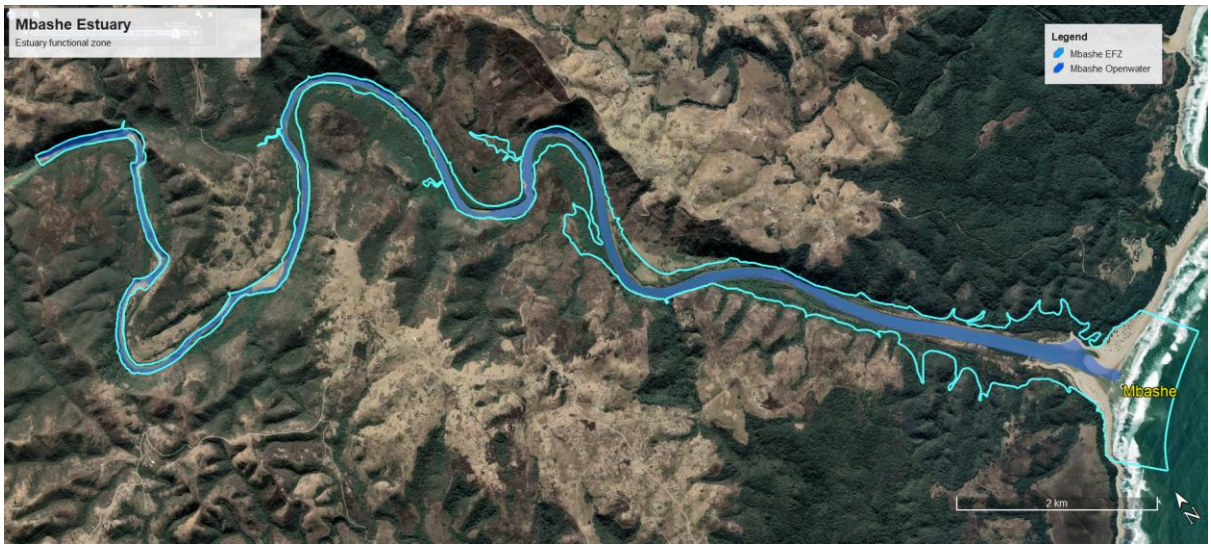

Figure 4-1: Geographical boundaries of the Mbashe Estuary based on the Estuary Functional Zone.

4.2 Description of hydrological scenarios

Table 4-1 provides a summary of a range of water resource development scenarios that could affect the Mbashe Estuary.

Table 4-1: Summary of flow scenarios

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity
Reference	Natural	786.88	100.0
Present	Present (no River EWR)	861.16	109.4
Scenario 1	Mid-term (no River EWR)	858.15	109.1
Scenario 2	Long-term (no River EWR)	853.72	108.5
Scenario 3*	50 % Transfer	819.21	104.1
Scenario 4*	No transfer scheme input	770.59	97.9

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity
Scenario 5*	Dam development (no River EWR)	682.56	86.7
Scenario 6*	Scenario 2 Long-term (no River EWR) with additional estuary restoration interventions	853.72	108.5

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

The present MAR into the Mbashe Estuary is 861.16 Million m^3. This is an **increase** of 9.4% compared to the natural MAR of 786.88 Million m^3.

4.3 Present Ecological State

The Mbashe Estuary in its present state is estimated to be 74% similar to natural conditions, which translates into a PES of a B/C Category. This is for the most part attributed to the following factors:

- Flow alterations with a focus on an increase in baseflow in the low flow period resulting in a decrease in salinity and a less constricted mouth;
- Severe over-exploitation of living resources (e.g. recreational fishing, small-scale fishing, and illegal gillnetting);
- A decline in water quality due to agricultural activities in catchment and estuary environs;
- Overgrazing of saltmarsh and degradation of mangroves as a result of cattle browsing. Trampling by cattle also compacts sediment which hinders the germination of plants.
- Agricultural activities in the EFZ cause loss of estuarine habitat; and
- Recreational activities in the lower and middle reaches affect bird abundance.

The overall current Estuarine Health Index (EHI) score as well as the percentage attributed to non-flow related pressures is given in **Table 4-2** below.

Table 4-2: Mbashe: Present Ecological State scores.

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence*
Hydrology	68	0 %	H
Hydrodynamics and mouth condition	78	0 %	L-M
Water quality	63	90 %	M
Physical habitat alteration	80	100 %	H-L
Habitat health score	**72**		
Microalgae	80	50 %	L-M
Macrophytes	80	20 %	M
Invertebrates	76	17 %	L
Fish	60	25 %	M
Birds	79	20 %	M

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence*
Biotic health score	75		
ESTUARY HEALTH SCORE	74		M
PRESENT ECOLOGICAL STATUS (PES)	B/C		

** Confidence levels: Very Low (VL), Low (L), Medium (M), High (H)*

4.4 Ecological consequences of future scenarios

The individual EHI scores, as well as the corresponding ecological category under different scenarios, are provided below in **Table 4-3**.

Scenarios 1 and 2 are similar to the present, Category B/C, with Scenario 2 representing a slight improvement. Scenarios 3 and 4 represent an improvement to Category B, but some of the higher trophic levels (e.g. invertebrates, fish and birds) are still in a degraded state. Scenario 5 represents a decline to Category C. Scenario 6, the flow regime of Scenario 2 with additional restoration interventions, improves the system to a Category B – thus meeting biodiversity requirements and restoring key ecosystem services such as nursery function (food security for the region) for and carbon sequestration (contribute to climate protection).

Table 4-3: Mbashe: Summary of ecological health scores under various scenarios

Component	PES	Scenarios					
		1	2	3	4	5	6
Hydrology	68	70	71	86	97	47	71
Hydrodynamics	78	78	79	87	97	79	79
Water quality	63	64	65	72	73	74	65
Physical habitat alteration	80	80	80	80	80	78	80
Habitat health score	**72**	**73**	**74**	**81**	**87**	**69**	74
Microalgae	80	80	80	82	81	70	80
Macrophytes	80	80	80	80	85	70	90
Invertebrates	76	76	76	78	80	62	80
Fish	60	60	60	60	60	50	80
Birds	79	79	80	82	80	67	85
Biotic health score	**75**	**75**	**75**	**76**	**77**	**64**	83
ESTUARINE HEALTH SCORE	74	74	75	79	82	67	78
PRESENT ECOLOGICAL STATUS	B/C	B/C	B/C	B	B	C	B

4.5 Recommendations to maintain or improve estuary condition

The PES for the Mbashe Estuary is a B/C Category, but as the estuary is degraded and of high biodiversity and conservation importance it should be in an A Category or BAS.

Given the high degree of land-use change in the Mbashe Catchment, the impact of the interbasin transfer scheme, and the present level of natural resource utilisation (fishing and grazing) the REC is a B Category (BAS).

The Recommended interventions to address the ongoing decline in condition and achieve the REC:

- Develop an Estuary Management Plan to identify key management actions required to achieve the REC and coordinate restoration efforts (requirement of National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008).
- Significantly reduce fishing pressure by managing access, increased compliance and community interactions to achieve MPA protection objectives and REC.
- Manage nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring riparian vegetation.
- Prevent disturbance of riparian vegetation, including cattle trampling, occurrence of fire, and removal of alien vegetation in the EFZ.
- Limit trampling and browsing of saltmarsh and browsing and harvesting of mangroves. Mangroves are legally protected by two separate pieces of legislation: National Forests Act (84 of 1998) and the Marine Resources Act (18 of 1998). The species *Bruguiera gymnorrhiza* and *Rhizophora mucronata* are further protected by the Protected Tree list (DWAF, 2010). All these would be addressed through an Estuary Management Plan. The sustainable use of mangroves should be encouraged with the harvesting of mangroves.

4.6 Ecological flow requirements

The flow requirements for the estuary are the same as those described for Scenario 2 below and are summarised in **Table 4-4.**

Table 4-4: Mbashe: Summary of the monthly flow distribution (in m^3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 6: Scenario 2 - Long-term with no River EWR with estuary restoration measures)

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	159.58	178.78	147.14	166.59	171.52	244.68	147.93	86.02	82.59	96.80	92.24	143.03
90	54.15	106.87	81.31	69.89	87.74	111.56	78.18	30.68	18.78	19.15	25.80	57.10
80	30.53	61.61	58.58	50.33	58.44	69.96	47.09	22.85	13.50	11.44	10.04	22.20
70	22.45	32.51	40.35	34.16	40.08	57.62	28.70	14.48	10.27	9.40	9.26	14.03
60	19.29	22.72	22.76	25.72	32.63	43.32	23.75	10.22	8.51	8.26	7.96	9.28
50	15.71	17.35	15.77	19.41	27.32	32.34	18.26	8.62	7.57	7.44	7.36	8.18
40	11.00	14.10	10.50	13.94	19.34	23.01	14.30	7.83	7.15	6.79	6.64	7.27
30	8.57	10.70	8.23	9.49	14.44	16.64	11.75	6.92	6.88	6.43	6.17	6.28
20	7.54	8.71	6.06	7.28	10.66	12.65	8.14	6.50	6.35	5.93	5.93	5.98
10	6.29	7.00	5.52	5.69	7.72	10.13	6.92	6.01	5.67	5.45	5.43	5.57
1	4.36	4.66	3.06	2.89	5.04	3.00	4.77	3.55	3.13	3.08	3.12	3.40

5. GREAT KEI ESTUARY

5.1 Geographical boundaries

The Great Kei Estuary is a predominantly open estuary located on the southern coast of South Africa, in the transition zone between the warm temperate and subtropical biogeographic regions. The length of the estuary is 17.5 km. The geographical boundaries of the Great Kei Estuary are defined as follows (**Figure 5.1**):

Downstream boundary:	32°40'44.39"S 28°23'12.31" E (estuary mouth)
Upstream boundary:	32°36'29.64"S; 28°17'36.45"E
Lateral boundaries:	Estuary functional zone along each bank (~5 m MSL contour)

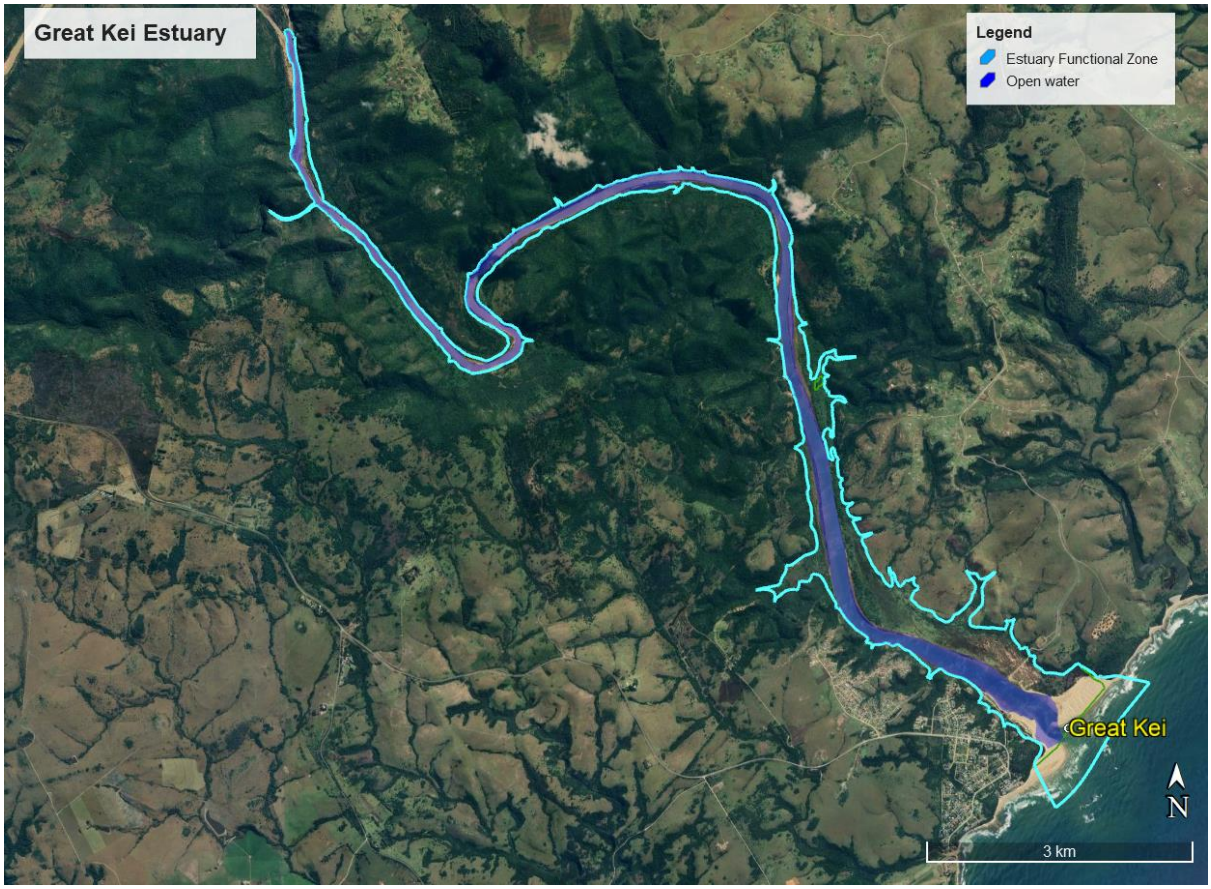

Figure 5-1: Geographical boundaries of the Great Kei Estuary based on the Estuary Functional Zone.

5.2 Description of hydrological scenarios

Table 5-1 provides a summary of a range of water resource development scenarios that could affect the Great Kei Estuary.

Table 5-1: Summary of flow scenarios.

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity
Reference	Natural	1040.71	100.0
Present	Present (no river EWR)	741.99	71.3
1*	Restoration (Present with river EWR + remove Invasive Aliens)	771.03	74.1
2	Present (with river EWR)	762.06	73.2
3	Mid-term (no river EWR)	742.24	71.3
4	Long-term (with river EWR)	754.82	72.5
5	Long-term (no river EWR)	734.80	70.6
6*	Long-term (no river EWR) and increased baseflow abstraction (3 m^3/s)	651.51	62.6
7*	Restoration (Present with river EWR + remove Invasive Aliens) with additional management interventions at the Estuary	771.03	74.1

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

The present MAR into the Great Kei Estuary is 742 Million m^3. This is a decrease of 29% compared to the natural MAR of 1 041 Million m^3.

5.3 Present Ecological Status

The Great Kei Estuary in its present state is estimated to be 68% similar to natural conditions, which translates into a PES of a C Category. This is largely attributed to the following factors:

- Flow reduction with a stress on baseflow reduction in the low flow period increasing salinity penetration;
- Severe over-exploitation of living resources (e.g. recreational fishing, small-scale fishing and illegal gill netting) impacting nursery function;
- A decline in water quality due to agricultural activities in the catchment;
- Overgrazing of saltmarsh and degradation of mangroves as a result of cattle browsing.
- Trampling by cattle of saltmarsh and within mangrove stands;
- Invasive alien plants within the EFZ, especially Spanish Reed which has replaced reeds along the banks in places;
- Agricultural activities in the EFZ causing loss of estuarine habitat; and
- Recreational activities in the lower reaches, particularly along the shoreline on the seaside affect bird abundance.

The overall current Estuarine Health Index (EHI) score as well as the percentage attributed to non-flow related pressures is given in **Table 5-2** below.

Table 5-2: Great Kei: Present Ecological State scores.

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence**
Hydrology	52	-*	H
Hydrodynamics and mouth condition	79	0%	L - H
Water quality	71	90%	M
Physical habitat alteration	75	90%	L-M
Habitat health score	69		
Microalgae	74	50%	L
Macrophytes	80	20%	M
Invertebrates	54	17%	L
Fish	70	25%	M
Birds	58	20%	M
Biotic health score	**67**		
ESTUARY HEALTH SCORE	**68**		**M**
PRESENT ECOLOGICAL STATUS (PES)	**C**		

**- Not applicable*
*** Confidence levels: Very Low (VL), Low (L), Medium (M), High (H)*

5.4 Ecological consequences of future scenarios

The individual EHI scores, as well as the corresponding ecological category under different scenarios, are provided below in **Table 5-3.**

Table 5-3: Great Kei: Summary of ecological health scores under various scenarios

Component	PES	Scenarios						
		1	2	3	4	5	6	7
Hydrology	52	62	61	53	62	53	36	62
Hydrodynamics	79	87	87	79	87	79	66	87
Water quality	71	71	71	71	70	71	74	71
Physical habitat alteration	75	75	75	75	74	74	73	75
Habitat health score	**69**	**74**	**73**	**69**	**73**	**69**	**62**	**74**
Microalgae	74	75	75	75	74	75	67	75
Macrophytes	80	85	85	80	85	80	70	85
Combined Inverts	54	69	69	55	69	55	25	75
Fish	70	75	75	70	75	70	65	80
Birds	58	72	72	60	72	59	34	80
Biotic health score	**67**	**75**	**75**	**68**	**75**	**68**	**52**	**79**
ESTUARINE HEALTH SCORE	**68**	**75**	**74**	**69**	**74**	**68**	**57**	**76**
PRESENT ECOLOGICAL STATUS	**C**	**B/C**	**B/C**	**C**	**B/C**	**C**	**D**	**B/C**

Scenarios 1, 2, and 4 (scenarios with River EWR release) improve estuary condition to a B/C Category, but some of the higher trophic levels (e.g. invertebrates, fish and birds) remain degraded and do not contribute optimally to ecosystem services and conservation objectives. Under Scenario 7 (Scenario 1 with additional management measures at the estuary), the estuary health improves to a B/C Category, and critical ecosystem services such as nursery

function and carbon sequestration meet biodiversity and conservation objectives. Overall, the estuary showed a ~6% improvement in health in response to the release of a river EWR. Under Scenarios 3 and 5 the estuary health remains similar to the present, i.e. shows little sensitivity to medium and long-term development scenarios. Under the 'worst-case' Scenario 6 the estuary declines further to a Category D – highlighting the estuary's sensitivity to flow reduction.

5.5 Recommendations to maintain or improve estuary condition

The PES for the Great Kei Estuary is a C Category, but as the estuary is of high biodiversity and conservation importance it should be in an A Category or BAS. **However, given the level of land use change in the catchment and the high level of resource use in and around the estuary, the REC is set as a B/C (BAS).**

Key interventions required to improve the condition of the Great Kei Estuary include:

- Develop an Estuary Management Plan for the Great Kei Estuary to identify key actions required to address the ongoing decline in condition and coordinate restoration efforts (requirement of National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008).
- Reduce fishing pressure by managing access, increased compliance, and community interactions and awareness.
- Ensure maintenance of low-flow conditions to prevent prolonged periods of increased water residency that promote the accumulation of phytoplankton and benthic microalgal communities.
- Manage nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring riparian vegetation.
- Prevent disturbance of riparian vegetation (especially mangroves), including trampling and grazing/browsing by cattle and fire.
- Remove alien vegetation within the EFZ.
- Manage/control recreational activities (e.g. boating and bait collection) in the lower and middle reaches, particularly along the shoreline on the seaside affecting bird abundance.

5.6 Ecological flow requirements

The REC for the Great Kei Estuary is Category C. The Recommended Flow Scenario is Scenario 7 – similar in river inflow requirement to Scenario 1 (Present with river EWR release and additional removal of invasive alien plants from catchment) coupled with the estuary management interventions listed above. The flow requirements for the estuary are the same as those described for Scenario 1 and are summarised in **Table 5-4.**

Table 5-4: Great Kei: Summary of the monthly flow distribution (in m3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 7: Restoration (Present with river EWR + remove Invasive Aliens from catchment) with additional management interventions at the Estuary).

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	230.3	328.5	197.0	189.0	318.3	513.5	230.6	146.2	77.6	101.8	160.7	164.8
90	51.1	124.4	87.0	106.6	109.5	135.9	78.9	41.5	20.4	15.6	26.8	46.9
80	28.4	68.4	63.8	65.6	83.8	96.0	49.8	21.7	13.4	13.2	11.5	20.7
70	20.4	28.4	42.6	38.7	62.0	62.3	37.8	14.2	10.3	9.8	9.6	13.8
60	15.9	21.3	25.6	30.6	42.1	37.8	26.7	11.7	9.4	8.2	8.2	11.6
50	13.1	15.3	18.7	20.4	32.6	34.2	19.4	10.1	8.0	7.6	7.2	9.0
40	10.4	13.1	14.1	17.4	23.0	27.4	16.3	9.1	7.2	6.6	6.6	7.2
30	8.9	10.8	9.7	12.6	16.4	24.0	12.8	7.5	6.6	6.2	6.3	6.5
20	6.8	9.0	7.0	7.0	13.0	17.0	10.1	6.6	6.0	5.7	5.7	5.6
10	5.2	6.8	5.1	5.2	9.1	11.4	7.9	5.8	5.2	5.1	5.0	5.1
1	3.7	3.7	3.5	2.6	3.4	4.3	4.6	4.7	4.0	3.7	3.6	3.7

6. KEISKAMMA ESTUARY

6.1 Geographical boundaries

The Keiskamma Estuary is located in the warm temperate region on the south coast of Southern Africa. The town of Hamburg is located on the south-west bank of the estuary (Ribbink and Ribbink, 2012). The geographical boundaries of the Keiskamma Estuary are defined as follows (**Figure 6.1**):

Downstream boundary:	33°16'52.93"S, 27°29'27.49"E (estuary mouth)
Upstream boundary	33°11'4.01"S, 27°22'38.01"E
Lateral boundaries:	Estuary functional zone along each bank (~5 m MSL contour)

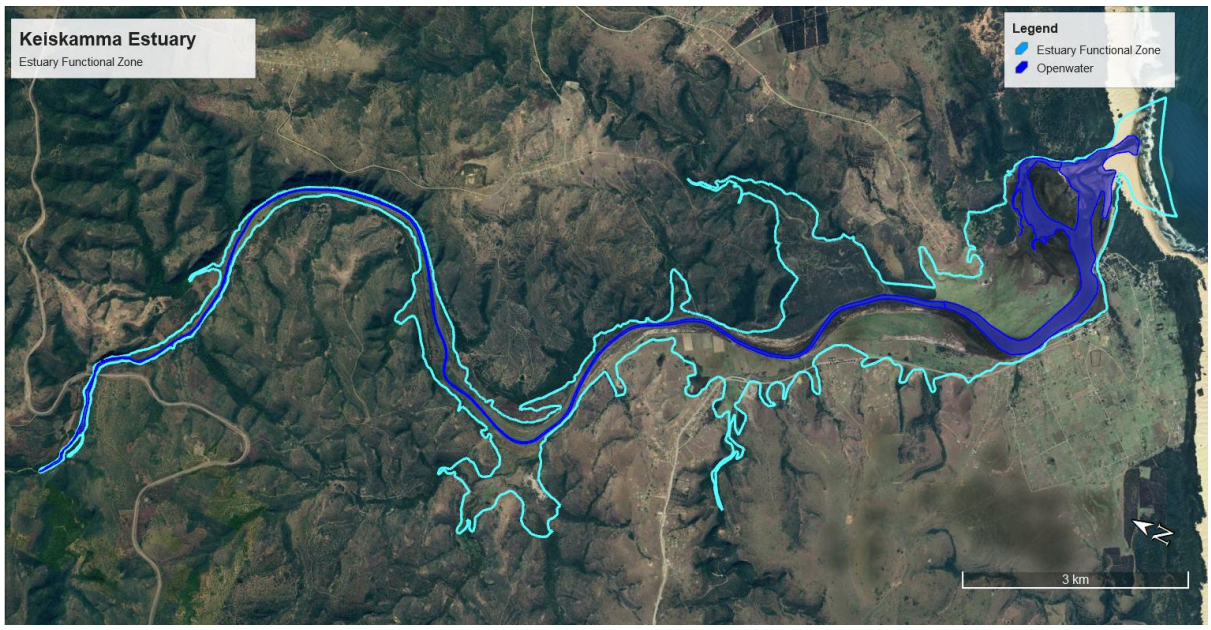

Figure 6-1: Geographical boundaries of the Keiskamma Estuary based on the Estuary Functional Zone.

6.2 Description of hydrological scenarios

Table 6-1 provides a summary of a range of water resource development scenarios that could affect the **Keiskamma Estuary.**

Table 6-1: Summary of flow scenarios.

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity
Reference	Natural	128.68	100.0
Present	Present (no River EWR)	86.43	67.2
1*	Restoration (Present with EWR + removal of invasive alien plants from catchment)	98.85	76.8
2	Present (with EWR)	88.48	68.8

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity
3	Long-term (with EWR)	85.07	66.1
4	Mid-term (no EWR)	82.85	64.4
5	Long-term (no EWR)	82.44	64.1
6*	Worse case (Long-term no EWR, increased baseflow abstraction, large dams)	72.58	56.4
7*	Scenario 1: Restoration (Present with EWR + invasive alien plant eradication) with estuary management interventions		

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

According to the hydrological data provided for this study, the present MAR into the Keiskamma Estuary is 86.4 Million m^3. This is a decrease of 33% compared to the natural MAR of 128.7 Million m^3.

6.3 Present Ecological Status

The Keiskamma Estuary in its present state is estimated to be 67% similar to natural conditions, which translates into a PES of a C Category. This is largely attributed to the following factors:

- Significant flow reduction with a focus on baseflow reduction in the low flow period increasing salinity penetration;
- Severe over-exploitation of living resources (e.g. recreational fishing, small-scale fishing and illegal gill netting) impacting nursery function;
- Severe overgrazing and trampling of saltmarsh by cattle;
- A decline in water quality due to agricultural activities in the catchment;
- Bait collection and recreational activities such as boating affect bird abundance (and potentially bank stability);
- Agricultural activities in the EFZ cause loss of estuarine habitat;
- Cutting of reeds and erosion of banks; and
- Invasive alien plants within the EFZ.

The overall current Estuarine Health Index (EHI) score as well as the percentage attributed to non-flow related pressures is given in **Table 6-2** below.

Table 6-2: Keiskamma: Present Ecological State scores

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence**
Hydrology	46	-*	M
Hydrodynamics and mouth condition	81	0%	L - H
Water quality	77	90%	M
Physical habitat alteration	70	90%	L-M
Habitat health score	**68**		

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence**
Microalgae	79	50%	L-M
Macrophytes	73	80%	M
Invertebrates	55	17%	L
Fish	60	25%	M
Birds	**59**	20%	M
Biotic health score	**65**		
ESTUARY HEALTH SCORE	**67**		**M**
PRESENT ECOLOGICAL STATUS (PES)	**C**		

- Not applicable
*** Confidence levels: Very Low (VL), Low (L), Medium (M), High (H)*

6.4 Ecological consequences of future scenarios

The individual EHI scores, as well as the corresponding ecological category under different scenarios, are provided below in **Table 6-3.**

Scenario 1 (Present with EWR release and invasive alien plant eradication from catchment) represents an improvement of the Estuary to a Category B, while Scenarios 2 and 3 represent only a half-category overall improvement. However, higher ecology remains stressed under these scenarios as a result of present estuary resource use levels. Scenarios 4 and 5 are similar to the Present with only a slight decline in estuary condition. Scenario 6 represents a significant decline in estuary condition as a result of further flow reduction, amplifying existing nutrient pressure. Scenario 7 (Scenario 1: Present with EWR release and invasive alien plant eradication from catchment) with estuary management interventions listed above) represents the only scenario in which all components of the ecosystem improve with a marked improvement in critical ecosystem services such as nursery function and carbon sequestration.

Table 6-3: Keiskamma: Summary of ecological health scores under various scenarios.

Component	Present	Scenarios						
		1	2	3	4	5	6	7
Hydrology	46	67	63	61	45	44	41	67
Hydrodynamics	81	95	94	94	80	79	75	95
Water quality	77	78	78	78	77	77	77	81
Physical habitat	70	74	66	63	69	69	65	75
Habitat health score	**68**	**79**	**75**	**74**	**68**	**67**	**65**	**79**
Microalgae	79	83	83	83	75	75	70	75
Macrophytes	73	83	75	75	70	70	60	90
Combined Inverts	55	80	80	80	51	51	42	80
Fish	60	75	75	65	75	60	65	80
Birds	59	80	80	80	56	56	48	85
Biotic health score	**65**	**80**	**79**	**77**	**65**	**62**	**57**	**82**

Component	Present	Scenarios						
		1	2	3	4	5	6	7
ESTUARINE HEALTH SCORE	67	79	77	75	66	65	61	81
PRESENT ECOLOGICAL STATUS	C	B	B/C	B/C	C	C	C/D	B

6.5 Recommendations to maintain or improve estuary condition

The PES for the Keiskamma Estuary is a C Category, but as the estuary is degraded and of high biodiversity and conservation importance it should be in an A Category or BAS. **Given the land-use change in the Keiskamma Catchment and estuary environs and the present level of natural resource utilisation of the estuary, the REC is set at a B Category (BAS).**

Key interventions required to improve the condition of the Keiskamma Estuary include:

- Develop an Estuary Management Plan for the Keiskamma Estuary to identify key actions require to address the ongoing decline in condition and coordinate restoration efforts.
- Reduce fishing pressure by managing access, increase compliance and improve community interactions.
- Ensure maintenance of low-flow conditions to prevent prolonged periods of increased water residency that promote the accumulation of microalgal communities.
- Manage nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring riparian vegetation.
- Restore saltmarsh areas that are fallow at present (see map in Adams *et al.,* 2023).
- Prevent disturbance of riparian vegetation, including trampling and severe overgrazing by cattle.
- Removal of alien vegetation from EFZ.

6.6 Ecological flow requirements

The REC for the Keiskamma Estuary is Category B. The Recommended Flow Scenario is Scenario 1: Restoration (Present with EWR + invasive alien plant eradication) coupled with interventions listed above.

The flow requirements for the estuary are the same as those described for Scenario 1 and are summarised in **Table 6-4**.

Table 6-4: Keiskamma: Summary of the monthly flow distribution (in m^3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 1: Present with EWR and invasive alien plant eradication) coupled with management interventions.

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	29.6	60.9	27.5	19.1	20.0	45.2	23.2	19.6	14.4	22.3	54.0	24.2
90	7.7	12.5	11.1	8.9	10.1	13.4	8.7	4.4	3.1	3.1	4.7	8.1
80	5.4	7.0	6.9	5.1	6.6	6.9	5.0	2.5	2.2	2.3	2.2	4.0
70	3.6	4.4	4.5	3.9	4.2	5.3	3.3	2.0	1.7	1.8	1.9	2.6
60	3.0	3.5	3.3	2.7	3.3	4.0	2.8	1.7	1.5	1.6	1.6	1.8
50	2.3	2.7	2.5	2.3	2.3	2.9	2.4	1.5	1.3	1.3	1.4	1.6
40	1.9	2.3	1.9	1.7	1.9	2.2	1.9	1.3	1.3	1.2	1.3	1.4
30	1.7	2.0	1.7	1.4	1.6	1.9	1.6	1.1	1.1	1.1	1.2	1.3
20	1.4	1.7	1.2	1.0	1.5	1.5	1.2	1.0	1.0	1.0	1.0	1.1
10	1.1	1.3	0.9	0.7	0.9	1.2	0.9	0.8	0.9	0.9	0.9	0.9
1	0.8	0.6	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.6	0.7	0.7

7. KARIEGA ESTUARY

7.1 Geographical boundaries

The Kariega Estuary is a warm temperate, predominantly open estuary situated on the east coast of South Africa. Its mouth opens just east of Kenton-on-Sea, and it is around 18 km in length and has an average midstream depth between 2.5 and 3.5 m. The Kariega Estuary is a marine-dominated system having a mean annual runoff of 22 x 10^6 m^6). The geographical boundaries of the Kariega Estuary are defined as follows (**Figure 7.1**):

Downstream boundary:	33°40'53.87"S, 26°41'4.23"E (estuary mouth)
Upstream boundary:	33°36'23.43"S, 26°38'17.77"E
Lateral boundaries:	Estuary functional zone along each bank (~5 m MSL contour)

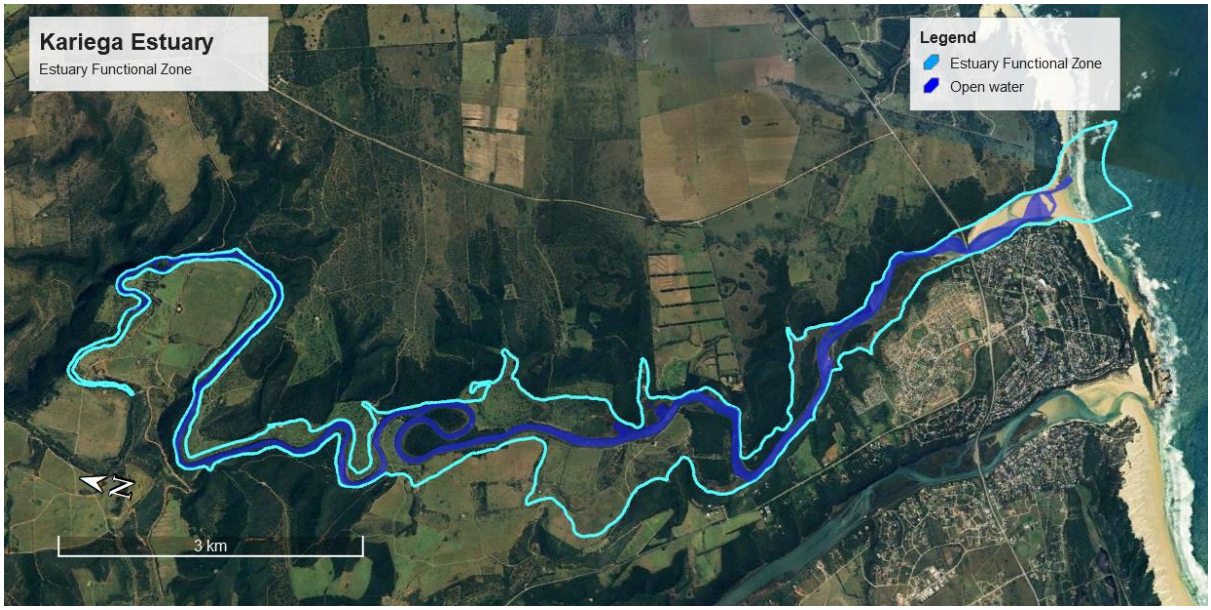

Figure 7-1: Geographical boundaries of the Kariega Estuary based on the Estuary Functional Zone.

7.2 Description of hydrological scenarios

Table 7-1 provides a summary of a range of water resource development scenarios that could affect the Kariega Estuary.

Table 7-1: Summary of flow scenarios

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity
Reference	Natural	21.89	100.0
Present	Present (no river EWR)	13.08	59.8

Scenarios	Description	MAR ($X10^6$ m^3)	% Similarity
1*	Restoration (strategic releases from the Settlers Dam (0.005 m^3/s) in the months in which the estuary does not receive incremental flows from below the dam,33% reduction in irrigation below the dam, and no support to Grahamstown from Settlers)	14.96	68.3
2	Medium/Long Term (no river EWR)	13.08	59.8
3*	Worse Case (full demand of Makhanda (Grahamstown) supplied from the Kariega (no Orange-Fish transfer)	9.89	45.2

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario.*

The present MAR into the Kariega Estuary is 13.1 Million m^3. This is a decrease of 40% compared to the natural MAR of 21.9 Million m^3.

7.3 Present Ecological Status

The Kariega Estuary in its present state is estimated to be 68% similar to natural conditions, which translates into a PES of a C Category. This is attributed to the following factors:

- Significant flow reduction with a focus on baseflow reduction in the low flow period resulting in an increase in salinity penetration and development of hypersalinity in the system;
- A decline in water quality due to agricultural activities and local housing development not on formal reticulation;
- Severe over-exploitation of living resources (e.g. recreational fishing, small-scale fishing and illegal gill netting) impacting nursery function;
- Agricultural activities and development in the EFZ cause loss of estuarine habitat; and
- Bait collection and recreational activities such as boating affect bird abundance (and potentially bank stability).

The overall current Estuarine Health Index (EHI) score as well as the percentage attributed to non-flow related pressures is given in **Table 7-2** below.

Table 7-2: Kariega: Present Ecological State scores

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence**
Hydrology	38	-*	M
Hydrodynamics and mouth condition	62	0%	L-M
Water quality	86	90%	M
Physical habitat alteration	75	80%	L
Habitat health score	**65**		
Microalgae	83	20%	L-M
Macrophytes	65	10%	M
Invertebrates	60	10%	L
Fish	70	20%	H

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence**
Birds	72	11%	M
Biotic health score	**70**		
ESTUARY HEALTH SCORE	**68**		**M**
PRESENT ECOLOGICAL STATUS (PES)	**C**		

**- Not applicable*
*** Confidence levels: Very Low (VL), Low (L), Medium (M), High (H)*

7.4 Ecological consequences of future scenarios

The individual EHI scores, as well as the corresponding ecological category under different scenarios, are provided below in **Table 7-3.** Under Scenarios 1 and 2 the estuary is in a Category C, the same as the PES, with Scenario 1 only representing a slight 3% increase in condition with a major impact on water resource allocation in the catchment. Scenario 3 resulted in an additional 15% decline in condition, resulting in a Category D.

Table 7-3: Kariega: Summary of ecological health scores under various scenarios

Parameter	Present	Scenarios		
		1	2	3
Hydrology	38	45	38	29
Hydrodynamics	62	68	62	42
Water quality	86	88	86	80
Physical habitat alteration	75	77	75	67
Habitat health score	65	69	65	54
Microalgae	83	83	83	62
Macrophytes	65	70	65	50
Combined Inverts	60	64	60	36
Fish	70	75	70	50
Birds	72	74	72	55
Biotic health score	**70**	**73**	**70**	**51**
ESTUARINE HEALTH SCORE	**68**	**71**	**68**	**53**
PRESENT ECOLOGICAL STATUS	**C**	**C**	**C**	**D**

7.5 Recommendations to maintain or improve estuary condition

The PES for the Kariega Estuary is a C Category, but as the estuary is degraded and of high biodiversity and conservation importance it should be in an A Category or BAS. **Given the small size of the catchment; the degree of land-use change in the catchment and lower parts of the estuary; and the present level of natural resource utilisation of the Kariega Estuary the REC is set as a C Category (BAS).**

Key interventions required to assist with species protection and to halt further decline in the condition of the Kariega Estuary include:

- Increase the protection of the estuary to ensure the protection of Estuarine pipefish and seagrass, i.e. stewardship agreements with Private Nature Reserve adjacent to the system.

- Develop an Estuary Management Plan for the Kariega Estuary to identify key actions required to improve/protect the system and coordinate restoration efforts (requirement of National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008) to coordinate management and restoration actions.
- Prevent further loss of low-flow conditions to limit the extent and duration of hypersalinity that leads to a loss of primary productivity. Increase base flows (e.g. through the removal of alien vegetation, unauthorised abstractions and/or forestry) to prevent mouth closure.
- Create interventions within the catchment and institute a buffer zone around the river and EFZ that would improve the nutrient status and help with sedimentation issues.
- Reduce fishing and bait collection pressure by managing access, increase compliance and improve community interactions to restore nursery function.
- Prevent disturbance of riparian vegetation, including trampling, cattle, fire, and removal of alien vegetation.
- Undertake restoration of the estuary floodplain and reduce agriculture impacts in the supratidal area of the system.

7.6 Ecological flow requirements

The REC for the Kariega Estuary is Category C. Scenario 2 yields the same scores as the Present. The Recommended Flow Scenario is thus Scenario 2 (Medium Term/Long Term development) coupled with the interventions above.

The flow requirements for the estuary are the same as those described for Scenario 2 and are summarised in **Table 7-4.**

Table 7-4: Kariega: Summary of the monthly flow distribution (in m^3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 2: Medium / Long term development)

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	7.767	11.136	4.886	1.388	1.297	8.587	7.097	6.468	9.654	5.122	11.310	10.232
90	0.501	0.494	0.605	0.209	0.160	0.554	0.451	0.386	0.205	0.247	0.662	1.213
80	0.341	0.221	0.167	0.048	0.062	0.285	0.183	0.107	0.090	0.060	0.097	0.296
70	0.206	0.120	0.068	0.027	0.033	0.082	0.117	0.053	0.051	0.045	0.051	0.062
60	0.086	0.054	0.037	0.019	0.021	0.046	0.080	0.037	0.040	0.034	0.034	0.040
50	0.052	0.041	0.026	0.009	0.017	0.034	0.033	0.030	0.031	0.026	0.026	0.027
40	0.032	0.031	0.011	0.004	0.004	0.026	0.023	0.022	0.027	0.022	0.019	0.023
30	0.018	0.014	0.000	0.000	0.000	0.011	0.015	0.015	0.019	0.018	0.015	0.019
20	0.007	0.004	0.000	0.000	0.000	0.004	0.003	0.007	0.015	0.011	0.010	0.011
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.008	0.007	0.004	0.000
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

8. GAMTOOS ESTUARY

8.1 Geographical boundaries

The Gamtoos Estuary is a permanently open estuary located on the south coast of South Africa and is approximately 24 km long. The geographical boundaries of the Gamtoos Estuary are defined as follows (**Figure 8.1**):

Downstream boundary:	33°58'8.20"S, 25° 2'30.36"E (estuary mouth - 2018)
Upstream boundary:	33°54'54.70"S, 24°56'16.56"E
Lateral boundaries:	Estuary functional zone along each bank (~5 m MSL contour)

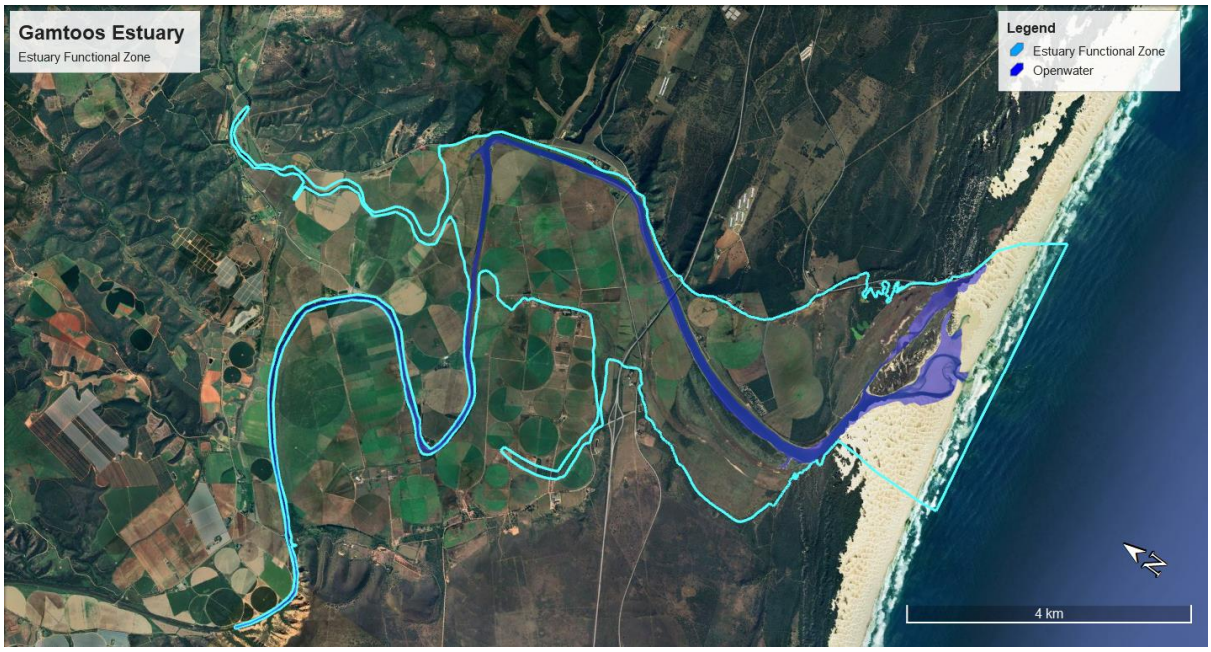

Figure 8-1: Geographical boundaries of the Gamtoos Estuary based on the Estuary Functional Zone.

8.2 Description of hydrological scenarios

Table 8-1 provides a summary of a range of water resource development scenarios that could affect the Gamtoos Estuary.

Table 8-1: Summary of flow scenarios

Scenario	Description	MAR (X 10^6 m^3)	% Similarity
Reference	Natural	404.23	100.0
Present	Present (no River EWR)	194.82	48.2
1*	Restoration Scenario (Present with River EWR, irrigation demands 33% decreased on Kouga Dam, all alien invasives have been removed - except for the Groot)	219.71	54.4

Scenario	Description	MAR (X 10^6 m^3)	% Similarity
2	Present (with River EWR)	209.19	51.8
3	Mid-term (no River EWR)	199.86	49.4
4	Long-term Desalination (no EWR)	199.59	49.4
5	Long-term Kouga Dam Raised (with River EWR)	198.60	49.1
6	Long-term Kouga Dam Raised (no River EWR)	192.57	47.6
7*	Long-term Worst case (Long-term demands, raised Kouga Dam, no EWR, no support from the Fish/ Sundays scheme)	175.04	43.3
8*	Present (with River EWR) with Estuary Management interventions	209.19	51.8

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario.*

According to the hydrological data provided for this study, the present MAR into the Gamtoos Estuary is 195 million m^3. This is a decrease of 52% compared to the natural MAR of 404 million m^3.

8.3 Present Ecological Status

The Gamtoos Estuary in its present state is estimated to be 54% similar to natural conditions, which translates into a PES of a D Category. This is mostly attributed to the following factors:

- Flow reduction with a focus on baseflow reduction in the low flow period resulting in a significant increase in salinity and the occurrence of mouth closure (a rare and worrisome event for an estuary that is normally open);
- A decline in water quality due to extensive agricultural activities in the catchment and in the floodplain of the estuary;
- Severe over-exploitation of living resources (i.e recreational fishing, small scale and illegal gill netting and bait collection) impacting nursery function and fisheries productivity;
- Agricultural activities in the EFZ cause loss of critical estuarine habitat;
- Overgrazing and trampling of saltmarsh on the floodplain impacting blue and teal carbon habitats and carbon sequestration;
- Bank destabilisation and bank hardening impacting coastal protection and habitat availability; and
- Bait collection and recreational activities in the lower and middle reaches affect bird abundance.

The overall current Estuarine Health Index (EHI) score as well as the percentage attributed to non-flow related pressures is given in **Table 8-2** below.

Table 8-2: Gamtoos: Present Ecological State scores

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence**
Hydrology	36	-*	H
Hydrodynamics and mouth condition	68	0%	L - H
Water quality	51	90%	M-H
Physical habitat alteration	70	90%	L
Habitat health score	56		
Microalgae	51	90%	L-H
Macrophytes	52	85%	M
Invertebrates	46	20%	L
Fish	55	20%	M
Birds	53	20%	M
Biotic health score	51		
ESTUARY HEALTH SCORE	**54**		**M**
PRESENT ECOLOGICAL STATUS (PES)	**D**		

**- Not applicable*
*** Confidence levels: Very Low (VL), Low (L), Medium (M), High (H)*

8.4 Ecological consequences of future scenarios

The individual EHI scores, as well as the corresponding ecological category under different scenarios, are provided below in **Table 8-3.**

Scenarios 1 and 2 (both include River EWR releases) represent a nearly 10% improvement in the health of the Gamtoos Estuary resulting in a Category C. The difference between Scenario 1 and 2 is minimal in benefits to the estuary, even though Scenario 1 represents a 33% decrease in irrigation demand from the Kouga Dam and all invasive alien plants removed from most of the catchment). Indicating that little ecological benefit can be derived at the expense of existing water resource allocation. Scenarios 3 to 6 largely remain similar to the present, with an additional 8 % decline in the condition expected under Scenario 7, but with the system remaining in a D category. Scenario 8 (Present with River EWR releases and additional estuary management interventions below) represents the scenario with the best ecological outcomes with important ecosystem services such as nursery function and carbon sequestration optimised even if conservation targets cannot be met overall.

Table 8-3: Gamtoos: Summary of ecological health scores under various scenarios

Parameter	PES	Scenarios							
		1	2	3	4	5	6	7	8
Hydrology	36	48	47	38	38	41	36	31	47
Hydrodynamics	68	86	86	69	69	75	69	59	86
Water quality	51	59	59	51	51	52	50	51	59
Physical habitat	70	71	68	72	72	67	68	65	68
Habitat health score	56	66	65	57	57	59	56	52	65
Microalgae	51	56	56	51	51	52	51	45	56
Macrophytes	52	60	57	52	52	54	47	40	60
Combined Inverts	46	64	64	46	46	54	46	40	70

Parameter	PES	Scenarios							
		1	2	3	4	5	6	7	8
Fish	55	70	70	55	60	60	55	30	80
Birds	53	68	69	53	53	60	53	49	74
Biotic health score	51	64	63	51	52	56	50	41	68
ESTUARINE HEALTH SCORE	54	65	64	54	55	57	53	46	66
PRESENT ECOLOGICAL STATUS	**D**	**C**	**C**	**D**	**D**	**D**	**D**	**D**	**C**

8.5 Recommendations to maintain or improve estuary condition

The PES for the Gamtoos Estuary is a D Category, however, as the estuary is degraded and of high biodiversity and conservation importance it should be in an A Category or BAS. **Given the degree of land-use change, specifically agriculture, in the catchment and estuary floodplain; concerns regarding water quality; and the present a very high level of natural resource utilisation of the Gamtoos Estuary the REC is a C Category (BAS).**

Key interventions required to improve the condition of the Gamtoos Estuary include:

- Develop an Estuary Management Plan for the Gamtoos Estuary to identify key actions required to halt the ongoing degradation of estuary condition and restore and coordinate restoration efforts (requirement of National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008).
- Increase base flows (e.g. through the removal of alien vegetation, unauthorised abstractions and/or forestry) to prevent mouth closure.
- Maintain a degree of natural hydrodynamic variability and periodic system flushing to prevent persistent eutrophic conditions (i.e., HABs, hypoxia, loss of species diversity).
- Reduce nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and irrigation) and restoring riparian vegetation.
- Institute a buffer zone around the river and EFZ that would improve the nutrient status and help with sedimentation issues.
- Develop and approve an Estuary Mouth/Maintenance Management Plan (required under the Environmental Impact Assessment regulations under the National Environmental Management Act (No. 107 of 1998)) to facilitate artificial breaching if required in future.
- Reduce fishing pressure by managing access, increase compliance and improve community interactions to restore nursery function.
- Prevent further disturbance of estuary riparian vegetation, including reducing trampling and grazing by livestock, prevention of fire, and remove alien vegetation from the EFZ.
- Undertake active restoration of the degraded estuary floodplain and reduce agriculture impacts in the supratidal area of the system (Adams *et al.* 2023).

8.6 Ecological flow requirements

The REC for the Gamtoos Estuary is Category C. The Recommended Flow Scenario is Scenario 8, which is a similar flow regime to Scenario 2: Present (with River EWR) coupled with estuary restoration interventions listed above. The flow requirements for the estuary are the same as those described for Scenario 2 and are summarised in **Table 8-4.**

Table 8-4: Gamtoos Estuary: Summary of the monthly flow distribution (in m3/s) for the Recommended Ecological Flow Scenario (i.e. Scenario 8: Present with River EWR with estuary restoration intervention).

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	32.9	69.9	57.2	68.2	97.8	122.3	57.8	54.2	48.1	37.1	112.3	48.1
90	7.8	8.9	7.2	6.2	20.8	32.4	20.7	5.6	5.1	8.7	26.1	30.4
80	5.1	4.3	3.1	3.0	6.0	12.5	6.6	2.6	2.3	2.4	5.5	9.0
70	3.3	3.4	2.5	2.0	3.1	7.6	3.4	2.1	1.9	2.0	3.6	3.7
60	2.1	2.9	1.9	1.7	2.2	6.6	1.9	1.7	1.7	1.7	3.0	2.7
50	1.7	2.6	1.5	1.2	1.7	4.0	1.5	1.3	1.4	1.5	2.4	2.2
40	1.4	2.2	1.2	0.8	1.3	2.7	1.3	1.1	1.2	1.2	1.9	1.7
30	1.2	1.4	1.0	0.5	1.0	2.0	1.0	1.0	1.0	1.1	1.6	1.2
20	1.0	1.2	0.9	0.4	1.0	1.5	0.9	0.9	0.9	1.0	1.3	1.1
10	0.9	1.0	0.9	0.4	0.8	1.0	0.6	0.7	0.8	0.8	1.1	0.9
1	0.4	0.7	0.7	0.3	0.5	0.8	0.4	0.4	0.4	0.6	0.8	0.8

9. KABELJOUS ESTUARY

9.1 Geographical boundaries

For the purposes of the EWR assessment, the geographical boundaries of the Kabeljous Estuary are defined as follows (**Figure 9.1**):

Downstream boundary:	34° 0'17.90"S, 24°56'7.46"E (estuary mouth)
Upstream boundary:	33°59'34.78"S, 24°55'34.55"E
Lateral boundaries:	Estuary functional zone along each bank (~5 m MSL contour)

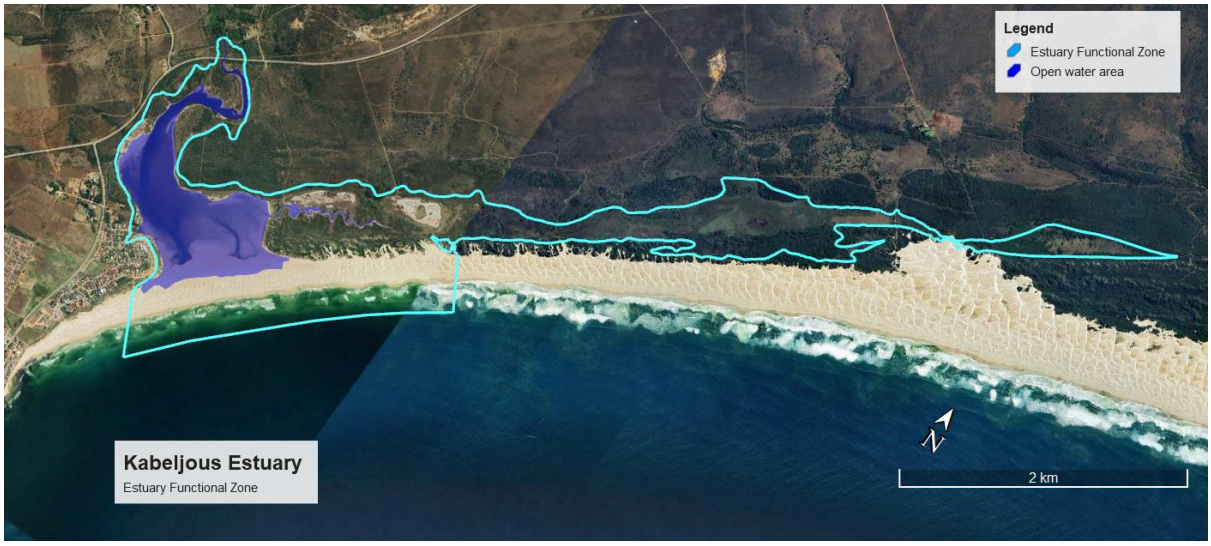

Figure 9-1: Geographical boundaries of the Kabeljous Estuary based on the Estuary Functional Zone.

9.2 Description of hydrological scenarios

Table 9-1 provides a summary of a range of water resource development scenarios that could affect the Kabeljous Estuary.

Table 9-1: Summary of flow scenarios

Scenario	Description	MAR	%Similarity
Reference	Natural (with 33 % more groundwater input)	5.27	100.0
Present	Present (no EWR)	4.70	89.3
1*	Restoration (20% decrease in dams and corresponding irrigation)*	4.90	93.0
2	Mid-term (no EWR)	4.72	89.6
3*	Worse case (~30% increase in dams and corresponding irrigation)*	3.99	75.8
4.*	Present with an additional 33% reduction in groundwater input	4.70	89.3

**Estuary EWR scenarios generated to assess estuary sensitivity to flow changes. Not formal operational/water resource development scenario*

The estuary is fed by the Kabeljous and Gheis River, with a total length of approximately 30 km). The total catchment of the area is ~238 km^2 (Bickerton and Pierce, 1988). The Kabeljous

Estuary receives a mean annual precipitation of approximately 450 mm. Historical studies have estimated the mean annual runoff of between 15 x 10^6 m^3 and 27 x 10^6 m^3 (Bickerton and Pierce, 1988; Klages, 2005), but this has recently been adjusted downwards in the Algoa Bay study. According to the hydrological data provided for this study, the present MAR into the Kabeljous Estuary is 4.7 Million m^3. This is a decrease of 11% compared to the natural MAR of 5.27 Million m^3. **However, it should be noted that this is of very low confidence as the presence of numerous farm dams in this small catchment indicates that surface and/or groundwater are substantially reduced. The EWR evaluation thus followed an inclusive approach and integrated the freshwater input to the coast.**

9.3 Present Ecological Status

The Kabeljous Estuary in its present state is estimated to be 78% similar to natural conditions, which translates into a PES of a B Category. This is largely attributed to the following factors:

- A reduction in groundwater input that assists in moderating hypersalinity and estuary water levels;
- Flow reduction with a focus on baseflow reduction resulting in an increase in salinity and a decrease in water levels;
- A decline in water quality due to agricultural activities in the catchment;
- Agricultural activities and development (including bridges) in the EFZ cause loss of estuarine habitat;
- Over-exploitation of living resources (i.e., illegal gillnetting and line fishing) – effectively mining fish in a closed small estuary;
- Recreational activities in the lower reaches affect bird abundance;
- Trampling and footpaths through saltmarshes; and
- Land invasion occurs in the important wetland area east of the mouth. This brings with it pressures such as habitat removal, nutrient and litter pollution. These freshwater wetlands contain the only viable remaining example of Humansdorp Shale Renosterveld, which has remnant Khoisan middens, and is the breeding and roosting area of the endangered black Harrier.

The overall current Estuarine Health Index (EHI) score as well as the percentage attributed to non-flow related pressures is given in **Table 9-2** below.

Table 9-2: Kabeljous: Present Ecological State scores

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence**
Hydrology	80	-*	L
Hydrodynamics and mouth condition	84	0%	L - M
Water quality	87	90%	L
Physical habitat alteration	76	90%	L
Habitat health score	**82**		
Microalgae	76	50%	L

Variable	Estuarine health score		
	Score	% attributed to non-flow related impacts	Confidence**
Macrophytes	80	40%	M
Invertebrates	71	24%	L
Fish	70	20%	M-L
Birds	77	14%	H
Biotic health score	**75**		
ESTUARY HEALTH SCORE	**78**		**L**
PRESENT ECOLOGICAL STATUS (PES)	**B**		

**- Not applicable*
*** Confidence levels: Very Low (VL), Low (L), Medium (M), High (H)*

9.4 Ecological consequences of future scenarios

The individual EHI scores, as well as the corresponding ecological category under different scenarios, are provided below in Table 9-3. Scenario 1 (Restoration: 20% decrease in dams and corresponding irrigation) represents only a 2% increase in estuary conditions despite its significant impact on the water allocation in the catchment. Scenario 2 (Medium-term development) represents a decline to a Category B/C, albeit only a 1% decline in overall condition. **Scenario 3 (~30% increase in dams/abstraction) and Scenario 4 (potential further 33% reduction in groundwater) both pose considerable risks to the estuary condition as they increase either the duration of hypersalinity conditions or the intensity of hypersalinity conditions, or both. Groundwater especially in closed shallow estuaries plays an important role in moderating the development of hypersalinity and water levels.** The present potential 33% reduction in groundwater is estimated to already play a role in the development of hypersalinity values of 55 to 60 (seawater = 35). While this study was of low confidence, it indicated that any additional freshwater allocation, albeit surface or groundwater, would severely impact the ecological health of this system.

Table 9-3: Kabeljous: Summary of ecological health scores under various scenarios.

Parameter	Present	Scenarios			
		1	2	3	4
Hydrology	80	82	80	69	63
Hydrodynamics and mouth condition	84	86	84	74	79
Water quality	87	87	87	87	67
Physical habitat alteration	76	80	76	58	63
Habitat health score	82	84	82	72	68
Microalgae	76	77	76	70	59
Macrophytes	80	85	80	75	65
Combined Inverts	71	71	69	67	63
Fish	70	70	70	60	50
Birds	77	77	75	71	71
Biotic health score	75	76	74	69	62
ESTUARINE HEALTH SCORE	**78**	**80**	**77**	**70**	**65**
PRESENT ECOLOGICAL STATUS	**B**	**B**	**B/C**	**C**	**C**

9.5 Recommendations to maintain or improve/maintain estuary condition

The PES for the Kabeljous Estuary is a B Category. **Given the degree of agriculture and development in the catchment and estuary environs; concerns regarding surface water and groundwater abstraction, declining water quality; and the high level of fishing effort the REC is also set at a B Category.**

Key interventions required to improve the condition of the Kabeljous Estuary include:

- Develop an Estuary Management Plan for the Kabeljous Estuary to identify key actions needed to improve the condition and coordinate restoration efforts (requirement of National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008).
- **Ensure maintenance of low-flow conditions (including groundwater) to prevent prolonged periods of mouth closure and the development of extreme hypersalinity that promotes microalgal and macroalgal accumulations.**
- **Increase base flows (e.g. through the removal of alien vegetation, unauthorised abstractions and/or forestry).**
- Reduce nutrient inputs by implementing agricultural best management practices (e.g., prevent overfertilization and over-irrigation) and restoring riparian vegetation.
- Reduce fishing pressure by managing access, increase compliance and improve community interactions to restore nursery function.
- Prevent disturbance of riparian vegetation, including trampling by humans and cattle, fire, and removal of alien vegetation.
- Prevent artificial breaching of the mouth (currently not a concern).

9.6 Ecological flow requirements

The REC for the Kabeljous Estuary is Category B. **The Recommended Flow Scenario is the present day flow regime for surface and groundwater coupled with interventions listed above to halt the further decline in estuary condition.**

The flow requirements for the estuary are the same as those described for the present day (PES) and are summarised in Table 9-4 below.

Table 9-4: Kabeljous: Summary of the monthly flow distribution (in m^3/s) for the Recommended Ecological Flow Scenario (i.e. Present)

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
99	2.862	1.807	0.711	0.164	0.543	0.627	0.311	1.288	1.073	0.534	8.318	8.460
90	0.318	0.202	0.080	0.035	0.027	0.038	0.059	0.132	0.116	0.171	0.254	0.475
80	0.199	0.140	0.065	0.026	0.021	0.028	0.035	0.054	0.081	0.105	0.163	0.204
70	0.164	0.119	0.046	0.024	0.019	0.016	0.027	0.041	0.060	0.080	0.120	0.147
60	0.123	0.092	0.039	0.020	0.014	0.011	0.019	0.029	0.051	0.061	0.095	0.118
50	0.107	0.076	0.032	0.015	0.010	0.009	0.015	0.021	0.033	0.051	0.075	0.104
40	0.092	0.061	0.025	0.014	0.010	0.009	0.011	0.015	0.028	0.044	0.060	0.076
30	0.073	0.054	0.023	0.011	0.007	0.008	0.009	0.014	0.024	0.036	0.051	0.061
20	0.054	0.043	0.017	0.009	0.006	0.006	0.009	0.012	0.016	0.029	0.040	0.051

%ile	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
10	0.041	0.035	0.014	0.006	0.006	0.003	0.006	0.006	0.012	0.021	0.030	0.043
1	0.005	0.018	0.007	0.003	0.003	0.002	0.003	0.002	0.003	0.006	0.007	0.021

10. CONCLUSION

10.1 Management of non-flow related impacts

Most of the estuaries assessed in the study had significant non-flow related pressures that were driving ongoing decline in condition. Key concerns include the impact of over-exploitation of fish (especially illegal gill netting) impacting on nursery function and overgrazing of saltmarsh (e.g. Keiskamma) and browsing of mangroves (Mbashe and Great Kei) compromising the ability of blue carbon habitats to contribute to carbon storage being key concerns. Increased nutrient levels from agricultural activities are also an emerging concern (e.g. Gamtoos Estuary). In several systems, the local disturbance of bird forging and roosting areas by fishers and other reactional activities (e.g. boating) also contribute to the decline.

It is thus of critical importance that future EWR allocations be supported by the development of an Estuary Mouth Management Plan (requirement of National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008) to coordinate the interventions required to improve/protect the systems and coordinate restoration efforts.

10.2 Management of flow related impacts

10.2.1 *Kabeljous Estuary*

Reducing either surface water or groundwater inputs to the Kabeljous Estuary poses considerable risks to the estuary condition as it will increase either the duration of hypersalinity conditions and/or the intensity of hypersalinity conditions. Groundwater, especially in closed shallow estuaries such as the Kabeljous, plays an important role in moderating the development of hypersalinity and water levels. The present potential reduction in groundwater in conjunction with surface water abstraction is estimated to already play a role in the development of hypersalinity values of 55 to 60 (seawater = 35). While this study was of low confidence, it indicated that any additional freshwater allocation, albeit surface or groundwater, would severely impact the ecological health of this system. If future allocations are to be considered, refinements to both the surface and groundwater models need to be made to guide allocations at the estuary process scale.

10.3 Climate Change

Most of the estuaries in the study area showed a negative trajectory of change. Climate change with predicted increases in drought, floods, and hotter temperatures will only accelerate these trajectories. Maintaining a degree of natural hydrodynamic variability and estuarine abiotic configuration, together with preventing catchment degradation (e.g., erosion, nutrient enrichment), is particularly critical in the face of climate change where predicted increases in temperature, drought, and storminess are likely to confound biotic responses. For example, a 2°C increase in water temperature can increase the distribution and frequency of problematic and fast-growing primary producer communities (i.e., HABs, invasive alien aquatic plants, and filamentous/floating macroalgae).

10.4 Environmental flows to the marine environment

This study did not address the importance of the Mbashe, Great Kei, Keiskamma and Gamtoos catchments in supplying sediments and detritus to the nearshore coastal environment where they play a critical role in maintaining beaches and nearshore spawning grounds of economically important marine species. It should be noted that any future large infrastructure development could impact this important catchment-to-coast process and should be evaluated before large infrastructure such as dams could reduce floods and sediment loads to the coast.

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