Department of Water Affairs and Forestry

DWAF PROJECT REFERENCE NO. 26/8/3/10/4

KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY

TECHNICAL COMPONENT

EWR ESTUARY REPORT: SEEKOEI

Coastal & Environmental Services

KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY – TECHNICAL COMPONENT

EWR ESTUARY REPORT: FINAL
SEEKOEI ESTUARY

June 2006

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DEPARTMENT OF WATER AFFAIRS and FORESTRY
DIRECTORATE: RESOURCE DIRECTED MEASURES

KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY – TECHNICAL COMPONENT EWR ESTUARY REPORT: FINAL SEEKOEI ESTUARY

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EXECUTIVE SUMMARY

Assumptions and Limitations

The following assumptions and limitations must be taken into account:

- The overall confidence in the hydrological data provided to the estuarine team by project hydrologist (Mr A Sparks, Ninham Shand consulting engineers, Cape Town) was low as limited accurate runoff data were available.

- The accuracy of predicted Abiotic State for the Seekoei Estuary and the distribution of these states under the Reference Conditions, Present State and Future Scenarios depends largely on the accuracy of the simulated runoff data (over the 73-year period) of river inflow at the head of the estuary, provided to the estuarine team by the project hydrologist.

- Water quality data of river inflow at the head of the estuary were provided to the estuarine team by the water quality specialists on the river component. However, the available data were very limited for the Seekoei Estuary and no data were available for the Reference Condition. For the Seekoei Estuary, Reference Condition characteristics for inorganic nutrients were therefore estimated by the water quality specialists on the river component using the Umgeni Water Water Quality Index ranges and experience in the Umgeni Water Operation Area (DWAF, 2002).

- For the purposes of the Ecological Reserve Determination, it is important to be able to correlate any measured salinity information to specfic river inflow patterns. Unfortunately such information was not historically captured, which made the interpretation of some of the available information difficult.

- Criteria for confidence limits attached to statements in this study are as follows:

Limit	Degree of confidence
Low	If no data were available for the estuary or similar estuaries (i.e. < 40%)
Medium	If limited data were available for the estuary or other similar estuaries (i.e. 40% – 80%)
High	If sufficient data were available for the estuary (i.e. > 80%)

- Data on the invertebrate component are very limited, but it is assumed that species composition is similar to other temporary open/closed systems in the region.

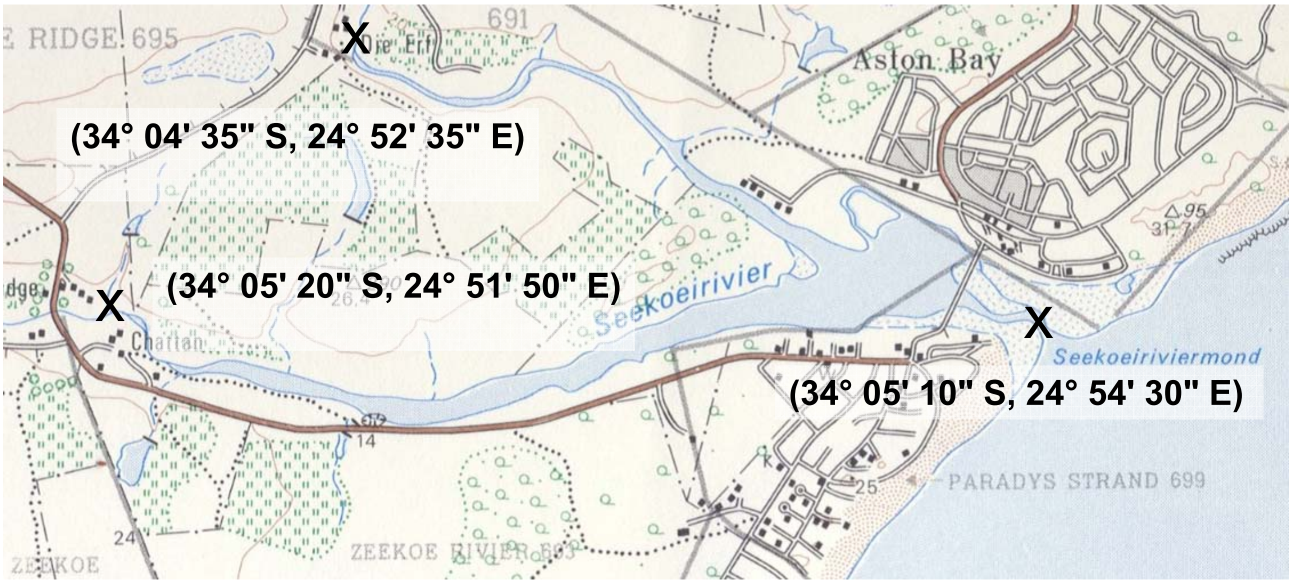
Geographic boundaries

For the purposes of this preliminary determination of the Ecological Reserve of the Seekoei Estuary, the geographical boundaries are defined as follows (Gauss Projection, Clarke 1880 Spheroid):

Downstream boundary: The estuary mouth (34° 05' 10" S, 24° 54' 30" E)

Upstream boundary: Seekoei River (34° 05' 20" S, 24° 51' 50" E)
Swart River (34° 04' 35" S, 24° 52' 35" E)

Lateral boundaries: 5 m contour above MSL along the banks.



Present Ecological Status (PES)

The Estuarine Health Index (EHI) scores allocated to the Seekoei Estuary (Present State) are:

Variable	Weight	Score	Weighted score
Hydrology	25	58	14
Hydrodynamics and mouth condition	25	40	10
Water quality	25	40	12
Physical habitat alteration	25	61	15
Habitat Health Score			**50**
Microalgae	20	35	7
Macrophytes	20	35	7
Invertebrates	20	30	6
Fish	20	35	7
Birds	20	40	8
Biotic Health Score			**35**
Estuarine Health Score			**42**

The EHI score for the Seekoei Estuary, based on its Present State, is 42, translating into a Present Ecological Status of D- as indicated below:

EHI Score	Present Ecological Status	General description
91 – 100	A	Unmodified, natural
76 – 90	B	Largely natural with few modifications
61 – 75	C	Moderately modified
41 – 60	**D**	**Largely modified**
21 – 40	E	Highly degraded
0 – 20	F	Extremely degraded

It is very important to note that although the Habitat Health of the systems equates to a D (50), the Biotic Health is in a Category E (35). It is therefore believed that the Seekoei Estuary is on a trajectory of change to a Present Ecological Status of a Category E and that management intervention is urgently required to prevent further degradation.

Importance of the Seekoei Estuary

The Estuarine Importance scores allocated to the Seekoei Estuary are as follows:

Criterion	Weight	Score	Weighted score
Estuary size	15	90	14
Zonal rarity type	10	10	1
Habitat diversity	25	80	20
Biodiversity importance	25	85	18
Functional importance	25	60	15
Estuarine Importance Score			**71**

The Estuarine Importance Score for the Seekoei Estuary based on its Present State is 71, indicating that the estuary is important, as listed below:

Importance Score	Description
81 – 100	Highly important
61 – 80	**Important**
0 – 60	Of low to average importance

Recommended Ecological Category for Seekoei Estuary

The recommended Ecological Reserve Category (ERC) represents the level of protection assigned to an estuary, which is used to determine the Ecological Reserve. For estuaries, the first step is to determine the 'minimum' ERC of an estuary, based on its Present Ecological Status (PES). The relationship between EHI Score, PES and ERC is set out below:

EHI Score	PES	Description	ERC
91 – 100	A	Unmodified, natural	A
76 – 90	B	Largely natural with few modifications	B
61 – 75	C	Moderately modified	C
41 – 60	D	Largely modified	D
21 – 40	E	Highly degraded	-
0 – 20	F	Extremely degraded	-

Note: Should the present status category of an estuary be either E or F, recommendations must be made as to how the status can be elevated to at least achieve a Category D (as indicated above).

PES sets the minimum Ecological Reserve Category. The degree to which the Ecological Reserve Category needs to be elevated higher than PES depends on level of **importance** and level of **protection or desired** protection of a particular estuary (see below).

Current/desired Protection Status and Estuary Importance	Recommended Ecological Reserve Category	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 class
Important	PES + 1, min C	Important estuaries should be in an A, B or C class
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D class

* = Best Attainable State (BAS)

The Seekoei Estuary is a Provincial Nature Reserve. According to the guidelines for assigning a recommended ERC, the estuary therefore needs to be in a Category A or the Best Attainable State (BAS).

At the specialist workshop (held on 25 February 2005 in Port Elizabeth), it was concluded that the changes that are largely contributing to the Present State of the estuary are numerous farm dam developments in the catchment, the causeway running through the estuary, an increase in suspended solids in the inflowing water and artificial mouth manipulation. At this stage, it is unlikely that these changes could be reversed sufficiently to attain a Category A. Therefore the workshop decided that it should be recommended that the Seekoei Estuary be improved into the highest achievable ERC, which is a **Category B**.

Quantification of Ecological Reserve Scenarios

A summary of the suite of future runoff scenarios evaluated as part of this project are provided below. Each comprises different inflow scenarios from the Seekoei Estuary.

Name	Seekoei Estuary	Volume (million m^3/year)	Percentage
Reference	Reference	20.27	100.0%
Present	Present Flows	11.36	56.0%
Scenario 1	River Class A release to the estuary	16.65	82.1%
Scenario 2	River Class B release to the estuary	11.97	59.1%
Scenario 3	River Class D release to the estuary	11.10	54.8%
Scenario 4	Limited Development	14.71	72.6%

The individual EHI scores, as well as the corresponding ERC for the different scenarios are as follows:

Variable	Weight	Present	Runoff Scenario			
			1	2	3	4
Hydrology	25	58	81	60	58	71
Hydrodynamics/mouth condition	25	40	85	45	20	80
Water quality	25	40	63	51	43	61
Physical habitat alteration	25	61	76	68	61	74
Habitat Health Score	**50**	**50**	**76**	**56**	**46**	**71**
Microalgae	20	35	70	40	25	65
Macrophytes	20	35	70	40	30	65
Invertebrates	20	30	75	50	35	75
Fish	20	35	80	40	35	70
Birds	20	40	80	55	40	70
Biotic Health Score	**50**	**35**	**75**	**45**	**33**	**69**
Estuarine Health Index Score		**42**	**76**	**51**	**39**	**70**
Ecological Reserve Category (ERC)		**D-**	**B**	**D**	**E**	**C**

Recommended Ecological Flow Requirements for Seekoei Estuary

The evaluation of the simulated runoff scenarios is used to derive the recommended Ecological Flow Requirement. The recommended Ecological Flow Requirement is defined as the runoff scenario (or a slight modification thereof) that represents the highest reduction in river inflow that will still protect the aquatic ecosystem of the estuary and keep it in the recommended ERC.

The Seekoei Estuary is a Provincial Nature Reserve. According to the guidelines for assigning a recommended ERC, the estuary therefore needs to be in a Category A or the Best Attainable State (BAS). However, due to the fact that the changes that are contributing to the Present State of the estuary (Category D-) are seen as partially irreversible the workshop decided that it should be recommended that the Seekoei Estuary be improved into the highest achievable ERC, which is a **Category B**.

The recommended Category B can be achieved through a combination of flow and non-flow related management interventions, as anthropogenic influences (other than flow) have had a significant influence on the estuary's health. An evaluation was therefore made of the combination of a **Category C Flow Scenario** and the **reversal of the non-flow related influences** by using the adjusted scores in the EHI, which is indicated that a Category B can be achieved through this combination.

Therefore, **Scenario 4** is selected as the recommended Ecological Flow Requirement (Scenario) for the Seekoei Estuary, with flow distributions as summarised below:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99%ile	**20.15**	**9.37**	**3.83**	1.03	**2.03**	**10.26**	**5.38**	**15.07**	**14.87**	**9.71**	**19.96**	**24.55**
90%ile	**4.69**	**3.40**	0.40	0.22	0.19	0.27	0.90	1.44	**2.18**	**2.25**	**3.34**	**6.93**
80%ile	**2.63**	1.71	0.28	0.22	0.19	0.22	0.36	1.08	1.09	1.43	**2.18**	**3.46**
70%ile	1.40	1.08	0.27	0.21	0.18	0.21	0.35	0.87	0.62	0.86	1.68	**2.24**
60%ile	0.97	0.62	0.25	0.20	0.16	0.19	0.32	0.74	0.51	0.62	1.24	1.81
50%ile	0.67	0.56	0.23	0.17	0.15	0.18	0.29	0.54	0.40	0.46	0.61	1.44
40%ile	0.52	0.44	0.18	0.14	0.12	0.14	0.24	0.43	0.32	0.35	0.39	1.10
30%ile	0.33	0.31	0.13	0.10	0.09	0.10	0.17	0.33	0.23	0.23	0.29	0.76
20%ile	0.18	0.19	0.07	0.07	0.05	0.07	0.11	0.18	0.14	0.15	0.20	0.46
10%ile	0.10	0.11	0.05	0.04	0.04	0.04	0.06	0.11	0.08	0.08	0.09	0.25
1%ile	0.07	0.08	0.04	0.03	0.02	0.03	0.04	0.08	0.06	0.06	0.07	0.18

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TERMINOLOGY AND ACRONYMS

DWAF	Department of Water Affairs and Forestry
ERC	Ecological Reserve Category
EHI	Estuarine Health Index
MSL	Mean Sea Level
PES	Present Ecological Status
RDM	Resource Directed Measures
RQO	Resource Quality Objectives
MAR	Mean Annual Run-off

1. INTRODUCTION

1.1 Background

The CSIR, Environmentek was commissioned by Coastal & Environmental Services (CES) to draft the summary report of the preliminary Ecological Reserve Determination on a Rapid Level of Seekoei Estuary. The results are included in this report.

1.2 Project team

The core specialist team appointed for this project was as follows:

Lead specialists	Role/expertise	Contact details
Dr Angus Paterson	Project coordination	Coastal & Environmental Services, a.paterson@cesnet.co.za
Ms Lara van Niekerk	Hydrodynamics Sediment dynamics Report preparation	CSIR, Stellenbosch, lvnieker@csir.co.za
Mr Piet Huizinga	Hydrodynamics Sediment dynamics	Private consultant, phuizing@adept.co.za
Ms Susan Taljaard	Water quality	CSIR, Stellenbosch, staljaar@csir.co.za
Prof Janine Adams	Estuarine vegetation	Nelson Mandela Metropolitan University, janine.adams@upe.ac.za
Prof Tris Wooldridge	Invertebrates	Nelson Mandela Metropolitan University, tris.wooldridge@upe.ac.za
Dr Alan Whitfield	Fish	South African Institute of Aquatic Biodiversity, A.Whitfield@ru.ac.za
Dr Jane Turpie	Birds	Anchor Environmental Consultants, jturpie@botzoo.uct.ac.za

The following persons formed part of the project team to support capacity building in the application of Ecological Reserve Determinations on Estuaries:

Person	Role/expertise	Contact details
Mr Gavin Snow	Estuarine vegetation	Nelson Mandela Metropolitan University, gavin.snow@nmmu.ac.za
Ms Chantel Bezuidenhout	Estuarine vegetation	Nelson Mandela Metropolitan University, chantel.bezuidenhout@nmmu.ac.za
Dr Tommy Bornman	Estuarine vegetation	Nelson Mandela Metropolitan University, tom.bornman@nmmu.ac.za

Present at the Estuarine Specialist Workshop that was held in Port Elizabeth on 25 February 2005 was:

Person	Affiliation/role	Contact details
Ms Delana Louw	Link to Rivers component	IWR Source-to-Sea iwre@icon.co.za

1.3 Overview of Determination of Ecological Reserve for Estuaries: Process

The preliminary determination of the Ecological Reserve can be conducted on different levels, namely:

- Comprehensive level
- Intermediate level
- Rapid level

Procedures for the comprehensive level for the preliminary Ecological Reserve Determination for estuaries in the context of the larger process are illustrated in Figure 1-1.

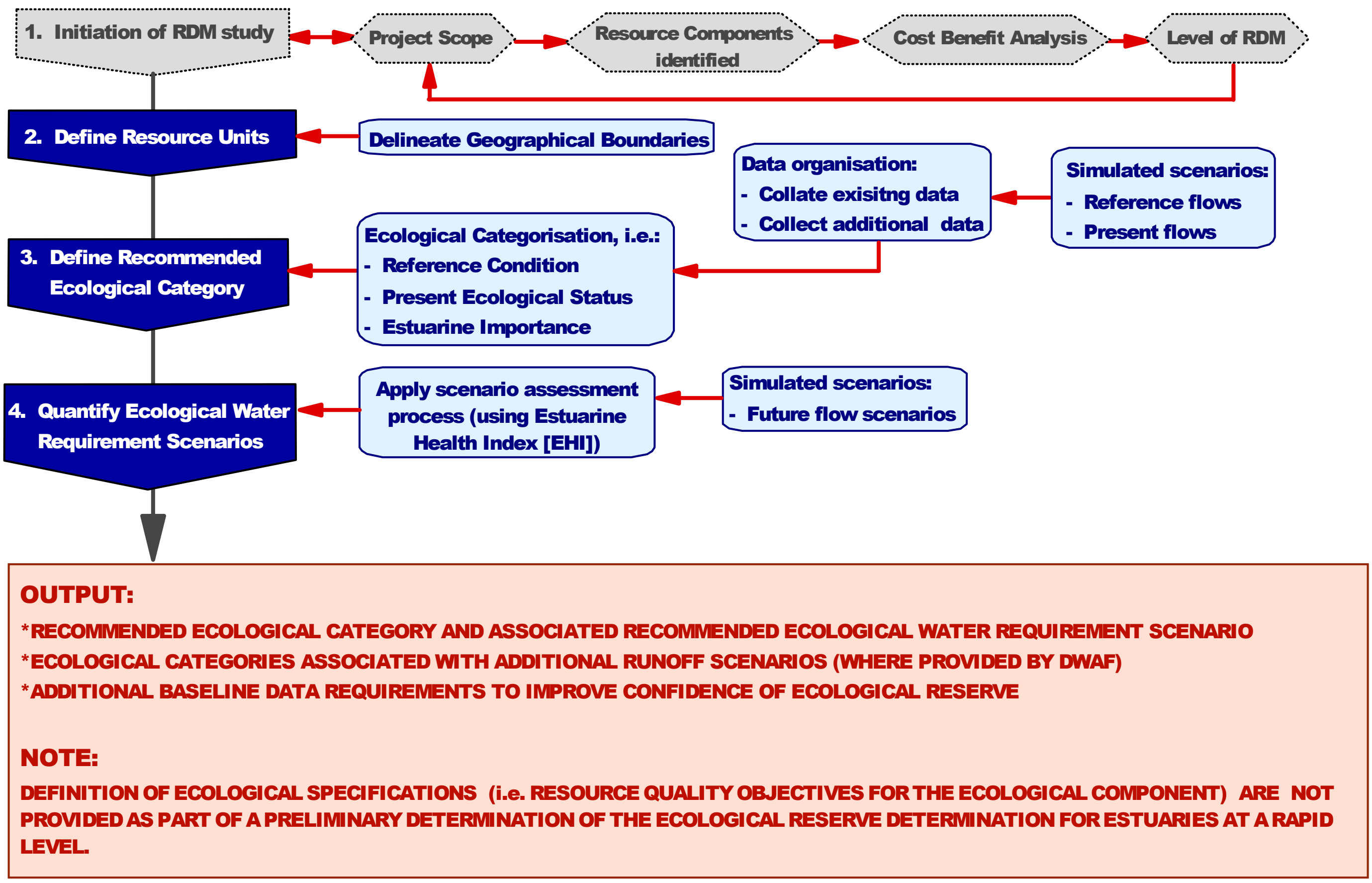


Figure 1-1 Procedures for a Rapid Ecological Reserve Determination on estuaries in context of the broader RDM process (components not addressed as part of the Ecological Reserve Determination process are indicated by non-solid line boxes) (DWAF, 2004)

The human resources required to conduct a Rapid Level Determination of the preliminary Ecological Reserve for estuaries are illustrated in Figure 1-2.

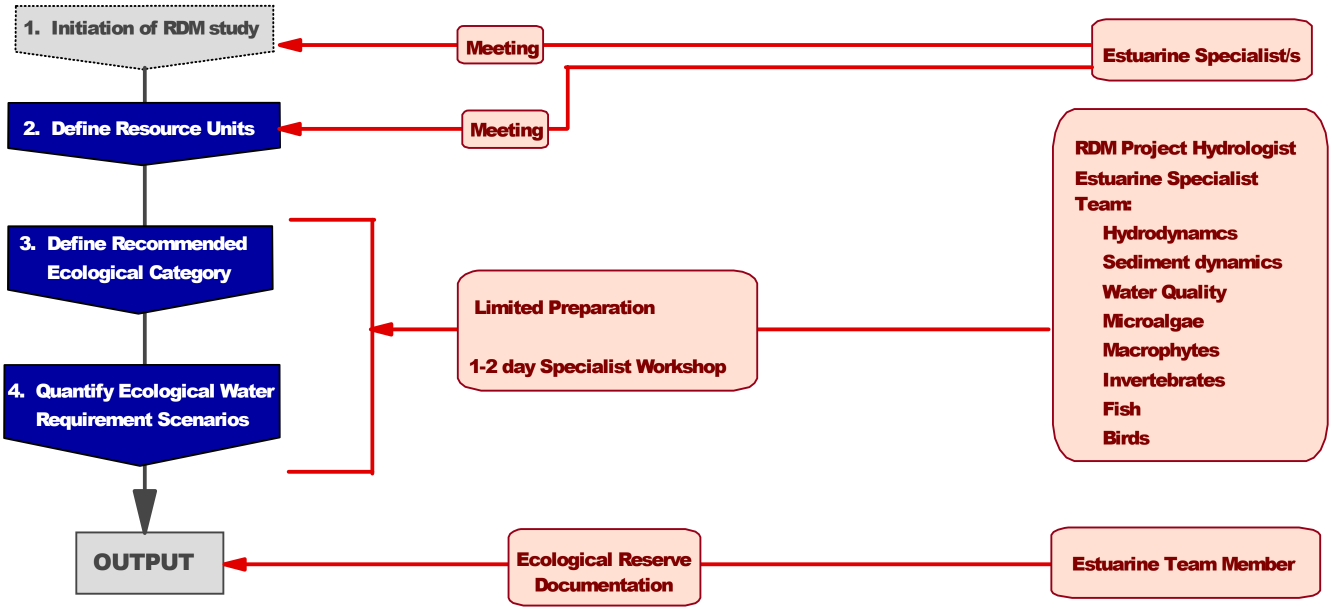


Figure 1-2 Indication of human resource requirements for a rapid Ecological Reserve Determination on estuaries (DWAF, 2004)

1.4 Assumptions and limitations for this study

The following assumptions and limitations must be taken into account:

- The accuracy of predicted Abiotic State for the Seekoei Estuary and the distribution of these states under the Reference Conditions, Present State and Future Scenarios depend largely on the accuracy of the simulated runoff data (over the 73-year period) on river inflow at the head of the estuary, provided to the estuarine team by the project hydrologist.

- The overall confidence in the hydrological data provided to the estuarine team by project hydrologist (Mr A Sparks, Ninham Shand consulting engineers, Cape Town) was low as limited accurate runoff data were available.

- Water quality data of river inflow at the head of the estuary were provided to the estuarine team by the water quality specialists on the river component. However, the available data were very limited for the Seekoei Estuary and no data were available for the Reference Condition. For the Seekoei Estuary, Reference Condition characteristics for inorganic nutrients were therefore estimated by the water quality specialists on the river component using the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996).

- For the purposes of the Ecological Reserve Determination, it is important to be able to correlate any measured salinity information to specfic river inflow patterns. Unfortunately such information was not historically captured, which made the interpretation of some of the available information difficult.

- Data on the invertebrate component are limited, but it is assumed that species composition is similar to other temporary open/closed systems in the region.

1.5 Available information and data

Data availability on sediment dynamics, hydrodynamics and water quality

Data required	Availability	Comment
Simulated monthly runoff data (at the head of the estuary) for Present State, Reference Conditions and the selected future runoff Scenarios over a 50 to 70-year period	Provided by Ninham Shand Consulting Engineers	Provided for 73-year period. Low confidence as runoff data are of low quality.
Simulated flood hydrographs for Present State, Reference Conditions and future runoff Scenarios: • 1:1, 1:2, 1:5 year floods (influencing aspects such as floodplain inundation) • 1:20, 1:50, 1:100, 1:200 year floods (influencing sediment dynamics)	None	
Aerial photographs of estuary (earliest available year as well as most recent)	1961, 1967, 1968, 1970, 1971, 1972, 1977, 1979, 1980, 1981, 1986, 1992	Collected for DEAT
Continuous water level recordings near mouth of the estuary	Water level data available for the last 2 years. Measured at the causeway.	Collected for DWAF
Longitudinal salinity and temperature profiles (*in situ*) collected over a spring and neap tide during high and low tide at: • end of low flow season (i.e. period of maximum seawater intrusion) • peak of high flow season (i.e. period of maximum flushing by river water)	Limited once-off data sets for Nov 1984 and Feb 2004 (collected as part of this study)	Bickerton and Pierce (1988)
Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: • end of low flow season • peak of high flow season	Limited once-off data sets for Nov 1984 (only system variables) and Feb 2004 (collected as part of this study)	Bickerton and Pierce (1988)
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary	No data	Not considered to be a major concern in this estuary
Water quality (e.g. system variables, nutrients and toxic substances) measurements on river water entering at the head of the estuary	No data received	
Water quality (e.g. system variables, nutrients and toxic substances) measurements on near-shore seawater	Limited data	DWAF (1995)

Data availability on microalgae

Data required	Availability	Comment
Chlorophyll-a measurements taken at 5 stations at the surface, 0.5 m and 1 m depths. Cell counts of dominant phytoplankton groups i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Measurements must be taken coinciding with typically high and low flow conditions.	Some unpublished data	Department of Botany, UPE
Intertidal and subtidal benthic chlorophyll-a measurements taken at 5 stations (at least). Epipelic diatoms need to be collected for	Some unpublished data	Department of Botany, UPE

Data required	Availability	Comment
identification. These measurements must be taken coinciding with a typical high and low flow condition (in temporarily closed estuaries measurements must include open as well as closed mouth conditions).		
Simultaneous measurements of flow, light, salinity, temperature, nutrients and substrate type (for benthic microalgae) need to be taken at the sampling stations during both the phytoplankton and benthic microalgal surveys.	Some unpublished data	Department of Botany, UPE

Data availability on macrophytes

Data required	Availability	Comment
Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the Present State, as well as the Reference Condition (if available) Available orthophoto maps	Surveys and mapping 1942, 1987, 2000	1942 photograph is of poor quality.
Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit.	Adams (1991); Adams *et al*. (1992); Adams and Bate (1994); Bickerton and Pierce (1988).	Details on distribution and biomass of macrophytes.
Permanent transects: - Measurements of percentage plant cover along an elevation gradient - Measurements of salinity, water level, sediment moisture content and turbidity	Adams (1991)	Transect data completed in 1990.

Data availability on invertebrates

Data required	Availability	Comment
Compile a detailed sediment distribution map of the estuary. Obtain a detailed determination of the extent and distribution of shallows and tidally exposed substrates. During each survey, collect sediment samples for analysis of grain size and organic content at the six benthic sites.	Unknown	Limited data are probably available
Surveys to determine salinity distribution pattern along the length of the estuary, as well as other system variables (e.g. temperature, pH and dissolved oxygen and turbidity) are required for different seasons and for different states of the tide. Seasonal (summer/winter) physico-chemical data are also required for each of the six benthic sampling sites	Limited once-off data sets for Nov 1984 and Feb 2004 (collected as part of this study). Ad hoc information also available, but scattered.	Bickerton and Pierce (1988)
Collect a set of six benthic samples each consisting of five grabs. Collect two each from sand, mud and interface substrates. If possible, spread sites for each between upper and lower reaches of the estuary. One mud sample should be in an organically rich area. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Seasonal (summer winter) data sets for at least one year are required, preferably collected at spring tides.	Some limited data available, including unpublished information	Bickerton and Pierce (1988)
Collect two sets of beam trawl samples (i.e. mud and sand). Lay two sets of five, baited prawn/crab traps overnight, one each in the upper and lower reaches of the estuary. Species should be identified to the	No data available	

Data required	Availability	Comment
lowest taxon possible and densities (animal/m^2) must also be determined. Survey as much shoreline as possible for signs of crabs and prawns and record observations. Seasonal (summer/winter) data sets for at least one year are required, preferably collected at spring tides.		
Additional trip(s) may be required to gather data on the occurrence/recruitment and emigration of key species such as *Varuna litterata*, *Callianassa* and *Upogebia* which require a connection to the marine environment at specific times of the year.		
Collect three zooplankton samples, at night, one each from the upper, middle and lower reaches of the estuary. Seasonal (summer/winter) data sets for at least one year are required, preferably collected at spring tides.	No data available	

Data availability on fish

Data required	Availability	Comment
In a small estuary (<5km) collect a minimum of three sets of samples from the lower, middle and upper reaches of the estuary. The samples should be representative of the different estuarine habitat types, e.g. *Zostera* beds, prawn beds, sand flats. At least one of the sample sets need to be in the 0 to 10 ppt reach of the estuary. Sampling should be representative of small fish (seine nets) and large fish (gill nets). In a larger estuary (>5km) sampling can either be at fixed intervals (every 2km) or have the upper, middle and lower reaches subdivided into at least a further three sections each. The samples should be representative of the different estuarine habitat types, e.g. *Zostera* beds, prawn beds, sand flats. At least one of the sample sets should be in the 0 to 1 ppt reach of the system. Sampling should be representative of small fish (seine nets) and large fish (gill nets). Sampling should be done during both the low and the high flow season for the full extent of the system (as far as tidal variation) to allow for predictive capabilities.	Bickerton and Pierce (1988); Harrison *et al*. (2000)	Published fish species lists from isolated surveys of the estuary but little quantitative information available.

Data availability on birds

Data required	Availability	Comment
Undertake one full count of all water associated birds, covering as much of the estuarine area as possible. All birds should be identified to species level and the total number of each counted. Seasonal (summer/winter) data sets for at least one year are required. It this is not possible, a minimum of four summer months and one winter month will be required (decisions on the extent of effort required will depend largely on the size of the estuary, extent of shallows present, as well as extent of tidally	Co-ordinated Waterbird Count (CWAC) data were available in the form of summer and winter counts from 1995 – 2004; in addition, a winter and summer count were conducted as part of this study; older (ca 1980) counts	

Data required	Availability	Comment
exposed areas).	are described in Bickerton and Pierce (1988)	

2. DEFINITION OF RESOURCE UNIT

For the purposes of this preliminary determination of the Ecological Reserve on the Seekoei Estuary, the geographical boundaries are defined as follows (Gauss Projection, Clarke 1880 Spheroid):

Downstream boundary: The estuary mouth (34° 05' 10" S, 24° 54' 30" E)

Upstream boundary: Seekoei River (34° 05' 20" S, 24° 51' 50" E)
Swart River (34° 04' 35" S, 24° 52' 35" E)

Lateral boundaries: 5 m contour above MSL along the banks.

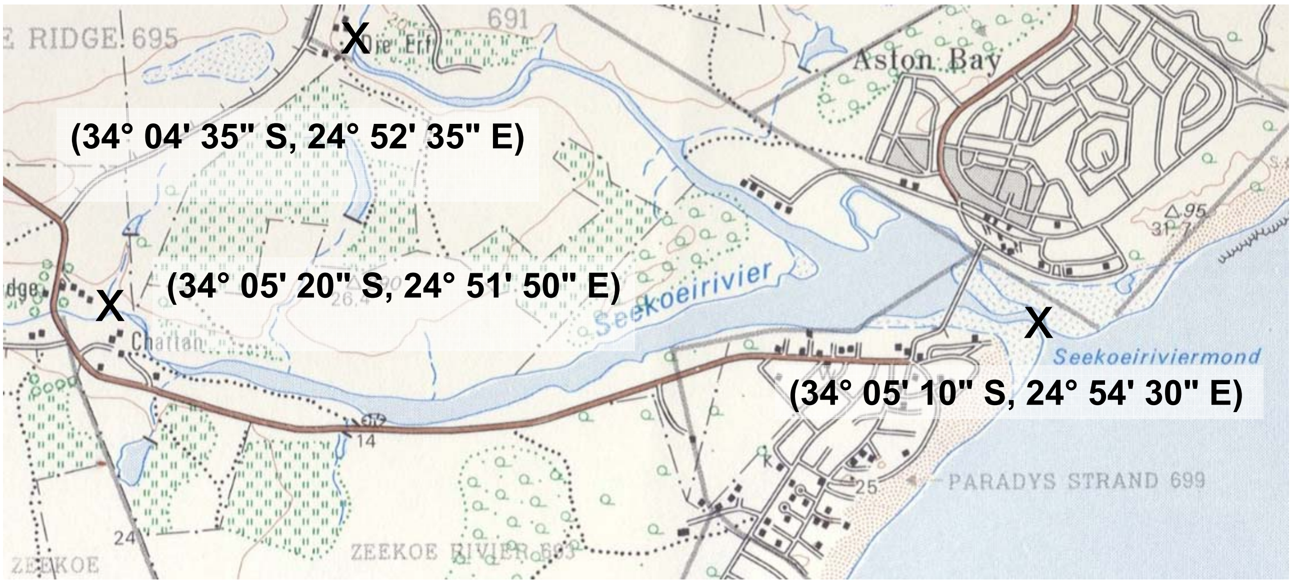


Figure 2-1 Map of the Seekoei Estuary

3. ECOLOGICAL RESERVE CATEGORISATION

3.1 Typical Abiotic States

A rapid level evaluation of the Seekoei Estuary's mouth dynamics indicated that in addition to changes in river inflow, two further important anthropogenic influences exist, (a) the construction of the causeway and (b) artificial breaching, which are influencing the timing and duration of open mouth conditions. Another major anthropogenic influence about ten years ago was the construction of the concrete canal through the berm and the efforts to force the inlet through this canal. Its floor level was at the average high water spring tide and the result was that normal tidal influences could not keep the mouth open and that it closed within a few days after a breaching. This canal has silted up completely and is no longer used.

Artificial breaching at too low water levels resulted in far less sediment being flushed out at breachings, indirectly resulting in ongoing sedimentation. In the long term this causes a reduction of open mouth conditions. This propensity for quick mouth closure was further aggravated by limited or even no tidal flows through the causeway because of bottleneck effects. Recent improvements to the culverts in the causeway have led to increased tidal flushing and longer periods of open mouth conditions.

It was therefore not possible to distinguish in this Rapid Reserve Determination on a monthly scale between the consequences of reduction in river inflow and the effects of the other anthropogenic influences. It was consequently decided to evaluate the Seekoei Estuary on its annual cycle of potentially open/closed mouth conditions.

Note: Based on the very limited river inflow data and the difficulty in relating river inflow ranges to mouth conditions (e.g. the Seekoei Estuary can remain open under zero river inflow as wave action plays an important role in this system) it was decided to rather develop typical annual abiotic states for the Seekoei Estuary (rather than seasonal states which is what is usually done). Based on expert opinion and limited data, two states could be derived. For this study the estuary's volume (i.e. ~ 2 million m^3) and evaporation and seepage losses (~ 1 million m$^{3)}$ were the key factors that determined the flow bands:

Annual flows above 3 million m^3 were considered to represent a year in which the estuary was predominantly open, while annual flows below 3 million m^3 were considered to be indicative of a year in which the estuary would have been predominantly closed.

State 1: Open Mouth	Annual runoff > 3 million m^3
State 2: Closed Mouth	Annual runoff < 3 million m^3

The transitions between the different states will not be instantaneous, as the resultant mouth conditions and salinity are both dependent on the flow rate and the duration of the occurrence of that flow.

ABIOTIC STATE 1: Open mouth

Typical flow patterns: River flow rates are not related to the state of the estuary mouth. The estuary mouth will breach at water levels between 2.0 and 2.5 m MSL.

The minimum annual breaching requirement is about 3 million m^3. This is because the estuary requires about 2 – 2.5 million m^3 of fresh water to reach its breaching level, plus an additional 0.892 million m^3 to compensate for annual evaporation.

Confidence: Low

State of the mouth: The mouth is open.

Confidence: Low

Flood plain inundation patterns: This state does not result in inundation of the flood plain.

Confidence: High

Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide): Tidal variation could typically range between 0 m (neap tide) and 0.5 m (spring tide). However, the estuary tends to fill up over spring tides and empties during neap tides. This causes an extra variation in water levels of up to 0.3 m.

Confidence: Low

Retention times of water masses: When the mouth is open there will still be higher retention time above the causeway, especially during neap tides. In the lower reaches, strong tidal flushing will result in short residence times, typically one to two tidal cycles at spring tides.

Confidence: Low

Total volume and/or estimated volume of different salinity ranges: Total volume on average tide is estimated 0.5×10^6 m^3.

Confidence: Medium

Salinity distributions in the estuary: During years when the Seekoei Estuary is considered to be mainly in the Open Mouth State, the salinity status is expected to vary between a saline to hypersaline condition and a condition where it has a strong salinity gradient to fresh. The monthly distribution of these two conditions within periods of Open Mouth will be estimated for each of the Scenarios using the median monthly flow over the simulation period. Median monthly flow above 0.5 million m^3/month = strong longitudinal salinity gradient to fresh and flows below 0.5 million m^3/month = saline to hypersaline.

During the initial part of the open state, the estuary develops a full salinity gradient, with marine water penetrating the system from the sea and freshwater entering at the top from the catchment.

As river flow decreases over time and the mouth remains open, the salinities in the estuary will gradually become that of sea water.

During periods of low, or no flow, and prolonged open mouth conditions (little wave action), hyper-saline conditions may start to develop in the upper reaches of the Swart and Seekoei tributaries due to evaporation.

Confidence: Low

System variables (Temperature, pH, suspended solids, turbidity and dissolved oxygen): Concentrations and levels of system variables in the Seekoei Estuary under State 1: Open Mouth is estimated as follows:

	Saline to hypersaline (Flow < 0.5 million m^3/month)	**Strong longitudinal salinity gradient to fresh (Flow > 0.5 million m^3/month)**
Temperature (ºC)	The temperature regime of the Seekoei Estuary is expected to show a strong seasonal pattern, with summer temperatures ranging between 20 and 25 ^{o}C and winter temperatures between 13 and 16 ^{o}C.	
pH	pH values in the Seekoei Estuary are expected to remain within the range of 7 to 8.5. Although the Swart River is a blackwater system which typically has low pH levels (<6), it is expected that this will not be typical of conditions in the estuary due to the strong buffering capacity of seawater (i.e. as soon as even a small amount of seawater mixes with this freshwater the pH will change to within the above-mentioned range).	
Turbidity (NTU)	During the open state, when river inflow is low, turbidity throughout the estuary can be expected to be low.	During period of higher river inflow, turbidity levels are expected to be elevated in the fresher, upper part of the estuary.
Dissolved oxygen (mg/L)	The Seekoei Estuary should generally be well-oxygenated being a shallow system (i.e. even during periods of low or no river inflow wind mixing maintains oxygenated conditions).	

Confidence: Low

Nutrients: Nutrient concentrations in the Seekoei Estuary under State 1: Open Mouth is estimated as follows:

	Saline to hypersaline (Flow < 0.5 million m^3/month)	**Strong longitudinal salinity gradient to fresh (Flow > 0.5 million m^3/month)**
Dissolved Inorganic Nitrogen (DIN)	Depleted (even though sediments have a high organic loading, remineralisation of inorganic nutrients into the water column does not seem to occur – could be attributed to well-oxygenated conditions)	River inflow is expected to elevate DIN levels into the estuary (300-500 µg/ℓ, assuming conditions to be similar to Kromme Estuary)
Dissolved Reactive Phosphate-P (PO_4-P)	~ 50 µg/ℓ	River inflow is expected to elevate PO_4-P levels into the estuary
Dissolved Reactive Silicate (SiO_4-Si)	~ 300 µg/ℓ	~ 3000 – 5000 µg/ℓ, assuming conditions to be similar to Kromme Estuary (higher due to stronger influence from river water)

Confidence: Low

ABIOTIC STATE 2: Closed mouth

Typical flow patterns: This state is to some extent flow independent, as the estuary mouth can stay open under low (even no flow conditions) depending on wave action near the mouth.

Confidence: Low

State of the mouth: The mouth is closed.

Confidence: Low

Flood plain inundation patterns: There can be extensive flooding of the surrounding flood plain as breaching levels are estimated to be 2 – 2.5 m MSL.

Confidence: Low

Amplitude of tidal variation (indicative of exposure of intertidal areas during low tide): No tidal variation in this state.

Confidence: High

Retention times of water masses: High retention time as the mouth is closed.

Confidence: Medium

Total volume and/or estimated volume of different salinity ranges: Total volume in the estuary just before breaching is estimated at 3 - 3.5 x 10^6 m^3, depending on the berm height.

Confidence: Low

Salinity distributions in the estuary: A vertical salinity gradient exists in the estuary during the initial part of this State. This is expected to disintegrate into a well mixed homogenous water body after a few weeks through wind mixing as the system is relatively shallow and very exposed. Ongoing evaporation after closure can result in the estuary largely drying out and hypersaline conditions developing. The estuary would only start to become fresher towards the end of the closed state as river inflow starts to increase.

Confidence: Low

System variables (Temperature, pH, suspended solids, turbidity and dissolved oxygen): Concentrations and levels of system variables in the Seekoei Estuary under State 2: Closed mouth are estimated as follows:

Temperature (ºC)	The temperature regime of the Seekoei Estuary is expected to show a strong seasonal pattern, with summer temperatures ranging between 20 and 25 ^oC and winter temperatures between 13 and 16 ^oC.
pH	pH values in the Seekoei Estuary are expected to remain within the range of 7 to 8.5.
Turbidity (NTU)	Limited data collected in 1983 and personal observations suggest that during the closed state, turbidity in the estuary seaward of the causeway is typically higher (Secchi disc depth > 1.5) than landward of the causeway (~0.3).
Dissolved oxygen (mg/L)	The Seekoei Estuary should generally be well-oxygenated being a shallow system (i.e. even during periods of low or no river inflow wind mixing maintain oxygenated conditions).

Confidence: Low

Nutrients: Nutrient concentrations in the Seekoei Estuary under State 2: Closed mouth are estimated as follows:

Dissolved Inorganic Nitrogen (DIN)	Depleted (even though sediments have high organic loads, remineralisation of inorganic nutrients into the water column does not seem to occur – could be attributed to well-oxygenated conditions)
Dissolved Reactive Phosphate-P (PO_4-P)	~ 50 µg/ℓ
Dissolved Reactive Silicate (SiO_4-Si)	~ 300 µg/ℓ

Confidence: Low

3.2 Description of Present State

3.2.1 Abiotic Components

i. Seasonal variability in river inflow

Monthly simulated runoff data for the Present State is provided in Table 3-1. A summary of flow distribution (mean monthly flows in m^3/s) for the Present State of the Seekoei Estuary, derived from the 73-year simulated data set, is provided below:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99%ile	19.70	7.20	2.69	0.92	2.26	6.75	4.71	14.63	11.89	9.04	17.65	23.74
90%ile	4.48	2.46	0.59	0.19	0.16	0.74	0.79	1.52	1.54	1.77	2.40	5.04
80%ile	2.19	1.26	0.34	0.04	0.02	0.33	0.46	0.61	0.77	0.91	1.50	2.73
70%ile	1.20	0.83	0.16	0.00	0.00	0.15	0.26	0.40	0.50	0.63	1.21	1.27
60%ile	0.91	0.49	0.04	0.00	0.00	0.07	0.18	0.25	0.37	0.52	0.90	0.98
50%ile	0.61	0.37	0.01	0.00	0.00	0.02	0.14	0.18	0.27	0.41	0.50	0.73
40%ile	0.45	0.23	0.00	0.00	0.00	0.00	0.09	0.14	0.23	0.34	0.34	0.47
30%ile	0.34	0.15	0.00	0.00	0.00	0.00	0.06	0.09	0.17	0.29	0.30	0.33
20%ile	0.26	0.11	0.00	0.00	0.00	0.00	0.02	0.05	0.14	0.22	0.26	0.24
10%ile	0.17	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.07	0.12	0.11
1%ile	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03

ii. Present flood regime

The dams present in the Seekoei and Swart catchments mostly reduce freshettes and small to medium size floods. Major floods still pass through the Seekoei and Swart catchments albeit in a reduced form. The extent of the reduction is dependent on the size of the farm dams.

For the Seekoei, months with flows of 10 m^3/s or more where estimated to represent flood events. Under the Present State these events occur 16 times in the 73-year period, in comparison with the 26 under the Reference Conditions. At present about 60% of the larger flood events still reach the estuary.

Confidence: Low

iii. Present sediment processes

Some siltation is expected due to the changes in land-use patterns in the Seekoei and Swart catchments, e.g. agriculture. An increase in the silt load to the estuary, in combination with an increase in salinity values, will potentially lead to a muddier substrate forming in the system, especially above the causeway. The causeway would also interfere with the re-suspension of silt deposited in the estuary during floods. In many estuaries re-suspended silt is flushed out to sea through tidal action.

The causeway could potentially also lead to reduced flushing during flood events. Inflowing waters are expected to dam up behind the causeway, which can lead to the deposition of sediment in the basin behind the causeway. This damming up effect can also lead to longer outflow periods, which in turn would assist in the deepening of the established channels.

The combination of low breaching levels and reduced scouring during breachings might have caused an increase in sedimentation between the causeway and the mouth. In general, the causeway has fixed and reduced the dynamic nature of the channel configuration in the lower estuary.

About ten years ago artificial breaching was often done trough a concrete channel (i.e. stabilised mouth position) to the north of the present breaching location. The bottom of this canal was on the level of Mean High Water spring tide and breaching the estuary through this channel prevented significant drainage of the estuary, reduced sediment scouring during breaching events, reduced tidal flushing and led to premature mouth closure, often within a few days.

Confidence: Low

iv. Occurrence and duration of Abiotic states during the Present State

An analysis of the Present State simulated monthly runoff Scenario indicated that the Seekoei Estuary currently receives only enough river inflow to breach three out of four years, i.e. in 17 out of 73 years the annual inflow is less than 3 million m^3.

The reduction in base flows to the system also implies that the estuary could close more easily and stay open for shorter periods than under the Reference Condition. Note, that the estuary can maintain an open mouth for longer periods under the current culvert configuration in the causeway, but it will still close under high wave condition and the reduction in baseflows will still have an impact.

Under the present conditions the duration of a mouth closure event is also longer as the reduced inflow to the estuary implies that it would take longer to reach the breaching level and to re-establish the connection to the sea.

In years where the Seekoei Estuary is likely to be in Abiotic State 1: Open mouth, the monthly distribution between saline to hypersaline (median monthly flow < 0.5 million m^3) conditions versus conditions when the estuary develops a strong longitudinal salinity gradient to becoming fresh (median monthly flow > 0.5 million m^3) is estimated to be as follows for the Present State:

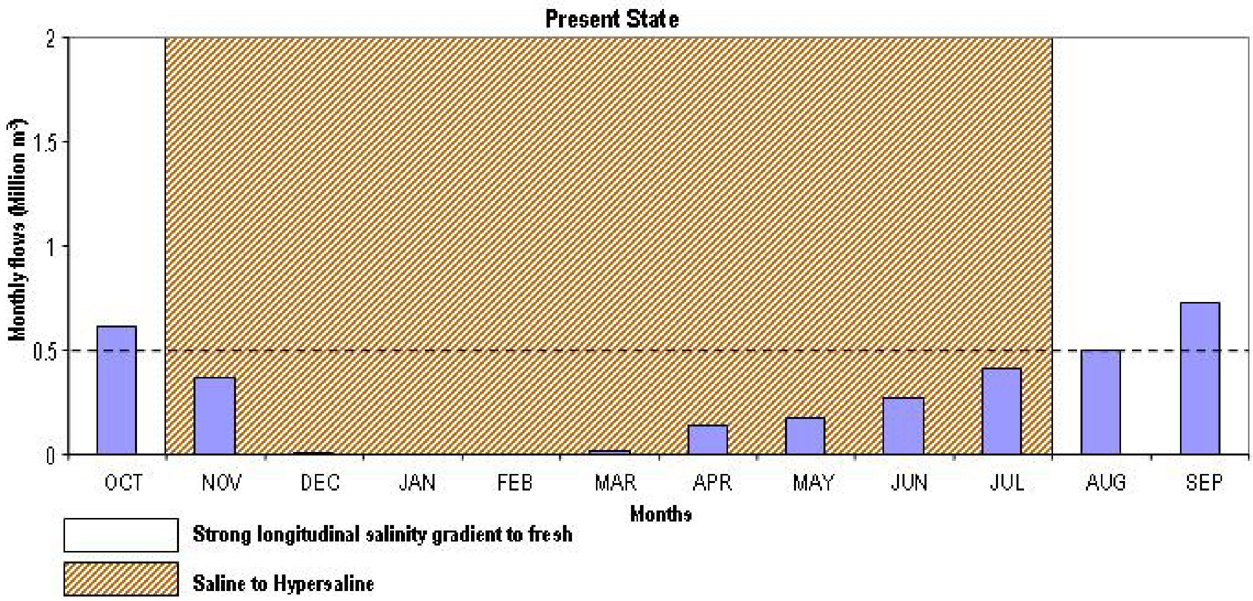

Present State
Monthly flows (Million m³)
2
1.5
1
0.5
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Months
Strong longitudinal salinity gradient to fresh
Saline to Hypersaline

Table 3-1 Present State: Simulated runoff data in million m^3 per month

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1927	0.26	0.16	0.00	0.00	0.00	0.26	0.16	0.12	0.31	0.45	0.68	0.76	3.16
1928	0.46	0.37	0.33	0.00	0.00	0.00	0.08	0.36	0.33	0.41	0.28	0.32	2.94
1929	0.13	6.60	2.56	0.07	0.10	0.22	0.18	0.51	0.65	0.82	1.25	0.69	13.78
1930	0.51	0.12	0.00	0.00	0.00	0.00	0.00	0.01	0.20	0.28	0.28	0.46	1.85
1931	0.51	0.16	0.39	0.00	0.00	0.05	0.26	0.37	0.42	0.41	0.47	1.00	4.03
1932	0.84	0.54	0.00	0.00	0.00	0.00	0.00	0.22	0.11	1.79	1.20	0.66	5.36
1933	1.06	1.86	0.25	0.00	0.00	0.03	0.02	0.30	0.27	0.22	0.57	0.28	4.86
1934	0.27	0.06	0.00	0.00	0.00	7.77	5.73	1.53	0.46	0.60	0.31	0.91	17.64
1935	0.48	0.69	0.16	0.00	0.00	0.00	0.05	0.19	0.14	0.54	0.29	1.32	3.86
1936	0.88	0.38	0.00	0.00	0.00	0.36	0.16	0.09	0.26	0.24	0.32	0.41	3.10
1937	0.31	0.16	0.00	0.00	0.00	0.00	0.14	0.06	0.07	0.69	0.37	0.55	2.35
1938	4.75	2.41	1.61	0.33	0.16	0.11	0.08	0.05	0.04	0.43	0.44	33.85	44.25
1939	13.17	4.59	0.92	0.02	0.00	0.00	0.00	0.18	0.16	0.15	1.49	1.15	21.82
1940	0.12	0.56	0.04	0.00	0.00	0.00	0.00	0.01	0.16	0.69	0.73	0.47	2.78
1941	2.29	0.89	0.20	0.00	0.00	0.00	0.15	8.16	5.94	1.65	1.44	0.92	21.64
1942	1.53	0.28	0.06	0.00	0.00	0.00	0.09	0.03	0.15	0.29	0.24	0.24	2.91
1943	0.42	2.33	0.78	0.00	0.00	0.13	0.09	0.06	0.28	0.29	0.15	0.68	5.22
1944	0.40	0.14	0.06	0.00	0.00	0.00	0.00	0.13	0.15	0.09	0.16	0.04	1.18
1945	0.30	0.01	0.00	0.00	0.50	0.55	0.18	0.13	0.20	0.37	2.39	1.24	5.87
1946	0.61	0.39	0.07	0.00	0.04	0.34	0.13	0.22	0.23	0.33	0.12	0.25	2.73
1947	0.05	0.11	0.00	0.00	0.00	0.00	0.07	0.00	0.74	0.37	0.27	0.26	1.87
1948	0.84	0.30	0.69	0.13	0.00	0.00	0.00	0.50	0.42	0.32	0.29	0.23	3.71
1949	0.54	0.47	0.00	0.00	0.00	0.00	0.10	0.01	0.47	0.59	1.13	1.93	5.24
1950	1.14	1.54	0.36	0.22	0.01	0.76	0.80	23.43	9.79	2.02	1.08	2.63	43.77
1951	0.58	0.13	0.00	0.00	0.00	0.00	0.00	1.20	1.05	0.55	1.63	1.79	6.93
1952	6.07	2.47	0.02	0.00	0.00	2.17	0.88	0.11	0.16	0.46	1.12	0.97	14.44
1953	1.33	0.09	0.00	0.00	0.00	0.41	0.24	0.66	0.83	1.70	1.73	0.47	7.47
1954	0.16	0.12	0.01	0.00	0.05	0.04	1.34	0.61	0.23	0.24	0.26	0.18	3.25
1955	2.25	1.18	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.03	0.02	0.08	3.61
1956	0.07	5.78	3.02	0.00	0.00	0.00	0.34	0.24	0.15	0.32	1.00	1.40	12.32
1957	1.26	1.28	0.45	1.47	0.52	0.18	0.04	0.17	0.24	0.96	1.25	10.56	18.38
1958	4.70	0.18	0.01	0.10	0.00	0.15	0.09	0.39	0.37	0.32	0.65	5.05	12.00
1959	3.11	0.42	0.16	0.00	0.00	0.00	0.00	0.07	0.17	0.50	1.64	11.38	17.44
1960	29.22	8.75	0.16	0.00	0.00	4.03	4.00	11.21	4.81	5.48	15.05	4.92	87.63
1961	0.42	0.12	0.00	0.00	1.48	0.95	0.38	0.16	0.17	0.34	6.81	3.09	13.92
1962	0.94	0.51	0.08	0.00	0.00	0.26	0.18	2.88	1.69	1.00	1.18	4.25	12.98
1963	16.00	5.66	2.29	0.37	0.22	0.20	0.19	0.15	0.72	0.95	1.51	16.21	44.45
1964	6.20	1.18	0.00	0.00	0.00	0.07	0.16	2.17	1.11	0.60	1.68	1.34	14.50
1965	1.50	1.06	0.00	0.39	0.14	0.30	0.75	0.61	0.39	0.52	1.19	1.05	7.90
1966	0.74	0.38	0.00	0.02	0.00	0.00	0.10	0.45	0.40	0.93	0.88	1.02	4.92
1967	0.31	0.12	0.00	0.00	0.01	0.41	0.71	1.09	0.79	0.82	1.23	0.95	6.43
1968	0.27	0.10	0.00	0.00	0.00	0.15	0.45	0.23	0.22	0.13	1.49	0.80	3.84
1969	0.36	0.11	0.00	0.04	0.00	0.64	0.57	0.42	0.35	0.36	0.46	0.34	3.65
1970	0.25	0.00	0.41	0.11	0.02	0.05	0.16	0.14	1.57	0.89	0.50	3.64	7.74
1971	1.86	1.33	0.14	0.00	0.00	0.00	0.09	0.40	0.28	0.31	0.28	0.10	4.79
1972	0.90	1.24	0.26	0.00	0.06	0.01	0.09	0.18	0.04	0.05	0.30	0.34	3.47
1973	0.19	0.30	0.00	0.00	0.00	0.15	0.32	0.74	0.58	0.44	0.68	0.76	4.16
1974	0.35	0.12	0.00	0.00	0.00	0.00	0.42	0.35	11.80	8.09	2.22	4.15	27.49
1975	0.89	0.32	0.00	0.00	0.00	0.09	0.11	0.08	0.13	0.16	0.15	0.09	2.03
1976	0.23	0.05	0.00	0.00	0.02	0.00	0.03	0.03	0.01	0.00	0.10	0.22	0.69
1977	0.15	0.21	0.17	0.00	0.00	0.13	3.41	2.63	1.42	11.48	24.32	7.40	51.31
1978	1.07	1.11	0.00	0.00	0.00	0.00	0.04	0.18	0.18	0.23	0.33	0.27	3.42
1979	0.02	0.00	0.00	0.00	0.00	0.00	0.15	0.19	0.23	0.06	0.05	0.11	0.81
1980	0.22	0.18	0.00	0.27	0.03	1.71	0.70	0.57	0.57	0.43	1.27	2.79	8.73
1981	2.31	0.18	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.28	0.33	0.61	3.80
1982	0.35	0.00	0.00	0.00	0.00	0.02	2.32	1.17	0.59	5.05	3.14	1.23	13.86
1983	2.69	1.05	0.04	0.00	0.13	0.13	0.18	1.72	1.07	0.57	0.34	4.99	12.91
1984	1.59	0.80	0.37	0.08	0.00	0.47	0.58	0.35	0.48	0.56	0.40	0.29	5.96
1985	0.69	1.52	0.34	0.21	0.00	0.02	0.00	0.09	0.23	0.89	14.61	7.55	26.14
1986	2.10	0.34	0.00	0.00	0.00	0.00	0.18	0.02	0.17	0.05	0.11	0.20	3.18
1987	0.51	0.25	0.00	0.71	0.36	6.35	4.31	1.48	1.69	0.94	4.26	1.73	22.58
1988	2.33	0.64	0.09	0.00	0.00	0.00	0.47	0.21	0.06	0.22	0.25	0.36	4.63
1989	0.35	0.23	0.00	0.00	0.00	0.00	0.01	0.04	0.07	6.52	4.94	0.73	12.89
1990	1.16	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.21	0.27	0.14	1.96
1991	0.19	0.00	0.00	0.12	0.32	0.00	0.05	0.10	0.34	0.40	0.33	0.08	1.94
1992	0.32	0.48	0.00	0.00	0.00	0.00	0.07	0.00	0.06	0.00	0.32	0.32	1.57
1993	1.01	0.57	0.01	0.00	0.00	0.00	0.00	0.00	0.54	0.30	0.12	0.51	3.06
1994	0.20	0.00	0.00	0.00	0.00	0.00	0.04	0.08	0.27	0.25	0.22	0.13	1.20
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.17	0.03	0.03	0.00	0.03	0.62
1996	3.63	3.58	0.46	0.00	0.00	0.02	0.66	0.47	0.97	0.68	0.45	0.35	11.27
1997	1.04	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.06	0.02	1.55
1998	0.27	0.03	0.01	0.00	4.26	1.58	0.02	0.08	0.25	0.35	2.40	1.24	10.50
1999	7.13	6.05	0.62	0.00	0.00	0.00	0.26	0.11	12.10	6.82	0.56	19.80	53.45
Median	0.61	0.37	0.01	0.00	0.00	0.02	0.14	0.18	0.27	0.41	0.50	0.73	
Average	1.94	1.04	0.24	0.06	0.12	0.43	0.47	0.97	0.98	1.05	1.64	2.43	

Monthly > 2 mil m^3 Annual < 3 mil

v. Anthropogenic influences, other than modification of river inflow, that are presently affecting the Abiotic characteristics in the estuary:

Structures (e.g. weirs, bridges, mouth stabilisation):
The construction of a causeway over the lower Seekoei Estuary has locally restricted the dynamic nature of the channel and may be contributing to the sedimentation problems in the system. Its main aim was apparently to prevent drainage of the system. Thereafter it came to be used more as an access between Paradise Beach and Aston Bay. Before culverts were installed it seriously blocked tidal flows resulting in premature closure of the mouth. The situation improved when culverts were installed. A tar road has been constructed on the causeway, but at a very low level. To prevent flooding and damage of this road, breaching is practised at a very low water level. Artificial breaching is practised at the estuary at low water levels, reducing the flushing of sediments at a breaching, which probably indirectly results in ongoing sedimentation. About ten years ago breaching was practised for a few years through a concrete channel to the north of the present mouth breaching position. The bottom of this canal is at the level of Mean High Water spring tide and breaching through the concrete channel prevented significant drainage of the system, almost completely blocking tidal flows and normally resulted in closure within a few days. Confidence: High

Discharges into estuary affecting water quality:
Anthropogenic waste inputs that could affect water quality is not expected to be a major issue in the Seekoei Estuary. However, the catchment is extensively used for agriculture which is most likely introducing nutrients and toxic substances, e.g. pesticides to the estuary. Under the Present State, $N0_x$-N and PO_4-P concentrations of 1100 µg/ℓ and 1700 µg/ℓ, respectively, have been measured by DWAF in the Swart River. Confidence: Low

3.2.2 Biotic Components

Microalgae
<u>Phytoplankton:</u> In 1990 a comparative survey was completed on phytoplankton biomass in the Kromme, Gamtoos, Kabeljous and Seekoei Estuaries. Each estuary was sampled on five occasions. Mean chlorophyll-a was low (2 µg l^{-1}) for the Kromme, Kabeljous and Seekoei Estuaries compared to the Gamtoos Estuary (8 µg l^{-1}). This was attributed to the low freshwater inflow and lack of nutrients. Mean salinity in the Seekoei Estuary was 20 ppt. **<u>Benthic microalgae:</u>** Grant (2003) found that benthic microalgal biomass increased with distance upstream. Low biomass on the seaward side of the causeway and in the lower reaches of the estuary was attributed to strong tidal action and sediment resuspension. At the time of the survey the mouth was open and the salinity was 35 ppt. Confidence: Medium

Macrophytes
The Seekoei Estuary is approximately 3.5 km long and covers a total area of 98 ha. Surveys in 1990 showed that the Seekoei Estuary at this time was mostly brackish (13-28 ppt) and was characterised by extensive *Ruppia* and *Cladophora* beds that covered an area of 29.4 and 14.01 ha respectively. When the water level is low the sandflat areas are colonised by the salt marsh succulent *Sarcocornia perennis*. In 1990 this plant covered an area of 1.2 ha. Grasses are the other dominant salt marsh plants and consist of species such as *Sporobolus virginicus*, *Paspalidium obtusifolium*, *Cynodon dactylon* and *Stenotraphrum secundatum*. These covered an area of 1.6 ha. Isolated patches of the common reed, *Phragmites australis* were found along the length of the estuary at sites of freshwater seepage, with

these reeds covering 0.18 ha. Compared to the Kromme, Gamtoos and Kabeljous estuaries the Seekoei had the lowest macrophyte species diversity (Adams, 1991; Adams *et al*., 1992). Visits to the estuary in 2004 indicated a dominant submerged macrophyte community with *Ruppia cirrhosa* co-existing with eelgrass *Zostera capensis*.

Confidence: High

Invertebrates

Zooplankton:

No information on the zooplankton of the Seekoei is available, but the species assemblage and biomass is expected to be low. Both numbers of species and biomass will increase at times of open mouth, but for different reasons. Mouth opening will cause a temporary influx of marine associated species, while the reduction in salinity further upstream will benefit typical estuarine species such as *Pseudodiaptomus hessei*. Upon mouth closure and a rapid return to high salinity values, biomass will again decrease to low levels.

Benthic invertebrates

Limited information on benthic invertebrates suggests that the community is not rich in species nor biomass, although the sandprawn *Callianassa kraussi* may reach high abundance levels below the causeway. Mudprawns were present above the causeway, but numbers were low.

Larger invertebrates

The crab, *Scylla serrata* probably occurs in low numbers.

Confidence: Low

Fish

The Seekoei Estuary has a diverse marine and estuarine fish assemblage but has lost the majority of freshwater species that may have occupied the headwaters under perennial river flow conditions. At present the physico-chemical conditions show wide inter-annual fluctuations and sometimes culminate in severe hypersaline conditions that devastate the fish community. Recovery of the fish assemblage after such events is rapid but the loss of productivity during hypersaline conditions is likely to be significant. The more frequent closure of the estuary mouth under the Present State will favour estuarine resident fish species but disadvantage the important marine migrant component.

Confidence: Medium

Birds

A total of 68 non-passerine waterbird species have been recorded on the estuary, with an average of 31-32 species per midsummer or midwinter count. Data spanning ten years show large fluctuations in numbers of individual species, functional groups and community composition. When the estuary is of average depth and of mixed to fairly high salinity, the bird community is dominated by waders in summer (about 600 birds) and has an even spread of taxonomic groups in winter, i.e. resembling conditions for a normal open estuary. Bird numbers average about 1 000 in summer and 600 in winter when in a typical estuary state. Large numbers of terns have also been recorded under these conditions, mostly using the lower estuary as a roosting area. When conditions lead to a shallow, hypersaline estuary, the estuary is dominated by waders in summer (about 600 birds) and wading birds and waders in winter, with flamingos making a visible appearance. Summer numbers peak at around 2 000 but winter numbers can drop to 300 when water levels are low. When the estuary is in a deep, relatively fresh state, it is dominated by waterfowl, whose numbers can approach 1 800 birds. Under these conditions, the number of waders decreases to about 200 birds, and numbers of wading birds, gulls and terns are also very small, but there can be a significant number of cormorants.

Confidence: High

vi. Effect of abiotic characteristics and processes, as well as other biotic components on estuarine biota:

Mouth condition (provide temporal implications where applicable)
Microalgae: Phytoplankton biomass and species diversity would be highest when there is freshwater inflow and an open mouth. Intertidal benthic microalgae would occur when the mouth is open and there is an exposed intertidal area. When the mouth closes and water levels rise then submerged benthic microalgae would be dominant. Biomass generally increases when the mouth is closed as long as there is a nutrient supply. Confidence: High
Macrophytes: During closed mouth conditions the submerged macrophytes such as *Ruppia* would flourish. Prolonged closed mouth conditions (> 4 months) can result in die-back of salt marsh as a result of high water levels and submergence Confidence: High
Invertebrates: All groups of invertebrates will be negatively affected during closed mouth conditions, this is linked to the higher salinity values experienced when the mouth is closed. Benthic species that have a marine phase of larval development will be most affected (e.g. *Upogebia Africana, Palaemon perengueyi*). Three months of mouth opening will result in some recruitment of estuarine populations. Confidence: Medium
Fish: Mouth opening during September-November is important for the recruitment of estuary-associated marine fish larvae. Closure of the mouth during late summer and winter increases the valuable habitat for the fish fauna in the estuary. Confidence: High
Birds: Little direct effect, only indirect, through impacts on habitat and food. Main effect is on terns, with open mouth providing suitable feeding conditions. Confidence: High:

Exposure of inter-tidal areas during low tide
Microalgae: Benthic microalgal biomass is usually higher in the intertidal zone compared to the subtidal zone. Grant (2003) also found this to be the case in the Seekoei Estuary. Confidence: High
Macrophytes: According to Bickerton and Pierce (1988) the causeway permanently raised the water level in the upper estuary and destroyed the natural intertidal and supratidal environment. Since then the causeway has been reconstructed with larger culverts, and the estuary is now quite tidal with a small functional intertidal area. Grasses are still the dominant species because species such as brakgras (*Sporobolus virginicus*) can withstand long periods of submergence. Confidence: High
Invertebrates: Rise and fall of the tides will lead to zonation of species along the gradient, but the intertidal area is currently very narrow, especially above the causeway. If the mouth is restrictred, the intertidal area will be further reduced. Confidence: Medium
Fish: Exposure of intertidal areas during low tide is a natural phenomenon, with the resulting increased microalgal biomass providing an important food resource for the various mullet species at high tide.

Confidence: Medium
Birds: Tidal exposure is essential for estuarine birds, with the majority of species depending on these habitats for food, and several more using intertidal areas for roosting. Confidence: High

Sediment processes and characteristics
Microalgae: Stable sediment conditions during the closed phase would promote benthic microalgal growth. Higher biomass is generally associated with fine and organically rich sediments. Confidence: Medium
Macrophytes: The highest sediment nutrient concentrations and organic matter content was associated with sites upstream of the causeway. This was ascribed to reduced flushing and sedimentation aggravated by the causeway (Adams, 1991). Confidence: High
Invertebrates: Sediment accumulation above the causeway is ongoing, creating large shallow areas. Temperature fluctuations become more rapid and this will negatively influence the presence of small invertebrates that live near the surface. Confidence: Low
Fish: Reduced flushing of sediments from the estuary has probably resulted in a shallower system which favours small fish size classes but not large predatory species. Confidence: Medium
Birds: Sediment characteristics affect the food and feeding methods of estuarine birds, with different species being adapted to different conditions. A change in characteristics is likely to affect bird community composition. Sediment particle size is important in determining species composition and bird densities, with muddy (not silty) habitats being important for foraging. Increased nutrient loading would lead to increased bird biomass due to increased food supplies Confidence: High

Retention times of water masses
Microalgae: When the mouth is open, phytoplankton biomass would depend on water retention time. High flows would flush the phytoplankton out of the estuary. Baseflow, nutrient input and the formation of a longitudinal salinity gradient would promote phytoplankton growth. Confidence: Medium
Macrophytes: Little influence on macrophytes. Confidence: High
Invertebrates: Retention of water masses is likely to be greater upstream of the causeway. Below the causeway a short residence time will flush out zooplankton and probably small benthic crustaceans. Confidence: Medium
Fish: Increased retention time that leads to increased pelagic productivity would be of benefit to plankton feeding fish species. Confidence: Medium

Birds: No direct impact Confidence: High

Flow velocities
Microalgae: High flow velocities would flush both phytoplankton and benthic microalgae out of the estuary. Confidence: High
Macrophytes: High velocities during floods would remove submerged macrophytes. Stagnant waters promote the growth of filamentous algae. Confidence: High
Invertebrates: High flow velocities would flush both zooplankton and benthic invertebrates out of the estuary. Confidence: High
Fish: High flow velocities during river flooding may result in the temporary emigration of marine fish species to the sea. Confidence: Medium
Birds: Flow velocities affect foraging by piscivorous birds, but only at very high velocities Confidence: High

Volume of water in estuary
Microalgae: The volume of water in the estuary determines the available habitat for phytoplankton. When levels are low and the water is hypersaline, microalgae may be one of the few living biotic components. Confidence: High
Macrophytes: The volume of water in the estuary determines the available habitat for submerged macrophytes. Low water levels and hypersaline conditions in the Seekoei Estuary in 1989 prior to the November rains resulted in an impoverished system. Submerged macrophytes were absent and salt marsh was limited. In 1990 the estuary was mostly closed and brackish with high water levels and dense *Ruppia cirrhosa* beds. Confidence: High
Invertebrates: The volume of water in the estuary determines the available habitat for invertebrates. When water levels are low and hypersaline this will impoverish the communities. Confidence: High
Fish: Reduced estuarine water volumes, for whatever reason, will result in smaller fish populations and a reduced fish biomass within the system. Confidence: High
Birds: No direct impact. Inundation of intertidal habitats would lead to a reduction in bird numbers. Confidence: High

Salinities
Microalgae: Species composition changes in response to changes in salinity. The influence of salinity on biomass is unknown.

Confidence: Medium
Macrophytes: In June 1989 salinity was 90 ppt in the Seekoei Estuary. This together with a drop in water level caused the dominant submerged plant *Ruppia cirrhosa* to die back. This plant is sensitive to desiccation but can survive in salinity from 0 – 75 ppt. It has a large seed bank and is therefore adapted to fluctuating environments such as the Seekoei Estuary. In November 1989 there was a flood and the estuary was fresh throughout. By July 1990 the salinity was 18 ppt and there was dense submerged macrophyte growth. In April 1991 salinity had increased to 37 ppt. Confidence: High
Invertebrates: High and very low salinity values will reduce invertebrate abundance levels as well as biomass. High values refer to those exceeding 35 ppt, while low values of less than 5 ppt will also change composition and structure of communities. Confidence: Medium
Fish: Hypersaline conditions (>90 ppt) during March 1989 caused a mass fish mortality within the Seekoei Estuary involving at least 11 fish species. Hypersaline conditions arising from reduced riverine input to the estuary could result in similar fish kills in the future. Confidence: Medium
Birds: Most estuarine birds tolerate a wide range of salinities, but a few species are typical of more freshwater or marine habitats, and the abundances of these species would be affected by change. Confidence: High

Other water quality variables
Microalgae: Fertilizer use in the catchment increases nutrient input and results in high microalgal biomass. Because the freshwater inflow is so low in the Seekoei Estuary, this is probably not a problem. Confidence: Medium
Macrophytes: A survey in 1990 (Adams, 1991) showed that the submerged macrophyte sites were associated with high sediment nutrients. It was thought that the sediment could act as a nutrient sink and in association with the *Ruppia* beds could play an important role in the recycling of nutrients within the estuary. Sediment nutrient concentrations were highest on the landward side of the causeway. This was attributed to the build-up of sediment and organic matter due to reduced tidal and freshwater flushing. Confidence: High
Invertebrates: Zooplankton biomass will respond to increased phytoplankton biomass as a result of higher nutrient input. The increase in macrophyte cover will also benefit some groups such as amphipods and isopods. Confidence: Medium
Fish: Low dissolved oxygen concentrations and excessive heating of the shallow waters during prolonged summer droughts has the potential to cause increased stress to the ichthyofauna and may result in fish kills. Confidence: Low
Birds: No direct impact Confidence: High

vii. Anthropogenic influences, other than modification of river inflow, that are presently directly affecting biotic characteristics in the estuary:

Structures (e.g. weirs, bridges, jetties, causeway)
Microalgae: The build-up of water on the landward side of the causeway would reduce the available habitat for intertidal benthic microalgae. Confidence: High
Macrophytes: The lack of diversity and area covered by emergent macrophytes in the Seekoei Estuary has been related to the fluctuating water levels and extreme salinities (Adams, 1991; Adams *et al*., 1992). This situation is aggravated by the causeway which causes macrophytes to be inundated for long periods. Confidence: High
Invertebrates: The causeway is unlikely to affect invertebrates directly, although other effects (stagnation of water in some areas, changes in sediment characteristics etc.) caused by the causeway will influence communities. Confidence: Medium
Fish: The causeway and associated culverts are unlikely to hamper the movement of fish within the estuary. The increased volume of water available to fish species above this structure would favour certain open water species. Confidence: Medium
Birds: The build-up of water upstream of the causeway affects estuary depth and hence the species that can utilise the estuary, reducing habitat availability for waders, gulls and terns, in particular. Habitat loss on the estuary margins may have had a negative effect on some waterfowl. Confidence: Medium

Human exploitation (consumptive and non-consumptive)
Macrophytes: Surrounding developments, the causeway and associated road have resulted in the loss of some macrophytes. Confidence: Medium
Invertebrates: Because of the small size of the system and mouth closure for much of the year, bait organisms will be heavily affected. This will be particularly severe on species that require access to the sea for part of their life cycle. Confidence: Medium
Fish: Fishing and bait collection will result in reduced fish stocks, especially if the mouth stays closed for extended periods. Floodplain developments, especially the artificial manipulation of the mouth, has had a negative influence on marine fish recruitment into the estuary and reduced the ability of mature fish to return to the sea to breed. Confidence: Medium
Birds: Direct human disturbance through recreational activity probably has a negative effect on bird numbers. Confidence: Medium

3.3 Reference Conditions

3.3.1 Abiotic Components

i. Seasonal variability in river inflow:

Monthly simulated runoff data for the Seekoei Estuary Reference (or natural) Condition is provided in Table 3-2. A summary of flow distribution (mean monthly flows in million m^3) for the Reference Condition, derived from the 73-year simulated data set, is provided below:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99%ile	**21.00**	**11.83**	**4.45**	**3.09**	**5.93**	**14.20**	**6.56**	**17.39**	**19.35**	**12.10**	**20.84**	**25.34**
90%ile	**6.84**	**5.15**	**2.30**	1.10	0.76	**2.28**	**2.22**	**2.87**	**2.70**	**3.10**	**4.42**	**7.23**
80%ile	**3.49**	**2.52**	1.31	0.75	0.58	0.91	1.36	1.48	1.74	1.90	**2.78**	**4.14**
70%ile	**2.46**	1.87	0.96	0.50	0.38	0.61	0.91	1.08	1.36	1.40	1.92	**2.24**
60%ile	1.84	1.33	0.89	0.44	0.31	0.41	0.57	0.79	0.97	1.22	1.62	1.80
50%ile	1.53	1.13	0.62	0.40	0.24	0.33	0.44	0.62	0.81	1.01	1.35	1.54
40%ile	1.24	0.99	0.58	0.35	0.21	0.24	0.35	0.52	0.58	0.90	1.08	1.27
30%ile	1.14	0.83	0.54	0.29	0.17	0.19	0.29	0.39	0.44	0.75	0.89	0.98
20%ile	0.84	0.72	0.42	0.24	0.15	0.14	0.21	0.28	0.38	0.56	0.68	0.75
10%ile	0.65	0.57	0.37	0.17	0.14	0.11	0.14	0.15	0.28	0.38	0.54	0.55
1%ile	0.36	0.29	0.20	0.09	0.06	0.06	0.05	0.08	0.07	0.10	0.28	0.32

ii. Flood regime for the Reference Condition:

All floods reached the estuary, from freshettes to major floods. This led to resetting of the salinity profile and scouring from especially the middle and lower reaches.

Confidence: Low

iii. Differences in sediment processes under reference compared with present:

It is considered that the system used to be more sandy under the Reference Condition as the natural vegetation would have prevented catchment erosion and the deposition of more silt in the river. Furthermore, the system would have been more fresh and therefore less flocculation of the silt would have occurred in the estuary. Resuspension of the silty material would have occurred throughout the estuary as the causeway would not have disrupted the flow. The estuarine channels would also have been more dynamic.

Confidence: Low

iv. Occurrence and duration of different Annual Abiotic states during the Reference Condition

An analysis of the Reference Condition simulated monthly runoff scenario indicated that the Seekoei Estuary received almost enough river inflow to breach annually, i.e. in 1 out of 73 years the annual inflow is less than 3 million m^3.

This indicates that the estuary remained nearly permanently open under the Reference Condition. Under the Reference Condition tidal flows would have contributed even more to open mouth conditions as there would have been no disruption or backing up above the causeway.

In the event of mouth closure due to storm events out at sea, the river inflow was sufficiently high to allow for breaching within a short period after closure (~month or less).

In years where the Seekoei Estuary is likely to be in Abiotic State 1: Open mouth, the monthly distribution between saline to hypersaline (median monthly flow < 0.5 million m^3) conditions versus conditions when the estuary develops a strong longitudinal salinity gradient to becoming fresh (median monthly flow > 0.5 million m^3) is estimated to be as follows for the Reference Condition:

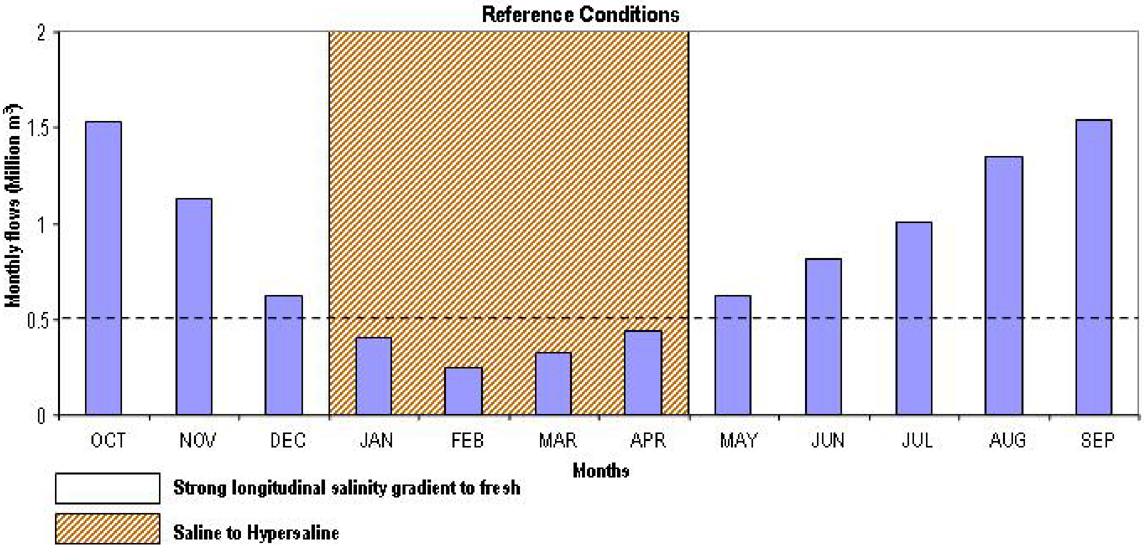


Table 3-2 Reference Conditions: Simulated runoff data in million m^3 per month

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1927	1.13	0.67	0.54	0.35	0.35	0.61	0.61	0.58	0.84	1.32	1.67	1.80	10.47
1928	1.32	0.98	1.45	0.75	0.33	0.24	0.37	0.85	0.85	0.98	0.92	0.75	9.79
1929	0.71	13.39	5.05	1.06	0.57	0.51	0.57	1.35	1.53	1.90	1.73	1.40	29.77
1930	1.18	0.99	0.61	0.35	0.24	0.17	0.14	0.31	0.64	0.67	0.94	1.09	7.33
1931	1.21	1.09	0.92	0.43	0.14	0.35	1.02	1.09	1.02	0.97	1.19	2.37	11.80
1932	2.14	1.27	0.67	0.27	0.16	0.11	0.24	0.52	0.44	4.48	2.84	1.90	15.04
1933	3.02	2.81	1.24	0.44	0.24	0.44	0.35	0.81	0.67	0.51	1.35	1.05	12.93
1934	0.64	0.73	0.54	0.27	0.21	15.81	5.97	0.75	0.57	0.51	0.55	1.35	27.90
1935	1.32	1.73	0.95	0.35	0.14	0.11	0.16	0.51	0.54	1.27	1.09	3.26	11.43
1936	2.07	0.89	0.47	0.21	0.35	1.12	0.78	0.54	0.61	0.58	1.02	0.98	9.62
1937	1.09	0.67	0.35	0.23	0.13	0.43	0.41	0.30	0.24	1.80	1.19	1.54	8.38
1938	10.11	4.18	3.90	1.70	0.38	0.41	0.30	0.21	0.27	1.01	1.02	35.92	59.41
1939	13.90	5.39	2.51	0.61	0.26	0.16	0.11	0.52	0.43	0.35	3.93	2.10	30.27
1940	0.78	1.66	0.92	0.38	0.24	0.24	0.21	0.26	0.38	1.90	1.80	1.27	10.04
1941	5.42	2.57	0.58	0.27	0.17	0.14	0.57	14.25	6.06	2.07	2.00	1.80	35.90
1942	1.50	1.22	0.81	0.38	0.16	0.13	0.34	0.38	0.35	0.68	0.58	0.57	7.10
1943	1.62	5.53	2.38	0.47	0.17	0.30	0.21	0.14	0.81	0.75	0.62	1.62	14.62
1944	1.24	1.02	0.89	0.47	0.20	0.14	0.30	0.30	0.34	0.38	0.37	0.37	6.02
1945	0.71	0.73	0.41	0.17	1.70	1.29	0.75	0.64	0.57	0.88	5.66	3.22	16.73
1946	1.70	1.57	1.04	0.75	0.64	0.81	0.58	0.51	0.54	0.78	0.68	0.81	10.41
1947	0.64	0.64	0.37	0.14	0.07	0.11	0.16	0.17	1.76	1.08	0.75	0.81	6.70
1948	2.00	1.19	2.37	1.22	0.34	0.14	0.14	1.43	1.29	0.95	0.89	0.78	12.74
1949	1.86	1.12	0.49	0.49	0.27	0.17	0.24	0.21	1.42	1.39	2.68	4.76	15.10
1950	2.44	2.21	1.33	0.52	0.47	2.32	2.27	25.45	9.81	1.76	1.45	2.11	52.14
1951	1.76	0.95	0.41	0.19	0.14	0.10	0.06	2.84	2.48	1.42	3.29	2.30	15.94
1952	7.77	3.36	0.62	0.24	0.17	5.64	2.37	0.47	0.38	0.81	1.36	1.16	24.35
1953	0.89	0.54	0.24	0.10	0.07	0.97	0.57	1.56	1.99	3.29	2.24	1.35	13.81
1954	0.92	0.71	0.57	0.30	0.11	0.20	3.40	1.59	0.64	0.58	0.61	0.67	10.30
1955	3.98	2.04	0.61	0.24	0.14	0.07	0.07	0.10	0.07	0.07	0.11	0.19	7.69
1956	0.17	11.23	4.21	0.31	0.17	0.13	0.95	0.62	0.35	0.75	2.34	1.73	22.96
1957	1.53	3.30	1.90	4.44	1.94	0.49	0.27	0.40	0.58	1.90	1.59	11.98	30.32
1958	5.16	1.04	0.64	0.54	0.61	0.35	0.21	0.92	0.88	0.75	1.53	7.10	19.73
1959	3.53	1.59	0.98	0.44	0.33	0.23	0.17	0.17	0.41	1.19	4.00	14.25	27.29
1960	30.66	10.15	1.21	0.52	0.19	7.76	4.07	11.01	5.09	5.37	15.67	6.04	97.74
1961	1.24	0.78	0.61	0.37	4.00	2.37	0.89	0.64	0.61	0.91	8.48	4.21	25.11
1962	1.60	1.76	1.08	0.41	0.30	0.62	0.44	6.13	2.99	1.40	1.45	5.15	23.33
1963	17.24	7.01	3.26	1.36	1.04	0.78	0.61	0.62	1.70	1.73	2.34	15.90	53.59
1964	7.20	1.59	0.58	0.19	0.06	0.62	0.44	5.13	2.72	1.21	3.02	2.20	24.96
1965	1.84	1.13	0.57	1.46	0.68	1.13	2.00	1.46	1.22	1.30	1.83	1.73	16.35
1966	1.86	1.16	0.61	0.81	0.40	0.20	0.24	1.06	0.98	2.20	1.87	1.53	12.92
1967	1.15	0.78	0.40	0.37	0.47	1.38	1.67	2.58	1.87	1.89	1.70	1.27	15.53
1968	1.01	0.71	0.43	0.27	0.21	0.65	1.29	0.82	0.51	0.44	3.73	2.11	12.18
1969	1.22	0.81	0.35	0.81	0.38	2.10	1.67	1.35	1.02	0.97	1.09	0.97	12.74
1970	0.78	0.64	1.30	1.11	0.52	0.40	0.38	0.33	3.73	2.11	1.19	6.34	18.83
1971	3.43	2.24	1.12	0.41	0.17	0.11	0.31	0.98	0.81	0.75	0.68	0.69	11.70
1972	2.65	3.50	1.49	0.75	0.58	0.38	0.31	0.44	0.40	0.38	0.89	0.98	12.75
1973	0.84	0.94	0.62	0.31	0.27	0.34	1.02	1.76	1.38	1.32	1.62	1.80	12.22
1974	1.40	0.88	0.43	0.17	0.14	0.16	1.40	1.19	19.33	7.93	2.24	4.04	39.31
1975	2.48	1.19	0.57	0.31	0.19	0.30	0.27	0.24	0.31	0.38	0.43	0.51	7.18
1976	0.55	0.41	0.23	0.19	0.17	0.11	0.07	0.07	0.06	0.11	0.41	0.51	2.89
1977	0.84	0.55	0.89	0.43	0.21	0.30	8.07	4.51	1.99	11.49	24.53	8.28	62.09
1978	1.33	1.22	0.65	0.24	0.24	0.21	0.35	0.44	0.44	0.54	0.78	0.67	7.11
1979	0.43	0.27	0.14	0.06	0.16	0.21	0.34	0.71	0.55	0.38	0.35	0.44	4.04
1980	0.51	0.78	0.43	0.75	0.75	4.04	1.93	1.36	1.35	1.09	2.24	4.64	19.87
1981	2.48	0.92	0.44	0.49	0.27	0.27	0.21	0.11	0.10	0.67	0.78	1.67	8.41
1982	1.15	0.64	0.41	0.23	0.14	0.67	5.86	2.88	1.46	6.95	3.87	1.83	26.09
1983	3.78	2.44	0.92	0.31	0.99	0.57	0.81	4.33	2.57	1.36	1.11	7.26	26.45
1984	3.59	2.24	1.40	0.51	0.14	1.62	1.54	1.08	1.13	1.21	1.30	1.13	16.89
1985	1.56	2.58	1.32	1.02	0.61	0.43	0.35	0.49	0.64	2.34	19.41	8.11	38.86
1986	1.94	1.05	0.57	0.49	0.24	0.11	0.47	0.35	0.41	0.41	0.38	0.47	6.89
1987	1.80	1.24	0.54	2.57	1.08	13.57	5.21	1.73	1.62	1.40	4.53	2.75	38.04
1988	3.60	2.04	0.75	0.40	0.21	0.26	1.12	0.68	0.37	0.61	0.92	0.92	11.88
1989	0.84	0.54	0.23	0.11	0.07	0.06	0.03	0.09	0.17	13.66	5.63	1.29	22.72
1990	1.05	0.78	0.41	0.14	0.06	0.21	0.16	0.11	0.21	0.78	0.65	0.62	5.18
1991	0.47	0.30	0.38	1.21	0.76	0.35	0.31	0.27	0.81	0.95	0.78	0.54	7.13
1992	0.75	1.13	0.84	0.71	0.35	0.21	0.17	0.14	0.14	0.17	0.78	0.75	6.14
1993	3.08	2.10	0.92	0.37	0.17	0.14	0.37	0.30	1.62	1.04	0.68	1.70	12.49
1994	1.16	0.51	0.24	0.11	0.47	0.33	0.57	0.57	0.97	0.92	0.92	0.81	7.58
1995	0.64	0.44	0.41	0.30	0.27	0.17	1.29	0.78	0.41	0.40	0.38	0.58	6.07
1996	9.29	7.06	2.02	0.41	0.67	0.71	2.04	1.49	2.62	1.94	1.47	1.33	31.05
1997	3.16	1.76	0.57	0.26	0.21	0.14	0.11	0.14	0.30	0.30	0.54	0.54	8.03
1998	1.33	0.84	0.89	0.41	10.88	4.07	0.51	0.57	0.92	1.16	4.67	2.78	29.03
1999	10.99	8.45	2.40	0.44	0.14	0.06	1.09	0.64	19.41	7.72	1.62	21.23	74.19
Median	1.53	1.13	0.62	0.40	0.24	0.33	0.44	0.62	0.81	1.01	1.35	1.54	13.81
Average	2.99	2.12	1.01	0.56	0.55	1.13	1.03	1.65	1.71	1.75	2.48	3.30	20.27

Monthly > 2 mil m3 Annual < 3 mil

3.3.2 Biotic Components

Predicted change in biotic characteristics from the Reference Condition to the Present State, as well as motivation to explain the cause of such changes

Microalgae
Reduced baseflow and an increase in salinity have decreased the number of freshwater and brackish species. The lack of freshettes and nutrient inflow has reduced the phytoplankton biomass. An increase in stable closed mouth conditions would promote benthic microalgal growth but only if nutrients were available. Confidence: Medium
Macrophytes
An increase in salinity has resulted in the loss of some species e.g. *Potamogeton pectinatus* (pondweed). Brackish reed and sedge species may have also been lost, as there is no longer a persistent longitudinal salinity gradient. There has probably been an increase in the abundance of submerged macrophytes and filamentous green algal mats at times when the mouth is closed and the estuary is brackish. This state occurs more frequently than it did in the past. High water levels would favour the development of submerged macrophytes i.e. *Ruppia* in the place of salt marsh. The lack of flushing increases the occurrence of filamentous green algal mats. Confidence: High
Invertebrates (including zooplankton, benthic invertebrates and macrocrustaceans)
Under the Reference Condition, all invertebrate groups would have been richer in species and biomass. Distinct communities would also have developed along the salinity gradient under natural conditions. As salinity becomes more homogeneous, zonation becomes less distinct and some communities (e.g. brackish water types) may disappear. Under natural conditions abundance and biomass levels would probably have fluctuated annually in accordance with salinity patterns and state of the mouth, but average levels would have been much higher than at present. Confidence: High
Fish
Extreme hypersaline conditions and associated mass fish mortalities would not have occurred under natural conditions. Marine fish species diversity and abundance would have been greater under natural conditions due to the more prolonged open mouth conditions and greater influence of the sea on the lower reaches. Freshwater fish species would have been located at the head of the estuary and would have retreated upstream when river flow declined. Confidence: Medium
Birds
In the Reference Condition the estuary was mostly in a typical estuarine state, whereas under the Present Condition, a full state and a very shallow, hypersaline state now occur more frequently. The full state means that intertidal and shallow-water foragers are excluded for significant periods of time, while providing a temporary haven for waterfowl. The increase in very shallow, hypersaline conditions since the Reference State will have led to the reduction in plant, invertebrate and fish productivity, hence reducing the overall numbers of species typical of the mid to lower reaches. In addition, these conditions discourage waterfowl which would typically have occupied the upper estuary on a more regular basis. Flamingos would have been fairly uncommon in the Reference State. Confidence: High

3.4 Present Ecological Status of the Seekoei Estuary

3.4.1 Abiotic Components

Hydrology

Variable	Score	Motivation	Confidence
1a. % similarity in period of low flows or Present MAR as a % of MAR in the Reference Condition	56	Under the Present State the Seekoei has an MAR of 11.36 million m^3 in comparison with the Reference Condition's 20.27 million m^3. At present 56% of the runoff is still reaching the estuary.	L
1b. % similarity in mean annual frequency of floods	60	For the Seekoei, months with flows of $10m^3/s$ or more were estimated to be indicative of flood events. Under the Present State these events occur 16 times in the 73-year period, in comparison of with the 26 under the Reference Condition. At present about 60% of the larger flood events still reach the estuary.	L
Hydrology score	**58**		

Hydrodynamics and mouth condition

Variable	Score	Motivation	Confidence
Change in mean duration of closure, e.g. over a 5 or 10-year period	40	Under the Present State the potential occurrence of open mouth conditions has been reduced to 77% (17 out of 73 years) from nearly permanently open (99%) under the Reference Condition. Following the guidelines stipulated in Table 3.2b (DWAF, 2004) this results in a score of 40.	L
Hydrodynamics and mouth conditions score	**40**		

Water quality

Variable	Score	Motivation	Confidence
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	30	During the Reference Condition, State 1: Open mouth prevailed for nearly 100% of the years within the simulation period. From May to Dec a strong longitudinal salinity gradient to fresh conditions would have occurred. Hyper salinity should not have been an issue. Under the Present State, State 1: Open mouth occurs for 75% of the years within the simulation period. This is indicative not only of a decrease in open mouth conditions from the Reference Condition, but also a decrease in the occurrence of strong salinity gradients or fresh conditions in the system. Also within State 1, strong longitudinal salinity gradient to fresh conditions now only occurs for 3 months (Aug to Oct) compared to 8 months under the Reference Condition. Under the Present State, when the estuary closes (State 2: Closed mouth)	L

		the system becomes saline, favouring hypersaline conditions (values of more than 65 ppt recorded) during drought years (due to reduced river inflow and evaporation). Hypersaline conditions can even develop under State 1, during extended periods of low flow in the upper reaches.	
2a. Nitrate/phosphate (inorganic nutrient) concentration in the estuary	51	The rivers (Swart and Seekoei) are the major inorganic nutrient sources to the Seekoei Estuary. With extensive agricultural development in the catchment, it is expected that nutrient concentrations in river inflow will also be higher compared to the Reference Condition. Using modification in MAR as proxy for modification in nutrients: The MAR reduced from 20.27 million m^3 in the Reference Condition to 11.36 million m^3 under the Present State (i.e. a reduction of 44%). Based on modification to river inflow, inorganic nutrient levels were reduced to about 56% of Reference Condition. Furthermore, agricultural activities in the catchment introduced higher inorganic nutrients into river inflow compared to the Reference Condition. As river flow has been drastically reduced the overall effect of this will, however, be limited – allow for a further 5% modification.	L
2b. Suspended solids (turbidity) in the estuary	46	River inflow into the estuary is expected to be one of the major sources of turbidity in the estuary. With extensive agricultural development in the catchment, it is expected that turbidity levels in river inflow will even be higher compared to the Reference Condition. Using modification in MAR as proxy for modification in turbidity: The MAR reduced from 20.27 million m^3 in the Reference Condition to 11.36 million m^3 under the Present State (i.e. a reduction of 44%). Based on modification to river inflow, turbidity levels were reduced to about 56% of Reference Condition. Furthermore, agricultural activities in the catchment introduced higher turbidity into river inflow compared to the Reference Condition. As river flow has been drastically reduced the overall effect of this will, however be limited – allow for a further 5 % modification. Also, with the increase in State 1 (closed mouth), average turbidity levels in the estuary seaward of the causeway would	L

		also have increased – allow for a further 5% modification.	
2c. Dissolved oxygen in the estuary	100	The Seekoei Estuary should generally be well-oxygenated, being a shallow system (i.e. even during periods of low or no river inflow, wind mixing maintains oxygenated conditions).	L
2d. Levels of toxins	80	There are no major urban or industrial areas in the catchment. However, extensive agricultural developments probably introduce some toxic substances (e.g. pesticides) into the system. Allow for a 20% change from Reference Condition to Present State.	L
Water quality score	**39.6**		

Physical habitat alteration

Variable	Score	Motivation	Confidence
1. Resemblance of intertidal sediment structure and distribution to Reference Condition			
1a. % similarity in intertidal area exposed	65	Increase in mouth closure events (23%) caused a decrease in intertidal area. The construction of the causeway also decreased intertidal areas as it influenced the tidal amplitude above (landwards of) the causeway.	L
1b. % similarity in sand fraction relative to total sand and mud	60	The causeway created a deposition mechanism for fines landward of the causeway, reducing the natural sediment habitat gradient from sandy to muddy further upstream. Presently there is a sharp differentiation between sand (below causeway) and muddy (above causeway). Land-use changes and reduced tidal flushing also favour development of muddy substrates. In general, there are more muddy substrates than under the Reference Condition.	L
2. Resemblance of subtidal estuary to Reference Condition: depth, bed or channel morphology	60	At present there is a stabilised channel configuration due to the causeway. The estuary is shallower between mouth and causeway, but the main channels are potentially deeper (especially near or at the causeway) where the flows are restricted. There is possible sedimentation upstream of the causeway due to the damming effect during flood events.	L
Anthropogenic influence			
Percentage of overall change in intertidal and supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	50	The increase in muddy substrate is seen as more significant than the changes in the intertidal habitat caused by the causeway. (Reduction in inflow have introduced mouth closure and the reduction in floods have also reduced the inundation of the supratidal habitat)	L
Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, bulkheads, training walls, jetties, marinas) rather than modifications to water flow into estuary	50	The majority of the changes to the subtidal habitat are related to artificial breaching, the causeway and the carpark. (Reduction in floods have had a 50% influence on modification of subtidal habitat)	L
Physical habitat score	**61**		

3.4.2 Biotic Components

Microalgae

Variable	Score	Motivation	Confidence
Phytoplankton			
1. Species richness	35 (60%)	The reduction in baseflows and the increase in salinity would result in a loss of freshwater/brackish species.	M
2a. Abundance	45	The lack of freshettes and pulses of nutrient rich freshwater inflow would result in low phytoplankton biomass. The current inflow (with enriched conditions) is too infrequent to have a major influence. However, the phytoplankton biomass was probably never very significant in the Seekoei Estuary (< 2 µg l^{-1}).	M
2b. Community composition	40	Loss of freshwater/brackish components and an increase in saline components.	M
Benthic microalgae			
1. Species richness	35 (60%)	The reduction in baseflow and increase in salinity would result in a loss of freshwater/brackish species.	M
2a. Abundance	45	Reduced flushing and an increase in sedimentation could increase benthic microalgal biomass. However, reduced freshwater inflow and low nutrient concentrations would decrease biomass.	M
2b. Community composition	40	Primary colonisers would be reduced due to lack of flushing, floods and resetting of the estuary.	M
Microalgae score	**35**		

Macrophytes

Variable	Score	Motivation	Confidence
1. Species richness	35 (60%)	An increase in salinity has resulted in the loss of some species e.g. *Potamogeton pectinatus* (pondweed). Brackish reed and sedge species may have also been lost as there is no longer a persistent longitudinal salinity gradient. Drought years and hypersaline conditions result in an impoverished estuary. At most 60% of the original species remain.	M
2a. Abundance/Biomass	40	There has been an increase in the abundance of submerged macrophytes and filamentous green algal mats as a result of increased mouth closure. High salinity and increased water levels has reduced the biomass of brackish reeds and sedges and some salt marsh species.	M
2b. Community composition	40	The mouth closes more frequently than in the past. High water levels would favour the development of submerged macrophytes i.e. *Ruppia* in the place of salt marsh. The lack of flushing increases the occurrence of filamentous green algal mats.	M
Macrophytes score	**35**		

Invertebrates

Variable	Score	Motivation	Confidence
Zooplankton			
1. Species richness	35 (60%)	A sharp decline in species richness i.e. lack of brackish/freshwater species due to increase in more saline conditions. The large fluctuation between brackish to hypersaline conditions also reduces the species richness.	M
2a. Abundance	30	Abundance would decrease because of a decrease in microalgae biomass and the increased fluctuations between the brackish vs. hypersaline conditions, causing high variability in breeding patterns. The extreme hypersaline values recorded also decrease abundance.	M
2b. Community composition	35	Mix of species will change as only the hardy species can tolerate the extreme hypersaline conditions and the effect on breeding. Breeding probably ceases when salinity increases above 50 ppt.	M
Macroinvertebrates (Benthos)			
1. Species richness	35 (60%)	Species richness has decreased due to the fluctuations between brackish and hypersaline conditions. Mouth closure and its effect on the salinity patterns has also contributed as this favours species that do not require a marine phase. The marine dependent species have probably disappeared. As a number of species show high fidelity to parent estuary (i.e. limited means of coming back) there is slow recruitment from other systems once a species is lost from the parent system. Species lost probably include mud prawns, marsh crabs and pencil bait. The loss of the sediment gradient from sandy to muddy vs sharp change at causeway under Present State was not a major factor for benthos.	M
2a. Abundance	50	Abundance has decreased due to fluctuations between brackish and hypersaline conditions. Mouth closure and its effect on salinity patterns will also have reduced abundance. The marginal *Zostera* would have had no major influence on abundance. There would have been sporadic die-back of invertebrates when severe hypersaline conditions developed (>50 ppt) during the closed mouth state, which influences the overall abundance. Because hypersalinity is more severe landward of the causeway where muddy sediments are dominant, the muddy species will be more affected by the hypersaline conditions.	M
2b. Community composition	50	The mix of species changed dramatically due to fluctuating salinity conditions with the result that only the hardy species now dominate. Sporadic die-back of invertebrates (during severe hypersaline, 50 ppt, conditions during the closed mouth	M

		state) would have influenced the overall community conditions. Because the hypersaline conditions are more severe landward of the causeway in the areas where muddy sediments dominate, the muddy species will be more affected by the hypersaline conditions.	
Macrocrustacea			
1. Species richness	35 (60%)	Species richness has decreased due to fluctuations between brackish and hypersaline conditions. Mouth closure and its effect on salinity patterns has also contributed as this favours species that do not require a marine phase. At least some marine dependent species have disappeared. As a number of species probably show high fidelity to a parent estuary (i.e. limited means of coming back) there is slow recruitment from other systems once a species is lost from the parent system.	M
2a. Abundance	50	Abundance has decreased due to fluctuations between brackish and hypersaline conditions. Mouth closure and its effect on the salinity patterns will also have reduced abundance. The marginal *Zostera* would have had no major influence on abundance. There would have been sporadic die-back of invertebrates (during severe hypersaline conditions > 50 ppt) during the closed mouth state.	M
2b. Community composition	60	The mix of species has probably changed dramatically due to fluctuation of salinity conditions, with the result that only the hardy species now dominate. Sporadic die-back of invertebrates during severe hypersaline conditions (>50 ppt when the mouth is closed) would have influenced the overall community.	M
Invertebrates score	**30**		

Fish

Variable	Score	Motivation	Confidence
1. Species richness	35 (60%)	A loss of certain freshwater and marine fish species would have occurred due to the loss of perennial river flow and reduced open mouth conditions respectively. Major fish kills during extended drought conditions could result in the loss of most fish species (due to severe hypersaline conditions developing > 50 ppt).	M
2a. Abundance	40	Reduction in pelagic productivity (i.e. decrease in phytoplankton) would have occurred and this would impact negatively on fish larvae and the adults of planktivorous fish species. Major fish kills during extended droughts would result in the temporary collapse of fish stocks (due to severe hypersaline conditions	M

		developing > 50 ppt).	
2b. Community composition	40	A reduction in the contribution by marine and freshwater taxa to the overall fish assemblage would be expected due to the loss of perennial river flow and reduced open mouth conditions respectively. Fish community composition would undergo considerable changes following fish kills that have been recorded in recent years (due to severe hypersaline conditions developing > 50 ppt).	M
Fish score	**35**		

Birds

Variable	Score	Motivation	Confidence
1. Species richness	65 (80%)	There has probably not been an overall loss in species richness, but a decrease in average instantaneous species richness, due to the decrease in available food resources (i.e. loss of reed marsh and salt marsh habitats, invertebrates and fish). In years when system is closed for prolonged periods and the water level high, this precludes intertidal foraging species (like waders).	M
2a. Abundance	60	Bird abundance is far more variable than in the Reference State, with numbers of certain species reaching very high levels under full conditions and very shallow hypersaline conditions, respectively. Even under typical estuarine conditions reminiscent of the Reference State, bird numbers are probably lower due to the loss of habitat (e.g. reed marsh and salt marsh habitats) and radical loss in invertebrate and (planktivorous) fish biomass that has occurred. (The score is not as drastic as is the case for fish and invertebrates as birds are more flexible in their diet.)	M
2b. Community composition	40	Presently the estuary is dominated by waterfowl during periods of prolonged closure and with high water levels, which did not occur under the Reference Condition. Flamingos now occur during severe hyper-saline conditions (during the closed mouth state), which was not common under the Reference Condition.	M
Bird score	**40**		

To establish the changes in Present State (compared with the Reference Condition) that are not as a result of changes in flow, but rather as a result of other anthropogenic activities, the table below indicates the percentage of overall change predicted in particular components that are non-flow related:

Component	% change caused by non-flow related activities	Motivation	Confidence
Microalgae	20	The causeway affects the intertidal areas and the sediment habitat characteristics. However most of the changes are related to a reduction in baseflow, lack of freshettes and floods and an increase in closed mouth conditions.	M
Macrophytes	50	Approximately 50% of the changes can be attributed to the causeway and mouth manipulations. The other changes are due to the increase in salinity and the loss of a longitudinal salinity gradient.	M
Invertebrates	30	The causeway influenced the mud/sand distribution patterns in the estuary and this influences the species that are sediment selective. The other changes are ascribed to the increase in salinity/hypersalinity and increase in closed mouth conditions.	M
Fish	20	Causeway and mouth manipulation has altered estuarine habitats and therefore the relative abundance of fish species. Recreational fishing is not a major factor in this estuary. The other changes are ascribed to the increase in salinity/hypersalinity and increase in closed mouth conditions.	M
Birds	10	Human disturbance may have led to a reduction in bird numbers, but this might be mitigated to some extent due to much of this activity being centred away from the main bird feeding areas.	M

The individual scores for each of the components (i.e. overall score listed) are incorporated into a Habitat Health Score and a Biological Health Score. This allows for the determination of the Estuarine Health Index (EHI) Score as illustrated in Table 3-3.

Table 3-3 Estuarine Health Score results for the Present State of the Seekoei Estuary

Variable	Weight	Score	Weighted Score
Hydrology	25	58	14
Hydrodynamics and mouth condition	25	40	10
Water quality	25	40	10
Physical habitat alteration	25	61	15
Habitat Health Score			**50**
Microalgae	20	35	7
Macrophytes	20	35	7
Invertebrates	20	30	6
Fish	20	35	7
Birds	20	40	8
Biotic Health Score			**35**
Estuarine Health Score			**42**

The EHI score for the Seekoei Estuary, based on its Present State, is 42, translating into a Present Ecological Status of D- as indicated in Table 3-4.

Table 3-4 Recommended guidelines for the classification of the Present Ecological Status (PES)

EHI Score	Present Ecological Status	General description
91 – 100	A	Unmodified, natural
76 – 90	B	Largely natural with few modifications
61 – 75	C	Moderately modified
41 – 60	**D**	**Largely modified**
21 – 40	E	Highly degraded
0 – 20	F	Extremely degraded

It is very important to note that although the Habitat Health of the system equates to a D (50), the Biotic Health is an E (35). It is therefore believed that the Seekoei Estuary is on a trajectory of change to a Present Ecological Status of an E and that management intervention is urgently required.

3.5 Importance of the Seekoei Estuary

Ecological importance is an expression of the value of a specific estuary to maintaining ecological diversity and functioning of estuarine systems on local and wider scales. The variables selected for the Estuarine Importance Rating Index were:

- Estuary size
- Zonal type rarity
- Habitat diversity
- Biodiversity importance
- Functional importance

Each of the above can be categorised as measures of rarity, abundance or ecological function. The rationale for selecting these variables, as well as further details on the estuarine importance index are discussed in detail in Appendix D of the *Resource directed measures for protection of water resource: Methodology for the Determination of the Ecological Water Requirements for Estuaries, Version 2* (DWAF, 2004).

For this study, the Ecological importance determination of the Seekoei Estuary was obtained from the *Estuarine Prioritisation for RDM* project (Turpie, 2004). The Functional Importance score, however, was derived at the Specialist Workshop held in Port Elizabeth on 25 February 2005.

The Estuarine Importance Index scores allocated to the Seekoei Estuary, based on its Present State, were as follows:

Estuary Size

Score	Motivation
90	Estuary size is defined as the total area (ha) within the geographical boundaries of the estuarine resource unit. Size is then converted to a measure of importance using scoring guidelines, which is based on 10% rank percentiles of estuaries of known size. With an area between 100.1- 200ha, the Seekoei Estuary is assigned a score of 90.

Zonal Type Rarity

Score	Motivation
10	The estuary is one of 85 temporarily closed within the warm temperate biogeographical zone. The Zonal Type Rarity index is thus 1/85 = 1. The score assigned is thus 10.

Habitat Diversity

Score	Motivation
80	This score is calculated on the basis of the amount of each habitat type present in the estuary in relation to the total area of this habitat in South African estuaries. The score (x ha/x ha) for each habitat is summed to obtain the rarity value. The value obtained falls within the eight 10% percentile for the scores generated.

Biodiversity Importance

Sub-components	Score	Motivation
Plants	80	This score is calculated by adding rarity scores for each species present in the estuary, where rarity scores for each species are calculated as 1/number of estuaries in which the species occurs in South Africa (based on actual records of presence). The summed value obtained falls within the third percentile for the scores generated from all South African estuaries, and is thus assigned a score of 80.
Invertebrates	100	This score is calculated by adding rarity scores for each species present in the estuary, where rarity scores for each species are calculated as 1/number of estuaries in which the species occurs in South Africa (based on interpolated presence records from species distributions). The summed value obtained falls within the top percentile for the scores generated from all South African estuaries, and is thus assigned a score of 100.
Fish	80	This score is calculated by adding rarity scores for each species present in the estuary, where rarity scores for each species are calculated as 1/number of estuaries in which the species occurs in South Africa (based on actual records of presence). The summed value obtained falls within the third percentile for the scores generated from all South African estuaries, and is thus assigned a score of 80.
Birds	90	This score is calculated by adding rarity scores for each species present in the estuary, where rarity scores for each species are calculated as 1/number of estuaries in which the species occurs in South Africa (based on actual records of presence). The summed value obtained falls within the second percentile for the scores generated from all South African estuaries, and is thus assigned a score of 90.
Biodiversity score	**85**	

Functional Importance

Sub-components	Score	Scoring guidelines
a. Estuary: Input of detritus and nutrients generated in estuary	20	None = 0 Little = 20 Some = 40 Important = 60 Very important = 80 Extremely important =100
b. Nursery function for marine-living fish and crustaceans	30	
c. Movement corridor for river invertebrates and fish breeding in sea	30	
d. Roosting area for marine or coastal birds	60	
e. Catchment detritus, nutrients and sediments to sea	20	
Functional Score	**60***	

* Using the maximum score of the above

The individual scores obtained above are incorporated into the final Estuarine Importance Score as illustrated in Table 3-5.

Table 3-5 Estuarine Importance scores for the Seekoei Estuary

Criterion	Score	Weight	Weighted Score
Estuary Size	90	15	14
Zonal Rarity Type	10	10	1
Habitat Diversity	80	25	20
Biodiversity Importance	85	25	18
Functional Importance	60	25	15
Estuarine Importance Score			71

The Estuarine Importance Score for the Seekoei Estuary, based on its Present State, is 71, indicating that the estuary is important, as indicated in Table 3-6.

Table 3-6 Interpretation of Estuarine Importance scores for estuaries

Importance Score	Description
81 – 100	Highly important
61 – 80	**Important**
0 – 60	Of low to average importance

3.6 Recommended Ecological Reserve Category for the Seekoei Estuary

The recommended Ecological Reserve Category (ERC) represents the level of protection assigned to an estuary. In turn, it is again used to determine the Ecological Reserve.

For estuaries the first step is to determine the 'minimum' ERC of an estuary, based on its Present Ecological Status (PES). The relationship between EHI Score, PES and ERC is set out in Table 3-7.

Table 3-7 Relationship between PES and minimum ERC

EHI Score	PES	Description	ERC
91 – 100	A	Unmodified, natural	A
76 – 90	B	Largely natural with few modifications	B
61 – 75	C	Moderately modified	C
41 – 60	D	Largely modified	D
21 – 40	E	Highly degraded	-
0 – 20	F	Extremely degraded	-

Note: Should the present status category of an estuary be either an E or F, recommendations must be made as to how the status can be elevated to at least achieve a Category D (as indicated above).

PES sets the minimum Ecological Reserve Category. The degree to which Ecological Category needs to be elevated higher than PES depends on level of **importance** and level of **protection or desired** protection of a particular estuary (Table 3-8).

Estuaries that currently have protected status and/or are on the current list of desired protected areas are given in Appendix C of the *Resource directed measures for protection of water resource: Methodology for the Determination of the Ecological Water Requirements for Estuaries, Version 2* (DWAF, 2004).

Table 3-8 Guidelines for assigning the Recommended Ecological Category

Current/desired protection status and Estuary Importance	Recommended Ecological Reserve Category	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 class
Important	PES + 1, min C	Important estuaries should be in an A, B or C class
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D class.

* BAS = Best Attainable State

The Seekoei Estuary is a Provincial Nature Reserve. According to the guidelines for assigning a recommended ERC, the estuary therefore needs to be in a Category A or the Best Attainable State (BAS).

At the specialist workshop (held on 25 February 2005 in Port Elizabeth) it was concluded that the changes that are mainly contributing to the Present State of the estuary are numerous farm dam developments in the catchment, the causeway running through the estuary, an increase in suspended solids in the inflowing water and artificial mouth manipulation.

At this stage, it is unlikely that these changes could be reversed sufficiently to attain a Category A. Therefore the workshop decided that it should be recommended that the Seekoei Estuary be improved into the highest achievable ERC, which is a **Category B**.

4. QUANTIFICATION OF ECOLOGICAL RESERVE SCENARIOS

4.1 Simulated Runoff Scenarios

Simulated Monthly Runoff was supplied to the estuarine team by Mr A Sparks, Ninham Shand Consulting Engineers. A summary of the various Simulated Monthly Runoff Scenarios is provided below.

Name	Seekoei Estuary	Volume (million m^3/year)	Percentage
Reference	Reference	20.27	100.0%
Present	Present Flows	11.36	56.0%
Scenario 1	River Class A release to the estuary	16.65	82.1%
Scenario 2	River Class B release to the estuary	11.97	59.1%
Scenario 3	River Class D release to the estuary	11.10	54.8%
Scenario 4	Limited Development	14.71	72.6%

The overall confidence in the hydrology is **Low** as limited accurate runoff data were available to base the Hydrological assessment on.

4.2 Scenario 1: River Class A Release to the Estuary

4.2.1 Abiotic Components

i. Seasonal variability in river inflow:

Monthly simulated runoff data for the Future Scenario 1 is provided in Table 4-1. A summary of flow distribution (mean monthly flows in m^3/s) for the Future Scenario 1, derived from the 73-year simulated data set, is provided below:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99%ile	**20.51**	**10.51**	**4.11**	1.56	**4.21**	**13.35**	**5.97**	**16.17**	**17.48**	**11.49**	**20.42**	**24.88**
90%ile	**6.43**	**4.83**	1.50	0.43	0.36	1.28	1.84	**2.57**	**2.58**	**2.51**	**3.79**	**7.06**
80%ile	**2.90**	**2.11**	0.73	0.41	0.35	0.67	0.63	1.07	1.37	1.65	**2.51**	**3.99**
70%ile	1.93	1.42	0.64	0.33	0.31	0.61	0.59	0.91	1.01	1.31	1.79	**2.37**
60%ile	1.45	1.15	0.47	0.25	0.21	0.41	0.47	0.75	0.82	1.09	1.41	1.68
50%ile	1.18	0.76	0.29	0.14	0.15	0.31	0.34	0.51	0.64	0.82	1.09	1.29
40%ile	0.98	0.52	0.16	0.08	0.08	0.19	0.20	0.33	0.46	0.55	0.48	0.97
30%ile	0.71	0.29	0.10	0.05	0.05	0.11	0.11	0.21	0.29	0.34	0.29	0.46
20%ile	0.40	0.20	0.08	0.05	0.04	0.08	0.07	0.12	0.16	0.19	0.17	0.32
10%ile	0.15	0.13	0.07	0.04	0.04	0.07	0.06	0.10	0.11	0.12	0.10	0.22
1%ile	0.10	0.12	0.07	0.04	0.04	0.06	0.05	0.08	0.07	0.09	0.09	0.20

ii. Predicted Flood regime for the Future Scenario 1

For the Seekoei, months with flows of $10m^3/s$ or more were estimated to be indicative of flood events.

Under Future Scenario 1 these events occur 21 times in the 73-year period, in comparison with the 26 under the Reference Condition. At present about 80% of the larger flood events still reach the estuary.

Confidence: Low

iii. Predicted sediment processes under Future Scenario 1 compared with Reference State:

Similar to Present State

Confidence: Low

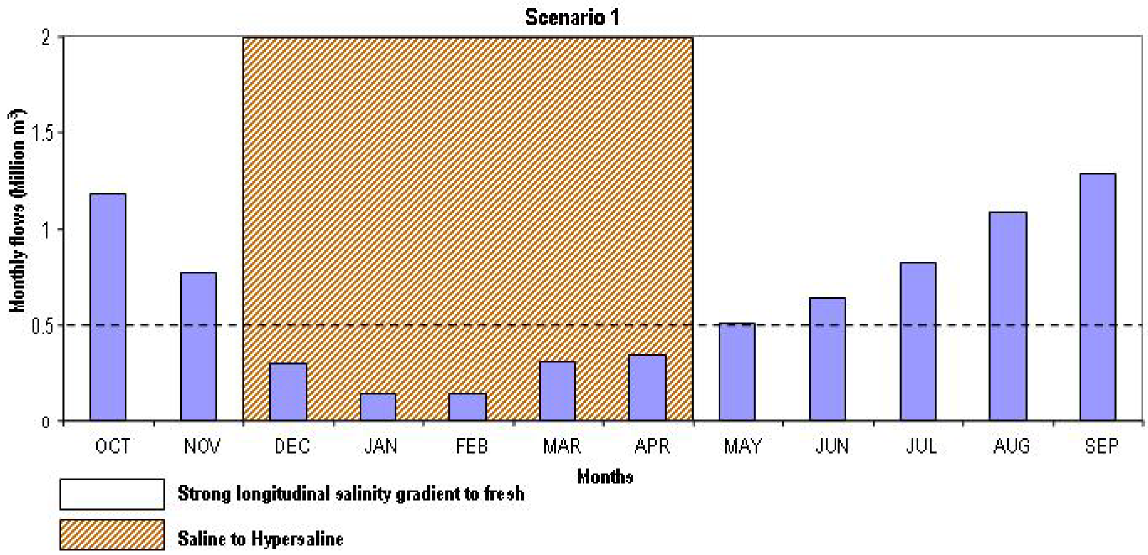
iv. Occurrence and duration of the Abiotic States during Scenario 1

An analysis of the Scenario 1 simulated monthly runoff indicates that the Seekoei Estuary would receive sufficient river inflow to breach during 93% of the years, i.e. in 5 out of 73 years the annual inflow is less than 3 million m^3 and the system will not breach.

The reduction in base flows to the system also implies that the estuary could close more easily, stay open for shorter periods than under the Reference Condition. Note that the estuary can maintain an open mouth for longer periods under the current culvert configuration in the causeway, but it will still close under high wave conditions and the reduction in baseflows will have some impact.

Under this Scenario the duration of a mouth closure might also be slightly longer than under the Reference Condition as the reduced inflow to the estuary implies that it would take longer to reach its breaching level and thereby re-establish its connection to the sea.

In years where the Seekoei Estuary is likely to be in Abiotic State 1: Open mouth, the monthly distribution between saline to hypersaline (median monthly flow < 0.5 million m^3) conditions versus conditions when the estuary develops a strong longitudinal salinity gradient to becoming fresh (median monthly flow > 0.5 million m^3) is estimated to be as follows for Scenario 1:



<u>Confidence</u>: Low

Table 4-1 Scenario 1 (River Class A): Simulated runoff data in million m^3 per month

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1927	0.19	0.14	0.10	0.08	0.27	0.60	0.49	0.44	0.68	1.09	0.84	1.50	6.41
1928	0.39	0.56	0.75	0.41	0.23	0.19	0.23	0.78	0.69	0.60	0.28	0.35	5.45
1929	0.32	**12.70**	**4.36**	0.42	0.35	0.51	0.47	0.94	1.20	1.69	1.77	1.21	25.94
1930	0.96	0.35	0.23	0.08	0.15	0.10	0.06	0.15	0.48	0.23	0.31	0.50	3.59
1931	1.18	0.50	0.74	0.21	0.04	0.34	0.60	0.90	0.85	0.59	0.48	**2.83**	9.25
1932	**2.00**	1.28	0.31	0.05	0.04	0.07	0.08	0.33	0.26	**2.57**	**2.99**	1.71	11.70
1933	**2.35**	**2.70**	0.70	0.25	0.15	0.44	0.20	0.75	0.51	0.17	0.56	0.47	9.24
1934	0.69	0.15	0.10	0.05	0.08	**14.00**	**5.95**	1.03	0.54	0.53	0.47	1.21	24.80
1935	1.00	1.36	0.59	0.08	0.04	0.07	0.06	0.31	0.34	1.00	0.38	**2.92**	8.15
1936	1.30	0.93	0.09	0.05	0.27	0.68	0.54	0.37	0.46	0.19	0.35	0.44	5.64
1937	0.73	0.35	0.07	0.05	0.04	0.43	0.29	0.13	0.11	1.33	0.45	0.99	4.96
1938	**9.40**	**3.77**	**3.12**	0.74	0.35	0.41	0.11	0.11	0.11	0.89	1.22	**35.52**	55.73
1939	**13.61**	**5.10**	1.92	0.39	0.17	0.09	0.05	0.33	0.23	0.12	**3.09**	**2.10**	27.20
1940	0.24	1.29	0.55	0.12	0.15	0.19	0.07	0.12	0.15	1.42	0.90	0.68	5.87
1941	**5.23**	1.98	0.44	0.05	0.05	0.08	0.47	**12.61**	**6.05**	1.91	1.82	1.51	32.19
1942	1.51	0.66	0.41	0.12	0.04	0.07	0.19	0.18	0.13	0.24	0.11	0.33	4.00
1943	1.03	**5.44**	1.83	0.30	0.05	0.27	0.07	0.10	0.64	0.32	0.38	1.67	12.10
1944	0.98	0.40	0.47	0.30	0.08	0.08	0.11	0.13	0.12	0.12	0.09	0.21	3.08
1945	0.11	0.15	0.07	0.04	0.36	0.68	0.53	0.54	0.40	0.48	**5.60**	**2.93**	11.90
1946	1.30	0.91	0.65	0.41	0.36	0.66	0.48	0.31	0.34	0.41	0.14	0.36	6.32
1947	0.14	0.24	0.07	0.04	0.04	0.07	0.06	0.10	1.02	0.75	0.16	0.31	3.00
1948	1.74	0.69	1.62	0.43	0.25	0.08	0.06	0.96	0.94	0.56	0.23	0.29	7.82
1949	1.15	1.26	0.10	0.32	0.18	0.10	0.08	0.11	0.97	1.19	1.40	**4.55**	11.40
1950	**2.26**	**2.19**	0.81	0.45	0.33	1.43	1.88	**25.34**	**9.78**	1.85	1.33	**2.31**	49.94
1951	1.32	0.30	0.07	0.05	0.04	0.07	0.05	1.16	**2.46**	1.30	**3.34**	**2.45**	12.61
1952	**7.35**	**3.07**	0.25	0.05	0.05	**4.00**	**2.05**	0.25	0.36	0.87	1.49	1.29	21.08
1953	1.12	0.19	0.07	0.04	0.04	0.67	0.47	0.97	1.29	**3.35**	**2.34**	1.02	11.58
1954	0.39	0.25	0.13	0.06	0.04	0.11	**2.54**	1.45	0.54	0.62	0.83	0.44	7.40
1955	**3.66**	1.84	0.23	0.05	0.04	0.07	0.05	0.09	0.07	0.07	0.09	0.19	6.45
1956	0.10	**9.55**	**4.02**	0.07	0.05	0.07	0.58	0.51	0.13	0.34	**2.39**	1.89	19.70
1957	1.45	**2.59**	1.05	**3.43**	1.20	0.49	0.10	0.41	0.56	1.69	1.69	**11.72**	26.38
1958	**5.00**	0.43	0.29	0.38	0.36	0.34	0.07	0.83	0.72	0.31	1.41	**6.93**	17.07
1959	**3.40**	0.95	0.63	0.25	0.23	0.18	0.06	0.10	0.19	0.89	**3.03**	**14.05**	23.95
1960	**30.07**	**9.66**	0.69	0.36	0.07	**6.68**	**4.07**	**11.05**	**4.99**	**5.39**	**15.40**	**5.65**	94.07
1961	0.95	0.26	0.23	0.11	**2.69**	**2.20**	0.92	0.54	0.46	0.53	**8.60**	**3.85**	21.32
1962	1.39	1.20	0.66	0.15	0.20	0.61	0.34	**4.98**	**2.70**	1.42	1.38	**4.83**	19.84
1963	**16.79**	**6.55**	**2.92**	0.83	0.49	0.65	0.49	0.51	1.38	1.60	**2.24**	**16.00**	50.43
1964	**6.85**	1.45	0.17	0.05	0.04	0.61	0.34	**3.17**	**2.59**	1.17	**2.70**	**2.20**	21.32
1965	1.71	1.09	0.13	0.55	0.36	0.68	1.71	1.42	0.94	1.21	1.86	1.63	13.28
1966	1.46	0.85	0.23	0.41	0.32	0.11	0.08	0.89	0.83	1.56	1.77	1.48	9.99
1967	0.73	0.27	0.07	0.11	0.33	0.68	0.64	**2.49**	**2.21**	1.71	1.72	1.29	12.24
1968	0.62	0.19	0.08	0.05	0.08	0.63	0.62	0.76	0.31	0.15	**2.60**	**2.11**	8.21
1969	0.67	0.23	0.07	0.41	0.31	0.69	0.97	0.98	0.85	0.82	1.09	0.81	7.89
1970	0.60	0.13	0.73	0.42	0.34	0.40	0.25	0.16	**3.36**	**2.27**	1.38	**5.95**	15.98
1971	**3.05**	1.94	0.68	0.15	0.05	0.07	0.16	0.85	0.64	0.31	0.14	0.25	8.29
1972	1.70	**2.90**	0.72	0.41	0.35	0.38	0.16	0.23	0.18	0.12	0.23	0.40	7.78
1973	0.43	0.65	0.25	0.07	0.18	0.32	0.60	1.10	1.37	1.09	1.66	1.88	9.58
1974	0.86	0.24	0.08	0.04	0.04	0.09	0.63	0.92	**17.91**	**7.95**	**2.21**	**4.08**	35.04
1975	1.90	0.73	0.13	0.07	0.07	0.27	0.10	0.11	0.12	0.12	0.10	0.21	3.92
1976	0.42	0.12	0.07	0.05	0.05	0.07	0.05	0.07	0.06	0.10	0.10	0.21	1.37
1977	0.13	0.13	0.47	0.21	0.08	0.27	**6.02**	**4.50**	1.98	**11.44**	**24.36**	**7.97**	57.55
1978	1.25	1.18	0.30	0.05	0.15	0.15	0.20	0.23	0.26	0.18	0.48	0.65	5.07
1979	0.10	0.12	0.07	0.04	0.04	0.15	0.19	0.63	0.35	0.12	0.09	0.21	2.12
1980	0.10	0.17	0.08	0.41	0.36	**2.70**	1.62	1.42	1.35	1.01	**2.35**	**4.29**	15.87
1981	**2.52**	0.39	0.09	0.32	0.18	0.23	0.07	0.09	0.10	0.23	0.17	1.20	5.59
1982	0.21	0.13	0.07	0.05	0.04	0.64	**3.43**	**2.71**	1.35	**7.24**	**3.64**	1.63	21.15
1983	**3.41**	1.97	0.55	0.07	0.36	0.57	0.55	**2.59**	**2.52**	1.42	0.82	**7.09**	21.92
1984	**2.93**	1.69	0.84	0.35	0.04	0.69	1.23	0.90	1.06	1.23	0.94	0.70	12.59
1985	1.38	**2.36**	0.74	0.44	0.36	0.43	0.20	0.26	0.48	1.57	**18.89**	**7.92**	35.04
1986	1.98	0.76	0.13	0.32	0.15	0.07	0.37	0.17	0.19	0.14	0.09	0.21	4.58
1987	0.73	0.67	0.10	0.84	0.78	**13.09**	**5.17**	1.64	1.64	1.26	**4.43**	**2.75**	33.09
1988	**2.85**	1.48	0.37	0.14	0.08	0.22	0.61	0.59	0.15	0.20	0.28	0.44	7.40
1989	1.02	0.53	0.07	0.04	0.04	0.06	0.03	0.09	0.10	**11.62**	**5.56**	1.09	20.25
1990	1.10	0.18	0.07	0.04	0.04	0.15	0.06	0.09	0.10	0.41	0.13	0.23	2.61
1991	0.10	0.12	0.07	0.43	0.36	0.34	0.16	0.12	0.64	0.56	0.17	0.21	3.29
1992	0.84	1.14	0.43	0.40	0.27	0.15	0.06	0.10	0.10	0.11	0.17	0.27	4.03
1993	1.51	1.40	0.55	0.11	0.05	0.08	0.23	0.13	1.00	0.69	0.14	1.27	7.15
1994	0.21	0.12	0.07	0.04	0.33	0.31	0.47	0.42	0.82	0.51	0.28	0.31	3.90
1995	0.11	0.12	0.07	0.06	0.18	0.10	0.62	0.71	0.19	0.14	0.09	0.22	2.61
1996	**6.73**	**6.72**	1.08	0.15	0.36	0.65	0.64	0.97	**2.08**	1.68	1.20	0.90	23.16
1997	**2.52**	1.06	0.13	0.05	0.08	0.08	0.05	0.10	0.12	0.11	0.10	0.21	4.61
1998	0.40	0.21	0.47	0.15	**8.12**	**3.43**	0.41	0.42	0.77	0.85	**3.83**	**2.78**	21.84
1999	**9.84**	**7.66**	1.60	0.25	0.04	0.06	0.61	0.54	**17.32**	**7.41**	1.23	**20.75**	67.29
Median	1.18	0.76	0.29	0.14	0.15	0.31	0.34	0.51	0.64	0.82	1.09	1.29	11.40
Average	2.54	1.69	0.59	0.26	0.34	0.92	0.74	1.40	1.49	1.47	2.14	3.05	16.65

Monthly > 2 mil m3 Annual < 3 mil

EHI for the Future Scenario 1

Hydrology

Variable	Score	Motivation	Confidence
1a. % similarity in period of low flows or Present MAR as a % of MAR in the Reference Condition	82	Under Scenario 1 the Seekoei has an MAR of 16.65 million m^3 in comparison of with the Reference Condition of 20.27 million m^3. Under Scenario 1, 82% of the runoff is still reaching the estuary.	L
1b. % similarity in mean annual frequency of floods	80	For the Seekoei months with flows of $10m^3/s$ or more were estimated to be indicative of flood events. Under Scenario 1 these events occur 21 times in the 73-year period, in comparison with the 26 under the Reference Condition. Under Scenario 1 about 80% of the larger flood events still reach the estuary.	L
Hydrology score	**81**		

Hydrodynamics and mouth condition

Variable	Score	Motivation	Confidence
Change in mean duration of closure, e.g. over a 5 or 10-year period	85	Under Scenario 1 the potential occurrence of open mouth conditions has been reduced to 93% (5 out of 73 years will not have breaching) from nearly permanently open (99%) under the Reference Condition. Following the guidelines stipulated in Table 3.3b (DWAF 2004), this results in a score of 85.	L
Hydrodynamics and mouth conditions Score	**85**		

Water quality

Variable	Score	Motivation	Confidence
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	80	During the Reference Condition, State 1: Open mouth prevailed for nearly 100% of the years within the simulation period. From May to Dec a strong longitudinal salinity gradient to fresh conditions would have occurred. Hypersalinity should not have been an issue. Under Scenario 1, State 1: Open mouth occurs for 93% of the years within the simulation period, indicating some decrease in the presence of strong salinity gradients to fresh conditions in the estuary. Within State 1, strong longitudinal salinity gradient to fresh conditions occurs from May to Nov. Under Scenario 1, State 2: Closed mouth would not occur for extended periods at a time as the river inflow is still sufficient enough to cause breaching after a few weeks. Hypersaline conditions are not likely to occur.	L
2a. Nitrate/phosphate (inorganic nutrients) concentration in the estuary	52	The rivers (Swart and Seekoei) are the major inorganic nutrient sources to the Seekoei Estuary. With extensive agricultural development in the catchment, it is expected that nutrient concentrations in river inflow will also be higher compared to the Reference Condition. Using modifications in MAR as proxy for modification in inorganic nutrients: The MAR reduced from 20.27 million m^3 in the Reference Condition to 16.65 million m^3 under Scenario 1 (i.e. a reduction of 18%). Based on modification to river inflow, inorganic nutrient levels were reduced to about 82% of the Reference Condition. Furthermore, agricultural activities in the catchment introduce higher inorganic nutrients into river inflow compared to the Reference Condition. Thus, river inflow will introduce higher nutrients into the system compared to the Reference Condition. Assume an additional modification of 30%.	
2b. Suspended solids present in inflowing freshwater	52	River inflow into the estuary is expected to be one of the major sources of turbidity in the estuary. With extensive agricultural development in the catchment, turbidity levels in river inflow will also be higher compared to the Reference Condition.	

		Using modifications in MAR as proxy for modification in turbidity: The MAR reduced from 20.27 million m^3 in the Reference Condition to 16.65 million m^3 under the Present State (i.e. a reduction of 18%). Based on modification to river inflow, turbidity levels were reduced to about 82% of Reference Condition. Furthermore, agricultural activities in the catchment have introduced higher turbidity levels into river inflow compared to the Reference Condition. Thus river inflow will introduce higher turbidity into the system compared to the Reference Condition. Assume an additional modification of 30%.	
2c. Dissolved oxygen in the estuary	100	The Seekoei Estuary should generally be well-oxygenated, being a shallow system (i.e. even during periods of low or no river inflow wind mixing maintains oxygenated conditions).	
2d. Levels of toxins	70	There are no major urban or industrial areas in the catchment. However, extensive agricultural developments probably introduce some toxic substances (e.g. pesticides) into the system. Allow for a 30% change from Reference Condition to Scenario 1 – 10% more than for the Present State as runoff to the estuary increased.	
Water quality score	**63.2**		

Physical habitat alteration

Variable	Score	Motivation	Confidence
1. Resemblance of <u>intertidal sediment</u> structure and distribution to Reference Condition			
1a. % similarity in intertidal area exposed	75	Less change in the intertidal areas as open mouth conditions occur 93% of the time. Some small changes in intertidal area due to the construction of the causeway.	L
1b. % similarity in sand fraction relative to total sand and mud	60	More muddy substrate due to land-use changes and reduce tidal flushing	L
2. Resemblance of subtidal estuary to Reference Condition: depth, bed or channel morphology	85	Less change in the intertidal areas as open mouth conditions occur 93% of the time. Still some changes will occur because of the stabilised channel configuration due to the causeway, the shallower areas between the mouth, the causeway and the main channels are potentially deeper especially near or at the causeway where the flow are restricted.	L
Physical habitat score	**76**		

4.2.2 Biotic Components

i. Predicted change in biotic characteristics of the future Scenario 1 compared with the Reference Condition, as well as the <u>causes</u> of these changes:

Microalgae
Baseflow is improved compared to the Present Condition. There is a longitudinal salinity gradient and freshwater, brackish and marine species should all be present. The increase in freshettes and inorganic nutrients would result in some phytoplankton biomass. However, agricultural enrichment may increase the occurrence of nuisance groups such as dinoflagellates (saline conditions) and blue-green algae (freshwater conditions). Confidence: Medium
Macrophytes
Brackish reed and sedge species and the pondweed, *Potamogeton pectinatus*, would return to the estuary if salinity in the upper reaches remained less than 15 ppt for approximately 4 months. Submerged macrophyte and filamentous algal biomass would be similar to the Reference Condition due to an increase in the frequency of open mouth conditions and a longitudinal salinity gradient. However the area covered by salt marsh plants would be smaller than that for the Reference Condition because of the unnatural water level fluctuations caused by the causeway. Inorganic nutrient input from surrounding agricultural activities may increase the occurrence of filamentous green algal mats. Confidence: Medium
Invertebrates (including zooplankton, benthic invertebrates and macrocrustaceans)
Because of increased baseflow, a salinity gradient would develop along the estuary and this would be suitable for the establishment of distinct communities along the gradient. Typical estuarine species would be well established with a relatively high biomass. A brackish water community will also become well established leading to greater species richness compared to present. Confidence: Medium
Fish
Fish composition and abundance would be similar to the Reference Condition due to the improved baseflow and mostly open mouth state. Recovery of the planktonic food chain would result in a more abundant planktivorous fish assemblage when compared to the Present State. Confidence: Medium
Birds
Avifaunal composition and abundance could be expected to recover to close to the Reference State, due to recovery of habitat, food supplies and maintenance of more stable estuarine conditions. Confidence: Medium

ii. EHI for the future scenario:

Microalgae

Variable	Score	Motivation	Confidence
Phytoplankton			
1. Species richness	80 (90%)	Baseflow is improved compared to the Present Condition. There is a longitudinal gradient and freshwater, brackish and marine species should all be present. 90% of the original species probably remain.	M
2a. Abundance	80	The increase in freshettes and pulses of inorganic nutrient rich freshwater inflow would result in an increase in phytoplankton biomass compared to Reference. Phytoplankton biomass was probably never very significant in the Seekoei Estuary (< 2 µg l^{-1}).	M
2b. Community composition	70	Freshwater, brackish and saline groups would be present. Increased flow and associated inorganic nutrient input from the surrounding agricultural areas may result in nuisance groups such as dinoflagellates (saline conditions) and	M

		blue-green algae (freshwater conditions).	
Benthic microalgae			
1. Species richness	70 (85%)	Baseflow is improved compared to the present condition. There is a longitudinal gradient and freshwater, brackish and marine species should all be present. The increase in muddy sediment upstream of the causeway can result in the loss of sand loving species. 85% of the original species probably remain.	M
2a. Abundance	80	The increase in open mouth conditions compared to Present would return the system closer to that of natural where subtidal benthic microalgal biomass was probably quite low. The increase in nutrients from surrounding agriculture could increase biomass. However, tidal flows would probably limit the development of high biomass.	M
2b. Community composition	70	The estuary would be more dynamic than at Present with floods and freshettes promoting primary colonisers and freshwater, brackish and saline assemblages. Increased flow and associated inorganic nutrient input from the surrounding agricultural areas may result in nuisance groups such as blue-green algae (freshwater conditions).	M
Microalgae score	**70**		

Macrophytes

Variable	Score	Motivation	Confidence
1. Species richness	70 (85%)	Brackish reed and sedge species and pondweed, *Potamogeton pectinatus*, would return to the estuary if salinity in the upper reaches remained less than 15 ppt for approximately 4 months. Hypersaline conditions no longer occur and therefore 85% of the original species remain. Agricultural nutrient input may promote the growth of weedy species that would outcompete other species.	M
2a. Abundance	80	Submerged macrophyte and filamentous algal biomass would return to the Reference Condition due to an increase in the frequency of open mouth conditions and a natural salinity gradient. Their biomass would be dependent on flow velocity and the availability of nutrients. The area covered by salt marsh plants may be reduced due to unnatural water level fluctuations caused by the causeway.	M
2b. Community composition	70	An increase in the frequency of open mouth conditions and a longitudinal salinity gradient would mean that freshwater, brackish and saline species would be present. Inorganic nutrient input from surrounding agricultural activities may increase the occurrence of filamentous green algal mats.	M
Macrophytes score	**70**		

Invertebrates

Variable	Score	Motivation	Confidence
Zooplankton			
1. Species richness	80 (90%)	A strong salinity gradient along the estuary would allow maximum species richness to develop that would be similar to the Reference Condition.	L
2a. Abundance	90	Abundance levels would be similar to the Reference Condition because of the full salinity gradient. Food availability would be greater and typical estuarine species would reach high levels. No severe hypersaline conditions would develop causing crashes in abundance that are presently experienced.	L
2b. Community composition	80	The brackish water component would be similar to that under the Reference Condition, but would decline or disappear during 1 month of hypersalinity.	L
Macroinvertebrates			
1. Species richness	80 (90%)	A strong salinity gradient along the estuary would allow maximum species richness to develop that would be similar to the Reference Condition.	L
2a. Abundance	85	Abundance levels would be similar to the Reference Condition because of the full salinity gradient. Food availability would be greater and typical estuarine species would reach high levels. No severe hypersaline conditions would develop causing crashes in abundance that are presently experienced.	L
2b. Community composition	75	The brackish water component would be similar to that under the Reference Condition, but would decline or disappear during 1 month of hypersalinity.	L
Macrocrustacea			
1. Species richness	80 (90%)	A strong salinity gradient along the estuary would allow maximum species richness to develop that would be similar to the Reference Condition.	L
2a. Abundance	85	Abundance levels would be similar to the Reference Condition because of the full salinity gradient. Food availability would be greater and typical estuarine species would reach high levels. No severe hypersaline conditions would develop causing crashes in abundance that are presently experienced.	L
2b. Community composition	75	The brackish water component would be similar to that under the Reference Condition, but would decline or disappear during 1 month of hypersalinity.	L
Invertebrates score	**75**		

Fish

Variable	Score	Motivation	Confidence
1. Species richness	80 (90%)	All the marine and estuarine species will be present, with only a few freshwater species missing during low flow periods due to an increase in salinities.	M
2a. Abundance	90	Fish abundance is likely to be very close to the natural (Reference) state due to the more natural functioning of the aquatic food web.	M
2b. Community composition	90	Fish community composition is also likely to closely resemble the Reference state due to the increased open mouth conditions and normal salinity gradient within the estuary.	M
Fish score	**80**		

Birds

Variable	Score	Motivation	Confidence
1. Species richness	90 (95%)	Most, if not all, of the original species should be found in the system	M
2a. Abundance	80	Abundance levels of different groups are expected to be more stable. Recovery of habitat and food supply leads to increased abundance in a typical estuary state.	M
2b. Community composition	80	Community composition would more consistently resemble the typical estuarine state. Freshwater species occur more consistently in the upper estuary.	M
Bird score	**80**		

4.3 Scenario 2: River Class B Release to the Estuary

4.3.1 Abiotic Components

i. Seasonal variability in river inflow

Monthly simulated runoff data for the Future Scenario 2 is provided in Table 4-2. A summary of flow distribution (mean monthly flows in m^3/s) for the Future Scenario 2, derived from the 73-year simulated data set, is provided below:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99%ile	**19.70**	**6.94**	**3.29**	0.37	0.64	**6.27**	**5.37**	**15.09**	**11.40**	**8.96**	**17.60**	**23.91**
90%ile	**3.09**	**2.99**	0.28	0.22	0.19	0.22	0.37	1.14	1.47	1.61	**2.17**	**5.52**
80%ile	1.63	1.11	0.28	0.22	0.19	0.22	0.36	1.00	0.64	0.68	1.40	**2.93**
70%ile	0.82	0.68	0.27	0.21	0.18	0.21	0.35	0.87	0.56	0.61	0.74	**2.20**
60%ile	0.70	0.62	0.25	0.20	0.16	0.19	0.32	0.74	0.49	0.53	0.61	1.80
50%ile	0.60	0.55	0.22	0.17	0.15	0.18	0.29	0.54	0.38	0.42	0.44	1.40
40%ile	0.43	0.44	0.18	0.14	0.12	0.14	0.24	0.43	0.32	0.34	0.36	1.07
30%ile	0.30	0.31	0.13	0.10	0.09	0.10	0.17	0.31	0.23	0.23	0.28	0.76
20%ile	0.18	0.19	0.07	0.07	0.05	0.07	0.11	0.18	0.14	0.14	0.17	0.46
10%ile	0.10	0.11	0.05	0.04	0.04	0.04	0.06	0.11	0.08	0.08	0.09	0.25
1%ile	0.07	0.08	0.04	0.03	0.02	0.03	0.04	0.08	0.06	0.06	0.07	0.18

ii. Predicted flood regime for the Future Scenario 2

For the Seekoei months with flows of $10m^3/s$ or more were estimated to be indicative of flood events. Under Scenario 2 these events would occur 16 times in the 73-year period, in comparison with 26 under the Reference Conditions and also 16 times under present day conditions. Under Scenario 2 about 62% of the larger flood events still reaches the estuary.

Confidence: Low

iii. Predicted sediment processes under Future Scenario 2 compared with Reference State

Similar to Present State

Confidence: Low

iv. Occurrence and duration of the Abiotic States during the Scenario 2

An analysis of the Scenario 2 simulated monthly runoff indicates that the Seekoei Estuary currently receives sufficient river inflow to breach about 85% of the years, i.e. in 11 out of 73 years the annual inflow is less than 3 million m^3 and the system will not breach.

The reduction in baseflows to the system also implies that the estuary could close more easily, stay open for shorter periods than under the Reference Condition. Note that the estuary can maintain an open mouth for longer periods under the current culvert configuration in the causeway, but it will still close under high wave conditions and the reduction in baseflows will have some impact.

Under this Scenario, the duration of a mouth closure might also be longer as the reduced inflow to the estuary implies that it would take longer to reach its breaching level and thereby re-establish its connection to the sea.

In years where the Seekoei Estuary is likely to be in Abiotic State 1: Open mouth, the monthly distribution between saline to hypersaline (median monthly flow < 0.5 million m^3) conditions versus conditions when the estuary develops a strong longitudinal salinity gradient to becoming fresh (median monthly flow > 0.5 million m^3) is estimated to be as follows for Scenario 2:

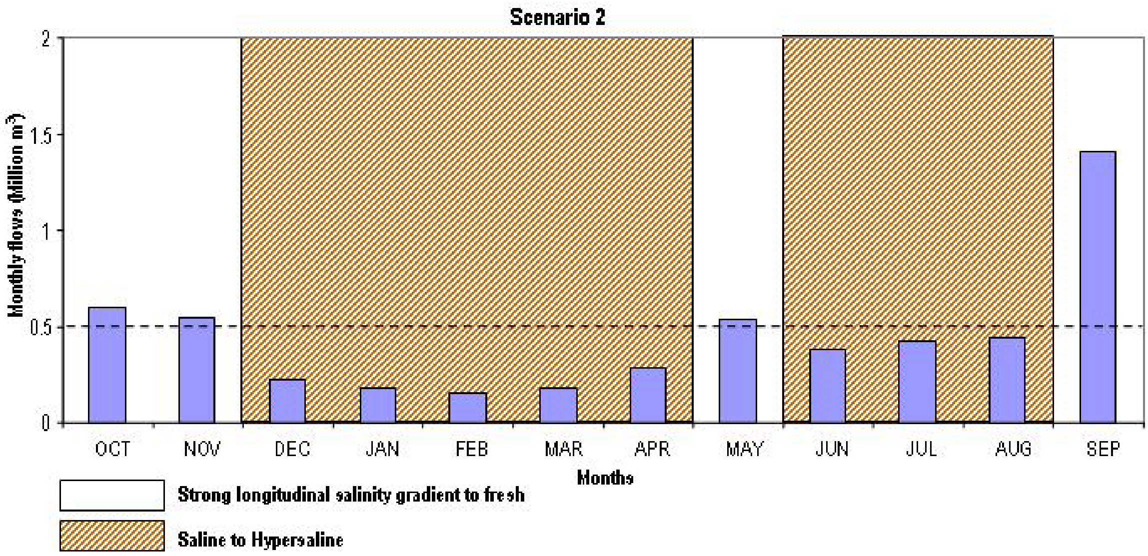


Table 4-2 Scenario 2 (River Class B): Simulated runoff data in million m^3 per month

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1927	0.28	0.14	0.13	0.14	0.18	0.21	0.33	0.50	0.40	0.54	0.58	1.80	5.24
1928	0.43	0.44	0.28	0.22	0.17	0.15	0.25	0.76	0.41	0.37	0.29	0.46	4.21
1929	0.12	**5.51**	**3.10**	0.22	0.19	0.21	0.32	0.92	0.59	0.65	0.88	1.17	13.87
1930	0.32	0.45	0.21	0.14	0.15	0.09	0.06	0.25	0.33	0.19	0.31	0.87	3.38
1931	0.35	0.52	0.26	0.19	0.04	0.18	0.35	0.86	0.51	0.36	0.39	**2.21**	6.22
1932	0.67	0.57	0.23	0.08	0.06	0.04	0.14	0.44	0.23	0.72	0.71	1.90	5.78
1933	0.73	0.75	0.27	0.20	0.15	0.20	0.24	0.74	0.34	0.12	0.44	0.83	5.01
1934	0.10	0.20	0.13	0.08	0.12	**7.53**	**5.93**	1.30	0.49	0.55	0.32	1.13	17.88
1935	0.43	0.64	0.26	0.14	0.04	0.04	0.07	0.42	0.27	0.51	0.36	**2.38**	5.56
1936	0.67	0.36	0.12	0.05	0.18	0.22	0.34	0.46	0.32	0.14	0.34	0.76	3.94
1937	0.27	0.14	0.04	0.06	0.03	0.20	0.27	0.19	0.07	0.61	0.39	1.29	3.57
1938	**2.91**	**3.10**	1.67	0.22	0.18	0.19	0.17	0.14	0.08	0.39	0.34	**34.49**	43.89
1939	**13.15**	**4.63**	0.86	0.21	0.15	0.09	0.04	0.44	0.21	0.06	0.75	**2.03**	22.62
1940	0.13	0.64	0.26	0.16	0.15	0.15	0.11	0.17	0.14	0.65	0.61	1.06	4.22
1941	0.82	0.68	0.18	0.08	0.09	0.07	0.32	**8.04**	**6.05**	1.66	1.48	1.80	21.28
1942	0.69	0.56	0.24	0.16	0.06	0.05	0.23	0.30	0.10	0.19	0.10	0.27	2.96
1943	0.53	0.69	0.28	0.20	0.09	0.17	0.11	0.10	0.38	0.23	0.12	1.47	4.36
1944	0.40	0.47	0.25	0.20	0.12	0.07	0.17	0.19	0.10	0.08	0.07	0.18	2.29
1945	0.12	0.20	0.06	0.04	0.19	0.22	0.34	0.56	0.30	0.31	0.79	**2.37**	5.48
1946	0.56	0.62	0.27	0.22	0.19	0.22	0.33	0.42	0.27	0.28	0.16	0.61	4.12
1947	0.10	0.13	0.05	0.03	0.02	0.04	0.07	0.12	0.64	0.42	0.20	0.61	2.42
1948	0.66	0.56	0.28	0.22	0.17	0.07	0.06	0.96	0.56	0.35	0.26	0.54	4.67
1949	0.62	0.54	0.12	0.21	0.16	0.09	0.14	0.14	0.57	0.57	0.70	**2.62**	6.48
1950	0.70	0.77	0.28	0.21	0.18	0.22	0.40	**25.32**	**9.76**	1.94	1.10	**2.49**	43.35
1951	0.58	0.40	0.06	0.04	0.04	0.03	0.04	1.09	0.67	0.58	0.72	**2.20**	6.46
1952	**6.51**	**2.56**	0.22	0.07	0.09	0.22	0.95	0.37	0.14	0.61	1.62	1.40	14.75
1953	1.34	0.10	0.04	0.03	0.02	0.22	0.32	1.01	0.65	0.70	**2.03**	1.13	7.58
1954	0.21	0.18	0.16	0.10	0.03	0.11	0.37	1.02	0.33	0.14	0.11	0.34	3.09
1955	1.27	1.54	0.21	0.07	0.04	0.03	0.04	0.08	0.06	0.06	0.07	0.18	3.63
1956	0.07	**4.81**	**3.78**	0.12	0.09	0.05	0.35	0.54	0.10	0.23	0.67	1.71	12.52
1957	0.71	1.27	0.28	0.77	0.19	0.21	0.16	0.32	0.31	1.10	1.80	**11.28**	18.39
1958	**4.71**	0.48	0.23	0.21	0.19	0.18	0.11	0.80	0.43	0.23	0.52	**4.34**	12.43
1959	**3.13**	0.62	0.27	0.20	0.17	0.14	0.08	0.12	0.18	0.47	0.75	**11.63**	17.75
1960	**29.17**	**8.82**	0.27	0.21	0.11	**3.79**	**4.07**	**11.11**	**4.83**	**5.43**	**15.02**	**4.97**	87.80
1961	0.40	0.26	0.21	0.16	0.19	0.22	0.65	0.56	0.32	0.32	**7.88**	**3.14**	14.30
1962	0.98	0.64	0.27	0.18	0.16	0.21	0.29	1.58	**2.16**	1.43	1.27	**4.27**	13.44
1963	**16.01**	**5.74**	**2.36**	0.22	0.19	0.22	0.33	0.54	0.62	0.61	1.79	**16.15**	44.77
1964	**6.23**	1.23	0.18	0.04	0.02	0.21	0.29	1.14	0.69	0.48	1.81	**2.11**	14.45
1965	1.55	1.07	0.16	0.22	0.19	0.22	0.36	0.98	0.55	0.53	0.67	1.71	8.20
1966	0.62	0.55	0.21	0.22	0.18	0.11	0.14	0.85	0.50	0.68	0.62	1.28	5.96
1967	0.29	0.26	0.06	0.16	0.18	0.22	0.36	1.09	0.64	0.64	0.59	1.06	5.54
1968	0.23	0.18	0.08	0.08	0.12	0.21	0.36	0.75	0.26	0.11	0.74	**2.04**	5.16
1969	0.37	0.29	0.04	0.22	0.18	0.22	0.36	0.92	0.51	0.36	0.36	0.75	4.59
1970	0.13	0.13	0.28	0.22	0.18	0.19	0.26	0.27	0.71	0.68	0.39	**3.96**	7.41
1971	**2.32**	1.42	0.27	0.18	0.09	0.04	0.21	0.82	0.38	0.23	0.16	0.37	6.49
1972	0.71	0.69	0.28	0.22	0.19	0.19	0.21	0.35	0.17	0.08	0.26	0.76	4.08
1973	0.18	0.39	0.22	0.12	0.16	0.18	0.35	1.06	0.57	0.54	0.56	1.80	6.13
1974	0.45	0.35	0.08	0.04	0.04	0.09	0.36	0.89	**11.61**	**8.00**	**2.20**	**4.12**	28.22
1975	0.79	0.56	0.16	0.12	0.11	0.17	0.16	0.16	0.09	0.08	0.07	0.18	2.63
1976	0.07	0.08	0.04	0.04	0.09	0.04	0.04	0.07	0.06	0.06	0.07	0.18	0.83
1977	0.18	0.10	0.25	0.19	0.12	0.17	0.94	**4.48**	1.98	**11.43**	**24.23**	**7.42**	51.48
1978	1.09	1.14	0.23	0.07	0.15	0.13	0.24	0.35	0.23	0.13	0.21	0.34	4.29
1979	0.07	0.08	0.04	0.03	0.06	0.13	0.23	0.63	0.27	0.08	0.07	0.18	1.85
1980	0.07	0.26	0.08	0.22	0.19	0.22	0.36	0.93	0.56	0.43	1.52	**3.68**	8.51
1981	**2.56**	0.37	0.11	0.21	0.16	0.16	0.11	0.08	0.06	0.19	0.21	1.58	5.77
1982	0.29	0.13	0.06	0.06	0.04	0.21	0.37	1.09	0.58	**6.92**	**3.18**	1.83	14.77
1983	**2.16**	1.14	0.26	0.12	0.19	0.21	0.34	1.14	0.68	0.56	0.37	**5.66**	12.82
1984	1.69	0.72	0.28	0.21	0.04	0.22	0.36	0.86	0.53	0.48	0.42	0.91	6.73
1985	0.50	0.68	0.28	0.22	0.19	0.20	0.24	0.38	0.33	0.69	**15.02**	**7.57**	26.28
1986	**2.03**	0.49	0.16	0.21	0.15	0.04	0.30	0.28	0.18	0.09	0.07	0.18	4.18
1987	0.60	0.56	0.13	0.22	0.19	**5.78**	**5.15**	1.49	1.66	0.97	**4.27**	**2.28**	23.31
1988	1.90	0.66	0.24	0.17	0.12	0.15	0.36	0.60	0.13	0.16	0.29	0.71	5.48
1989	0.18	0.10	0.04	0.03	0.02	0.03	0.03	0.08	0.06	**5.90**	**5.46**	1.07	12.99
1990	0.81	0.26	0.06	0.03	0.02	0.13	0.07	0.08	0.06	0.28	0.14	0.30	2.24
1991	0.07	0.08	0.05	0.22	0.19	0.18	0.21	0.18	0.38	0.35	0.21	0.25	2.35
1992	0.13	0.55	0.25	0.22	0.18	0.13	0.08	0.10	0.06	0.06	0.21	0.46	2.40
1993	0.74	0.66	0.26	0.16	0.09	0.07	0.25	0.19	0.60	0.40	0.16	1.64	5.22
1994	0.30	0.08	0.04	0.03	0.18	0.18	0.32	0.49	0.49	0.33	0.29	0.61	3.33
1995	0.10	0.08	0.06	0.10	0.16	0.09	0.36	0.71	0.18	0.09	0.07	0.27	2.26
1996	0.85	**5.24**	0.28	0.18	0.19	0.22	0.36	0.99	0.68	0.65	0.49	1.11	11.25
1997	0.74	0.64	0.16	0.08	0.12	0.07	0.04	0.10	0.09	0.06	0.09	0.25	2.43
1998	0.43	0.32	0.25	0.18	1.79	**2.20**	0.31	0.49	0.46	0.46	1.27	**2.29**	10.45
1999	**8.13**	**6.20**	0.28	0.20	0.04	0.03	0.35	0.56	**11.33**	**6.82**	0.56	**19.80**	54.30
Median	0.60	0.55	0.22	0.17	0.15	0.18	0.29	0.54	0.38	0.42	0.44	1.40	5.96
Average	1.79	1.07	0.33	0.15	0.15	0.40	0.46	1.21	0.99	1.01	1.55	2.86	11.97

Monthly > 2 mil m^3

Annual < 3 mil m^3

v. EHI for the Future Scenario 2

Hydrology

Variable	Score	Motivation	Confidence
1a. % similarity in period of low flows OR Present MAR as a % of MAR in the Reference Condition	59	Under Scenario 2 the Seekoei has a MAR of 11.97 million m^3 in comparison with the Reference Condition of 20.27 million m^3. At present 59% of the runoff is still reaching the estuary.	L
1b. % similarity in mean annual frequency of floods	62	For the Seekoei months with flows of $10m^3/s$ or more were estimated to be indicative of flood events. Under Scenario 2 these events occur 16 times in the 73-year period, in comparison with 26 under the Reference Condition. At present about 62% of the larger flood events still reach the estuary.	L
Hydrology score	**60**		

Hydrodynamics and mouth condition

Variable	Score	Motivation	Confidence
Change in mean duration of closure, e.g. over a 5 or 10 year period	45	Under Scenario 2 the potential occurrence of open mouth conditions has been reduced to 85% (11 out of 73 years the system will not breach) from nearly permanently open (99%) under the Reference Condition. Following the guidelines stipulated in Table 3.3b (Taljaard *et al*, 2003) this results in a score of 45.	L
Hydrodynamics and mouth condition score	**45**		

Water quality

Variable	Score	Motivation	Confidence
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	40	During the Reference Condition, State 1: Open mouth prevailed for nearly 100% of the years within the simulation period. From May to Dec a strong longitudinal salinity gradient to fresh conditions would have occurred. Hyper salinity should not have been an issue. Under Scenario 2, State 1: Open mouth occurs for 85% of the years within the simulation period. This is indicative not only of a decrease in open mouth conditions from the Reference Condition, but also a decrease in the occurrence of strong salinity gradients or fresh conditions in the system. Also within State 1, strong longitudinal salinity gradient to fresh conditions now occurs for only 4 months (May, Sep-Nov) compared to 8 months under the Reference Condition. Under Scenario 2, when the estuary closes (State 2: Closed mouth) the system becomes saline, favouring hypersaline conditions (>50 ppt) during	L

		drought years (due to reduced river inflow and evaporation). Hypersaline conditions can develop even under State 1, particularly during drought years.	
2a. Nitrate/phosphate concentration in the estuary	54	The rivers (Swart and Seekoei) are the major inorganic nutrient sources to the Seekoei Estuary. With extensive agricultural development in the catchment, it is expected that nutrient concentrations in river inflow will also be higher compared to the Reference Condition. Using modifications in MAR as proxy for modification in inorganic nutrients: The MAR reduced from 20.27 million m^3 in the Reference Condition to 11.97 million m^3 under Scenario 2 (i.e. a reduction of 41%). Based on modification to river inflow, inorganic nutrients levels will be reduced to about 59% of Reference Condition. Furthermore, agricultural activities in the catchment introduced higher inorganic nutrients into river inflow compared to the Reference Condition. As river flow will be drastically reduced the overall effect of this will, however, be limited. Allow for a further 5% modification.	L
2b. Suspended solids present in inflowing freshwater	52	River inflow into the estuary is expected to be one of the major sources of turbidity in the estuary. With extensive agricultural development in the catchment, turbidity levels in river inflow will also be higher compared to the Reference Condition. Using modification in MAR as proxy for modification in turbidity: The MAR reduced from 20.27 million m^3 in the Reference Condition to 11.97 million m^3 under the Present State (i.e. a reduction of 41%). Based on modification to river inflow, turbidity levels were reduced to about 59% of Reference Condition. Furthermore, agricultural activities in the catchment introduce higher turbidity into river inflow compared to the Reference Condition. As river flow will be drastically reduced the overall effect of this will, however be limited. Allow for a further 5% modification. Also, with the increase in State 1 (closed mouth) compared to Reference Condition average turbidity levels in the estuary seaward of the causeway will also increase slightly. Allow for a further 2% modification (slightly less compared to the Present State).	L

2c. Dissolved oxygen in the estuary	100	The Seekoei Estuary should generally be well-oxygenated being a shallow system (i.e. even during periods of low or no river inflow wind mixing maintain oxygenated conditions).	L
2d. Levels of toxins	80	There are no major urban or industrial areas in the catchment. However, extensive agricultural developments probably introduce some toxic substances (e.g. pesticides) into the system. Allow for a 20% change from Reference Condition to Scenario 2.	L
Water quality score	**51.2**		

Physical habitat alteration

Variable		Score	Motivation	Confidence
1. Resemblance of intertidal sediment structure and distribution to Reference Condition				
1 a	% similarity in intertidal area exposed	73	Some improvement on the exposed intertidal areas as open mouth conditions prevail for about 85% of the years. There is still some small changes in the intertidal area due to the construction of the causeway.	L
1 b	% similarity in sand fraction relative to total sand and mud	60	More muddy substrate due to land-use changes and reduced tidal flushing.	L
2	Resemblance of subtidal estuary to Reference Condition: depth, bed or channel morphology	70	Some improvement on the exposed intertidal areas as open mouth conditions prevail for about 85% of the years. Still some change due to stabilised channel configuration, the shallower area between the mouth, the causeway and the potential deepening of the main channels near or at the causeway where the flows are restricted.	L
Physical habitat score		**68**		

4.3.2 Biotic Components

i. Predicted change in biotic characteristics of the future Scenario 2 compared with the Reference Condition, as well as the causes of these changes:

Microalgae
Reduced baseflow and an increase in salinity have decreased the number of freshwater and brackish species. The lack of freshettes and nutrient inflow has reduced the phytoplankton biomass. An increase in stable closed mouth conditions would promote subtidal benthic microalgal growth but only if nutrients were available. Intertidal benthic microalgae would be lost during closed mouth periods. Confidence: Medium
Macrophytes
An increase in salinity has resulted in the loss of some species e.g. *Potamogeton pectinatus* (pondweed). High salinity and increased water levels have increased the abundance of submerged macrophytes and filamentous green algal mats but decreased the abundance of brackish reeds, sedges and salt marsh. Drought years and hypersaline conditions result in an impoverished estuary. Confidence: Medium
Invertebrates (including zooplankton, benthic invertebrates and macrocrustaceans)
Some species (brackishwater community) would be lost from the system because of an increase in salinity. Abundance and biomass levels would also be reduced compared to natural conditions, particularly during drought years. Some species of invertebrates require a marine phase of development, but because of increased mouth closure, recruitment would decline compared to natural conditions. Confidence: Medium
Fish
Loss of freshwater fish species from the head of the estuary would reflect increased salinities throughout the estuary. Reduced marine fish recruitment would occur due to reduced olfactory cues being carried out to sea and the increase in closed mouth phase. The planktivorous fish assemblage would differ considerably from the Reference State and hypersaline conditions during drought years could result in major fish kills. Confidence: Medium
Birds
Relative to the Reference Condition, this scenario leads to an increase in the occurrence of the shallow, hypersaline state, as well as the deep, freshwater state, the latter occurring particularly in spring. This leads to greater variability in bird community composition, with numbers of certain species starting to fluctuate much more than under the Reference Condition. Numbers of birds in the typical estuarine state will be lower due to reductions in invertebrate and fish production. Confidence: Medium

ii. EHI for the Future Scenario 2

Microalgae

Variable	Score	Motivation	Confidence
Phytoplankton			
1. Species richness	40 (65%)	The reduction in baseflow and increase in salinity would result in a loss of freshwater/brackish species. Approx-imately 65% of the original species would remain.	M
2a. Abundance	48	The lack of freshettes and pulses of nutrient rich freshwater inflow would result in low phytoplankton biomass. However, phytoplankton biomass was probably never very significant in the Seekoei Estuary (< 2 µg l^{-1}).	M
2b. Community composition	45	There would be a loss of freshwater/brackish components and an increase in saline components due to the increase in salinity.	M
Benthic microalgae			
1. Species richness	40 (65%)	The reduction in baseflow and increase in salinity would result in a loss of freshwater/brackish species.	M
2a. Abundance	48	Reduced flushing and an increase in sedimentation could increase benthic microalgal biomass. However, reduced freshwater inflow and low nutrient concentrations would decrease biomass.	M
2b. Community composition	45	Primary colonisers would be reduced due to lack of flushing, floods and resetting of the estuary.	M
Microalgae score	**40**		

Macrophytes

Variable	Score	Motivation	Confidence
1. Species richness	40 (65%)	An increase in salinity has resulted in the loss of some species e.g. *Potamogeton pectinatus* (pondweed). Brackish reed and sedge species may have also been lost as there is no longer a persistent longitudinal salinity gradient. Drought years and hypersaline conditions result in an impoverished estuary. At most 65% of the original species remain.	M
2a. Abundance/Biomass	50	There has been an increase in the abundance of submerged macrophytes and filamentous green algal mats as a result of increased mouth closure. High salinity and increased water levels has reduced the biomass of brackish reeds and sedges and some salt marsh species.	M
2b. Community composition	50	The mouth is closed more frequently than in the past. High water levels would favour the development of submerged macrophytes i.e. *Ruppia* in the place of salt marsh. The lack of flushing increases the occurrence of filamentous green algal mats.	M
Macrophytes score	**40**		

Invertebrates

Variable	Score	Motivation	Confidence
Zooplankton			
1. Species richness	50 (70%)	Because of greater mouth closure and hypersaline conditions developing for much of the year, brackish water and marine associated species would disappear.	L
2a. Abundance	55	Phytoplankton biomass is considerably less under this Scenario, and this would affect food availability for the zooplankton. Abundance levels will decline severely.	L
2b. Community composition	50	Community composition will be severely reduced because of closed mouth conditions and high salinity values.	L
Macroinvertebrates			
1. Species richness	50 (70%)	Because of greater mouth closure and hypersaline conditions developing for much of the year, brackish water and marine associated species would disappear.	L
2a. Abundance	55	Abundance levels will decline for some species because of the increase in macrophyte coverage, but this will benefit other species.	L
2b. Community composition	55	Because of the increase in macrophyte coverage, community composition will change.	L
Macrocrustacea			
1. Species richness	50 (70%)	Because of greater mouth closure and hypersaline conditions developing for much of the year, brackish water and marine associated species would	L

		disappear.	
2a. Abundance	55	Abundance levels will decline for some species because of the increase in macrophyte coverage, but this will benefit other species.	L
2b. Community composition	55	Because of the increase in macrophyte coverage, community composition will change.	L
Invertebrate score	**50**		

Fish

Variable	Score	Motivation	Confidence
1. Species richness	40 (65%)	Loss of certain freshwater and marine fish species would occur due to the loss of perennial river flow and reduced open mouth conditions, respectively.	M
2a. Abundance	60	Reduction in pelagic productivity would occur and this would impact negatively on fish larvae and the adults of planktivorous fish species.	M
2b. Community composition	60	A reduction in the contribution by marine and freshwater taxa to the overall fish assemblage would be expected due to the loss of perennial river flow and reduced open mouth conditions, respectively.	M
Fish score	**40**		

Birds

Variable	Score	Motivation	Confidence
1. Species richness	75	Average species richness would decline due to the greater frequency of extreme conditions that favour certain groups over others.	M
2a. Abundance	65	Variability in abundance increases considerably as the system moves between different states. Abundance levels in typical estuary state are lower due to reduction in food supply	M
2b. Community composition	55	Community composition fluctuates much more, with the community sometimes bearing little resemblance to that typical of the Reference State.	M
Bird score	**55**		

4.4 Scenario 3: River Class D release to the estuary

4.4.1 Abiotic Components

i. Seasonal variability in river inflow

Monthly simulated runoff data for the Future Scenario 3 is provided in Table 4-3. A summary of flow distribution (mean monthly flows in m^3/s) for the Future Scenario 3, derived from the 73-year simulated data set, is provided below:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99%ile	**19.70**	**7.16**	**3.30**	0.39	0.55	**6.45**	**5.36**	**15.09**	**11.67**	**8.96**	**18.57**	**24.12**
90%ile	**3.77**	**3.00**	0.10	0.08	0.07	0.08	0.20	0.66	1.46	1.61	**2.47**	**6.65**
80%ile	1.98	1.25	0.10	0.08	0.07	0.08	0.20	0.57	0.36	0.94	1.80	**2.92**
70%ile	1.11	0.56	0.09	0.07	0.07	0.08	0.19	0.49	0.30	0.42	0.85	1.65
60%ile	0.50	0.37	0.09	0.07	0.06	0.07	0.18	0.41	0.26	0.30	0.38	1.31
50%ile	0.35	0.33	0.08	0.07	0.06	0.07	0.16	0.29	0.19	0.21	0.27	0.96
40%ile	0.24	0.27	0.07	0.06	0.05	0.06	0.14	0.24	0.16	0.17	0.19	0.65
30%ile	0.15	0.19	0.06	0.05	0.04	0.05	0.10	0.19	0.12	0.12	0.15	0.45
20%ile	0.10	0.12	0.04	0.04	0.03	0.04	0.07	0.11	0.08	0.09	0.11	0.29
10%ile	0.07	0.08	0.04	0.03	0.03	0.03	0.04	0.08	0.06	0.06	0.07	0.17
1%ile	0.06	0.06	0.03	0.03	0.02	0.03	0.03	0.06	0.05	0.05	0.06	0.13

ii. Predicted flood regime for the Future Scenario 3

For the Seekoei months with flows of $10m^3/s$ or more were estimated to be indicative of flood events. Under the Scenario 3 these events occur 16 times in the 73-year period, in comparison with 26 under the Reference Condition. Under Scenario 3 about 62% of the larger flood events still reach the estuary.

<u>Confidence</u>: Low

iii. Predicted sediment processes under Future Scenario 3 compared with Reference State

Similar to Present State

<u>Confidence</u>: Low

iv. Occurrence and duration of the abiotic states during the Scenario 3

An analysis of the Scenario 3 simulated monthly runoff indicates that the Seekoei Estuary under this scenario would receive sufficient river inflow to breach about 2 out of 3 years, i.e. in 25 out of 73 years that the annual inflow is less than 3 million m^3 and the system will not breach.

The reduction in baseflows to the system also implies that the estuary could close more easily, stay open for shorter period than under the Reference Condition. Note that the estuary can maintain an open mouth for longer periods under the current culvert configuration in the causeway, but it will still close under high wave conditions and the reduction in baseflows will have some impact.

Under this Scenario the duration of a mouth closure might also be longer as the reduced inflow to the estuary implies that it would take longer to reach its breaching level and thereby re-establish its connection to the sea.

In years where the Seekoei Estuary is likely to be in Abiotic State 1: Open mouth, the monthly distribution between saline to hypersaline (median monthly flow < 0.5 million m^3) conditions versus conditions when the estuary develops a strong longitudinal salinity gradient to becoming fresh (median monthly flow > 0.5 million m^3) is estimated to be as follows for Scenario 3:

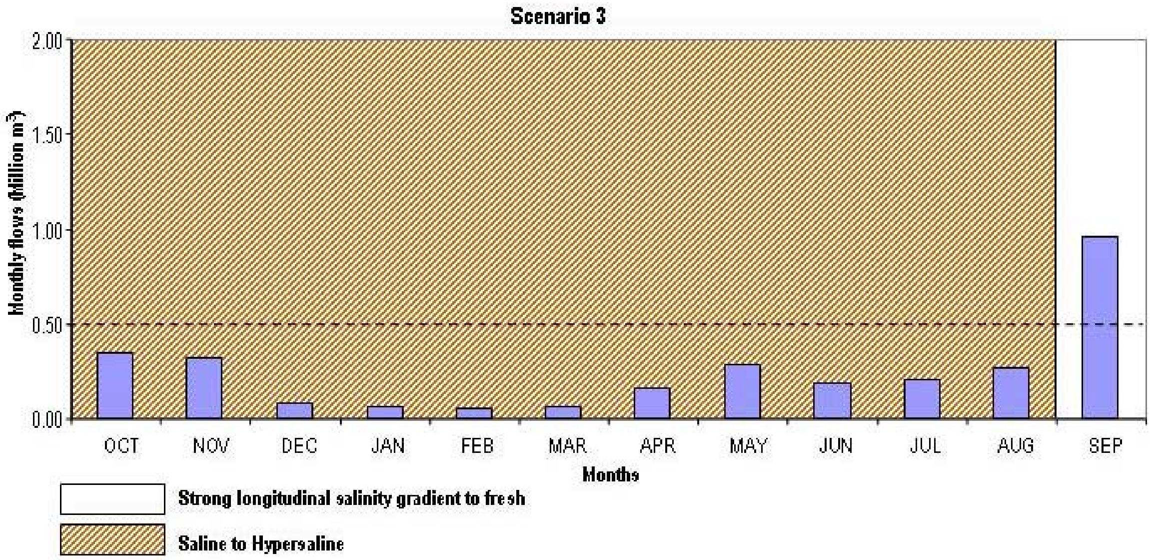


Table 4-3 Scenario 3 (River Class D): Simulated runoff data in million m^3 per month

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1927	0.14	0.10	0.06	0.06	0.06	0.08	0.18	0.27	0.20	0.27	0.28	1.10	2.81
1928	0.20	0.26	0.10	0.08	0.06	0.06	0.14	0.43	0.20	0.18	0.15	0.29	2.14
1929	0.08	6.51	3.11	0.08	0.07	0.07	0.18	0.52	0.30	0.94	1.79	0.82	14.48
1930	0.55	0.27	0.08	0.06	0.06	0.04	0.04	0.15	0.17	0.10	0.16	0.51	2.18
1931	0.17	0.31	0.09	0.07	0.03	0.07	0.20	0.49	0.26	0.18	0.19	1.31	3.35
1932	0.32	0.33	0.08	0.04	0.03	0.03	0.09	0.24	0.12	0.38	0.36	1.13	3.15
1933	0.49	2.59	0.10	0.07	0.06	0.07	0.14	0.41	0.17	0.08	0.21	0.49	4.87
1934	0.07	0.13	0.06	0.04	0.05	7.54	5.93	1.30	0.49	0.56	0.32	0.94	17.43
1935	0.41	0.71	0.09	0.06	0.03	0.03	0.05	0.23	0.14	0.26	0.18	1.42	3.60
1936	0.32	0.22	0.06	0.03	0.06	0.08	0.19	0.25	0.16	0.09	0.17	0.45	2.07
1937	0.14	0.10	0.04	0.04	0.03	0.07	0.16	0.12	0.05	0.31	0.19	0.74	1.98
1938	3.93	3.10	1.68	0.08	0.07	0.07	0.10	0.09	0.06	0.19	0.56	35.00	44.92
1939	13.15	4.63	0.86	0.08	0.06	0.04	0.04	0.24	0.11	0.05	0.38	1.86	21.49
1940	0.09	0.37	0.09	0.06	0.06	0.06	0.07	0.11	0.08	0.34	0.30	0.61	2.23
1941	0.95	0.90	0.20	0.04	0.04	0.04	0.18	8.94	6.05	1.65	1.47	1.10	21.56
1942	1.39	0.33	0.09	0.06	0.03	0.03	0.13	0.17	0.07	0.11	0.07	0.18	2.67
1943	0.24	0.40	0.73	0.07	0.04	0.06	0.07	0.07	0.19	0.12	0.08	0.85	2.93
1944	0.19	0.28	0.09	0.07	0.05	0.04	0.10	0.12	0.07	0.06	0.06	0.13	1.25
1945	0.08	0.13	0.04	0.03	0.07	0.08	0.19	0.30	0.15	0.16	0.40	2.12	3.75
1946	0.54	0.36	0.09	0.08	0.07	0.08	0.18	0.23	0.14	0.14	0.09	0.37	2.37
1947	0.07	0.10	0.04	0.03	0.02	0.03	0.05	0.08	0.33	0.21	0.11	0.37	1.43
1948	0.31	0.33	0.10	0.08	0.06	0.04	0.04	0.55	0.28	0.17	0.14	0.33	2.42
1949	0.29	0.32	0.06	0.07	0.06	0.04	0.09	0.09	0.29	0.29	0.35	1.57	3.53
1950	1.25	2.17	0.10	0.18	0.07	0.08	0.85	25.32	9.77	1.94	1.09	2.49	45.30
1951	0.47	0.24	0.04	0.03	0.03	0.03	0.04	0.63	0.35	0.30	1.61	2.58	6.34
1952	6.60	2.55	0.08	0.04	0.04	0.08	1.28	0.20	0.08	0.84	1.62	1.41	14.83
1953	1.33	0.08	0.03	0.03	0.02	0.08	0.18	0.58	0.34	1.35	2.47	0.65	7.13
1954	0.11	0.12	0.07	0.05	0.02	0.05	0.20	0.58	0.17	0.09	0.26	0.22	1.93
1955	2.81	1.53	0.08	0.04	0.03	0.03	0.04	0.06	0.05	0.05	0.06	0.13	4.89
1956	0.06	5.08	3.78	0.05	0.04	0.03	0.19	0.29	0.07	0.12	0.47	2.03	12.23
1957	1.30	1.27	0.10	0.95	0.07	0.07	0.09	0.21	0.52	1.32	1.80	11.28	18.98
1958	4.71	0.29	0.08	0.08	0.07	0.07	0.07	0.45	0.21	0.12	0.25	5.99	12.38
1959	3.14	0.36	0.09	0.07	0.06	0.06	0.05	0.08	0.10	0.24	0.38	13.06	17.69
1960	29.18	8.81	0.10	0.08	0.05	4.15	4.07	11.11	4.83	5.43	15.02	4.97	87.79
1961	0.36	0.16	0.08	0.06	0.07	0.40	0.92	0.30	0.16	0.16	8.45	3.14	14.27
1962	0.98	0.38	0.10	0.07	0.06	0.08	0.16	2.45	2.17	1.42	1.26	4.28	13.40
1963	16.02	5.74	2.37	0.08	0.07	0.08	0.18	0.29	0.37	1.38	2.05	16.15	44.77
1964	6.23	1.23	0.07	0.03	0.02	0.08	0.16	0.66	0.64	1.08	2.12	1.76	14.08
1965	1.91	1.07	0.07	0.08	0.07	0.08	0.20	0.56	0.28	0.63	1.88	1.40	8.21
1966	0.73	0.33	0.08	0.08	0.07	0.05	0.09	0.48	0.25	0.36	0.68	1.40	4.58
1967	0.15	0.16	0.04	0.06	0.07	0.08	0.20	0.63	0.34	0.94	1.74	1.33	5.73
1968	0.13	0.12	0.05	0.04	0.05	0.08	0.20	0.42	0.13	0.07	0.37	1.20	2.85
1969	0.18	0.18	0.04	0.08	0.07	0.08	0.20	0.52	0.26	0.18	0.18	0.45	2.39
1970	0.09	0.10	0.10	0.08	0.07	0.07	0.15	0.16	0.38	0.36	0.19	5.08	6.80
1971	2.33	1.42	0.10	0.07	0.04	0.03	0.12	0.46	0.19	0.12	0.09	0.24	5.21
1972	0.34	0.40	0.10	0.08	0.07	0.07	0.12	0.19	0.10	0.06	0.14	0.45	2.10
1973	0.10	0.24	0.08	0.05	0.06	0.07	0.20	0.61	0.29	0.27	0.27	1.10	3.34
1974	0.21	0.21	0.05	0.03	0.03	0.04	0.20	0.50	11.61	8.00	2.21	4.11	27.20
1975	0.78	0.33	0.07	0.05	0.05	0.06	0.09	0.10	0.06	0.06	0.06	0.13	1.84
1976	0.06	0.06	0.03	0.03	0.04	0.03	0.04	0.06	0.05	0.05	0.06	0.13	0.64
1977	0.10	0.08	0.09	0.07	0.05	0.06	1.04	4.48	1.98	11.43	24.22	7.42	51.03
1978	1.09	1.14	0.08	0.04	0.06	0.05	0.14	0.19	0.12	0.08	0.11	0.22	3.33
1979	0.06	0.06	0.03	0.03	0.03	0.05	0.13	0.35	0.14	0.06	0.06	0.13	1.14
1980	0.06	0.16	0.05	0.08	0.07	0.08	0.20	0.52	0.29	0.47	2.47	3.67	8.12
1981	2.56	0.23	0.05	0.07	0.06	0.06	0.07	0.06	0.05	0.10	0.11	0.92	4.35
1982	0.15	0.10	0.04	0.04	0.03	0.08	0.21	0.63	0.62	7.53	3.18	1.26	13.84
1983	2.73	1.13	0.09	0.05	0.07	0.08	0.19	0.66	0.36	0.89	0.25	6.81	13.31
1984	1.69	0.72	0.10	0.07	0.03	0.08	0.20	0.48	0.27	0.91	0.27	0.53	5.36
1985	0.36	2.00	0.10	0.08	0.07	0.07	0.14	0.21	0.17	0.36	16.37	7.56	27.48
1986	2.04	0.29	0.07	0.07	0.06	0.03	0.17	0.16	0.10	0.06	0.06	0.13	3.24
1987	0.28	0.33	0.06	0.08	0.07	6.03	5.15	1.49	1.66	0.96	4.26	1.78	22.14
1988	2.40	0.46	0.09	0.07	0.05	0.06	0.20	0.33	0.08	0.09	0.15	0.42	4.39
1989	0.10	0.08	0.03	0.03	0.02	0.03	0.03	0.06	0.05	5.92	5.46	0.74	12.55
1990	1.13	0.16	0.04	0.03	0.02	0.05	0.05	0.06	0.05	0.14	0.09	0.20	2.03
1991	0.06	0.06	0.04	0.08	0.07	0.07	0.12	0.11	0.19	0.17	0.11	0.17	1.25
1992	0.08	0.32	0.09	0.08	0.06	0.05	0.05	0.07	0.05	0.05	0.11	0.29	1.31
1993	0.35	0.39	0.09	0.06	0.04	0.04	0.14	0.12	0.31	0.20	0.09	0.96	2.79
1994	0.15	0.06	0.03	0.03	0.07	0.07	0.18	0.27	0.25	0.16	0.15	0.37	1.78
1995	0.07	0.06	0.04	0.05	0.06	0.04	0.20	0.39	0.10	0.06	0.06	0.19	1.32
1996	0.42	5.68	0.10	0.07	0.07	0.08	0.20	0.57	0.36	0.34	0.24	0.64	8.76
1997	0.36	0.38	0.07	0.04	0.05	0.04	0.04	0.07	0.06	0.05	0.06	0.17	1.38
1998	0.20	0.20	0.09	0.07	1.79	2.21	0.17	0.27	0.23	0.23	2.08	1.38	8.91
1999	9.01	6.20	0.10	0.07	0.03	0.03	0.20	0.30	11.83	6.82	0.46	19.90	54.95
Median	0.35	0.33	0.08	0.07	0.06	0.07	0.16	0.29	0.19	0.21	0.27	0.96	4.58
Average	1.80	1.06	0.24	0.07	0.07	0.33	0.38	1.03	0.86	0.97	1.58	2.69	11.10

Monthly > 2 mil m^3 **Annual** < 3 mil

v. EHI for the Future Scenario 3

Hydrology

Variable	Score	Motivation	Confidence
1a. % similarity in period of low flows or Present MAR as a % of MAR in the Reference Condition	55	Under Scenario 3 the Seekoei has a MAR of 11.10 million m^3 in comparison with the Reference Conditions of 20.27 million m^3. Under Scenario 3, 55% of the runoff is still reaching the estuary.	L
1b. % similarity in mean annual frequency of floods	62	For the Seekoei months with flows of $10m^3/s$ or more were estimated to be indicative of flood events. Under Scenario 3 these events occur 16 times in the 73-year period, in comparison with 26 under the Reference Condition. Under Scenario 3 about 62% of the larger flood events would still reach the estuary.	L
Hydrology score	**58**		

Hydrodynamics and mouth condition

Variable	Score	Motivation	Confidence
Change in mean duration of closure, e.g. over a 5 or 10-year period	20	Under Scenario 3 the potential occurrence of open mouth conditions has been reduced to 66% (25 out of 73 years will not breach) from nearly permanently open (99%) under the Reference Condition. Following the guidelines stipulated in Table 3.3b (DWAF, 2004) this results in a score of 20.	L
Hydrodynamics and mouth condition score	**20**		

Water quality

Variable	Score	Motivation	Confidence
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	40	During the Reference Condition, State 1: Open mouth prevailed for nearly 100% of the years within the simulation period. From May to Dec a strong longitudinal salinity gradient to fresh conditions would have occurred. Hypersalinity should not have been an issue. Under Scenario 3, State 1: Open mouth occurs for 66% of the years within the simulation period. This is indicative not only of a decrease in open mouth conditions from the Reference Condition, but also a decrease in the occurrence of strong salinity gradients or fresh conditions in the system. Also within State 1, strong longitudinal salinity gradient to fresh conditions now only occurs for 1 month (Sept) compared to 8 months under the Reference Condition. Under Scenario 3, when the estuary closes (State 2: Closed mouth) the system becomes saline, favouring hypersaline conditions (> 65 ppt) during drought years (due to reduced river inflow and evaporation).	L
2a. Nitrate/phosphate concentration in the estuary	50	The rivers (Swart and Seekoei) are the major inorganic nutrient sources to the Seekoei Estuary. With extensive agricultural development in the catchment, it is expected that nutrient concentrations in river inflow will also be higher compared to the Reference Condition. Using modification in MAR as proxy for modification in nutrients: The MAR reduced from 20.27 million m^3 in the Reference Condition to 11.1 million m^3 under the Present State (i.e. a reduction of 45%). Based on modification to river inflow, inorganic nutrient levels will be reduced to about 55% of Reference Condition. Furthermore, agricultural activities in the catchment introduced higher inorganic nutrients into river inflow compared to the Reference Condition. As river flow will be drastically reduced the overall effect of this will, however, be limited. Allow for a further 5% modification.	L
2b. Suspended solids present in inflowing freshwater	45	River inflow into the estuary is expected to be one of the major sources of turbidity in the estuary. With extensive agricultural development in the catchment, turbidity levels in river inflow will also be higher compared to the	L

		Reference Condition. Using modification in MAR as proxy for modification in turbidity: The MAR reduced from 20.27 million m^3 in the Reference Condition to 11.36 million m^3 under the Present State (i.e. a reduction of 45%). Based on modification to river inflow, turbidity levels will be reduced to about 55% of Reference Condition. Furthermore, agricultural activities in the catchment introduced higher turbidity into river inflow compared to the Reference Condition. As river flow will be drastically reduced the overall effect of this will, however, be limited. Allow for a further 5 % modification. Also, with the increase in State 1 (closed mouth) compared to the Reference Condition, average turbidity levels in the estuary seaward of the causeway will increase – allow for a further 5% modification.	
2c. Dissolved oxygen in the estuary	100	The Seekoei Estuary should generally be well-oxygenated being a shallow system (i.e. even during periods of low or no river inflow, wind mixing maintains oxygenated conditions)	L
2d. Levels of toxins	80	There are no major urban or industrial areas in the catchment. However, extensive agricultural developments probably introduce some toxic substances (e.g. pesticides) into the system. Allow for a 20% change from Reference Condition to Scenario 3.	L
Water quality score	**43**		

Physical habitat alteration

Variable	Score	Motivation	Confidence
1. Resemblance of intertidal sediment structure and distribution to Reference Condition			
1a. % similarity in intertidal area exposed	65	Similar to Present.	L
1b. % similarity in sand fraction relative to total sand and mud	60	Similar to Present.	L
2. Resemblance of subtidal estuary to Reference Condition: depth, bed or channel morphology	60	Similar to Present.	L
Physical habitat score	**61**		

4.4.2 Biotic Components

i. Predicted change in biotic characteristics of the future Scenario 3 compared with the Reference Condition, as well as the <u>causes</u> of these changes:

Microalgae
This scenario differs from the Present State as there will only be a longitudinal salinity gradient for 1 month of the year compared to 3 months. Reduced baseflow and an increase in salinity have decreased the number of freshwater and brackish species. The lack of freshettes and nutrient inflow has reduced the phytoplankton biomass. An increase in stable closed mouth conditions would promote subtidal benthic microalgal growth but only if nutrients were available. Intertidal benthic microalgae would be lost during closed mouth periods. Confidence: Medium
Macrophytes
An increase in salinity has resulted in the loss of some species e.g. *Potamogeton pectinatus* (pondweed). High salinity has decreased the abundance of brackish reeds, sedges and salt marsh. The mouth is closed more frequently than in the past. High water levels would favour the development of submerged macrophytes i.e. *Ruppia* in the place of salt marsh. The lack of flushing increases the occurrence of filamentous green algal mats. Drought years and hypersaline conditions result in an impoverished estuary. Confidence: Medium
Invertebrates (including zooplankton, benthic invertebrates and macrocrustaceans)
The invertebrate community will be similar to present day conditions, with no zonation of communities because of the lack of a horizontal salinity gradient for 11 months of the year. Abundance levels and species composition will be sharply reduced compared to the natural state of the estuary. Confidence: Medium
Fish
Loss of freshwater fish species from the head of the estuary would reflect increased salinities throughout the estuary. Reduced marine fish recruitment would occur due to reduced olfactory cues being carried out to sea and the increase in closed mouth phase. The planktivorous fish assemblage would differ considerably from the Reference State and hypersaline conditions during drought years could result in major fish kills. Confidence: Medium
Birds
This scenario leads to an increase in the deepwater state since the mouth is closed more frequently than in the past, as well as an increase in the occurrence of the shallow, hypersaline state. This leads to greater variability in bird community composition, with numbers of certain species starting to fluctuate much more than under the Reference Condition. Numbers of birds in the typical estuarine state will be lower due to reductions in invertebrate and fish production. Confidence: Medium

ii. EHI for the future scenario

Microalgae

Variable	Score	Motivation	Confidence
Phytoplankton			
1. Species richness	25 (50%)	The reduction in baseflow and increase in salinity would result in a loss of freshwater/brackish species. Approximately 50% of the original species would remain.	M
2a. Abundance	35	The lack of freshettes and pulses of nutrient rich freshwater inflow would result in low phytoplankton biomass. However, phytoplankton biomass was probably never very significant in the Seekoei Estuary (< 2 µg l^{-1}).	M
2b. Community composition	30	Loss of freshwater/brackish components and an increase in saline components.	M
Benthic microalgae			
1. Species richness	25	The reduction in baseflow and increase in salinity would result in a loss of freshwater/brackish species.	M
2a. Abundance	35	Reduced flushing and an increase in sedimentation could increase benthic microalgal biomass. However, reduced freshwater inflow and low nutrient concentrations would decrease biomass.	M
2b. Community composition	30	Primary colonisers would be reduced due to lack of flushing, floods and resetting of the estuary.	M
Microalgae score	**25**		

Macrophytes

Variable	Score	Motivation	Confidence
1. Species richness	30 (55%)	An increase in salinity has resulted in the loss of some species e.g. *Potamogeton pectinatus* (pondweed). Species of brackish reed and sedges may also have been lost as there is no longer a persistent longitudinal salinity gradient. Drought years and hypersaline conditions result in an impoverished estuary. At most 55% of the original species remain.	M
2a. Abundance	35	There has been an increase in the abundance of submerged macrophytes and filamentous green algal mats as a result of increased mouth closure. High salinity and increased water levels has reduced the biomass of brackish reeds and sedges and some salt marsh species.	M
2b. Community composition	35	The mouth is closed more frequently than in the past. High water levels would favour the development of submerged macrophytes i.e. *Ruppia* in the place of salt marsh. The lack of flushing increases the occurrence of filamentous green algal mats.	M
Macrophytes score	**30**		

Invertebrates

Variable	Score	Motivation	Confidence
Zooplankton			
1. Species richness	40 (65%)	Strong hypersalinity will reduce species richness severely. More frequent mouth closure will exclude marine associated species in the lower reaches and the lack of a brackishwater zone will exclude freshwater associated species.	M
2a. Abundance	35	Zooplankton abundance will be considerably lower compared to the natural state.	M
2b. Community composition	40	Increased mouth closure and high salinity values will reduce community composition severely.	M
Macroinvertebrates			
1. Species richness	40 (65%)	Strong hypersalinity will reduce species richness severely. More frequent mouth closure will reduce or exclude species having a marine phase of development. The brackish water zone will be absent or small and this will exclude many freshwater associated species.	M
2a. Abundance	55	Although abundance of benthic species associated with macrophytes will increase (increased macrophyte coverage), species requiring non-vegetated areas will decrease. However, abundance of many species will decline irrespective of vegetation coverage if the mouth remains closed for extended periods.	M
2b. Community composition	55	Macroinvertebrate composition will be considerably lower compared to the natural state for the reasons outlined	M

		above.	
Macrocrustacea			
1. Species richness	40 (65%)	Strong hypersalinity will reduce species richness. More frequent mouth closure will reduce or exclude species having a marine phase of development.	M
2a. Abundance	55	Abundance of benthic species associated with macrophytes may increase (increased macrophyte coverage), but this will depend on the state of the mouth.	M
2b. Community composition	65	Macrocrustacea composition will be considerably lower compared to the natural state for the reasons outlined above.	M
Invertebrates score	**35**		

Fish

Variable	Score	Motivation	Confidence
1. Species richness	35 (60%)	Loss of certain freshwater and marine fish species would occur due to the loss of perennial river flow and reduced open mouth phase respectively.	M
2a. Abundance	50	Reduction in pelagic productivity would occur and this would impact negatively on fish larvae and the adults of planktivorous fish species.	M
2b. Community composition	50	A reduction in the contribution by marine and freshwater taxa to the overall fish assemblage would be expected for the reasons outlined in species richness motivation.	M
Fish score	**35**		

Birds

Variable	Score	Motivation	Confidence
1. Species richness	65 (80%)	Average species richness would decline due to the greater frequency of extreme conditions that favour certain groups over others.	M
2a. Abundance	60	Variability in abundance increases considerably as the system moves between different states, abundance levels in typical estuary state are lower due to reduction in food supply.	M
2b. Community composition	40	Community composition fluctuates much more, with the community bearing little resemblance to that typical of the Reference State.	M
Bird score	**40**		

4.5 Scenario 4: Limited Development

4.5.1 Abiotic Components

i. Seasonal variability in river inflow

Monthly simulated runoff data for Future Scenario 4 is provided in Table 4-4. A summary of flow distribution (mean monthly flows in m^3/s) for the Future Scenario 4, derived from the 73-year simulated data set, is provided below:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99%ile	**20.15**	**9.37**	**3.83**	1.03	**2.03**	**10.26**	**5.38**	**15.07**	**14.87**	**9.71**	**19.96**	**24.55**
90%ile	**4.69**	**3.40**	0.40	0.22	0.19	0.27	0.90	1.44	**2.18**	**2.25**	**3.34**	**6.93**
80%ile	**2.63**	1.71	0.28	0.22	0.19	0.22	0.36	1.08	1.09	1.43	**2.18**	**3.46**
70%ile	1.40	1.08	0.27	0.21	0.18	0.21	0.35	0.87	0.62	0.86	1.68	**2.24**
60%ile	0.97	0.62	0.25	0.20	0.16	0.19	0.32	0.74	0.51	0.62	1.24	1.81
50%ile	0.67	0.56	0.23	0.17	0.15	0.18	0.29	0.54	0.40	0.46	0.61	1.44
40%ile	0.52	0.44	0.18	0.14	0.12	0.14	0.24	0.43	0.32	0.35	0.39	1.10
30%ile	0.33	0.31	0.13	0.10	0.09	0.10	0.17	0.33	0.23	0.23	0.29	0.76
20%ile	0.18	0.19	0.07	0.07	0.05	0.07	0.11	0.18	0.14	0.15	0.20	0.46
10%ile	0.10	0.11	0.05	0.04	0.04	0.04	0.06	0.11	0.08	0.08	0.09	0.25
1%ile	0.07	0.08	0.04	0.03	0.02	0.03	0.04	0.08	0.06	0.06	0.07	0.18

ii. Predicted Flood regime for Future Scenario 4

For the Seekoei months with flows of $10m^3/s$ or more were estimated to be indicative of flood events. Under Future Scenario 4 these events occur 19 times in the 73-year period, in comparison with 26 under the Reference Condition. Under this scenario about 73% of the larger flood events still reach the estuary.

<u>Confidence</u>: Low

iii. Predicted sediment processes under Future Scenario 4 compared with Reference State

Similar to Present State

<u>Confidence</u>: Low

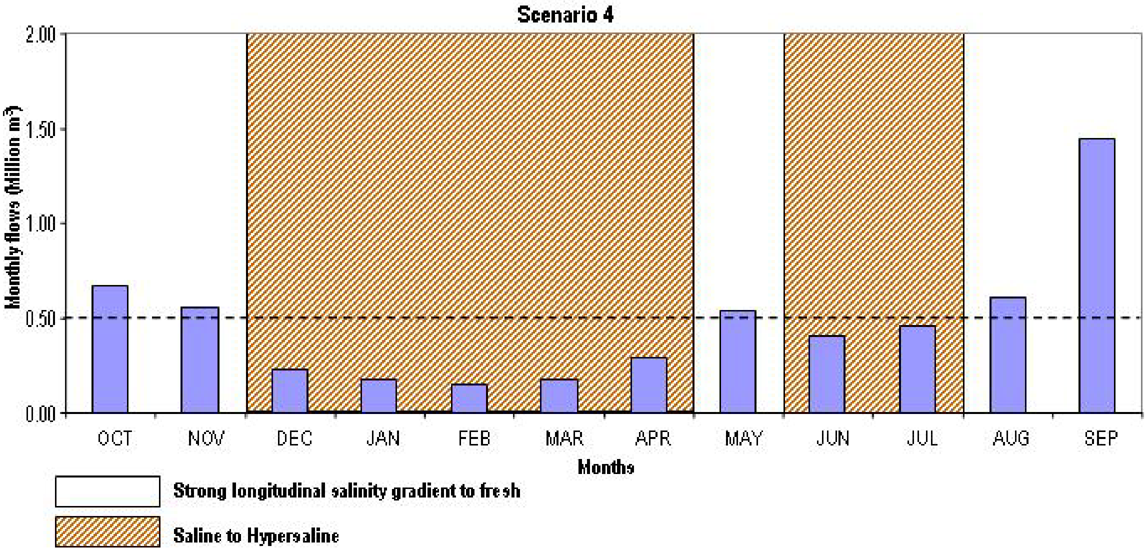
iv. Occurrence and duration of the Abiotic States during Scenario 4

An analysis of the Scenario 4 simulated monthly runoff indicates that the Seekoei Estuary currently receives sufficient river inflow to breach 89% of the time, i.e. in 8 out of 73 years the annual inflow is less than 3 million m^3.

The reduction in base flows to the system also implies that the estuary could close more easily, stay open for shorter period than under the Reference Condition. Note, that the estuary can maintain an open mouth for longer periods under the current culvert configuration in the causeway, but it will still close under high wave conditions and the reduction in baseflows will have some impact.

Under Scenario 4 the duration of a mouth closure might also be slightly longer as the reduced inflow to the estuary implies that it would take longer to reach its breaching level and thereby re-establish its connection to the sea.

In years where the Seekoei Estuary is likely to be in Abiotic State 1: Open mouth, the monthly distribution between saline to hypersaline (median monthly flow < 0.5 million m^3) conditions versus conditions when the estuary develops a strong longitudinal salinity gradient to becoming fresh (median monthly flow > 0.5 million m^3) is estimated to be as follows for Scenario 4:



Confidence: Low

Table 4-4 Future Scenario 4 (13 million m^3 release): Simulated runoff data in million m^3 per month

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1927	0.28	0.14	0.13	0.14	0.18	0.21	0.33	0.50	0.40	0.54	0.58	1.80	5.24
1928	0.43	0.44	0.28	0.22	0.17	0.15	0.25	0.76	0.41	0.37	0.29	0.46	4.21
1929	0.12	**9.61**	**3.80**	0.22	0.19	0.21	0.32	0.92	0.69	1.52	1.78	1.17	20.54
1930	0.65	0.45	0.21	0.14	0.15	0.09	0.06	0.25	0.33	0.19	0.31	0.87	3.71
1931	0.35	0.52	0.26	0.19	0.04	0.18	0.35	0.86	0.51	0.36	0.39	**2.21**	6.22
1932	0.67	0.58	0.23	0.08	0.06	0.04	0.14	0.44	0.23	0.72	**2.19**	1.90	7.27
1933	1.46	**2.65**	0.27	0.20	0.15	0.20	0.24	0.74	0.34	0.12	0.44	0.83	7.64
1934	0.10	0.20	0.13	0.08	0.12	**10.83**	**5.94**	1.17	0.52	0.54	0.40	1.13	21.16
1935	0.71	1.07	0.26	0.14	0.04	0.04	0.07	0.42	0.27	0.51	0.36	**2.38**	6.27
1936	0.67	0.36	0.12	0.05	0.18	0.22	0.34	0.46	0.32	0.14	0.34	0.76	3.94
1937	0.27	0.14	0.04	0.06	0.03	0.20	0.27	0.19	0.07	0.61	0.39	1.29	3.57
1938	**6.66**	**3.48**	**2.48**	0.22	0.18	0.19	0.17	0.14	0.08	0.46	1.30	**35.29**	50.66
1939	**13.41**	**4.89**	1.45	0.21	0.15	0.09	0.04	0.44	0.21	0.06	1.71	**2.03**	24.69
1940	0.13	0.74	0.26	0.16	0.15	0.15	0.11	0.17	0.14	0.65	0.61	1.06	4.32
1941	**3.19**	1.51	0.33	0.08	0.09	0.07	0.32	**10.94**	**6.04**	1.81	1.67	1.80	27.86
1942	0.99	0.56	0.24	0.16	0.06	0.05	0.23	0.30	0.10	0.19	0.10	0.27	3.26
1943	0.53	**3.08**	1.37	0.20	0.09	0.17	0.11	0.10	0.38	0.23	0.12	1.47	7.84
1944	0.47	0.47	0.25	0.20	0.12	0.07	0.17	0.19	0.10	0.08	0.07	0.18	2.36
1945	0.12	0.20	0.06	0.04	0.19	0.22	0.34	0.56	0.30	0.31	**3.25**	**2.70**	8.27
1946	0.97	0.62	0.27	0.22	0.19	0.22	0.33	0.42	0.27	0.28	0.16	0.61	4.53
1947	0.10	0.13	0.05	0.03	0.02	0.04	0.07	0.12	0.64	0.42	0.20	0.61	2.42
1948	0.66	0.56	0.28	0.22	0.17	0.07	0.06	0.96	0.56	0.35	0.26	0.54	4.67
1949	0.62	0.54	0.12	0.21	0.16	0.09	0.14	0.14	0.57	0.57	0.70	**3.35**	7.21
1950	**2.12**	**2.18**	0.40	0.42	0.18	0.75	1.55	**25.33**	**9.77**	1.90	1.23	**2.40**	48.21
1951	0.95	0.40	0.06	0.04	0.04	0.03	0.04	1.09	0.67	0.71	**3.36**	**2.52**	9.92
1952	**7.02**	**2.84**	0.22	0.07	0.09	**2.10**	1.80	0.37	0.14	0.82	1.56	1.34	18.36
1953	1.23	0.10	0.04	0.03	0.02	0.22	0.32	1.01	0.65	**2.80**	**2.40**	1.13	9.94
1954	0.21	0.18	0.16	0.10	0.03	0.11	0.37	1.30	0.46	0.63	0.93	0.34	4.81
1955	**3.29**	1.71	0.21	0.07	0.04	0.03	0.04	0.08	0.06	0.06	0.07	0.18	5.82
1956	0.07	**7.58**	**3.91**	0.12	0.09	0.05	0.35	0.54	0.10	0.23	1.40	1.96	16.40
1957	1.39	**2.01**	0.36	**2.60**	0.60	0.28	0.16	0.42	0.54	1.53	1.75	**11.52**	23.15
1958	**4.87**	0.48	0.23	0.21	0.19	0.18	0.11	0.80	0.43	0.23	0.52	**6.79**	15.04
1959	**3.28**	0.62	0.27	0.20	0.17	0.14	0.08	0.12	0.18	0.47	1.73	**13.94**	21.19
1960	**29.67**	**9.29**	0.27	0.21	0.11	**5.69**	**4.07**	**11.08**	**4.91**	**5.41**	**15.24**	**5.36**	91.31
1961	0.69	0.26	0.21	0.16	0.72	**2.09**	0.92	0.56	0.32	0.32	**8.48**	**3.54**	18.26
1962	1.21	0.73	0.27	0.18	0.16	0.21	0.29	**4.15**	**2.46**	1.42	1.33	**4.59**	17.00
1963	**16.45**	**6.19**	**2.67**	0.40	0.19	0.22	0.33	0.54	1.23	1.51	**2.16**	**16.07**	47.95
1964	**6.58**	1.35	0.18	0.04	0.02	0.21	0.29	1.40	**2.50**	1.13	**2.44**	**2.11**	18.27
1965	1.69	1.09	0.16	0.22	0.19	0.22	0.74	1.40	0.70	1.14	1.87	1.71	11.12
1966	0.96	0.61	0.21	0.22	0.18	0.11	0.14	0.85	0.50	0.68	1.54	1.44	7.44
1967	0.37	0.26	0.06	0.16	0.18	0.22	0.36	1.09	**2.16**	1.57	1.73	1.32	9.47
1968	0.30	0.18	0.08	0.08	0.12	0.21	0.36	0.75	0.26	0.11	0.74	**2.04**	5.23
1969	0.37	0.29	0.04	0.22	0.18	0.22	0.36	0.92	0.51	0.36	0.36	0.75	4.59
1970	0.13	0.13	0.28	0.22	0.18	0.19	0.26	0.27	1.90	**2.34**	1.47	**5.65**	13.03
1971	**2.73**	1.71	0.27	0.18	0.09	0.04	0.21	0.82	0.38	0.23	0.16	0.37	7.19
1972	0.71	1.01	0.28	0.22	0.19	0.19	0.21	0.35	0.17	0.08	0.26	0.76	4.40
1973	0.18	0.39	0.22	0.12	0.16	0.18	0.35	1.06	0.57	0.54	0.56	1.80	6.13
1974	0.45	0.35	0.08	0.04	0.04	0.09	0.36	0.89	**14.84**	**7.97**	**2.21**	**4.10**	31.41
1975	1.41	0.56	0.16	0.12	0.11	0.17	0.16	0.16	0.09	0.08	0.07	0.18	3.25
1976	0.07	0.08	0.04	0.04	0.09	0.04	0.04	0.07	0.06	0.06	0.07	0.18	0.83
1977	0.18	0.10	0.25	0.19	0.12	0.17	**3.84**	**4.49**	1.98	**11.44**	**24.30**	**7.73**	54.78
1978	1.18	1.16	0.23	0.07	0.15	0.13	0.24	0.35	0.23	0.13	0.21	0.34	4.40
1979	0.07	0.08	0.04	0.03	0.06	0.13	0.23	0.63	0.27	0.08	0.07	0.18	1.85
1980	0.07	0.26	0.08	0.22	0.19	0.22	0.85	1.45	1.34	0.95	**2.41**	**4.02**	12.05
1981	**2.54**	0.37	0.11	0.21	0.16	0.16	0.11	0.08	0.06	0.19	0.21	1.58	5.75
1982	0.29	0.13	0.06	0.06	0.04	0.21	1.00	**2.59**	1.29	**7.38**	**3.44**	1.83	18.33
1983	**2.76**	1.61	0.26	0.12	0.19	0.21	0.34	1.14	**2.18**	1.44	0.58	**6.97**	17.79
1984	**2.39**	1.27	0.39	0.21	0.04	0.22	0.63	0.86	0.87	1.24	0.65	0.91	9.69
1985	0.65	**2.20**	0.30	0.22	0.19	0.20	0.24	0.38	0.33	0.69	**18.28**	**7.76**	31.42
1986	**2.00**	0.55	0.16	0.21	0.15	0.04	0.30	0.28	0.18	0.09	0.07	0.18	4.21
1987	0.60	0.56	0.13	0.22	0.19	**10.03**	**5.16**	1.57	1.65	1.13	**4.36**	**2.28**	27.89
1988	**2.69**	1.03	0.24	0.17	0.12	0.15	0.36	0.60	0.13	0.16	0.29	0.71	6.64
1989	0.18	0.10	0.04	0.03	0.02	0.03	0.03	0.08	0.06	**9.04**	**5.51**	1.07	16.18
1990	0.98	0.26	0.06	0.03	0.02	0.13	0.07	0.08	0.06	0.28	0.14	0.30	2.41
1991	0.07	0.08	0.05	0.22	0.19	0.18	0.21	0.18	0.38	0.35	0.21	0.25	2.35
1992	0.13	0.55	0.25	0.22	0.18	0.13	0.08	0.10	0.06	0.06	0.21	0.46	2.40
1993	0.74	0.66	0.26	0.16	0.09	0.07	0.25	0.19	0.60	0.40	0.16	1.64	5.22
1994	0.30	0.08	0.04	0.03	0.18	0.18	0.32	0.49	0.49	0.33	0.29	0.61	3.33
1995	0.10	0.08	0.06	0.10	0.16	0.09	0.36	0.71	0.18	0.09	0.07	0.27	2.26
1996	**3.95**	**6.29**	0.31	0.18	0.19	0.22	0.36	0.99	0.68	0.92	0.93	1.11	16.14
1997	1.38	0.64	0.16	0.08	0.12	0.07	0.04	0.10	0.09	0.06	0.09	0.25	3.07
1998	0.43	0.32	0.25	0.18	**5.41**	**2.90**	0.31	0.49	0.46	0.46	**3.14**	**2.29**	16.64
1999	**9.36**	**7.02**	0.88	0.20	0.04	0.03	0.35	0.56	**14.96**	**7.15**	0.90	**20.38**	61.83
Median	0.67	0.56	0.23	0.17	0.15	0.18	0.29	0.54	0.40	0.46	0.61	1.44	7.44
Average	2.12	1.38	0.40	0.18	0.21	0.60	0.55	1.33	1.21	1.22	1.91	3.04	14.17

Monthly > 2 mil   Annual < 3 mil

v. EHI for the Future Scenario 4

Hydrology

Variable	Score	Motivation	Confidence
a. % similarity in period of low flows or Present MAR as a % of MAR in the Reference Condition	70	Under Scenario 4 the Seekoei has a MAR of 14.17 million m^3 in comparison with the Reference Condition of 20.27 million m^3. Therefore 70% of the runoff is still reaching the estuary.	L
b. % similarity in mean annual frequency of floods	73	For the Seekoei, months with flows of $10m^3/s$ or more were estimated to be indicative of flood events. Under Scenario 4 these events occur 19 times in the 73-year period, in comparison with 26 under the Reference Condition. Therefore about 73% of the larger flood event would still reach the estuary.	L
Hydrology score	**71**		

Hydrodynamics and mouth condition

Variable	Score	Motivation	Confidence
Change in mean duration of closure, e.g. over a 5 or 10 year period	80	Under Scenario 4 the potential occurrence of open mouth conditions has been reduced to 89% (8 out of 73 years the system will not breach) from nearly permanently open (99%) under the Reference Condition. Following the guidelines stipulated in Table 3.3b (DWAF, 2004) this results in a score of 80.	L
Hydrodynamics and mouth condition score	**80**		

Water quality

Variable	Score	Motivation	Confidence
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	70	During the Reference Condition, State 1: Open mouth prevailed for nearly 100% of the years within the simulation period. From May to Dec a strong longitudinal salinity gradient to fresh conditions would have occurred. Hypersalinity should not have been an issue. Under Scenario 4, State 1: Open mouth occurs for 89% of the years within the simulation period. This is indicative not only of a decrease in open mouth conditions from the Reference Condition, but also a decrease in the occurrence of strong salinity gradients or fresh conditions in the system. Also within State 1, strong longitudinal salinity gradient to fresh conditions now only occurs for 5 months (May, Aug to Nov) compared to 8 months under the Reference Condition. Under Scenario 4, State 2: Closed mouth would not occur for extended periods at a time as the river inflow is still sufficient. Hypersaline conditions are less likely to occur than at present and values less than 45ppt are expected.	L
2a. Nitrate/phosphate concentration in the estuary	55	The rivers (Swart and Seekoei) are the major inorganic nutrient sources to the Seekoei Estuary. With extensive agricultural development in the catchment, it is expected that nutrient concentrations in river inflow will also be higher compared to the Reference Condition. Using modification in MAR as proxy for modification in inorganic nutrients: The MAR reduced from 20.27 million m^3 in the Reference Condition to 14.17 million m^3 under Scenario 2 (i.e. a reduction of 30%). Based on modification to river inflow, inorganic nutrient levels will be reduced to about 70% of Reference Condition. Furthermore, agricultural activities in the catchment introduced higher inorganic nutrients into river inflow compared to the Reference Condition. Thus, river inflow will introduce higher nutrients into the system compared to Reference Conditions. Assume an additional modification of 15%.	L
2b. Suspended solids present in inflowing freshwater	55	River inflow into the estuary is expected to be one of the major sources of turbidity in the estuary. With extensive agricultural development in the	L

		catchment, turbidity levels in river inflow will also be higher compared to the Reference Condition. Using modification in MAR as proxy for modification in turbidity: The MAR reduced from 20.27 million m^3 in the Reference Condition to 14.17 million m^3 under the Present State (i.e. a reduction of 30%). Based on modification to river inflow, turbidity levels were reduced to about 70% of Reference Condition. Furthermore, agricultural activities in the catchment introduce higher turbidity into river inflow compared to the Reference Condition. Thus, river inflow will introduce higher turbidity into the system compared to Reference Conditions. Assume an additional modification of 15%.	
2c. Dissolved oxygen in the estuary	100	The Seekoei Estuary should generally be well-oxygenated being a shallow system (i.e. even during periods of low or no river inflow, wind mixing maintains oxygenated conditions).	L
2d. Levels of toxins	75	There are no major urban or industrial areas in the catchment. However, extensive agricultural developments probably introduce some toxic substances (e.g. pesticides) into the system.	L
Water quality Score	**61**		

Physical habitat alteration

Variable	Score	Motivation	Confidence
1. Resemblance of <u>intertidal sediment</u> structure and distribution to Reference Condition			
1a. % similarity in intertidal area exposed	74	Less change in the intertidal areas as open mouth conditions occur 89% of the time. Some small changes in intertidal area due to the construction of the causeway.	L
1b. % similarity in sand fraction relative to total sand and mud	60	There will still be more muddy substrate due to land-use changes and reduced tidal flushing.	L
2. Resemblance of subtidal estuary to Reference Condition: depth, bed or channel morphology	80	Less change in the intertidal areas as open mouth conditions occur 89% of the time. Still some changes will occur because of the stabilised channel configuration due to the causeway, the shallower areas between the mouth, the causeway and the main channels are potentially deeper especially near or at the causeway where the flow are restricted.	L
Physical habitat score	**73.5**		

4.5.2 Biotic Components

i. Predicted changes in biotic characteristics of Future Scenario 4 compared with the Reference Condition, as well as the causes of these changes:

Microalgae
Baseflow is improved compared to the Present Condition. There is a longitudinal gradient and freshwater, brackish and marine species should all be present. The increase in freshettes and pulses of nutrient rich freshwater inflow would result in an increase in phytoplankton biomass relative to the Reference Condition. Increased flow and associated nutrient input from the surrounding agricultural areas may result in nuisance groups such as dinoflagellates (saline conditions) and blue-green algae (freshwater conditions). The increase in open mouth conditions compared to present would return the system nearer to that of natural, where subtidal benthic microalgal biomass was probably quite low. Confidence: Medium
Macrophytes
Brackish reed and sedge species and pondweed, *Potamogeton pectinatus*, would return to the estuary if salinity in the upper reaches remained less than 15 ppt for approximately 4 months at a time. Submerged macrophyte and filamentous algal biomass would return to the Reference Condition due to an increase in the frequency of open mouth conditions and a natural salinity gradient. The area covered by salt marsh plants may be reduced due to unnatural water level fluctuations caused by the causeway. Nutrient input from surrounding agricultural activities may increase the occurrence of filamentous green algal mats. Confidence: Medium
Invertebrates (including zooplankton, benthic invertebrates and macrocrustaceans)
Invertebrate communities would approach composition and structure similar to the Reference Condition, with typical zonation patterns for most of the time (as a consequence of salinity gradients). More frequent pulsing compared to present would also elevate average biomass through increased food availability. Increased habitat availability, associated with brackish water zones would also increase. Confidence: Medium
Fish
Fish composition and abundance would tend towards the Reference Condition due to the improved baseflow, absence of hypersaline conditions and increased habitat diversity. Recovery of the planktonic food chain would result in a more abundant planktivorous fish assemblage when compared to the Present State. Confidence: Medium
Birds
Avifaunal composition and abundance would be expected to recover towards the Reference Condition due to recovery of habitat and food supplies, as well as the estuary being in a typical estuarine state for most of the time. Confidence: Medium

ii. EHI for the Future Scenario 4

Microalgae

Variable	Score	Motivation	Confidence
Phytoplankton			
1. Species richness	65 (80%)	Baseflow is improved compared to the present condition. There is a longitudinal gradient and freshwater, brackish and marine species should all be present. 80% of the original species probably remain.	M
2a. Abundance	70	The increase in freshettes and pulses of nutrient rich freshwater inflow would result	M

		in an increase in phytoplankton biomass relative to the Reference Condition. However, phytoplankton biomass was probably never very significant in the Seekoei Estuary (< 2 µg l^{-1}).	
2b. Community composition	65	Freshwater, brackish and saline assemblages would be present. Increased flow and associated nutrient input from the surrounding agricultural areas may result in nuisance groups such as dinoflagellates (saline conditions) and blue-green algae (freshwater conditions).	M
Benthic microalgae			
1. Species richness	65 (80%)	Baseflow is improved compared to the Present Condition. There is a longitudinal gradient and freshwater, brackish and marine species should all be present. The increase in muddy sediment upstream of the causeway can result in the loss of sand loving species. 80% of the original species probably remain.	M
2a. Abundance	70	The increase in open mouth conditions compared to present would return the system closer to that of natural, where subtidal benthic microalgal biomass was probably quite low. The increase in nutrients from surrounding agriculture could increase biomass. However, tidal flows would probably limit the development of high biomass.	M
2b. Community composition	65	The estuary would be more dynamic than at present with floods and freshettes promoting primary colonisers and freshwater, brackish and saline assemblages. Increased flow and associated nutrient input from the surrounding agricultural areas may result in nuisance groups such as blue-green algae (freshwater conditions).	M
Microalgae score	**65**		

Macrophytes

Variable	Score	Motivation	Confidence
1. Species richness	65 (80%)	Brackish reed and sedge species and the pondweed, *Potamogeton pectinatus*, would return to the estuary if salinity in the upper reaches remained less than 15 ppt for approximately 4 months at a time. Hypersaline conditions are unlikely to occur and therefore 80% of the original species remain. Agricultural nutrient input may promote the growth of weedy species that would outcompete other species.	M
2a. Abundance	70	Submerged macrophyte and filamentous algal biomass would return to the Reference Condition due to an increase in the frequency of open mouth conditions and a natural salinity gradient. Their biomass would be dependent on flow velocity and the availability of inorganic nutrients. The area covered by salt marsh	M

		plants may be reduced due to unnatural water level fluctuations caused by the causeway.	
2b. Community composition	65	An increase in the frequency of open mouth conditions and a longitudinal salinity gradient would mean that freshwater, brackish and saline species would be present. Nutrient input from surrounding agricultural activities may increase the occurrence of filamentous green algal mats.	M
Macrophytes score	**65**		

Invertebrates

Variable	Score	Motivation	Confidence
Zooplankton			
1. Species richness	80 (90%)	The presence of a more regular salinity gradient and more frequent mouth opening would ensure that species richness would be maximum most of time (due to increase in baseflows).	M
2a. Abundance	80	Abundance levels would increase in response to the more frequent pulsing of the system through freshwater inflow. Average abundance levels would therefore be higher compared to present.	M
2b. Community composition	80	Similarly, community composition would be similar to the natural condition as a consequence of the presence of salinity gradients and the more frequent opening of the estuary mouth.	M
Macroinvertebrates			
1. Species richness	80 (90%)	The presence of a more regular salinity gradient and more frequent mouth opening would ensure that species richness would approach maximum most of time (due to increase in baseflows).	M
2a. Abundance	75	Abundance levels would increase in response to the more frequent pulsing of the system through freshwater inflow. Average abundance levels would therefore be higher compared to present. However, recovery would be slower compared to the zooplankton community and some windows of suitable conditions may not persist for long enough to enable all species to reach maximum abundance.	M
2b. Community composition	75	Similarly, community composition would be similar to the natural condition as a consequence of the presence of salinity gradients and the more frequent opening of the estuary mouth. However, recovery would be slower compared to the zooplankton community and some windows of suitable conditions may not persist for long enough to enable all species to recolonise.	M
Macrocrustacea			
1. Species richness	80 (90%)	The presence of a more regular salinity gradient and more frequent mouth opening would ensure that species richness would	M

		be maximum most of time (due to increase in baseflows).	
2a. Abundance	75	Abundance levels would increase in response to the more frequent pulsing of the system through freshwater inflow. Average abundance levels would therefore be higher compared to present. However, recovery would be slower compared to the zooplankton community and some windows of suitable conditions may not persist for long enough to enable all species to reach maximum abundance.	M
2b. Community composition	75	Community composition would also be similar to the natural condition as a consequence of the presence of salinity gradients and the more frequent opening of the estuary mouth. However, recovery would be slower compared to the zooplankton community and some windows of suitable conditions may not persist for long enough to enable all species to recolonise.	M
Invertebrate score	**75**		

Fish

Variable	Score	Motivation	Confidence
1. Species richness	73 (85%)	Most marine and estuarine species will be present due to the improvement in mouth and salinity conditions. There are only a few freshwater species missing during low river flow periods.	M
2a. Abundance	70	Fish abundance is likely to improve considerably when compared to the Present State due to the more natural functioning of the aquatic food web and elimination of lethal hypersaline conditions.	M
2b. Community composition	70	Fish community composition is likely to be more similar to the Reference State due to the increased open mouth conditions and more normal salinity gradients within the estuary.	M
Fish score	**70**		

Birds

Variable	Score	Motivation	Confidence
1. Species richness	85	Most of the original bird species are likely to occur on the estuary, but instantaneous species richness may be slightly lower due to occasional occurrence of relatively full or dry conditions.	M
2a. Abundance	75	Abundance will bear a closer resemblance to natural state because of the more steady state of the system and recovery of habitat and food supplies.	M
2b. Community composition	70	Community composition is likely to bear closer resemblance to the Reference State, but may differ somewhat during low flow periods.	M
Bird score	**70**		

4.6 Ecological Reserve categories associated with different scenarios

The individual EHI scores, as well as the corresponding ERC for the different scenarios are provided in Table 4-5.

Table 4-5 EHI score and corresponding ERC for the different runoff scenarios

Variable	Weight	Present	Runoff Scenario			
			1	2	3	4
Hydrology	25	58	81	60	58	71
Hydrodynamics/mouth condition	25	40	85	45	20	80
Water quality	25	40	63	51	43	61
Physical habitat alteration	25	61	76	68	61	74
Habitat Health Score	**50**	**50**	**76**	**56**	**46**	**71**
Microalgae	20	35	70	40	25	65
Macrophytes	20	35	70	40	30	65
Invertebrates	20	30	75	50	35	75
Fish	20	35	80	40	35	70
Birds	20	40	80	55	40	70
Biotic Health Score	**50**	**35**	**75**	**45**	**33**	**69**
Estuarine Health Index Score		**42**	**76**	**51**	**39**	**70**
Ecological Reserve Category (ERC)		**D-**	**B**	**D**	**E**	**C**

4.7 Recommended Ecological Flow Requirement for the Seekoei Estuary

The evaluation of the simulated runoff scenarios is used to derive the recommended Ecological Flow Requirement which is defined as the runoff scenario (or a slight modification thereof) that represents the highest reduction in river inflow that will still protect the aquatic ecosystem of the estuary and keep it in the recommended ERC.

The Seekoei Estuary is a Provincial Nature Reserve. According to the guidelines for assigning a recommended ERC, the estuary therefore needs to be in a Category A or the Best Attainable State (BAS). However, due to the fact that the changes that are contributing to the Present State of the estuary (Category D-) are seen as partially irreversible, the workshop decided that it should be recommended that the Seekoei Estuary be improved into the highest achievable ERC, which is a **Category B**.

The recommended Category B can be achieved through a combination of flow and non-flow related management interventions, as anthropogenic influences (other than flow) have had a significant influence on the estuary's health. An evaluation was therefore made of the combination of a **Category C Flow Scenario** and the **reversal of the non-flow related influences** by using the adjusted scores in the EHI. This indicated that a Category B can be achieved through this combination.

Therefore, **Scenario 4** is selected as the recommended Ecological Flow Requirement (Scenario) for the Seekoei Estuary, with flow distributions as summarised below:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99%ile	**20.15**	**9.37**	**3.83**	1.03	**2.03**	**10.26**	**5.38**	**15.07**	**14.87**	**9.71**	**19.96**	**24.55**
90%ile	**4.69**	**3.40**	0.40	0.22	0.19	0.27	0.90	1.44	**2.18**	**2.25**	**3.34**	**6.93**
80%ile	**2.63**	1.71	0.28	0.22	0.19	0.22	0.36	1.08	1.09	1.43	**2.18**	**3.46**
70%ile	1.40	1.08	0.27	0.21	0.18	0.21	0.35	0.87	0.62	0.86	1.68	**2.24**
60%ile	0.97	0.62	0.25	0.20	0.16	0.19	0.32	0.74	0.51	0.62	1.24	1.81
50%ile	0.67	0.56	0.23	0.17	0.15	0.18	0.29	0.54	0.40	0.46	0.61	1.44
40%ile	0.52	0.44	0.18	0.14	0.12	0.14	0.24	0.43	0.32	0.35	0.39	1.10
30%ile	0.33	0.31	0.13	0.10	0.09	0.10	0.17	0.33	0.23	0.23	0.29	0.76
20%ile	0.18	0.19	0.07	0.07	0.05	0.07	0.11	0.18	0.14	0.15	0.20	0.46
10%ile	0.10	0.11	0.05	0.04	0.04	0.04	0.06	0.11	0.08	0.08	0.09	0.25
1%ile	0.07	0.08	0.04	0.03	0.02	0.03	0.04	0.08	0.06	0.06	0.07	0.18

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Appendix A

A Desktop Assessment of the physical dynamics of the Seekoei River Estuary

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CSIR, Environmentek

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TERMINOLOGY AND ACRONYMS

DWAF	Department of Water Affairs and Forestry
m	metre
MAR	Mean Annual Run-off
MSL	Mean Sea Level

1. INTRODUCTION

The CSIR, Environmentek was commissioned by Coastal & Environmental Services (CES) to undertake a desktop assessment on the physical dynamics of the Seekoei Estuary as part of a preliminary Ecological Reserve Determination on a Rapid Level. The results are included in this report.

2. THE SEEKOEI ESTUARY

Under natural conditions the mouth of the Seekoei Estuary (Figure A-1) was predominantly open. In the recent past, the mouth was closed with occasional opening events, lasting for only a few days. Recently, the mouth has remained open for longer periods, at times extending into months.

Important information for the management of the Seekoei Estuary is available in an earlier report by the CSIR (1990), "Seekoeiriviermond, ondersoek na probleme en moontlike oplossings", which includes the results of an earlier investigation by the CSIR in co-operation with the University of Stellenbosch undertaken for the Algoa Regional Service Council.

The main findings from this earlier report on the Seekoei Estuary are:

1. The reduction in run-off from the catchment

   Current hydrology indicates that historically the mouth of the Seekoei River used to be predominantly open. These open mouth conditions were maintained by continuous low river inflow (baseflow) from the catchment and farm dam developments in the catchment had reduced this baseflow to such an extent that it had often stopped completely.

   This aspect will be discussed in greater detail later in the report.

2. Artificial breachings at lower water levels

   Natural breachings of estuaries along the South African coast normally occur at water levels between + 2.5 and + 3.0 m MSL. The previous report (CSIR, 1990) recommends that mouth breaching of the Seekoei should be undertaken when a water level of + 1.4 m MSL is reached to prevent damage to low lying properties.

   As mentioned, breachings at such low water levels will drastically reduce the flushing potential of sediments and therefore result in ongoing sedimentation. This is likely the main reason why the Seekoei Estuary is shallow.

3. The existence of the causeway across the estuary

   Aerial photographs indicate that this causeway near the mouth, constructed between 1970 and 1971, occasionally prevents the Seekoei Estuary from draining completely after breaching. It is not known whether it was also intended to keep the water in the estuary fresh and to use it for other purposes such as irrigation.

   Later a road was constructed across the causeway to provide a convenient connection for traffic between Ashton Bay and Paradise Beach. It formed a major bottleneck to the tidal flows at open mouth conditions and also at river floods, as described in the earlier report (CSIR, 1990). Since the construction of the causeway, reduction in river flow has resulted in the mouth closing faster and extra sedimentation occurring due of the restricted flow. The earlier study (CSIR, 1990) therefore recommended that further upgrading of this causeway should not be undertaken. Exploration into the removal of the causeway was also suggested as well as the development of an alternative road connection.

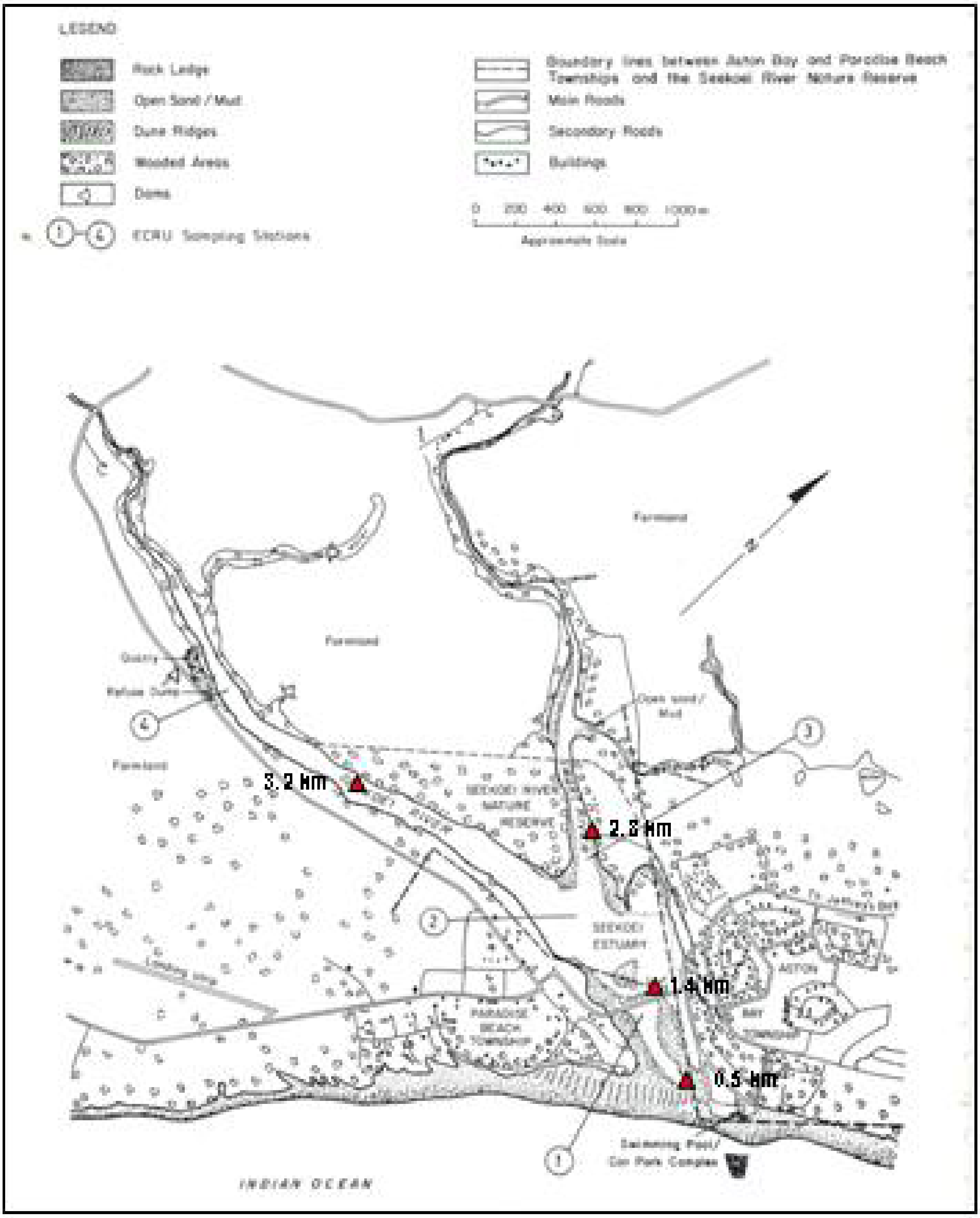

Figure A-1 Locality map of the Seekoei Estuary

A recent upgrading of the causeway to a tar road has been undertaken. This tar road is affected by flooding problems at high water levels and therefore an additional need to breach the estuary mouth at lower water levels has developed.

The effects of the causeway on the estuary will be discussed later.

4. The concrete canal at the eastern end of the estuary mouth

A concrete canal was constructed where, historically, the mouth of the estuary was located, connecting the main channel to the sea. Outflow used to occur here over a rocky sill.

The purpose of the concrete canal, which has an elevated floor level at that of the average high water springtide, was apparently to prevent the Seekoei Estuary from draining completely during open mouth conditions (Mr Le Roux, Town Engineer pers. comm.). Again it is not known whether the intention was also to keep the water in the estuary fresh for other purposes such as irrigation.

Limited tidal exchange took place through this canal and after a mouth breaching closure occurred when the water level had dropped sufficiently. The mouth normally only stayed open for a few days because of the obstruction of the canal to tidal flows. Only limited influx of seawater occurred at high water during springtides. Mouth closure often occurred in front of the canal and artificial mouth breaching was regularly undertaken. Considerable sedimentation occurred at the lower end of the canal and major efforts were regularly required to remove this.

The construction of such a canal was not recommended in the earlier report by the CSIR (1990). It did not function at all and after a few years the efforts to keep it open were stopped.

The mouth is at present breached further to the west and regularly stays open for several months to more than a year at a time.

3. BACKGROUND

3.1 The functioning of estuaries

The functioning of an estuary is mainly maintained by the two most important external driving forces:

- The variable river inflow (floods and baseflow)

- The tidal influence of the sea

Salinity distribution, sediment processes and mouth dynamics are crucial for the ecological functioning of an estuary.

Sediment dynamics and mouth conditions

Large amounts of sediments are flushed out to sea during major river floods and the baseflow is the main force maintaining an open mouth at small estuaries. Reduction in river flow can therefore cause serious negative effects on an estuary. Unfortunately, such reductions in river flow have occurred and are occurring in almost every river system to meet agricultural, domestic and industrial water demands.

Artificial mouth breachings at low water levels strongly reduce the flushing potential of sediments and therefore indirectly result in ongoing sedimentation in estuaries. The flushing potential of sediments at breachings increases exponentially with the increase of the water levels before breachings. Developments of properties at low levels along almost every estuary have resulted in the need for artificial breachings and this contributes indirectly to the ongoing sedimentation.

Changes in the two main external forces, river inflow and tidal influence from the sea, can therefore have strong effects on an estuary. The management of an estuary should especially be based on ensuring that any changes in these forces be kept as minimal as possible.

Management rules for mouth breachings should, however, take two aspects into account. Firstly mouth breachings should preferably be undertaken at as high water levels as possible. Secondly, damage could occur to low lying properties if mouth breachings are undertaken at higher water levels than at present.

3.2 Data availability on the functioning of estuaries

Only limited data is available for the Seekoei Estuary. The data available for the Seekoei includes:

- Anecdotal information on the condition of the mouth in the past
- Continuous water level recordings in the estuary. A recorder has been operated in the Seekoei Estuary from January 2003.
- Records of openings and closures of the estuary mouth. Such records were obtained for the Seekoei Estuary from June 1995 from Mr G. Ferreira of the Eastern Cape Department of Nature Conservation.
- Recordings of river inflow are not available for the Seekoei Estuary. Only simulated runoff data, with a low level of confidence, was obtained from Ninham Shand Consulting Engineers.
- Bathymetric surveys of the estuary upstream of the mouth, to be repeated at time intervals of approximately five years and extra surveys to be undertaken after major floods. Such data was collected for the lower estuary by the CSIR for the Department of Environment Affairs and Tourism.
- Limited water quality data.

3.2.1 Anecdotal information on the condition of the estuary mouth

The mouth of the estuary was predominantly open in the past according to anecdotal information. It was the perception that this was the case because of continuous river flow and also because the mouth was often located on a rocky sill at the eastern end of the berm (Table A-1).

The construction of the causeway in the 1970s probably resulted in an obstruction to tidal flows and in more frequent mouth closure. Its purpose was to prevent the estuary from draining and running dry. It is not known whether the purpose was also to keep seawater out and the salinities lower so that the water could be used for other purposes such as irrigation.

3.2.2 Information from aerial photographs

Table A-1 Summary of the Seekoei mouth conditions from historical aerial photographs.

Date	Mouth Status	Comments	Flows m^3/S
1961	Closed	Lower estuary almost dry, deeper mainly in western tributary	
03/10/1967	Closed		0.43
19/12/1968	Closed		0.16
02/05/1970	Closed	Causeway not present	0.50
22/11/1971	Open	Causeway across estuary. Mouth meanders in SW direction	0.86
25/09/1972	Closed	Causeway largely submerged	0.27
08/04/1977	Closed		0.03
20/04/1979	Closed		0.14
09/04/1980	Open	Straight channel, sandy causeway with breach	0.13
12/1980	Open	Channel runs out straight	0.16
12/1981	Open	Mouth runs along groyne	0.16
09/06/1986	Closed		0.25
1992	Closed	Lower estuary almost dry	

This information shows that the mouth was closed on several occasions in the 1960s and 1970s. This contradicts to some extent the likelihood of a permanently open mouth under natural conditions. However, this discrepancy is probably the result of the construction of the causeway in the 1970s and its effect on tidal flows.

The simulated runoff data in average flows (for the months in which there are photographs) are listed in the column on the right. However, it is not advisable to use this data as a result of the low confidence in the hydrology and the effect of the other anthropogenic influences.

3.2.3 Information from mouth observations

Information on open and closed mouth conditions is included in Table A-2.

Table A-2 Summary of the Seekoei Estuary open and closed mouth conditions since 1995

Date	Mouth condition	Notes
06/01/1995	Canal open	Weir overflows into sea
06/09/1995	Canal open	Fish deaths - cause unknown
06/12/1995	Canal closes	
	Period open -12 days	
13/06/1995	Closed	Springtide - sea fills lagoon
19/06/1995	Canal opened	Road repairs
30/06/1995	Canal closes	
	Period open -16 days	
07/03/1995	Canal opened	Road repairs
07/06/1995	Canal closed	

Date	Mouth condition	Notes
	Period open -3 days	
13/07/1995	Canal semi opened	Road repairs
07/10/1995	Canal opened	Road repairs
20/07/1995	Canal closes	
	Period open -10 days	
08/04/1995	Closed	Effort to open canal
16/08/1995	Canal opened	Road repairs
24/08/1995	Canal closes	
	Period open -8 days	
29/08/1995	Canal opened	Road repairs
14/09/1995	Canal closes	
	Period open -16 days	
24/01/1996	Closed	Algae bloom - bad smell
20/03/1996	Closed	Canal silted up completely
23/10/1996	Natural mouth open	Heavy rain
21/11/1996	Natural mouth open	Heavy rain causeway under water
03/04/1997	Open	Busy closing
29/05/1997	Open	Heavy rain
26/08/1997	Open	Heavy rain
03/09/1998	Closes	Water level very low
	Period open -17 months	**Regular heavy rains**
17/07/1999	Closed	6m swells fills lagoon
03/06/2000	Closed	Heavy rain - high water level
04/06/2000	Canal opened	River runs empty
	Period open -?	**Must have closed within a short period**
18/11/2001	Closed	Flamingo leave after heavy rain
25/05/2002	Closed	Flamingo return
17/08/2002	Mouth opened	Heavy rain - trench dug to assist breach
11/05/2002	Mouth still open	Very heavy swells flattens berm, cause-way - sea took 3m deep sand away
21/02/2003	Open	Springtide fills lagoon
19/06/2003	Closes	
	Period open -10 months	
21/08/2003	Canal opened	Fails to drain lagoon
26/08/2003	Trench dug in mouth	Hightide closes trench
27/08/2003	Mouth opened	Berm breached with deeper trench
05/01/2004	Closes	
	Period open -9 months	
12/10/2004	Closed	Very high water level
24/12/2004	Opened	Heavy flash flood
22/1/2005	Open	

These data show that the mouth was breached six times between June 1995 and January 1996 but that it only remained open between 3 and 16 days. According to Mr Ferreira of Eastern Cape Nature Conservation, mouth breachings were still undertaken through the concrete canal. This did not work as the length of mouth opening events was much shorter than seen previously.

From October 1996 the mouth remained open for long periods of time, for 17, 10 and 9 months, while the river flow was low or zero at times during these periods.

According to Mr Ferreira the concrete canal was not used for the mouth breaching and at each event a direct connection between the estuary and the sea was established.

3.2.4 Information from water level recordings

Summary results for 2003 and for the first half of 2004 are included in Figures A-2 and A-3 and, as a typical example, the results for October 2003 are shown in Figure A-4.

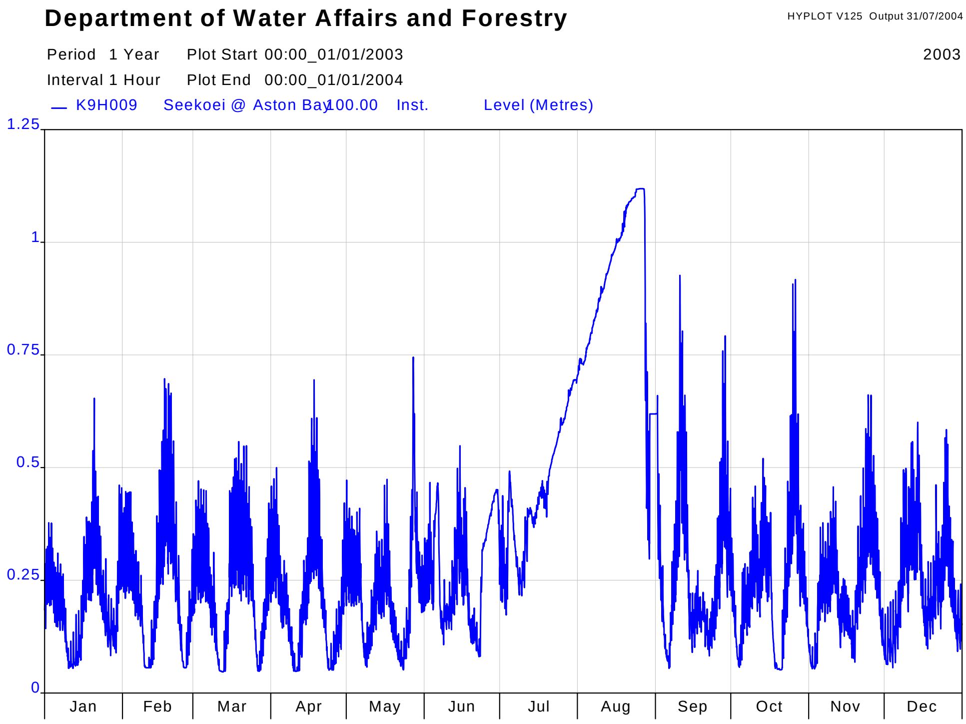

Figure A-2 Water level recordings during 2003

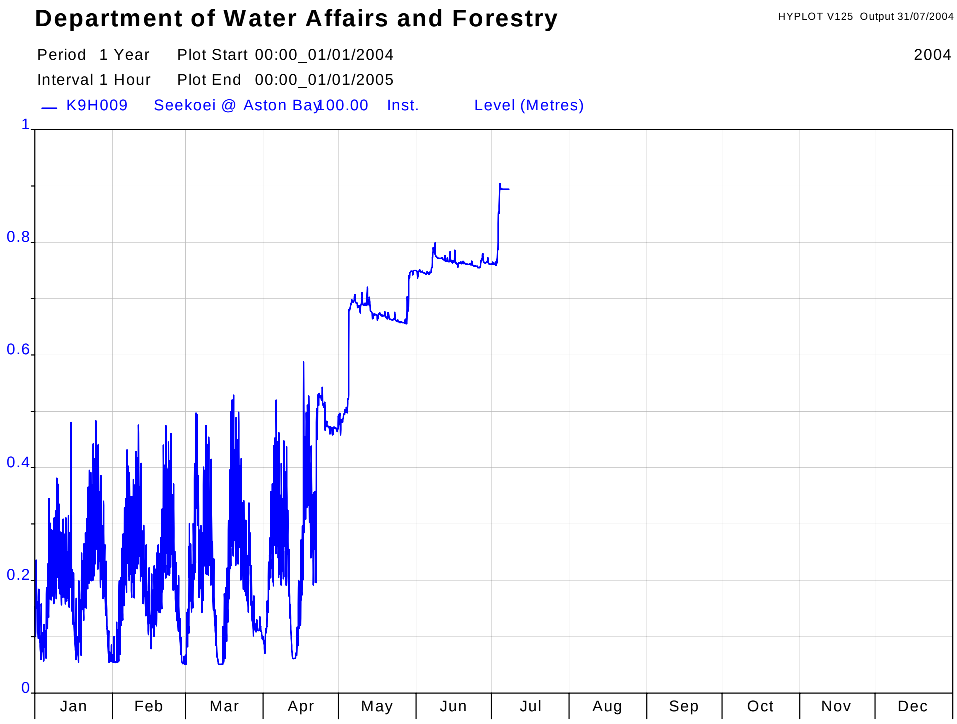

Figure A-3 Water level recordings during 2004

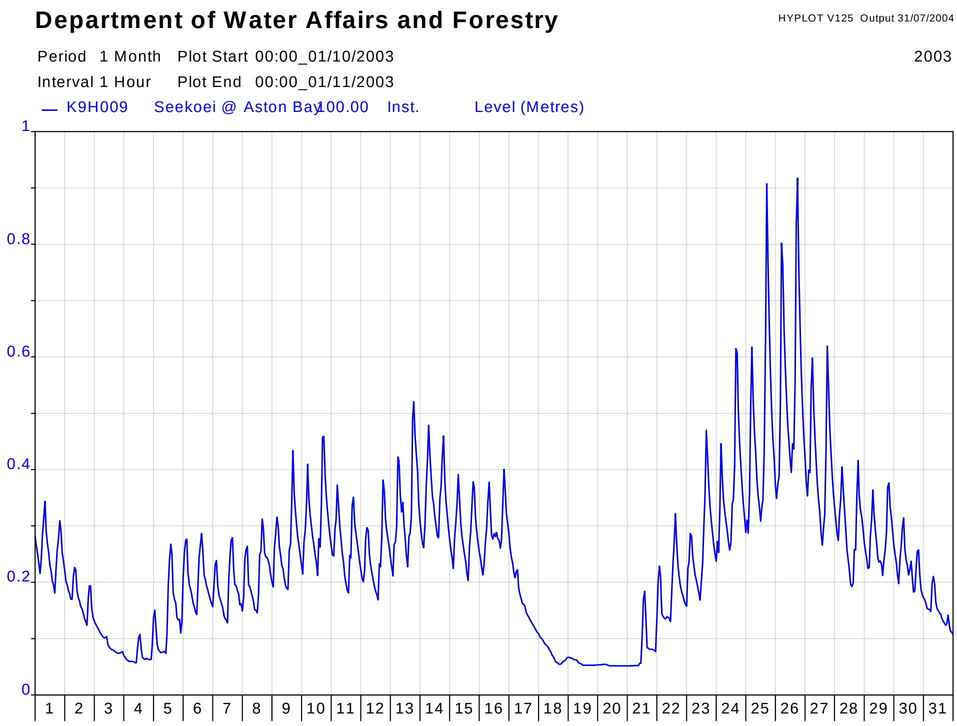

Figure A-4 Water level recordings during October 2003.

These water level recordings confirm the mouth observations (section 3.2.3) and also show that the mouth has been open for periods of several months. For example, the mouth was opened in August 2003 and closed again in May 2004 after more than 8 months. This is even more interesting because the rainfall was low during this period.

The recording for October 2003 shows how the water levels at low tide increase during spring tides and how they drop during neap tides. This means that the estuary gradually fills up at each incoming flood tide during spring tide and that not all the water drains out again during the following ebbtide. At neap tide the opposite happens. At each ebb tide more water flows out than enters the estuary during the following flood tide. Neap tide is the critical period when closure can occur. Closure of such a mouth normally occurs when high waves occur while the tidal flows are low at neap tides.

The fact that the mouth remains open for several months means that this dynamic process of filling of the estuary at springtides and emptying during neaptides is generally effective at keeping the mouth open permanently.

Obstruction to tidal flows, such as the concrete canal and the causeway, will reduce the possibility that the mouth stays open. This is also illustrated by the data of mouth observations.

3.2.5 Available Water Quality data

Date	Stn No	Time	Distance mouth (km)	Long	Lat	Depth	Temp	Sal	pH	DO (mg/L)	Turbidity (NTU)	Secchi (m)	NO_2-N (µg/L)	NO_3-N (µg/L)	NH_3-N (µg/L)	PO_4-P (µg/L)	SiO_4-Si (µg/L)
22/11/1984	1	09:45:00	0.6			0.0	17.5	27.0	8.0	7.7		>1.5					
						1.5	17.6	27.0		7.4							
21/11/1984	2	17:24:00	1.0			0.0	18.2	26.0	8.0	7.5		0.5					
						0.8	18.1	26.0		8.0							
21/11/1984	3	11:30:00	1.5			0.0	18.8	27.0	8.0	7.4		0.7					
						1.2	17.7	27.0		7.7							
21/11/1984	4	17:03:00	3.5			0.0	18.5	26.0	6.75 (?)	7.9		0.8					
						1.6	18.6	26.0		7.9							
19/02/2004	Mouth	15:20:00	0.2	34 05.167	24 54.622	0.0	22.5	34.9	8.1	7.35	0.1		<10	<10	<10	12	135
	Causeway	15:40:00	0.7	34 05.042	24 54.245	0.0	24.5	36.0	8.1	6.8	0.2		<10	13	<10	35	398
	Swart	16:00:00	1.6	34 04.903	24 53.647	0.0	25.7	39.6	8.2	7.8	0.4		<10	<10	<10	111	305
	Seekoei	16:20:00	2.8	34.05.398	24 52.376	0.0	25.7	41.7	8.1	7.4	0.1		<10	<10	<10	60	583

Bickerton, I. B. and Pierce, S. M. 1988. *Estuaries of the Cape: Part II: Synopsis of available information on individual systems*. Report No. 33 Krom (CMS 45), Seekoei (CMS 46) and Kabeljou (CMS 47). Heydorn, A E F and Morant, O D (eds.). Stellenbosch, CSIR Research Report **432**.

4. CONCLUSIONS

The main conclusions from this desktop assessment, based on limited reliable information are:

4.1 Mouth conditions

The periods of open and closed mouth conditions are often crucial for the ecological functioning of an estuary such as the Seekoei. The mouth of the estuary was predominantly open under natural conditions. Later it became temporarily open/closed and after breachings it only remained open for short periods, unless a strong river flow was maintained. Four main influences probably caused this reduction in open mouth conditions:

- Reduction in riverflow because of farm dam developments and irrigation in the catchment.
- Obstructions to tidal flows at the mouth because of the construction of the causeway, before the openings in the causeway were increased.
- Obstructions to tidal flows after the construction of the concrete canal with the floor level at that of average high spring tide in the sea. Fortunately this concrete canal is no longer used, but major expenses were involved in its construction.
- Breachings of the mouth at too low water levels.

More recently, after the concrete canal was no longer in use and the opening in the causeway was increased, the mouth remained open for much longer periods of up to 18 months, even while the river flow was very low or even zero.

Different ways should be explored to allow an increase in water levels before breaching. This will likely be difficult because of the low lying properties. Yet, unless a real effort is made to allow an increase of the water level at mouth breachings, a further increase in sedimentation should be expected.

The water level at which the mouth should be breached should be as high as possible and if possible breaching should occur naturally.

As mentioned, the mouth of the Seekoei is breached at much lower levels (+ 1.4 m MSL) than the natural breaching level (approximately + 2.5 m MSL). It is probably not realistic to change this overnight because considerable damage to properties could occur, however, ways should be explored to improve the situation.

4.2 Salinity distributions

It is important for a healthy ecological functioning of the estuary that certain salinity distributions and gradients are maintained in the estuary. The baseflow plays an important role in this respect. The strong reduction in baseflow at present therefore has a negative impact on the ecology of the estuary. It is expected that an estimate of the baseflow requirements will be found in the Rapid Reserve Determination.

5. REFERENCES

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