PROJECT NAME : PRE-FEASIBILITY STUDY INTO MEASURES TO IMPROVE THE MANAGEMENT OF THE LOWER ORANGE RIVER AND TO PROVIDE FOR FUTURE DEVELOPMENTS ALONG THE BORDER BETWEEN NAMIBIA AND SOUTH AFRICA

REPORT TITLE : Specialist Report on the Determination of the Preliminary Ecological Reserve on a Rapid Level for Orange River Estuary

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Submitted on behalf of the Project Team by Lower Orange River Consultants:

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LIST OF REPORTS

TITLE	REPORT NUMBER		
	DWAF RSA	DWA Namibia	LORC (NS)
Main Report	PB D000/00/4703	400/8/1/P-13	3749/97331
Synopsis	PB D000/00/4703	400/8/1/P-13	3749/97331
Legal, Institutional, Water Sharing, Cost Sharing, Management and Dam Operation	PB D000/00/4603	400/8/1/P-10	3692/97331
Specialist Report on the Environmental Flow Requirements - Riverine	PB D000/00/4503	400/8/1/P-07	3519/97331
Specialist Report on the Determination of the Preliminary Ecological Reserve on a Rapid Level for Orange River Estuary	**PB D000/00/4503**	**400/8/1/P-08**	**3663/97331**
Water Requirements	PB D000/00/4202	400/8/1/P-02	3486/97331
Hydrology, Water Quality and Systems Analysis (Volume A)	PB D000/00/4303	400/8/1/P04	3736/97331
Hydrology, Water Quality and Systems Analysis (Volume B)	PB D000/00/4303	400/8/1/P-03	3485/97331
Water Conservation and Demand Management	PB D000/00/4903	400/8/1/P-12	3487/97331
Dam Development Options and Economic Analysis – Volume 1	PB D000/00/4403	400/8/1/P-05	3484/97331
Dam Development Options and Economic Analysis – Volume 2 (Appendices)	PB D000/00/4403	400/8/1/P-05	3484/97331
Environmental Assessment of the Proposed Dam Sites on the Orange River	PB D000/00/4503	400/8/1/P-06	3873/97331
Vioolsdrift/Noordoewer Joint Irrigation Scheme: Assessment of Viability	PB D000/00/4803	400/8/1/P-11	3525/97331
Public Consultation	PB D000/00/4503	400/8/1/P-09	3869/97331
Inception Report	PB D000/00/4102	400/8/1/P-01	3365/97331

EXECUTIVE SUMMARY

Assumptions and Limitations

The following assumptions and limitations need to be taken into account for this study:

- *It was agreed among the different parties that the determination of the Ecological Reserve on a Rapid level for the Orange River Estuary be based on the methodology for estuaries as set out by South Africa's Department of Water Affairs and Forestry in Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component (Version 1.0) (DWAF, 1999) and subsequent revisions of the methods of which the documentation is currently in preparation (B Weston, RDM Directorate, DWAF, pers. comm.).*

- *The ecological Importance rating of the Orange River Estuary was based on a national (SA) perspective. In future, the ecological importance rating of trans-boundary systems need to be based on a more regional perspective (e.g. southern Africa), rather than only a national (SA) perspectives.*

- *The determination of the Ecological Reserve on a Rapid level for the Orange River Estuary was based on published or readily available data and information as listed in Appendix A and discussed in the Specialist Reports (Appendices B to E).*

- *The results of this study were based on the simulated runoff data provided to the study team by the DWAF (SA). The data were reviewed by the Namibian consultants, who concluded the following: "The general impression is that the work has been carried out thoroughly as far as the data will allow. There is no reason to disagree with the hydrological files being used as input for the system analysis". The need to update the hydrology for the incremental Orange River Catchment upstream of Vanderkloof Dam, as well as for the Orange River downstream of Van der Kloof Dam to the Orange River Mouth (Fish River excluded) was also expressed as a concern by the Namibian consultants, as this hydrology is already more than a decade old (Mr M Maré, Water Resource Planning, DWAF, pers. comm.).*

  A high confidence level can be placed on the hydrology generated as part of the Vaal River System Analysis Update (VRSAU) Study, which includes the Senqu hydrology in Lesotho. Almost 70% of the natural runoff is generated in these catchments, which clearly represents the bulk of the runoff generated in the Orange River catchment. Approximately 23% of the natural flow is generated in the Orange River incremental catchment upstream of Vanderkloof Dam and downstream of Lesotho (Caledon River catchment included). Although this hydrology is old, a relatively high confidence level can be placed on the hydrology.

  A medium to low confidence level can be placed on the hydrology downstream of Vanderkloof Dam (excluding the Vaal and Fish Rivers). The runoff generated in this catchment, however, represents only 3% of the total natural runoff. The fact that the accuracy of the hydrology used for this extremely large incremental catchment is not at the required level, will due to the volume of runoff generated, have an insignificant effect on the analysis.

  As part of the Lower Orange River Management Study (LORMS) a simplified rainfall/runoff modelling was carried out to obtain updated hydrology for the Fish River (Namibia). A detailed rainfall/runoff assessment was therefore not carried out for the Fish River (Namibia), partly due to time constraints, but also due to the fact that the natural runoff from the Fish River catchment only represents approximately 4% of the total Orange River runoff.

  Although the bulk of the hydrology can be regarded as reliable, the main problem regarding the accuracy of observed flows is with regards to flows and specifically low flows measured in the Lower Orange River (LOR). Most of the gauging weirs in the Lower Orange River are long weirs, so that the slightest increase in flow depth, results in a significant increase in the flow rate. It is therefore extremely difficult to tell from the observed flows, how much water is flowing in the Lower Orange River and specifically the flow that enters the river mouth. This problem is further complicated by the fact that the bulk of the abstractions are for irrigation purposes for which there is basically no observed data available. A large volume of water is also lost due to evaporation from the river, for *which a fairly good indication was obtained of the average river evaporation losses from studies carried out by the WRC. This will however vary depending on the actual weather conditions and flow in the river.*

To conclude, the inflows to Gariep and Vanderkloof Dams, as well as the outflow from the Vaal River catchment entering the Orange River, can be used with confidence, the actual observed flows in the Lower Orange River are not at the required level and need to be improved significantly (Mr M Maré, Water Resource Planning, DWAF, pers. comm.).

The results contained in this report were those of the specialist team. Although the observers participated in the workshop, the final decisions on, for example the recommended Ecological Category and the recommended Ecological Flow Scenario was that of the specialist team.

- *Criteria for confidence limits attached to statements throughout this report 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%)

- *It was not within the brief of this study to address the freshwater requirements of the marine environment adjacent to the Orange River. The National Water Act 36 of 1998 of South Africa does not classify marine waters as a resource and, as a result, it does not make provision for freshwater requirements of the marine environment. However, in the case of the Orange River, input from the river, e.g. sediment and detritus, is expected to have a marked influence on the ecological processes of the adjacent marine environment, ranging from local to regional scales. For example, sediment export replenishes the nearshore habitats that are continuously eroded by oceanic currents and also provides a refuge for many fish by increasing turbidity. Sediment and detrital export may be important to detrivores (e.g. mullet), as well as to species that may require a specific sediment habitat type for foraging, spawning nursery area. Turbidity also tends to increase the catch ability of many species, especially the larger individuals that move into the turbid environment in search of concentrated prey. Freshwater flows (and associated plumes) also provide cues for the migration of estuarine-dependent juvenile and adult fish into and out of the estuarine environment (refer to **Appendix F**).*

  Based on the above, it is strongly recommended that freshwater requirements of the marine environment be assessed prior to any further water abstraction projects on the Orange River and its tributaries.

Geographical Boundaries

For the purposes of the Rapid Ecological Reserve determination on the Orange River Estuary, the geographical boundaries are estimated as follows (Gauss Projection, Clarke 1880 Spheroid):

- ***Downstream boundary:*** *The estuary mouth (28º38'30"S, 16º27'45"E)*
- ***Upstream boundary:*** *Head of tidal influence, approximately 9.5 km for mouth (28º33'45"S, 16º30'15"E)*
- ***Lateral boundaries:*** *5 m contour above MSL along the banks.*

NOTE:

The precise extent of tidal variation has not been confirmed for the Orange River Estuary and needs to be verified through monitoring. It is also recommended that in future studies, in which new data is collected, the upper boundary be extended to include the area upstream from the bridge, i.e. the planned extension to the Ramsar site.

Present Ecological Status (PES) of the Orange River Estuary

The Present Ecological Status is determined using the Estuarine Health Index (EHI). The Health Index consists of a Habitat health score and a Biological Health score. The scores are 'percentage deviation' from the Reference Condition, e.g., if the Present State is still the same as the Reference Condition, then the score is 100. The average of these two scores provides the Estuarine Health score:

VARIABLE	WEIGHT	SCORES FOR PRESENT STATE
Hydrology	25	58
Hydrodynamics and mouth condition	25	50
Water quality	25	72
Physical habitat alteration	25	86
Habitat health score		**67**
Microalgae	20	50
Macrophytes	20	50
Invertebrates	20	40
Fish	20	60
Birds	20	26
Biotic health score		**45**
ESTUARINE HEALTH SCORE		**56**

*The EHI score for the Orange River Estuary, based on its Present State, is 56, translating into a **Present Ecological Status of D+:***

EHI SCORE	PRESENT ECOLOGICAL STATUS	GENERAL DESCRIPTION
91 – 100	A-/A+	Unmodified, natural
76 – 90	B-/B+	Largely natural with few modifications
61 – 75	C-/C+	Moderately modified
41 – 60	**D-/D+**	**Largely modified**
21 – 40	E	Highly degraded
0 – 20	F	Extremely degraded

Importance of the Orange River Estuary

The Orange River Mouth Wetland was designated a Ramsar status, i.e. a wetland of international importance, in 1991. In September 1995 this Ramsar site was placed on the Montreaux Record as a result of a belated recognition of the severely degraded state of the salt marsh on the south bank (the Montreaux Record is a list of Ramsar sites around the world that are in a degraded state).

The Orange River Estuary is ranked as the 7th most important system in South African in terms of conservation importance. The prioritisation study calculated conservation importance on the basis of size, habitat, zonal type rarity and biodiversity) importance. The individual scores obtained above are incorporated into the final Estuarine Importance Score:

CRITERION	SCORE	WEIGHT	WEIGHTED SCORE
Estuary Size	100	15	15
Zonal Rarity Type	90	10	10
Habitat Diversity	90	25	23
Biodiversity Importance	88	25	22
Functional Importance	100	25	25
ESTUARINE IMPORTANCE SCORE			**95**

The Estuarine Importance Score for the Orange River Estuary, based on its Present State, is 95, indicating that the estuary is considered as 'Highly Important':

IMPORTANCE SCORE	DESCRIPTION
81 – 100	**Highly important**
61 – 80	Important
0 – 60	Of low to average importance

Recommended Ecological Category for the Orange River Estuary

The recommended Ecological Category represents the level of protection assigned to an estuary. In turn, it is again used to determine the Ecological Water Requirement Flow Scenario.

For estuaries the first step is to determine the 'minimum' EC of an estuary, equivalent to Present Ecological Status (PES). The relationship between Estuarine Health Index Score, Present Ecological Status and Ecological Category is set out below:

ESTUARINE HEALTH INDEX SCORE	PRESENT ECOLOGICAL STATUS	DESCRIPTION	ECOLOGICAL CATEGORY	CORRESPONDING MANAGEMENT CLASS
91 – 100	A	Unmodified, natural	A-/A+	Natural (Class I)
76 – 90	B	Largely natural with few modifications	B-/B+	Good (Class II)
61 – 75	C	Moderately modified	C-/C+	Fair (Class III)
41 – 60	D	Largely modified	D-/D+	
21 – 40	E	Highly degraded	E	Poor (unacceptable)
0 – 20	F	Extremely degraded	F	

NOTE: Should the present ecological status of an estuary be either a Category 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).

The degree to which the 'minimum' Ecological Category (EC) (based on its Present Ecological Status) needs to be modified to assign a recommended EC depends on:

- Importance of the estuary.
- Modifying determinants, i.e. protected area status and desired protected area status - a status of 'area requiring high protection' should be assigned to estuaries that are identified as vital for the full and most efficient representation of estuarine biodiversity.

The proposed rules for allocation of the recommended Ecological Category are as follows:

CURRENT/DESIRED PROTECTION STATUS AND ESTUARINE IMPORTANCE	ECOLOGICAL 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)	A or BAS	
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.

The Orange River Estuary is considered to be an estuary of 'high importance'. In addition, it is also a Ramsar site (i.e., protected area in particular for water birds). According to the guidelines the recommended Ecological Category should therefore be a Category A - if not possible then the Best Attainable State (BAS).

At the workshop the following was concluded:

- With major dam developments in the catchment that have reduced river inflow to the estuary by more than 50% (considered to be irreversible), it is unlikely that the estuary could be returned to a Category A.

- Anthropogenic developments along the banks of the estuary (i.e., non-flow related modifications), such as the road across the salt marsh area, seepage of saline water from mining developments and human disturbance (of birds) also contribute largely to the Present Ecological Status of a Category D. It is therefore not considered possible to reverse modifications and to improve the Ecological Category to a Category B, through river flow adjustments only.

- *The Best Attainable Status for the estuary is therefore considered to be an **Ecological Category C**, with a strong recommendation that mitigating actions to reverse modifications caused by the non-flow related activities and developments in the estuary be investigated by the responsible authorities.*

Thus, the recommended Ecological Category for the Orange River Estuary is estimated as Category C. (Confidence = Low)

Quantification of Ecological Water Requirement Scenarios

A summary of the simulated future runoff scenarios (in comparison to the Present State flows) is provided below:

FUTURE SCENARIO:	MAR ($x10^6$ m^3)	% REMAINING
Reference Condition	10 833.01	100
Present State (with hydropower water releases as up to 2000)	4 743.46	43.79
Scenario 1: Present State (2005) with out hydropower releases	4 423.46	40.83
Scenario 2: Vanderkloof lower level storage	4 296.43	39.66
Scenario 3: Vioolsdrift reregulating dam	4 082.1	37.68
Scenario 4: Large Vioolsdrift	3 369.92	31.11
Scenario 5: River Class C	1 969.50	18.18
Scenario 6: River Class D	1 558.10	14.38
Scenario 7: Modified River Class D	4 529.93	41.73
Scenario 8: Modified River class D with Natural losses	4 345.67	40.12
Scenario 9: River class C with floods	4 979.99	45.97
Scenario 10: River Class D with floods	4 758.93	43.93

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

VARIABLE	WEIGHT	Present State	FUTURE SCENARIOS									
			1	2	3	4	5	6	7	8	9	10
Hydrology	25	58	48	48	43	31	45	30	48	48	68	63
Hydrodynamics	25	50	50	50	0	0	55	25	60	0	70	70
Water quality	25	72	68	68	54	43	76	68	68	58	78	76
Physical habitat	25	86	86	86	75	71	10	10	86	75	86	86
Habitat Score	**50**	**67**	**63**	**63**	**43**	**36**	**47**	**33**	**66**	**45**	**76**	**74**
Microalgae	20	50	40	40	35	17	50	40	40	40	80	65
Macrophytes	20	50	40	40	35	20	25	20	40	35	80	65
Invertebrates	20	40	40	40	25	10	35	25	35	35	60	35
Fish	20	60	40	40	25	17	17	10	40	25	60	70
Birds	20	26	26	26	20	15	24	24	30	20	50	50
Biological Score	**50**	**45**	37	**37**	**28**	**16**	**30**	**24**	**37**	**31**	**66**	**57**
EHI INDEX SCORE		**56**	**50**	**50**	**36**	**26**	**38**	**29**	**51**	**39**	**71**	**65**
EC		**D+**	**D-**	**D-**	**E**	**E**	**E**	**E**	**D+**	**E**	**C+**	**C-**

*To select the recommended 'Ecological Water Requirement Scenario', the guideline for estuaries states that, the simulated runoff scenario representing the largest modification in flow, but that which would still keep the estuary in the recommended Ecological Category (in this case a **Category C)** should be the recommended 'Ecological Water Requirement Scenario'.*

For the purposes of this rapid assessment, a preliminary estimate of the ***recommended 'Ecological Water Requirement Scenario'*** *for the Orange River Estuary (to meet the recommended* ***Ecological Category of C****) is estimated at a MAR of 4 758.93 x 10^6 m^3 (equivalent to Scenario 10) with the following distribution:*

MONTH	FLOW (m^3/s) – flow should ≥ % in given month									
	90%ile	80%ile	70%ile	60%ile	50%ile	40%ile	30%ile	20%ile	10%ile	1%ile
OCT	54.95	53.72	50.64	46.25	39.4	32.11	25.65	20.05	18.1	5.93
NOV	178.06	82.19	76.11	67.59	55.37	43.18	34.06	28.53	26.19	14.73
DEC	228.73	120.75	96.31	78.53	59.44	43.42	35.94	31.54	29.99	27.44
JAN	545.82	147.26	82.87	70.39	54.06	47.74	41.1	37.92	36.72	27.64
FEB	1427.02	581.97	388.17	212.81	146.25	98.86	77.24	65.15	62.76	41.33
MAR	777.46	493.45	284.44	189.07	135.57	105.94	78.48	61.99	59.04	43.63
APR	736.15	218.39	145.73	103.03	96.22	74.42	64.29	58.27	54.21	43.9
MAY	223.13	81.83	47.96	44.89	41.77	38.29	35.68	33.51	32.5	26.28
JUN	61.89	30.69	29.17	28.44	27.31	25.17	23.3	21.9	21.17	19.77
JUL	24.81	24.56	23.85	22.82	21.96	20.57	19.18	18.08	17.46	17.24
AUG	23.14	22.85	22.36	21.59	20.12	18.75	17.45	16.31	15.73	13.53
SEP	21.03	20.51	19.88	19.17	17.99	17	15.62	14.03	8.96	6.11

White = State 1 (river dominated); Blue = State 2: Strong marine influence; Red = State 3: Mouth closure

Of particular significance is that the distribution of Abiotic States in this Scenario resembles that of the Reference Condition, namely a river dominated state (State 1) during the autumn/summer, with stronger marine influence (State 2) during late winter/spring and mouth closure (State 3) only occurring occasionally during spring. As a result the predicted biotic response is closer to that of the Reference Conditions (presently, State 2 [i.e. stronger marine influence] is dominant during the spring/summer, while the river dominated state [State 1] dominates during autumn/winter – almost a reversal of Reference Conditions).

NOTE:

The recommended Ecological Flow scenario for an Ecological Category C can still be refined. It is however important that the revised flow scenario maintains the distribution of Abiotic States presented in the current recommended scenario (see above).

It is estimated, that to maintain the estuary in its ***Present Ecological Status of a Category D+,*** *a flow (and abiotic State) distribution represented by* ***Scenario 7*** *(MAR = 4 529.73 x 10^6 m^3) is required:*

MONTH	FLOW (m^3/s) – flow should ≥ % in given month									
	90%ile	80%ile	70%ile	60%ile	50%ile	40%ile	30%ile	20%ile	10%ile	1%ile
OCT	28.17	27.63	26.25	24.3	21.25	18	15.13	12.64	11.85	11.66
NOV	229.69	35.27	33.68	31.45	28.45	25.55	22.7	21.26	20.68	16.75
DEC	236.25	113.03	38.42	36.78	32.51	30.18	26.85	25.63	25.2	23.19
JAN	545.17	148.81	74.47	42.26	37.73	31.13	27.47	25.71	25.1	19.89
FEB	1373.57	607.65	381.22	218.67	145.99	94.69	70.18	58.39	54.85	46.62
MAR	790.16	469.72	278.09	174.22	93.14	62.56	52.26	44.27	43.1	42.13
APR	713.61	206.18	139.12	76.9	62.42	47.61	38.31	34.94	30.17	26.65
MAY	213.14	102.63	54.34	43.68	37.87	33.01	28.79	25.29	23.67	21.16
JUN	63.03	33.68	31.69	30.69	29.11	26.51	24.08	22.28	21.32	19.85
JUL	26.4	26.13	25.35	24.23	23.29	21.77	20.24	19.05	18.38	18.13
AUG	23.21	22.98	22.49	21.66	20.18	18.8	17.49	16.35	15.83	15.14
SEP	24.42	23.35	22.06	20.6	18.17	16.14	13.28	11.9	11.12	7.58

White = State 1 (river dominated); Blue = State 2: Strong marine influence; Red = State 3: Mouth closure

Recommendations on Additional Data Requirements

Data requirements to improve the confidence of the preliminary Ecological Reserve determination are set out in the method for Estuaries. It is recommended that the following monitoring be conducted to improve the confidence of the Ecological Reserve determination on the Orange River Estuary (largely based on the recommended data requirements for a Comprehensive Ecological Reserve Determination).

NOTE:

It is strongly recommended that surveys to collect the additional data requirements on the different abiotic and biotic components (see below) in the Orange River Estuary be coordinated (i.e. undertaken simultaneously) to prevent duplication and to enable scientists to quantify linkage between different abiotic and biotic processes, a key requirements in predicting the effects of the modification in river inflow..

Abiotic components (hydrodynamics)

- *Continuous river flow gauging at the head of the estuary (e.g. Brandkaros).*
- *Additional continuous water level recordings near mouth of the estuary and in the salt marsh area near the beach.*
- *Daily observations on the state of the mouth, if the mouth is closed or almost closed state.*
- *Aerial photographs of estuary - colour, geo-referenced rectified aerial photographs at 1: 5 000 scale covering the entire estuary (based on the geographical boundary), and taken at low tide in summer, are required. These photographs must include the breaker zone near the mouth.*

Abiotic components (sediment dynamics)

- *Series of cross-section profiles along the beach, bar, mouth and lower basin region (at about 25 m intervals) as well as upstream along the entire estuary (at ~300 m intervals from the +5 m MSL contour on the left bank, trough the estuary to the +5 m MSL contour on the right bank), using D-GPS and echo-sounding). This should be done every 3 years (and immediately after a flood) to quantify the sediment deposition rate in the estuary.*
- *Series of sediment grab samples for the analysis of particle size distribution (PSD), cohesive nature and organic content, taken every 3 years (and immediately after a flood) along the length of the estuary (at ~ 100 to 300 m intervals across the estuary including the inter- and supratidal areas). Representative samples should also be collected from the adjacent beach and sand bar.*
- *A series of sediment core samples for historical sediment characterisation taken once-off, but ideally just after a medium to large flood as well as a year (or two) later along the same grid as the grab samples (see above).*
- *Sediment load near the head of estuary (including grain size distribution and particulate carbon - detritus component): Daily intervals for a minimum 5 years. Ideally, both suspended- and bed-load should be monitored. The measurements could be done at Brandkaros, but ideally within a few kilometers upstream of the Oppenheimer Bridge.*

Abiotic components (water quality)

- *At least monthly water quality measurements on system variables [conductivity, temperature, pH, dissolved oxygen, turbidity, suspended solids], inorganic nutrients [e.g. nitrate, ammonium and reactive phosphate] and, if possible, toxic substances in river water entering at the head of the estuary (Oppenheimer Bridge). Ideally, particulate organic carbon input (see also sediment dynamics) should be recorded.*
- *Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at:*
  - *low flow season (i.e. period of maximum seawater intrusion), but when the mouth is still open.*
  - *during mouth closure (this may require a series of surveys to capture the dynamic nature of this state).*
- *Water quality measurements on system variables [pH, dissolved oxygen, turbidity, suspended solids], inorganic nutrients [e.g. nitrate, ammonium and reactive phosphate] taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at:*
  - *end of low flow season when the mouth is still open.*
  - *during mouth closure (this may require a series of surveys to capture the dynamic nature of this state).*
- *Ideally organic nutrients (i.e. dissolved and particulate organic carbon should also be recorded).*
- *Measurements of toxic substances (e.g. trace metals) in sediments across the estuary, focussing on depositional areas, characterised by finer, often organic rich sediments.*

Microalgae

- *Chlorophyll-a measurements taken at 5 stations (at least) at the surface, 0.5 m and 1 m depths thereafter. Cell counts of dominant phytoplankton groups i.e. flagellates, dinoflagellates, diatoms and blue-green algae.*

  Measurements should be taken coinciding with the different Abiotic States, particularly State 2 (marine influence) and State 3 (closed mouth conditions).

- *Inter-tidal and sub-tidal benthic chlorophyll-a measurements taken at 5 stations.*

  Epipelic diatoms need to be collected for identification.

  Measurements should be taken coinciding with the different Abiotic States, particularly State 2 (marine influence) and State 3 (closed mouth conditions).

The microalgal survey must be done at the same time as the water quality survey.

Macrophytes

- *Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the present state, as well as the reference condition (earliest year available). A GIS map of the estuary must be produced indicating the present and reference condition distribution of the different plant community types.*

- *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. The extent of anthropogenic impacts (e.g. trampling, mining) must be noted.*

- *Permanent transects (fixed monitoring stations that can be used to measure change in vegetation in response to changes in salinity and inundation patterns) must be set up along an elevation gradient:*

  - *Measurements of percentage plant cover of each plant species in duplicate quadrats (1 m^2).*
  - *Measurements of sediment salinity, water content, depth to water table and water table salinity.*

Invertebrates

- *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 [1] and organic content [2] at the ten benthic sites.*
- *During each survey determine the longitudinal distribution of salinity, as well as other system variables (e.g., temperature, pH and dissolved oxygen and turbidity)[3] at each of the ten benthic sampling sites.*
- *Collect a set of benthic samples from ten sites, each consisting of six replicate grabs stored separately. Collect two of these from sandy areas, and the remainder spread between 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 (i.e. quarterly) data sets for at least one year are required, preferably collected at neap tides (weaker current velocities improve sampling efficiency).*
- *Collect replicated hyperbenthic samples at the same benthic sites identified above (i.e,. two replicates at each of the ten sites). 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 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 (i.e. quarterly) data sets for at least one year are required, preferably collected at neap tides (weaker current velocities improve sampling efficiency).*
- *Collect replicated zooplankton samples at each of the ten benthic sites (i.e. two replicates at each of the ten sites) at night. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at neap tides (weaker current velocities improve sampling efficiency – zooplankton also moves into the water column more effectively, providing a better estimate of abundance).*
- *Additional trip(s) may be required to gather data on the occurrence/recruitment and emigration of key that require a connection to the marine environment at specific times of the year.*

Fish

- *The Orange Estuary needs to be sampled quarterly over at least one year to account for the seasons followed by another year covering summer and winter.*

- *Seine-nets to sample small and juvenile fish and gillnets to sample adults are the appropriate gear. Monofilament gill nets should comprise at least 3 different mesh sizes within the range of 40-150 mm stretched mesh. Seine nets should be 30 m long, 1.7 m deep with a 15 mm bar mesh in the wings and a 5 mm bar mesh in the purse. All species in the catch should be identified, counted and measured in total length.*

- *Given the uncertainty as to the dominant food sources and the possible seasonal changes in them, a representative sample should be retained for stomach content analysis.*

- *Salinity, temperature, turbidity and if possible oxygen need to be recorded at each sampling site.*
- *The Orange Estuary needs to be sampled from the mouth to Brandkaros 35 km upstream. Samples in the estuary proper up until the Ernst Oppenheimer Bridge (10 km) should be 1 km apart thereafter at 2 km intervals to Brandkaros covering all habitat types (sand, channel, saltmarsh, etc). This gives 23 sites in total. Given the evident links between the estuary and adjacent surfzone, it would also be advisable to sample the surf-zone with the seine-net, to at least 1 km either side of the mouth. All the salinity regimes must be covered. These typically include: Fresh (representative of river), 0 – 10 ppt, 10 – 20 ppt and 20 – 35 ppt.*

Birds

- *Continue with full count of all water associated birds bi-annually covering as much of the estuarine area as possible, (as part of the requirements of Ramsar). All birds should be identified to species level and the total number of each counted.*

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ABBREVIATIONS

BAS:	Best Attainable State
CSIR:	Centre for Scientific and Institutional Research
DWA:	Department of Water Affairs (Namibia)
DWAF:	Department of Water Affairs and Forestry (RSA)
EC:	Ecological Category
EHI:	Estuarine Health Index
GIS:	Geographical Information System
LOR:	Lower Oranger River
LORMS:	Lower Orange River Management Study
MAR:	Mean Annual Runoff
ORRS:	Orange River Re-planning Development Study
PES:	Present Ecological Status
RDM:	Resource Directed Measures
VRSAU:	Vaal River System Analysis Update
WRC:	Water Research Commission (RSA)

1. INTRODUCTION

1.1 Background

The Centre for Scientific and Institutional Research (CSIR), Environmentek, was commissioned by Lower Orange River (LOR) Consultants, Ninham Shand Consulting Engineers to conduct a preliminary Ecological Reserve determination on the Orange River Estuary on a Rapid level.

The specialist team appointed for this project was as follows:

TEAM MEMBER	ROLE/EXPERTISE	CONTACT DETAILS
Ms L van Niekerk	Project coordinator/Hydrodynamics	CSIR, Stellenbosch lvnieker@csir.co.za
Ms S Taljaard	Report Preparation/Water quality	CSIR, Stellenbosch staljaar@csir.co.za
Mr P Huizinga	Hydrodynamics (advisory role)	Private Consultant p.huizing@adept.co.za
Mr A Theron	Sediment dynamics	CSIR, Stellenbosch atheron@csir.co.za
Dr J Adams	Microalgae &Macrophytes	University of Port Elizabeth btajba@upe.ac.za
Prof T Wooldridge	Invertebrates	University of Port Elizabeth zlathw@zoo.upe.ac.za
Mr S Lamberth	Fish	Private Consultant lamberth@mcm.wcape.gov.za
Mr M Anderson	Birds	Northern Cape Dept of Agriculture, Land Reform, environment & Conservation manderson@grand.ncape.gov.za

The following people also attended the workshop as observers:

PERSON	AFFILIATION	CONTACT DETAILS
Mr P Heyns	Dept of Water Affairs (Namibia), MAWRD	heynsp@mawrd.gov.na
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Mr M Luger	Ninham Shand Consulting Engineers	Mike.luger@shands.co.za

1.2 Assumptions and Limitations

The following assumptions and limitations need to be taken into account for this study:

- It was agreed among the different parties that the determination of the Ecological Reserve on a Rapid level for the Orange River Estuary be based on the methodology for estuaries as set out by South Africa's Department of Water Affairs and Forestry (DWAF) in *Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component (Version 1.0)* (DWAF, 1999) and subsequent revisions of the methods of which the documentation is currently in preparation (B Weston, RDM Directorate, DWAF, pers. comm.).

- Ecological Importance rating of the Orange River Estuary was based on a national (SA) perspective. In future, ecological importance rating of trans-boundary systems need to be based on a more regional perspective (e.g. southern Africa), rather than only a national (SA) perspective.

- The determination of the Ecological Reserve on a Rapid level for the Orange River Estuary was based on published or readily available data and information as listed in **Appendix A** and discussed in the Specialist Reports (**Appendices C to G**).

- The results of this study are based on the simulated runoff data provided to the study team by the DWAF (SA). The data was reviewed by the Namibian consultants, which concluded the following: *"The general impression is that the work has been carried out thoroughly as far as the data will allow. There is no reason to disagree with the hydrological files being used as input for the system analysis".* The need to update the hydrology for the incremental Orange River Catchment upstream of Vanderkloof Dam, as well as for the Orange River downstream of Vanderkloof Dam to the Orange River Mouth (Fish River excluded) was also expressed by them, as this hydrology is already more than a decade old (Mr M Maré, Water Resource Planning, DWAF, pers. comm.).

  A high confidence level can be placed on the hydrology generated as part of the VRSAU study, which includes the Senqu hydrology in Lesotho. Almost 70% of the natural runoff is generated in these catchments, which clearly represents the bulk of the runoff generated in the Orange River catchment. Approximately 23% of the natural flow is generated in the Orange River incremental catchment upstream of Vanderkloof Dam and downstream of Lesotho (Caledon River catchment included). Although this hydrology is old, a relatively high confidence level can be placed on the hydrology.

  A medium to low confidence level can be placed on the hydrology downstream of Vanderkloof Dam (excluding the Vaal and Fish Rivers). The runoff generated in this catchment, however, represents only 3% of the total natural runoff. The fact that the accuracy of the hydrology used for this extremely large incremental catchment is not at the required level, will due to the volume of runoff generated, have an insignificant effect on the analysis.

  As part of the Lower Orange River Management Study (LORMS), a simplified rainfall/runoff modelling was carried out to obtain updated hydrology for the Fish River (Namibia). A detailed rainfall/runoff assessment was therefore not carried out for the Fish River (Namibia), partly due to time constraints, but also due to the fact that the natural runoff from the Fish River catchment only represents approximately 4% of the total Orange River runoff.

  Although the bulk of the hydrology can be regarded as reliable, the main problem regarding the accuracy of observed flows is with regards to flows and specifically low flows measured in the Lower Orange River (LOR). Most of the gauging weirs in the LOR are long weirs, so that the slightest increase in flow depth, results in a significant increase in the flow rate. It is therefore extremely difficult to tell from the observed flows, how much water is flowing in the LOR and specifically the flow that enters the river mouth. This problem is further complicated by the fact that the bulk of the abstractions are for irrigation purposes for which there is basically no observed data available. A large volume of water is also lost due to evaporation from the river, for which a fairly good indication was obtained of the average river evaporation losses from studies carried out by the Water Research Commission (WRC). This will, however, vary depending on the actual weather conditions and flow in the river.

  To conclude, the inflows to Gariep and Vanderkloof Dams, as well as the outflow from the Vaal River catchment entering the Orange River, can be used with confidence, the actual observed flows in the LOR are not at the required level and need to be improved significantly (Mr M Maré, Water Resource Planning, DWAF, pers. comm.).

  The results contained in this report are as decided upon by the specialist team as listed above. Although the observers participated in the workshop, the final decisions on, for example the recommended Ecological Category (EC) and the recommended Ecological Flow Scenario were those of the specialist team.

- Criteria for confidence limits attached to statements <u>throughout this report</u> 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%)

- It was not within the brief of this study to address the freshwater requirements of the marine environment adjacent to the Orange River. The National Water Act 36 of 1998 of South Africa does not classify marine waters as a resource and, as a result, it does not make provision for freshwater requirements of the marine environment. However, in the case of the Orange River, input from the river, e.g., sediment and detritus, is expected to have a marked influence on the ecological processes of the adjacent marine environment, ranging for local to regional scales. For example, sediment export replenishes the nearshore habitats that are continuously eroded by oceanic currents and also provides a refuge for many fish by increasing turbidity. Sediment and detrital export may be important to detrivores (e.g. mullet), as well as to species that may require a specific sediment habitat type be it for foraging, spawning nursery area. Turbidity also tends to increase the catchability of many species, especially the larger individuals that move into the turbid environment in search of concentrated prey. Freshwater flows (and associated plumes) also provide cues for the migration of estuarine-dependent juvenile and adult fish into and out of the estuarine environment (refer to **Appendix E** for further details).

  Based on the above, it is strongly recommended that freshwater requirements of the marine environment be assessed prior to any further water abstraction projects on the Orange River and its tributaries.

1.3 Process for Preliminary Determination of Ecological Reserve (Rapid Level) for Estuaries

The process followed in the preliminary determination of the Ecological Reserve on a Rapid level for estuaries is illustrated in **Figure 1.1**. The rapid determination is generally based on available information. It is therefore important that a desktop assessment of available information on the different abiotic and biotic components is conducted prior to the workshop. The process comprises of the following steps:

Step 1: Initiation of RDM study. During the initiation of a Resource Directed Measures (RDM) Study, it is important to establish the level at which the study needs to be conducted (e.g., rapid, intermediate or comprehensive), as well as the reserve components that need to be addressed (e.g., rivers, estuaries, wetlands or groundwater). The key outcome of Step 1 is therefore the detailed scope of the RDM Study. In the case of the Orange River Estuary, it was decided to conduct the Ecological Reserve Study on the estuary at a Rapid level.

Step 2: Definition of Resource Units. Each estuary is delineated as a separate resource unit within a larger catchment, characterized by site dependent abiotic and biotic characteristics. For estuaries, the default geographical boundaries are defined as follows:

- **Downstream boundary:** The estuary mouth (However, there are systems where the 'estuary' often expands to the near-shore marine environment and where this boundary definition may need to be reconsidered in future).
- **Upstream boundary:** The extent of tidal influence, i.e., the point up to where tidal variation in water levels can still be detected or the extent of saline intrusion which ever is furthest upstream.
- **Lateral boundaries:** The 5 m above MSL contour along each bank.

The geographical boundaries for the Orange River Estuary are addressed in Chapter 2 of this report.

Step 3: Ecological Categorisation. The main outcome of this step is to define a recommended Ecological Category for the estuary. For the Orange River Estuary, the ecological categorisation step is dealt with in **Chapter 3**.

The method for estuaries uses simulated runoff scenarios, where scenarios are typically simulated over a 50-70-year period and are presented as average monthly flows that represent inflows at the head of the estuary. For the definition of the recommended EC simulated runoff scenarios for the *present state* and the *reference condition* are used.

Firstly, the Present State of an estuary is defined as a quantitative description of the present abiotic and biotic characteristics and functioning of the system (**Chapter 3.1**). For estuaries, the following components are usually:

Abiotic (or driving components):

- Physical dynamics (including hydrodynamics and sediment dynamics); and

- Water quality.

Biotic (response) components:

- Estuarine flora (microalgae and macrophytes); and
- Estuarine fauna (invertebrates, fish and birds).

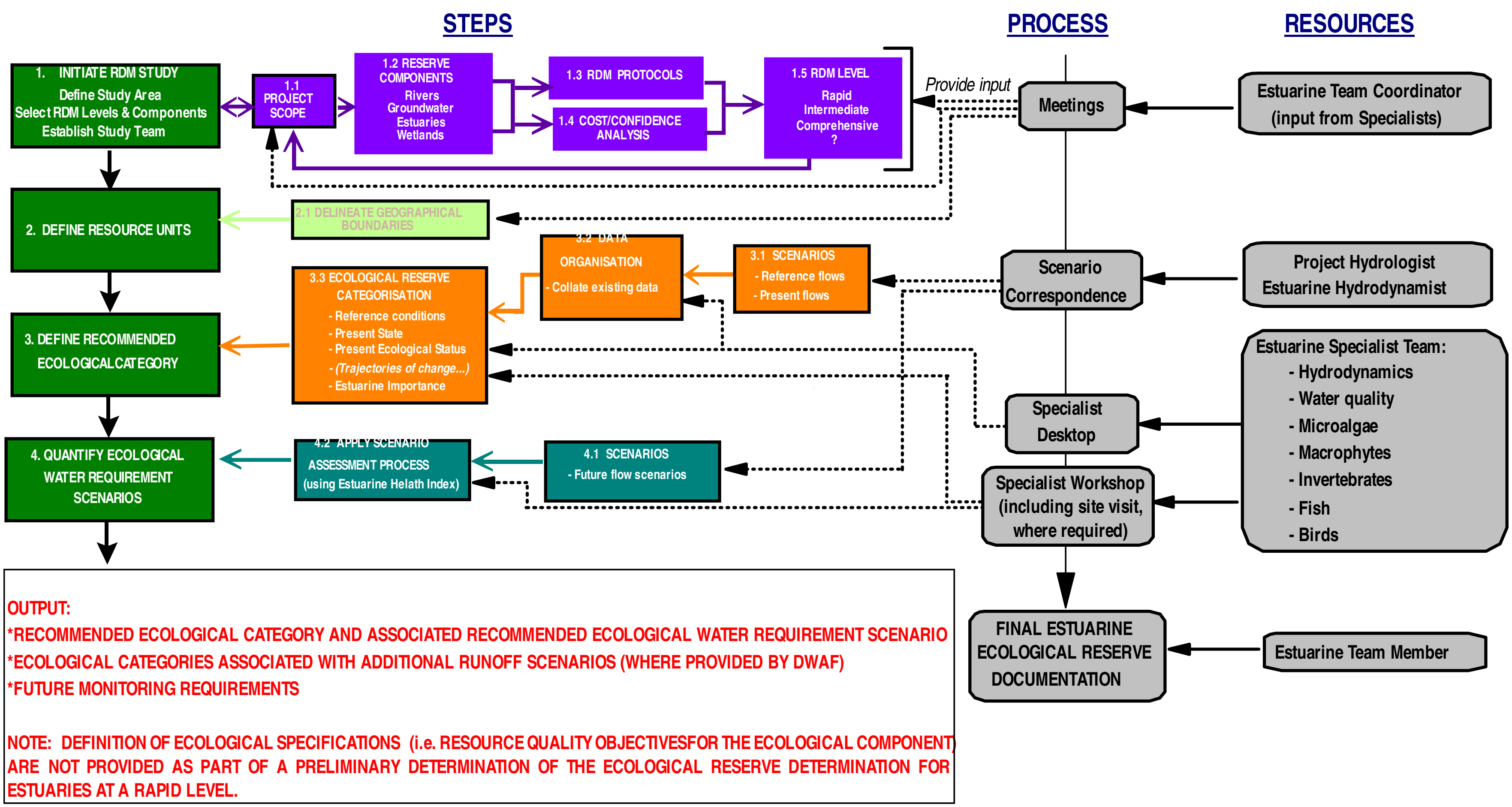


Figure 1.1: Flow diagram showing the process followed in the preliminary determination of the Ecological Reserve determination on a Rapid level for estuaries

Thereafter the Reference Condition of an estuary is defined (**Chapter 3.2**). For the purposes of the preliminary determination of the Ecological Reserve, the reference condition of an estuary refers to the ecological status that it would have had:

- when receiving 100% of the natural MAR;
- before any human development in the catchment or within the estuary; and
- before any mouth manipulation practices (e.g. artificial breaching).

Typically, the reference conditions in an estuary refer to its ecological status 50 to 100 years ago.

The present state and reference condition of an estuary are then used to determine the Present Ecological Status (PES) (**Chapter 3.3**). The PES is a measure of the health of a resource, based on a comparison between the reference condition and the present state. An Estuarine Health Index (EHI) is used to determine the PES for estuaries.

Also included in this step is an assessment of the Estuarine Importance (ecological) of an estuary (**Chapter 3.4**). Estuarine importance is an expression of the importance of an estuary to the maintenance of ecological diversity and functioning on local and wider scales. Variables were discussed in a workshop setting, regarding their suitability for inclusion in an Estuarine Importance Index. The importance scores have been derived for most South African estuaries as part of a project entitled: *Classification and prioritisation of South African estuaries on the basis of health and conservation status for determination of the estuarine water reserve* (Turpie *et al*., 2002). The only importance score that needs to be derived by the estuarine ecological reserve team (at the specialist workshop) is the functionality score (e.g., link with freshwater and marine environment).

Finally, the PES and estuarine importance score are used to come to a recommended EC for an estuary, according to pre-defined guidelines as is discussed in **Chapter 3.5**.

Step 4: Quantification of Ecological Water Requirement Scenarios. The method for the preliminary determination of the Ecological Reserve for estuaries uses a ‘top down’ approach, i.e., simulated runoff scenarios are used to assess the response of the estuary to changes in freshwater input. For the quantification of Ecological Water Requirement Scenarios simulated flows for a range of future scenarios are required. Scenarios are typically simulated over a 50-70 year period and are presented as average monthly flows, and should represent inflows at the head of the estuary. For the Orange River Estuary, 10 future runoff scenarios were provided by the DWAF.

To determine the EC of the estuary associated with each of the flow scenarios, the runoff simulations together with an understanding of the present state are used to determine changes in abiotic states within an estuary for each of the scenarios. Changes in abiotic characteristics are then assessed in terms of the biological implications, using the same estuarine health index that was used to derive the PES. Results from these evaluations are then used to select the ‘recommended Ecological Water Requirement scenario’, defined as the run-off 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 EC.

The quantification of ecological reserve scenarios for the Orange River Estuary is dealt with in **Chapter 4**.

The preliminary determination of the Ecological Reserve on a Rapid level does not require the determination of Ecological Specifications (i.e. Resource Quality Objectives for the Ecological Component).

Although the rapid method also does not require the preparation of a detailed Resources Monitoring Programme, key baseline data requirements, that would be required to improve the confidence of the rapid preliminary ecological reserve determination, should be provided. In this regard, the data requirements recommended in the methodologies for the intermediate and comprehensive ecological reserve determinations need to be consulted.

The output of a preliminary determination of the Ecological Reserve on a Rapid level provides:

- Recommended Ecological Category and the associated recommended Ecological Water Requirement Scenario.
- Ecological Categories for different runoff scenarios assessed as part of Step 4.
- Additional baseline requirements to improve the confidence of the preliminary Reserve determination (if requested).

2. DEFINITION OF RESOURCE UNIT

The estuary, situated between the towns of Alexander Bay in the Northern Cape Province, South Africa and Oranjemund in Namibia, has an area of about 2,000 ha (2 298 ha in GIS coverage).

For the purposes of the Rapid Ecological Reserve determination on the Orange River Estuary, the geographical boundaries are estimated as follows (Gauss Projection, Clarke 1880 Spheroid):

- **Downstream boundary:** The estuary mouth (28º38'30"S, 16º27'45"E).
- **Upstream boundary:** Head of tidal influence at the Sir Ernest Oppenheimer bridge, approximately 9.5 km for mouth (28º33'45"S, 16º30'15"E).
- **Lateral boundaries:** 5 m contour above MSL along the banks.

NOTE:

The precise extent of tidal variation has not been confirmed for the Orange River Estuary and needs to be verified through monitoring. It is also recommended that in future studies, in which new data are collected, the upper boundary be extended to include the area upstream from the bridge, i.e. the planned extension to the Ramsar site.

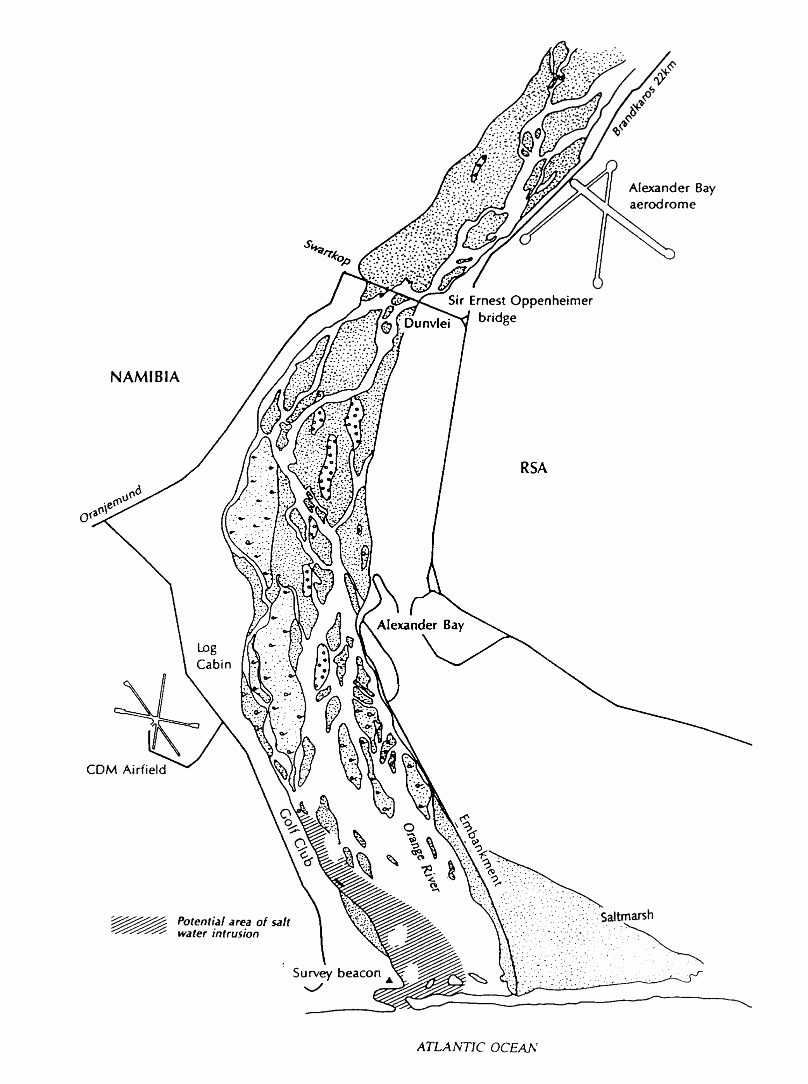


Figure 2.1: Map of the Orange River Estuary (CSIR, in prep.)

3. ECOLOGICAL CATEGORISATION

3.1. Description of Present State

3.1.2 Abiotic components

a. Seasonal variability in river inflow

Monthly-simulated runoff data for Present State, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 3.1**. The mean annual runoff (MAR) under the Present State is 4 743.46 x 10^6 m^3 (43.8% of the natural MAR). A statistical analysis of the monthly-simulated runoff data in m^3/s for Present State is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	28.64	252.38	259.27	563.92	1439.88	771.99	715.57	242.30	130.04	75.67	31.70	17.06
80%ile	23.24	32.38	140.43	185.04	524.90	477.87	231.91	111.37	64.55	72.63	21.60	14.81
70%ile	22.82	26.62	53.56	105.54	300.10	279.17	138.37	66.21	59.48	71.65	20.94	14.48
60%ile	22.25	23.88	30.20	40.01	123.75	200.03	73.68	50.13	57.71	71.42	20.76	13.94
50%ile	21.69	22.65	25.35	28.94	57.69	112.18	60.04	46.15	57.26	71.18	20.66	13.61
40%ile	21.47	21.82	23.39	24.83	39.43	58.42	50.62	45.31	56.99	71.14	20.63	13.53
30%ile	21.42	21.59	21.71	22.93	29.43	43.40	41.72	44.68	56.95	71.08	20.59	13.48
20%ile	21.36	21.47	21.45	21.68	22.69	36.97	37.12	44.56	56.86	71.05	20.57	13.47
10%ile	21.36	21.37	21.36	21.47	21.75	31.02	36.08	44.24	56.80	71.01	20.54	13.46
1%ile	21.36	21.35	21.36	21.36	21.56	28.26	34.99	44.12	56.74	70.93	20.48	13.46

Confidence: Low

b. Present flood regime

There where no detailed analysis done on the reduction in the magnitude and frequency of floods for the Orange River system, but preliminary analysis show that even smaller floods, such as those with a 1:2 and 1:5 year return period, played a important role in shaping the habitat of the Orange River Systems, i.e. influencing channel configuration and determining the braided nature of the upper estuary. Preliminary analyses, provided by Ninham Shand, indicate that these smaller floods have been reduced by as much as 85% (1:2) and 74% (1:5), respectively, i.e., 15% (1:2) and 26% (1:5) remaining.

Larger floods (indicated by months with average flows greater than 5000 x $10^6 m^3$) in turn play an important role in resetting the habitat of the estuary. An evaluation of the Present state simulated runoff scenario indicates that there has been a marked reduction in the occurrence of monthly flows greater than 5000 x $10^6 m^3$ (representative of major flood events), from 20 under the Reference condition to 9 at present. On average, the highest monthly flows under the Present state have been reduced to 71% of Reference condition flows.

Confidence: Low

c. Present sediment processes and characteristics

The available information indicates that generally the depth and bed morphology are relatively similar to that of the Reference Condition over most of the estuary. Under the Present State, the braided/meandering channels in the upper estuary are deemed to be more stable, but probably slightly narrower and/or shallower, due to reduced intermediate river flows.

Due to the reduction in large floods from the Reference condition to the Present State, the resetting of the system occurs less frequently at present (and the channels may have exhibited an even less meandering nature).

Although the flow volumes and velocities, and therefore related sediment carrying capacity were reduced, and the major impoundments are trapping much sediment from Reference condition to the Present State, the sand/mud ratio is still very similar in the river load, i.e., river sediment is still mostly dominant over marine sediment intrusion. The potential load reduction is probably offset to some extent by increased erosion in the mid- and LOR catchment (because of less vegetation cover) and therefore increased sediment load of the river. It is also estimated that the overall reduction in intermediate flows cause the average extent of the marine sediment (of a more non-cohesive and coarser nature than river sediment) intrusion to be only slightly further upstream.

Confidence: Low

Table 3.1: Monthly runoff data (in m3/s) for Present State, simulated over a 68-year period

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Closed
1920	22.89	21.37	22.00	21.57	170.97	80.08	117.53	88.12	64.63	73.29	20.58	14.72	0
1921	23.24	173.97	487.38	140.91	21.71	28.22	34.96	44.11	56.78	70.90	20.96	13.62	0
1922	21.36	434.75	145.17	560.23	624.27	375.53	200.76	46.54	58.88	71.54	20.59	14.71	0
1923	21.36	21.59	21.36	21.59	22.14	170.57	70.91	44.65	56.85	71.03	20.57	13.72	0
1924	21.36	23.11	40.34	34.15	365.78	3509.65	1851.69	712.19	146.81	85.29	23.97	14.72	0
1925	22.63	21.36	21.43	23.65	21.63	47.29	50.29	45.27	58.51	71.18	20.60	13.46	0
1926	21.47	22.46	22.17	21.51	21.60	37.11	40.61	44.19	56.78	71.13	20.65	13.48	0
1927	21.83	21.69	22.72	39.00	37.33	259.74	62.61	44.37	56.86	71.04	20.62	14.17	0
1928	21.50	24.14	22.11	24.87	22.65	124.17	54.12	44.66	57.25	71.55	22.46	22.93	0
1929	23.93	22.85	327.48	170.24	55.98	36.68	35.64	44.20	56.82	70.97	21.82	13.91	0
1930	21.42	22.04	21.58	52.37	55.90	159.23	40.53	44.92	56.95	71.28	20.62	13.46	0
1931	21.61	24.56	22.78	21.52	39.96	37.35	36.20	44.66	57.48	71.14	20.55	13.94	0
1932	30.13	21.37	21.39	21.39	21.82	28.44	35.29	44.14	56.85	71.18	20.49	13.46	0
1933	21.36	27.50	116.26	1136.89	923.27	476.01	55.10	99.37	61.19	71.18	37.00	14.70	0
1934	22.46	405.94	695.38	23.81	24.45	202.23	136.68	216.11	88.11	71.08	20.58	13.46	0
1935	21.36	23.99	21.67	23.57	26.41	199.48	65.93	198.94	90.02	71.14	20.65	13.83	0
1936	21.46	950.23	231.61	626.08	1370.26	246.10	35.80	44.43	56.89	71.05	20.61	13.48	0
1937	21.36	21.35	24.91	186.84	59.40	35.27	52.09	46.20	57.11	72.58	20.95	13.49	0
1938	21.93	87.13	23.72	35.39	1434.65	327.48	36.68	44.54	56.97	72.17	29.42	15.33	0
1939	23.23	186.57	145.17	27.11	90.62	64.93	242.72	227.54	57.71	71.05	20.55	14.38	0
1940	21.53	25.01	133.32	311.19	685.31	115.25	157.53	45.13	57.36	71.12	20.54	13.51	0
1941	21.37	21.38	21.36	21.50	354.21	41.62	69.89	49.62	57.20	71.15	20.75	13.46	0
1942	28.63	23.60	219.59	182.33	21.76	29.41	903.33	1177.15	233.67	441.36	147.75	54.68	0
1943	503.65	1830.62	1494.52	572.53	2112.78	551.75	36.66	44.58	63.48	71.51	20.82	14.92	0
1944	100.81	60.02	21.47	22.80	22.56	302.06	84.75	44.30	56.86	73.45	20.59	13.51	0
1945	21.76	21.50	21.36	23.92	28.94	44.87	67.73	56.46	58.94	71.16	20.64	13.70	0
1946	21.54	21.42	21.37	21.95	22.52	59.60	37.12	44.63	56.92	71.02	20.55	13.57	0
1947	23.81	21.47	25.77	26.82	55.68	703.54	367.43	47.54	56.99	71.15	20.59	13.46	0
1948	21.47	21.71	21.39	33.50	29.46	109.11	41.71	44.13	56.89	70.96	20.51	13.46	0
1949	21.36	21.40	23.79	22.87	340.88	479.11	232.27	309.62	123.28	100.20	221.36	14.87	0
1950	22.20	21.59	49.42	44.06	23.44	29.94	36.75	45.25	58.27	71.50	20.61	13.46	0
1951	23.08	21.55	21.36	21.40	314.37	43.24	35.00	44.12	56.77	83.53	22.76	13.48	0
1952	21.44	21.45	21.48	21.38	228.67	100.04	114.60	45.64	56.81	71.03	20.82	13.55	0
1953	21.46	21.90	61.56	27.34	32.56	530.18	231.37	62.36	57.58	71.67	20.84	13.60	0
1954	21.41	21.35	21.42	103.83	1849.41	461.28	145.19	90.93	57.11	71.10	20.99	13.60	0
1955	21.36	23.85	26.37	50.34	354.66	1041.29	466.25	93.75	56.95	71.11	20.64	13.52	0
1956	21.36	22.04	834.13	514.97	144.34	179.33	36.71	44.25	59.66	72.08	21.27	1373.53	0
1957	1621.29	407.02	206.57	1056.43	190.58	31.13	59.52	263.38	102.14	71.05	20.56	13.55	0
1958	21.36	21.82	28.98	29.49	28.85	31.10	35.49	233.26	85.42	129.69	20.60	13.46	0
1959	21.36	21.65	23.09	21.97	121.31	254.96	138.55	61.88	56.92	71.15	20.87	13.47	0
1960	21.42	21.55	172.64	123.08	22.75	279.60	769.64	203.90	269.14	73.26	96.63	16.50	0
1961	21.54	28.87	94.45	21.52	1056.27	275.26	44.08	66.64	56.80	70.98	21.05	13.65	0
1962	21.36	26.80	24.81	613.06	297.76	724.73	891.15	88.12	57.26	71.26	20.73	13.48	0
1963	22.94	32.79	54.02	21.67	21.56	32.26	259.59	44.25	57.02	70.99	20.47	13.46	0
1964	82.38	441.50	157.77	165.88	45.88	50.37	52.38	45.49	56.74	71.43	20.64	13.55	0
1965	21.36	21.37	21.62	47.54	300.36	38.32	50.70	44.55	56.85	70.96	20.49	13.46	0
1966	21.59	21.65	21.68	131.47	1452.10	521.07	1138.35	464.54	341.76	72.67	20.79	14.72	0
1967	22.46	28.36	21.42	21.36	21.56	122.48	88.09	101.43	64.43	71.20	20.70	13.53	0
1968	21.44	24.77	30.55	21.69	30.55	53.71	60.56	52.18	61.28	71.41	20.70	13.53	0
1969	21.90	21.45	21.36	21.37	33.61	30.82	36.49	44.63	59.54	73.87	20.56	13.48	0
1970	28.67	21.96	23.47	34.54	97.35	39.67	37.29	45.32	56.96	71.10	20.74	13.50	0
1971	22.04	21.52	21.43	309.67	77.01	718.18	151.83	46.09	56.97	71.08	20.58	13.97	0
1972	21.39	21.37	21.36	21.36	90.18	70.10	64.90	46.75	56.91	71.05	20.56	14.19	0
1973	21.40	21.48	31.06	762.49	2698.52	2369.15	692.40	293.23	145.82	79.87	336.15	14.88	0
1974	22.19	24.35	323.81	460.98	1979.92	922.75	174.19	47.19	57.74	71.19	20.68	14.70	0
1975	21.36	23.13	666.19	2009.81	2981.03	2865.58	976.40	586.44	184.81	84.41	23.56	15.41	0
1976	1047.64	658.75	60.62	105.73	849.67	882.27	103.51	55.50	58.50	71.92	21.28	14.44	0
1977	22.94	31.77	26.44	430.20	375.84	270.83	1113.07	118.00	57.01	71.52	21.14	14.48	0
1978	21.39	21.35	42.80	23.48	40.47	36.88	37.13	45.41	57.68	71.74	26.15	15.18	0
1979	23.11	22.94	21.48	22.03	69.43	107.89	41.76	44.85	56.98	71.05	46.28	38.77	0
1980	26.43	33.40	30.11	28.39	133.47	373.35	43.28	60.93	152.43	71.03	105.72	58.37	0
1981	23.70	23.41	27.20	24.67	21.93	30.32	49.42	49.11	56.84	72.77	20.67	13.46	0
1982	22.77	21.81	26.67	22.73	21.56	28.28	42.41	45.61	57.56	71.24	20.56	13.48	0
1983	21.42	37.23	41.83	25.83	21.59	46.20	52.28	44.97	56.97	71.05	20.66	13.46	0
1984	22.47	21.52	21.36	26.42	29.43	49.87	35.20	44.23	56.76	70.95	20.48	13.46	0
1985	24.87	27.57	63.97	33.71	34.79	38.06	40.33	45.38	63.77	73.13	20.66	14.14	0
1986	22.54	22.10	24.48	21.36	42.49	33.74	37.26	44.56	56.73	71.08	20.54	18.36	0
1987	22.82	30.94	24.94	44.30	3180.71	3733.57	609.83	118.31	91.54	71.92	20.79	316.98	0

1: Open (River)	>50.0	2: Open (Brackish)	10.0-50.0	3: Closed	< 10.0	Floods	> 2000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
< 10.0	0	0	0	0	0	0	0	0	0	0	0	0
10.0-50.0	63	57	47	44	31	25	26	41	0	0	63	64
>50.0	5	11	21	24	37	43	42	27	68	68	5	4

d. Typical Abiotic State for the Orange River Estuary

Based on the limited data available, three Abiotic States were derived for the Orange River Estuary, of which the occurrence and duration varies depending on river inflow rate. These states are:

STATE	FLOW RANGE
1: Open, river dominated	> 50 m^3/s
2: Predominantly Open, with marine influence	10.0 – 50.0 m^3/s
3: Closed, for extended period	< 10.0 m^3/s

The transitions between the different states will not be instantaneous, but will gradually take place. The estimates of the occurrences of the different states by direct correlation with river flow is based on expert opinion and limited data available from Vioolsdrift Gauging Station (D8H003).

e. Typical Abiotic Characteristics of the Abiotic States identified for the Orange River Estuary

ABIOTIC STATE 1: OPEN, RIVER DOMINATED

Typical flow patterns: At river flows greater than 50 m^3/s the mouth will normally be open and because of the strong river flow limited or no seawater intrusion in the estuary will take place.

Confidence: Low

State of the mouth: The mouth of the Orange River Estuary will be fully open at this state. Generally the mouth is a relatively narrow (100 – 400 m) opening in the beach spit. After a flood the mouth would be considerable wider by a few hundred metres, as the spit is know to be extensively eroded.

Confidence: Low

Flood plain inundation patterns: The water level will be very high during floods inundating the flood plains. Such floods will scour the mouth and after the flood the water level can drop very low at low tides until the mouth becomes restricted again. At flows between 50 and 300 m^3/s the mouth will normally be wide open and only limited backing up of water, increasing the water level and flooding of floodplain would occur. At flows higher than 300 m^3/s significant back flooding starts to occur.

Confidence: Low

Amplitude of tidal variation (indicative of exposure of inter-tidal areas during low tide): Limited tidal variation will occur during a flood when the water level is high, but tidal variations will occur again when the flood flows are reduced.

Confidence: Medium

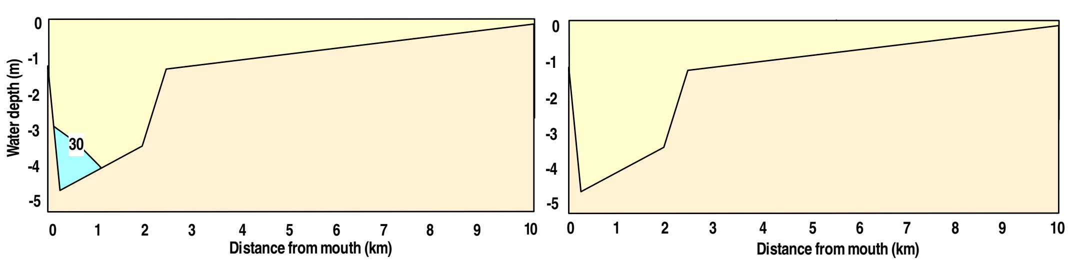
Retention times of water masses: The retention time will normally be less than one day. Some backwater areas might have longer retentions periods of a few days at a time.

Confidence: Low

Total volume: No data available to provide any details on total volume

Confidence: Low

Salinity distributions in the estuary: **T**he estuary will be mostly fresh during this open river dominated state, with limited salinity penetration in the mouth area at high tide.



Confidence: Low

ABIOTIC STATE 1: OPEN, RIVER DOMINATED CONTINUED…

System variables (Temperature, suspended solids, turbidity and dissolved oxygen):

Temperature varies seasonally depending when this state occurs, with lower temperatures (~15 ^{0}C) in winter and higher temperatures (~25 ^{0}C) in summer.

pH typically range between 7.1 and 8.5.

Turbidity will be high, with Secchi depth around 0.25 m.

System will be well-oxygenated.

Confidence: Low

Inorganic Nutrients: Nutrient concentrations will typically be low, characteristic of concentrations in river inflow.

Confidence: Low

ABIOTIC STATE 2: PREDOMINANTLY OPEN, WITH MARINE INFLUENCE

Typical flow patterns: At inflows 10 – 50 m^3/s the mouth will predominantly be open.

Confidence: medium

State of the mouth: The mouth will predominantly be open. Generally the mouth is a relatively narrow (100 – 400 m) opening in the beach spit.

Mouth closure will occur occasionally, but only for a few days at a time. For example, the mouth closure events of December 1995.

Confidence: Medium

Water levels and flood plain inundation patterns: The water level will probably vary between 0.0 and + 1.1 m MSL because of tidal influence. This will be much lower than in the Closed state and much of the flood plain will be permanently exposed. Flooding and drying of the intertidal area will occur.

Limited inundation of surrounding flood plain and saltmarshes might occur, due to brief mouth closure. The extent to which the flood plain will be inundated will depend on the water level in the estuary and the height of the berm. For example, the maximum water level reached in the estuary at mouth breachings in December 1994 and December 1995, when the mouth was only closed for a few days, was about + 2.30 m MSL.

Confidence: Medium

Amplitude of tidal variation (indicative of exposure of inter-tidal areas during low tide): The mean tidal range at the mouth of the Orange River is approximately 0.4 m and can be as much as 1.0 m during spring tides.

Confidence: High

Retention times of water masses: The retention time will be longer than in the 1: Open, river-dominated state varying from a day to a few days (if brief closure should occur) depending on the inflow. Pretension time will also be longer in side channels and backwater areas.

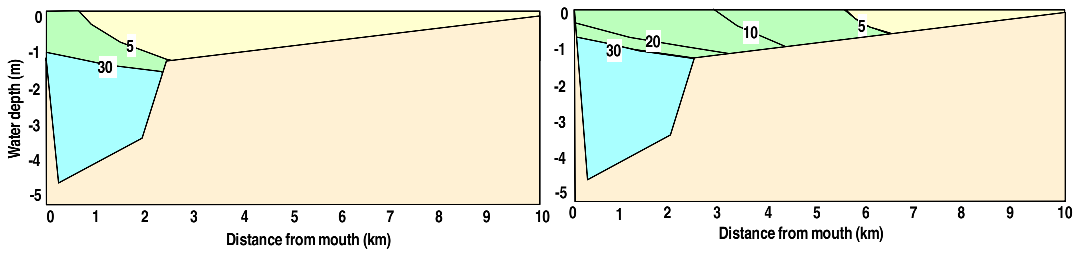
Confidence: Low

Total volume: No data available to provide any details on total volume.

Confidence: -

ABIOTIC STATE 2: PREDOMINANTLY OPEN, WITH MARINE INFLUENCE CONTINUED…

Salinity distributions in the estuary: For the higher flow range (~50 m^3/s), strong vertical stratification occurs in the deeper basin area in the lower reaches, with salinities of greater than 30 ppt in bottom waters and between 0 and 10 ppt in the surface layer. Moving further upstream salinities decrease markedly with 0 ppt occurring approximately 3 km from the mouth. At the lower flow range, (~10 m^3/s) strong vertical stratification is still present in the deeper basin. Further upstream as the estuary becomes shallower, salinities decrease gradually with 0 ppt reached about 7 km from the mouth.



Confidence: Low

System variables (Temperature, pH, suspended solids, turbidity and dissolved oxygen):

Temperature varies seasonally depending when this state occurs, with lower temperatures (around 15 ^{0}C) in winter and higher temperatures (around 25 ^{0}C) in summer. In the deeper basin in the lower reaches (salinities < 30 ppt), temperatures can be expected to remain low (around 14-16^{0}C), even during summer.

pH typically range between 7.1 and 8.5.

Turbidity will be high, with Secchi depth around 0.25 m.

System will be well-oxygenated.

Confidence: Low

Inorganic Nutrients: Nutrient concentrations will typically be low, except in the event where upwelling at sea could introduce inorganic nutrients to the estuary, but this will be limited to the deeper basin in the lower reaches during summer.

Confidence: Low

ABIOTIC STATE 3: CLOSED FOR EXTENDED PERIOD

Typical flow patterns: At inflows lower than 10 m^3/s the mouth will predominantly be close. The water losses because of seepage of water through the berm and evaporation will be similar to the river flow entering the estuary. The water level on the estuary will depend on the river flow, seepage and the height of the berm. A breaching will occur when the inflow increases the water level in the estuary so that it exceeds the height of the berm.

Confidence: Low

State of the mouth: Mouth closed for extended periods at a time

Confidence: Low

Water levels and flood plain inundation patterns: Extended inundation of surrounding flood plain and saltmarshes, due to mouth closure and related back flooding will occur, and especially at the higher water levels associated with long periods of closure. The extent to which the flood plain will be inundated, will depend on the water level in the estuary and the height of the berm before the next breaching occurs. The berm of a closed estuary mouth normally builds up to levels of between + 2.5 to + 3.0 m MSL. If the mouth should close for extensive periods at a time, the berm can even build up to 3.5 m MSL.

Confidence: Low

Amplitude of tidal variation (indicative of exposure of inter-tidal areas during low tide): No tidal variation.

Confidence: High

Retention times of water masses: The retention time will vary from a weeks to months depending on the duration of the closed state. Under new present day conditions mouth closure could occur for a few weeks at a time, depending on the extend of the hydropower releases.

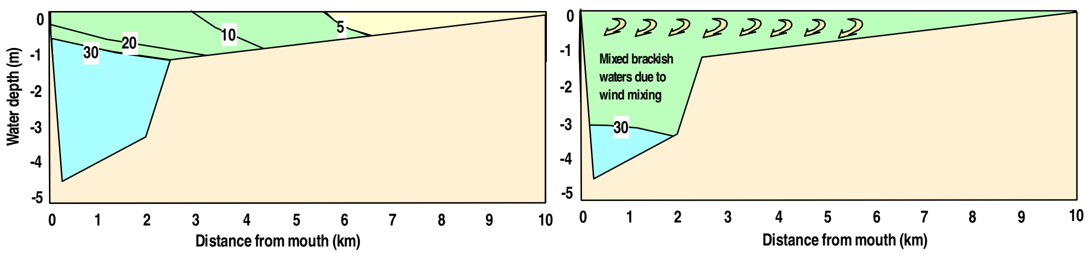
Confidence: Low

Total volume: No data available to provide any details on total volume

Confidence: -

ABIOTIC STATE 3: CLOSED FOR EXTENDED PERIOD, CONTINUED…

Salinity distributions in the estuary: Taking into account the strong stratification that occurs in the lower reaches of the estuary during the tidal phase (see above), it is expected that at the onset of mouth closure salinity distribution pattern will be similar to that of the tidal phase. With time, turbulence caused by wind mixing will eventually create a brackish zone throughout estuary, except perhaps in the deeper basin in the lower reaches where salinities could remain around 30 ppt for extended periods, (i.e. turbulence generated by wind mixing may not be sufficient to erode this denser saline water at such depths). The estuary will become fresher due to continuous inflow of fresh water and decreasing of overwash events (at higher berms levels).



Confidence: Low

System variables (Temperature, pH, suspended solids, turbidity and dissolved oxygen):

Temperature variation will be seasonal depending when this state occurs, with lower temperatures (around 15 ^{0}C) in winter and higher temperatures (around 25 ^{0}C) in summer.

pH typically range between 7.1 and 8.5.

Still expected to be relatively turbid (Secchi depth around 0.25 m), except when river inflow becomes very low (~ 1 m^3/s).

System will be well-oxygenated, but during prolonged closure, dissolved oxygen levels in bottom waters (> 30 ppt) of the deeper basin these waters could decrease. The severity of such a decrease will depend on the duration of closures, as well as the organic content of the bottom waters and sediments at the time.

Confidence: Low

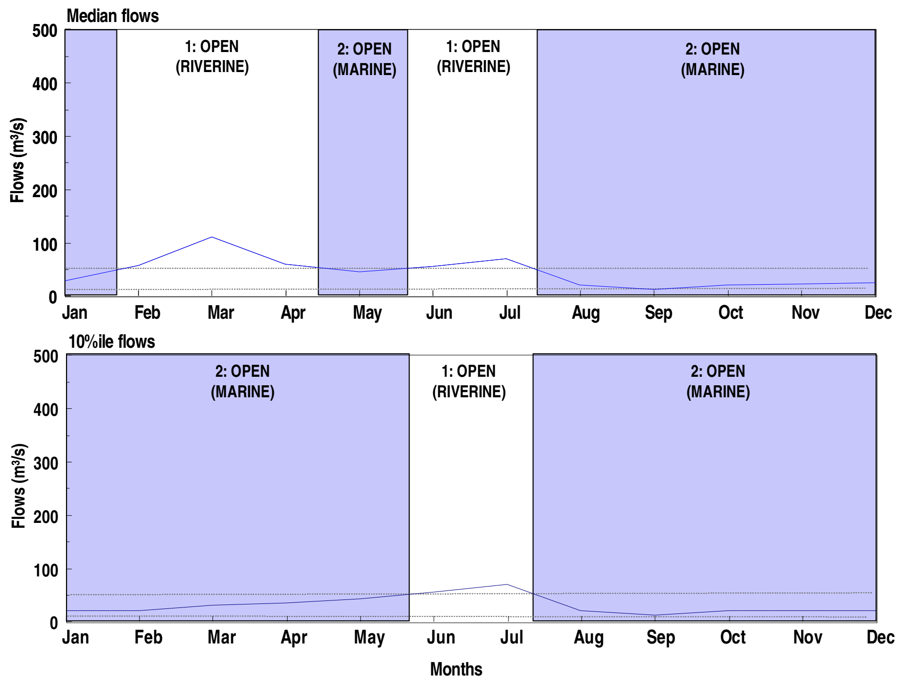
Inorganic Nutrients: Estuary will become nutrient depleted.

Confidence: Low

f. Occurrence and duration of different Abiotic states during the Present State

The occurrence and duration of the different Abiotic States during the Present State are illustrated in the simulated monthly river flow table (**Table 3.1**).

To provide a conceptual overview of the annual distribution of Abiotic States under the Present State, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



g. Non-flow related anthropogenic influences that are presently affecting Abiotic characteristics

Structures (e.g. weirs, bridges, mouth stabilization): The estuary has been disturbed by human development such as the agricultural developments at Alexander Bay, the levees protecting these developments, the oxidation pond system near the village of Alexander Bay, the road across the salt marsh to the river mouth on the south bank and the golf course, protected by a dyke on the north bank.

Confidence: Medium

Human exploitation (e.g. sand mining): N/A

Confidence: -

Wastewater discharges affecting water quality (e.g. dump sites, storm water, sewage discharges, etc): Agricultural activities in the catchment are likely to be diffuse sources inorganic nutrients (nitrogen and phosphate) to the river. Although some enrichment could have occurred in the estuary, it is, however, it is expected that river vegetation will largely acts as a 'filter' for nutrients resulting in water reaching the estuary not being that enriched.

Anthropogenic activities in the catchment are also likely to result in pH levels occasionally increasing to about 9.

It has also been reported that on occasions, algal blooms occur, for example in the Spitskop Dam further upstream. These make there way downstream, resulting in river water entering the system being almost anoxic.

Also, wastewater discharges from the mining activities at Alexander Bay also tend to modify interstitial/groundwater salinity levels in the adjacent saltmarsh area.

Confidence: Low

Input of toxic substances from catchment: There are no information on the toxic inputs for mining operations and the adjacent town and developments or agricultural (e.g., pesticide use). This will have to be confirmed through measurements.

Confidence: Low

Other: N/A

Confidence: -

3.1.2 Biotic components

a. Description of the Present State of biotic components

MICROALGAE

No data available. Phytoplankton are probably unimportant because of high flows and flushing which would preclude the development of resident populations. Benthic microalgal biomass could be high in quiet backwater areas. They would be important primary colonizers after floods. Their mucilage secretions would help stabilize newly formed sandbanks.

Confidence: Low

MACROPHYTES

The vegetation of the lower reaches of the Orange River is described by O'Callaghan (1984), Burns (1989) and Morant and O'Callaghan (1990) and Raal (1996). Subsequent reports e.g., Anon. (2002) have used the data from these reports and no recent comprehensive vegetation survey data are available. These reports state that estuarine plant communities were distributed primarily along the southern bank of the estuary, corresponding to the 2 to 2.5 km limit of saltwater penetration.

Scirpus littoralis occurred close to the mouth in small clumps but was replaced by the dominant species Phragmites australis (common reed) along the shallow edge habitats further upstream. Both species thrive in brackish conditions when salinity is less than 15 ppt. The submerged macrophyte Potamogeton pectinatus (pondweed) was associated with Phragmites australis (CSIR 1991). This plant grows best at salinity less than 10 ppt.

The vegetation on the braided system of islands within the lower reaches of the river is ephemeral due to periodic flooding. The pioneers such as Sporobolus virginicus (brakgras) and Scirpus maritimus dominate these communities and are normally in a sub-climax state. The peripheral marshes are dominated by Sporobolus viginicus, but various herbs, sedges and grasses such as Cotula coronopifolia, Juncus kraussii (sharp rush), Apium graveolens and Cyperus laevigatus also occur. All these species would thrive under brackish conditions (< 15 ppt). Recent aerial photographs (2002) indicate that two large vegetated areas occur on the south bank of the main river channel. These areas are probably composed of a mosaic of brackish species as described above.

The following species formed a mosaic of salt marsh vegetation: Cotula coronopifolia, Triglochin spp., Juncellus laevigatus, Sporobolus virginicus and Sarcocornia pillansii. Sarcocornia perennis formed a salt marsh on the right bank of the river near the mouth (Morant and O'Callaghan 1990). This species usually occurs in the intertidal zone of permanently open estuaries. Sarcocornia pillansii was dominant in the salinized lower floodplains. On the south bank of the river, a large area of desertified saltmarsh exists. In 1986 approximately 90 % of this saltmarsh had died. Saltmarsh communities that were still present at elevated zones were dominated by Sarcocornia pillansii. This species usually occurs in the supratidal saltmarsh zone of South African estuaries. It has a wide salinity tolerance range (0-70 ppt) and in the Olifants Estuary survives the semi-arid conditions by utilizing saline groundwater (Bornman 2002).

Because of the threatened status of the saltmarsh, the wetland was placed on the Montreux Record in 1995. South Africa is obliged, as a signatory of the Ramsar Convention, to ensure that the ecological character of the site is restored (CSIR 1991, Raal 1996). In 1995, Alexkor together with the CSIR initiated a rehabilitation programme. The road embankment at the mouth was removed to allow for regular tidal flushing of the lower reaches of the degraded saltmarsh area. Recent aerial photographs (September 2002) indicate some success of this programme, however, a vegetation survey would be necessary to confirm this.

Confidence: Medium

INVERTEBRATES (INCLUDING ZOOPLANKTON)

Estuarine benthic invertebrates are described from two sets of data collected in the river mouth area below the Ernest Oppenheimer Bridge. The first set of data was collected by UCT who sampled the intertidal zone only. Brown described the results from the survey in 1959. This data indicate that the intertidal benthic fauna at the time was extremely poor, in both species number and biomass. Because the intertidal zone is influenced mostly by near-surface water, salinity values will fluctuate between fresh brackish estuarine in the lower mouth area, depending on the state of the tide and time of the year. These fluctuating abiotic conditions create a harsh environment for intertidal communities and only the hardiest survive. However, there are likely to be pockets among the mosaic of channels where conditions are more stable and communities may become better established over time.

No information is available on the subtidal benthic community. However, the deeper section immediately inside the mouth (or other deeper sections) allows a lens of marine water to persist for some months when the sea influences the lower mouth area (between July/Aug and Jan/Feb). An estuarine fauna may begin to develop during these brief windows of time when condition (e.g. salinity) become more favourable for them. Such a situation may also arise during times of mouth closure when overtopping occurs. Although similar events of saltwater intrusion may occur in May when the mouth is open, the window is probably to brief for the community to establish itself and only hardy estuarine species may be present, but in low numbers. However, like the Thukela, faunal characteristics are probably extremely variable.

Very little information (brief comments) exists for the zooplankton in the main channel. It is described as consisting of freshwater species that are present in very low numbers. This community is unlikely to establish itself because of strong flushing at the surface. However, a bottom estuarine type community may establish itself at times when the lens of saline water exists in deeper areas (see above), but no hard data are available. Because of stratification, an estuarine type community may exist below a near surface brackish/freshwater community that will not be able to maintain itself effectively because of flushing. No samples have been collected in sub-surface waters.

The invertebrates present in the sheltered wetland on the southern bank near the mouth of the Lower Orange are likely to assume estuarine characteristics, although there are no hard data to support this. Salinity values are probably suitable for much of the time.

However, an estuarine type community probably exists (benthos and zooplankton) in the more sheltered backwaters, but no data are available to substantiate this.

Confidence: Low

FISH

Twenty-nine species of fish representing 14 families have been recorded from the Orange River Estuary. Three of these, the estuarine round herring (Gilchristella aestuaria), barehead goby (Caffrogobius nudiceps) and klipvis (probably Clinus superciliosus) live and breed in estuaries but the latter two also have marine breeding populations. Three species, white steenbras (Lithognathus lithognathus), leervis (Lichia amia) and flathead mullet (Mugil cephalus) are dependent on estuaries for at least their first year of life.whereas another two, elf (Pomatomus saltatrix) and harder (Liza richardsonii) are partially estuarine dependent. Six species such as west coast steenbras (Lithognathus aureti) and silver kob (Argyrosomus inodorus) are marine species that occasionally venture into estuaries whereas 14, such as largemouth yellowfish (Labeobarbus kimberleyensis) and river sardine (Mesobola brevianalis) are freshwater species whose penetration into the estuary is determined by salinity tolerance. One catadromous species the longfin eel Anguilla mossambica has been recorded from the Orange River near Kakamas and it is assumed that recruitment occurred through the estuary notwithstanding the possibility that it entered the system through one of the inter-basin transfer schemes that connect the catchment with rivers on the east coast. Overall, 31 % of the fish species recorded from the Orange River Estuary are either partially or completely estuarine dependent, 21 % are marine and 48 % freshwater in origin.

Two species of kob, silver kob Argyrosomus inodorus and Angolan kob A. coronus are known from the Orange River Estuary, the latter only been caught by anglers in the mouth region. Interestingly, on the east coast of South Africa dusky kob (A, japonicus) are dependent on estuarine nursery areas whereas A. inodorus seldom if ever ventures into estuaries. On the west coast however, A. inodorus frequently (& predictably) occurs in the Berg, Olifants and Orange Estuaries whereas A. coronus is predominantly caught on the beaches immediately adjacent to their mouths (Lamberth unpublished data). Therefore, A. inodorus may show some degree of estuarine dependence on the west coast of South Africa. All three of the kob species mentioned prefer turbid waters such as that in the Orange River Estuary.

On the whole, the current fish assemblage and the presence of estuarine residents such as G. aestuaria suggests that the Orange River Estuary functions as a viable nursery area and refuge for juvenile and adult estuarine fish though not as well as under natural conditions. Historically, it was likely that estuarine and freshwater fish escaped floods and high flows by either swimming upstream or moving onto the inundated floodplain and saltmarshes. Nowadays obstructions such as the dykes and causeway have removed much of this temporary refuge and the chances of being flushed from the system are higher and may even occur at slightly lower flows. Reduced inundation of the marginal and channel areas of the saltmarsh are also likely to have seen a reduction in habitat and numbers of benthic species such as the goby Caffrogobius nudiceps. Higher flows in the winter months may have reduced the residence time and / or numbers of marine and estuarine dependent species entering the system whereas lower flows during the summer months may have seen fewer fish escaping cold upwelling events in the sea. Higher winter flows are also likely to have resulted in the freshwater species persisting in the estuary throughout winter whereas previously they would have moved back into the upper reaches in response to increased salinity.

The fish community is typical of a freshwater dominated and temporarily open / closed estuarine system comprising a relatively small group of species such as L. richardsonii, G. aestuaria and L. amia that are tolerant of low salinities and of being cut off from the sea for extended periods. Available habitat is not confined to the tidal influence but extends into the freshwater reaches as evidenced by P. saltatrix and L. richardsonii being recorded at 35 km and 150 km from the mouth respectively.

On a cautionary note, comparing present and reference conditions there appears to have been an almost complete (75 %) seasonal reversal in flows from the reference to the present state with marine conditions dominating in previously freshwater months and vice versa. The impact that this has had on recruitment, migratory or spawning cues is unknown but may have resulted in a decline in abundance or the loss of some species from the system.

Confidence: Low

BIRDS

The number of waterbirds recorded at the estuary has varied considerably since 1980 when the first comprehensive survey was conducted (Ryan & Cooper 1985). The highest number of waterbirds was recorded during the first survey, January 1980 (21,512 waterbirds; Ryan & Cooper 1985), and second survey, December 1985 (20,563-26,653 waterbirds; Williams 1986). Subsequent surveys, beginning seven years later, never recorded such high numbers. From December 1995 to August 2001 an average of 6873 (±1719SD; n=6) and 5547 (±2039SD; n=7) waterbirds was recorded during summer and winter, respectively; less than a third of early 1980s totals (Anderson et al. 2003).

Despite this drop in the numbers of birds present, species richness of waterbirds remained relatively constant from 1980 to 2001: an average of 52 species (±5.1SD) was recorded. A total of 87 different waterbird species was recorded during the 20 surveys (Ryan & Cooper 1985; Williams 1986; 17 recent surveys). There are however records of at least another 15 waterbird species being recorded at the estuary since 1964 (Anderson et al. 2003).

The number of waterbirds has declined by 74% between the early (January 1980 and December 1985) surveys (Ryan & Cooper 1985; Williams 1986) and the 12 most recent surveys (average of 5909 waterbirds) (Anderson et al. 2003). This is primarily accounted for by the virtual absence of Cape Cormorants and Common Terns during the latter surveys. Cape Cormorants have declined from an average of 6400 (±3861) individuals from January 1980 – January 1994 to 212 (±612) individuals during 16 surveys conducted from April 1994 to August 2001. During this same period, Common Terns have declined from an average of 3928 (±3678) individuals to 425 (±731) individuals. If these two species are excluded from the analysis, a lower appreciable decline between the 1980s (9027.7±4195.6) and the 1990s (4265.3±1853.) is evident. The collapse in the population of these two species is due to both onsite and offsite factors (Anderson *et al.* 2003), including: (1) depletion of food reserves (Crawford & Dyer1995; Crawford 1997, 1999, 2000; Schwartzlose *et al.* 1999), (2) increased disturbance by humans (Cooper et al. 1982; Crawford 1997, 2000), (3) disturbance and trampling by livestock (K. van Zyl pers. comm.), (4) predation and disturbance by feral dogs and cats, (5) change in the architecture of the mouth and islands (Swart *et al.* 1988; Morant & O'Callaghan 1990) with a consequent effect on roost site availability, (6) more suitable roosting sites elsewhere (R.E. Simmons pers. comm.), (7) disease (avian cholera Pasteurella multocida) (Crawford *et al.* 1992; Crawford & Dyer 1995), and (8) oiling.

Several other waterbird species that were particularly numerous in January 1980 (Ryan & Cooper 1985) have not subsequently attained their original numbers. These include Black-necked Grebe, Great Cormorant and Redknobbed Coot, both freshwater and saline species. Several waders too have shown this pattern, with lower numbers of Common Ringed Plover, Common Greenshank and others being recorded during the subsequent 19 surveys. The reason for this is unclear, but it could be related to the deterioration of the saltmarsh and the corresponding decrease in available mud-flat habitat for many of these species. Subsequent to 1980 there has, however, not been a significant decline in the numbers of the three main wader groups.

During the 20 waterbird surveys, 12 different waterfowl species (ducks and geese) have been recorded, with from 7-10 different species being recorded during a specific count. Since January 1995, there has been an increase in the numbers of ducks and geese utilising the estuary. There are two possible reasons for this observation: (1) an increase in the area under irrigated agriculture, such as at Beauvallon (K. van Zyl pers. comm.) and (2) a halt in the hunting of these birds within the estuary and surrounding area (P. Laubscher pers. comm.). What is noticeable too, is the seasonal change in usage of the estuary by ducks and geese. Fewer waterfowl are present during the winter months, the time of year in this winter-rainfall area when they probably disperse to smaller, ephemeral wetlands.

One of the criteria originally used to designate the Orange River estuary as a Ramsar site was that it supported an appreciable assemblage of rare and endangered bird species, 14 of which are listed in either the South African (Brooke 1984) and Namibian (Barnard 1998; Simmons et al. in prep) red data books. The South African red data book has subsequently been revised, using the new IUCN criteria (Barnes 2000). Using these new criteria, the estuary now supports 21 red data species, 14 regularly occurring and an additional seven occasionally occurring species (as listed in either Barnes (2000), Barnard (1998), Simmons et al. (in prep) or BirdLife International (2000)).

This assessment of recent survey data has shown that the Orange River estuary still meets three of the four Ramsar criteria under which it was originally designated in 1991 (Anderson et al. 2003). In particular, the estuary continues to support more than 1% of the southern African and global populations of all the waterbird species listed by Williams (1990) under criterion 4. The site no longer regularly supports in excess of 20,000 waterbirds, primarily as a result of the decline in the numbers of Cape Cormorant and Common Tern, and thus presently does not meet criterion 3. The criteria for identifying Wetlands of International Importance have recently been rationalised (Ramsar Convention Bureau 1999) to a list of eight criteria based on wetland types, species and ecological communities, waterbirds and fish. The estuary currently complies with five criteria (Anderson et al. 2003).

Confidence: High

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

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
Mouth condition (provide temporal implications where applicable)	**Microalgae:** An open mouth, the interaction between seawater and freshwater and increase in available nutrients would be important in stimulating phytoplankton growth. However, the short water retention time may preclude the development of phytoplankton biomass. **Confidence: Low**
	Macrophytes: Mouth closure did occur in August and September under reference conditions (i.e. 10% of the time for a 68-year period under drought conditions when flow was < 10 m^3/s.) Back flooding of the desertified saltmarsh area would then have occurred. This event would have flushed out accumulated salts and lowered groundwater salinity. The mouth no longer closes because of continuous releases of water from the dams for the generation of electricity and for irrigation purposes (refer to **Appendix B**). An open mouth is important for the recovering saltmarsh on the south bank. Since the causeway has been removed in the vicinity of the mouth, the saltmarsh now shows signs of recovery that is dependent on regular tidal inundation. **Confidence:** Medium
	Invertebrates: An open mouth at times when freshwater flow volumes are <50 m^3/sec enables a seawater lens to develop immediately inside the mouth. Such conditions occur between July/Aug and Jan/Feb. This will provide suitable salinity conditions for an estuarine subtidal benthic community to develop temporarily. However, flushing of the lens above a freshwater flow volume >50 m^3/sec will probably lead to the disappearance of this temporary estuarine community. Floods will also scour these lenses and possibly remove large volumes of sediment together with benthic animals. An important element not generally considered is the potential importance of the backwaters on the south bank (and possibly elsewhere among the mosaic of channels) as potential enclaves where estuarine species survive. If seawater/estuarine water (salinity above ca 5 ppt) enters these areas because of tidal action, trapped water may persist for varying lengths of time (a saltmarsh community is present under natural conditions). This may allow typical estuarine communities to develop and survive. No data are available on the physico-chemical dynamics of these backwaters, but their potential role as nursery areas or enclaves where estuarine communities survive must not be underestimated. **Confidence:** Medium
	Fish: Mouth closure and backflooding in the winter provides increased habitat, refuge and foraging area for small and juvenile fish. The estuary will also provide a fairly calm environment as opposed to storm conditions in the adjacent surf-zone. Wind mixing increases salinity in the upper reaches of the estuary increasing the available area suitable for survival of marine species trapped by the berm. Overall, the fish community is typical of a temporarily open / closed system and tolerant of extended mouth closure. Depending on the timing of cessation of winter releases, mouth closure either persisting or occurring into spring and early summer may prevent or reduce recruitment of the juveniles of some species e.g. L. lithognathus & L. amia. Extended mouth closure during the winter may result in a decline in numbers of A. inodorus entering the estuary. This species is predominantly caught during the winter months in west coast estuaries. **Confidence:** Low

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Birds: It is expected that a close simulation of historical flow regimes and thus mouth open and closure would be most beneficial to the estuary's waterbirds. Low flow during late winter and early summer would result in mouth closure and thus back flooding and inundation of the saltmarsh, an area important for a variety of bird species. Although the saltmarsh area does not presently (and probably did not historically) support a large proportion of the estuary's waterbirds, certain species (such as Ethiopian Snipe and Wood Sandpiper) may have been more common in this habitat. Lower flow rates and limited back flooding have probably changed the salinity of the saltmarsh. There is no inflow of freshwater via river channels. This portion of the wetland is now fed with highly saline water during tidal interchange via the recently opened channel in the road embankment. This suggestion is supported by the species composition of birds that now frequent the "lake" in the saltmarsh, namely Cape Shovellers, Cape Teals, Black-winged Stilt, Avocet, and various other species of wading birds (all species which prefer wetlands with higher salinities). An open mouth during the summer months will allow for tidal interchange, exposing mudflats at low tide, and thus providing feeding habitat for wading birds. It is not known to what extent the estuary is used for feeding by piscivorous birds (especially terns, gulls and cormorants). Mouth dynamics which favour an increased number and diversity of fish species (and possibly also juvenile fish) would be most beneficial to the estuary's birds. It is believed that the maintenance of the processes in the saltmarsh is quite complex; i.e. interplay between freshwater inflow via the river, backflooding and tidal interchange. With more constant flow rates and an altered seasonal flow regime, it is anticipated that the restoration of the saltmarsh will not be easily achieved (especially as much of the vegetation is gone and the dust effects [from the slimes dam and dumps] have not been removed). **Confidence:** Medium
Exposure of intertidal areas during low tide	**Microalgae:** In the Orange the exposure of intertidal areas would promote the growth of intertidal benthic microalgae, which generally have greater biomass than subtidal populations. **Confidence:** Low
	Macrophytes: Large stands of intertidal salt marsh have been reported in the past, i.e. on the south bank. Morant and O'Callaghan (1990) found 10 ha of the intertidal salt marsh plant Sarcocornia perennis prior to the 1998 flood. This plant typically occurs in the intertidal zone of permanently open estuaries. A vegetation survey is needed to verify the area currently covered by intertidal salt marsh. Because of continuous flow water levels are more stable, sandbanks are continuously exposed and have become vegetated (refer to **Appendix B**). There is evidence of this is in the 2002 photographs which show two large vegetated areas on the south bank close to the mouth in the main channel. **Confidence:** Low
	Invertebrates: Available evidence suggests that the intertidal invertebrate community is extremely poor (based on two brief surveys). However, there is no information on the dynamics of intertidal communities in the lower reaches of the Orange River. It is probable that a brackish water intertidal community is present near the mouth (although not substantiated by the two previous surveys, but these may have been undertaken at times of low abundance), changing to a freshwater assemblage within a few kilometres of the mouth. **Confidence:** Low
	Fish: Beware the mudsharks. Droppings from roosting and foraging birds may be a source of food to mullet species when re-suspended on the rising tide. L. richardsonii has been observed feeding on suspended guano at Dassen Island (pers. obs.). May be insignificant considering the high detrital load coming from upstream. **Confidence:** Low
	Birds: Exposure of intertidal areas during low tide will benefit wading birds, such as Little Stint and Curlew Sandpiper. This is of particular importance during the austral summer, when large numbers of Palaearctic migrant wading birds are present in southern Africa. The intertidal areas, especially the sandbars and the berm, are also used by roosting terns and cormorants during low tide. **Confidence:** Medium
Sediment processes and characteristics	**Microalgae:** Unstable sediment environment in the estuary would reduce opportunities for benthic microalgal colonization. Turbid water may also restrict the growth of microalgae due to the reduction in available light. **Confidence:** Low

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Macrophytes: Due to the reduction in floods from the Reference condition to the Present state, more stable braided/meandering channels currently characterize the upper estuary. Under the Reference condition the system would have been reset more frequently and channels would have been of a less meandering nature (refer to Appendix B). The vegetation on the braided system of islands within the lower reaches of the river is ephemeral due to periodic flooding. Scouring of the island surfaces or deposition of high sediment loads maintains the plant communities. The pioneers such as Sporobolus virginicus and Scirpus maritimus dominate these communities and are normally in a sub-climax state (CSIR 1991, Raal 1996). **Confidence:** Medium
	Invertebrates: Compared to the reference condition, the present state (braided channel conditions more prevalent) would provide more sheltered backwaters that potentially provide habitat for invertebrates (riverine or estuarine). A more open channel system would also be exposed to stronger currents that would be less suitable for the invertebrates because of scour effects. A braided channel system may also provide more enclaves where suitable conditions (e.g. trapped pockets of brackish/estuarine water) develop for estuarine animals. If salinity conditions are not suitable for estuarine type communities, these protected backwaters will favour a freshwater/brackish water type community. **Confidence:** Medium
	Fish: As with the invertebrates, braided conditions would provide more sheltered backwater habitats perhaps partially compensating for the loss of inundated saltmarsh channels at certain times of year. A high detrital load in the sediment would favour the detritivores M. cephalus and L. richardsonii. An increase in mud favours the goby C. nudiceps whereas sandy areas are favourable for foraging L. lithognathus. High turbidity reduces the risk of predation from piscivorous birds and fish. **Confidence:** Low
	Birds: The islands are used by birds for breeding, feeding and roosting purposes. The sheltered backwaters of the channels are important for foraging and breeding purposes. It has been suggested that changes in the structure of the mouth architecture (fewer island or perhaps islands of a different structure) may have contributed to the virtual disappearance of breeding Cape Cormorants and roosting terns (Anderson *et al*. 2003). Deposition of sediments during low flow periods and scouring of channels during floods may be importance for the maintenance of these breeding/roosting sites. Sedimentation may be one of the causes for increased areas covered by macrophytes (such as Phragmites), which would have both positive effects (establishment of roosting and breeding habitat) and negative effects (loss of open habitats and mud flats) on the estuary's waterbirds. As the islands are now more permanent, they have become well-vegetated and may now be unsuitable for use by cormorants and terns. A high sediment load would negatively influence the ability of piscivorous birds to locate and capture their prey. **Confidence**: Medium
Retention times of water masses	**Microalgae:** The high flow and low water retention time probably precludes the development of phytoplankton and water column chlorophyll-a is probably low. **Confidence:** Low
	Macrophytes: Greater water retention time would provide better opportunities for nutrient uptake by macrophytes. Rooted submerged macrophytes are not a dominant feature of the estuary probably because of the high flows and low water retention times. **Confidence:** Low
	Invertebrates: The retention time of water in the lower Orange River is very short in near-surface waters and it is unlikely that any zooplankton establishes itself, except possibly in sheltered backwaters where they exist. An estuarine benthic community probably exists in the deeper areas where pockets of estuarine water persist during times when river flow is $<50m^3/sec$. **Confidence:** Low
	Fish: The low phytoplankton production would indicate that G. aestuaria, which depending on the food available, switches from filter to selective feeding, is likely to be actively selecting zooplankton. Considering that zooplankton production is also likely to be low, G. aestuaria may be relying to a large extent on freshwater invertebrates drifting down from upstream or alternatively the bulk of the population may be residing in the freshwater reaches. Increased retention time is likely to favour the eggs and larvae of this species. Low retention times and the lack of rooted submerged macrophytes would be a contributing factor to the low numbers of gobies and other species that favour these habitats. **Confidence:** Low

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Birds: Effects of retention time on the estuary's avifauna will probably be minimal. Lower flow and retention times in some areas (such as the saltmarsh) may have provided favourable roosting, feeding and breeding habitats for certain bird species. **Confidence:** Low
Flow velocities	**Microalgae:** The high flow and low water retention time probably precludes the development of phytoplankton and water column chlorophyll-a are probably low. **Confidence:** Low
	Macrophytes: Rooted submerged macrophytes are not a dominant feature of the estuary probably because of the high flows and low water retention times. Flow velocity and the stability of the sediment influence colonisation by emergent macrophytes such as reeds and sedges. It has been said that the vegetation on the braided system of islands within the lower reaches of the river are ephemeral due to periodic flooding. Scouring of the island surfaces or deposition of high sediment loads maintains the plant communities. **Confidence:** Low
	Invertebrates: All invertebrate communities are affected by flow velocity. An estuarine zooplankton community is probably absent under most present day conditions in open channel areas. Benthic communities will be influenced by changes in particle size as flow velocities change. **Confidence:** Medium
	Fish: High flow velocities would increase delivery of the freshwater invertebrate food source from upstream. Juveniles, larvae & eggs have a greater chance of being swept out of the system at high velocities but tend to either actively or passively find refuge in eddies. Increased flow velocities may provide the cue for some species such as L. richardsonii & M.cephalus to migrate further upstream. A piscivorous predator e.g., L.amia tends to maintain position in eddies and ambush prey being swept past or moving out of the shallows on a receding tide. The reduction in the marginal saltmarsh refuge in the Orange River Estuary suggests that high flow velocities are likely to be more of an issue with juvenile and small fish than under reference conditions. **Confidence:** Low
	Birds: As high flow velocities affect the estuary's invertebrates and fishes, there would be less food available for the area's avifauna. Seasonal variation in flow rates (low flows during late-winter and early summer) and high flow rates during late-summer may be important for maintaining the dynamics of the estuary, i.e. scouring channels, deposition of sediment as islands, etc. These habitats would be used by a variety of bird species, including cormorants, waterfowl and rails. Lower flow velocities in some areas (such as previously in the saltmarsh and presently in the braided channel system) provide favourable roosting, feeding and breeding habitats for certain bird species. **Confidence**: Medium
Volume of water in estuary	**Microalgae:** The larger the volume of water the more habitats there is available for phytoplankton (microalgae in the water column). **Confidence:** High
	Macrophytes: N/A **Confidence: -**
	Invertebrates: Not applicable in the present context – the lower Orange (channel area) is not an estuary in the true sense. However, a larger volume is likely to favour freshwater organisms, provided other conditions are suitable. **Confidence:** Low
	Fish: Large volume likely to be associated with summer floods or the backfllooding due to mouth closure in winter and spring. Both lead to inundation of saltmarsh & marginal areas increasing foraging habitat and refuge for most fish species. Freshwater fish will also move down into the estuary under these conditions. The greater the volume, the bigger the search area for piscivorous predators and the lesser the chance that small and juvenile fish will be eaten. **Confidence:** Low
	Birds: Although more water would mean a greater area available to waterbirds, it is likely that excessive volumes (such as during floods) are, in the short term, detrimental to the estuary's birds. This is because there would be a temporary loss of various important habitats, including riparian vegetation refuges, mud flat feeding areas, island roosting and breeding areas. Animal and plant life in the estuary would have adapted over millenia to a specific seasonal flow regime, with a higher volume of water in late summer. **Confidence:** Medium

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Microalgae: Phytoplankton biomass is usually highest in the river-estuary interface zone of estuaries where the water is brackish (< 15 ppt) and nutrient availability is high. The flow in the Orange River Estuary is probably too high for a river-estuary interface zone to develop for any length of time. **Confidence**: High
	Macrophytes: Salinity is mostly less than 15 ppt and the macrophytes present in the main river channel reflect this. In the desertified salt marsh area in 1994, a layer of crystallized salt occurred on the sediment surface and this was a highly saline environment (pers. obs). The salt marsh plant Sarcocornia pillansii occurred in some of the elevated areas. This plant has a wide salinity tolerance range of 0-70 ppt (Bornman 2002). Since the road embankment near the mouth has been removed and tidal exchange has occurred in the desertified marsh area, one could expect salt marsh zonation typical of a saline (35 ppt) permanently open estuary in the low-lying areas. To re-establish Sarcocornia pillansii in the elevated areas the salts would need to be flushed out. CSIR (1991) believed that prior to the cut-off of freshwater input to the marsh the area would have supported a mosaic of communities associated with freshwater and brackish conditions (e.g. reeds and sedges such as Phragmites and Scirpus). When the desertified marsh area was cut-off from the main channel an isolated coastal lake developed behind the dunes in the lower part of the salt marsh and the water in this lake became highly saline, mainly because of ongoing evaporation (CSIR 1990). If tidal exchange is not currently maintained in the marsh area, it could revert back to a saline lake. **Confidence:** Medium
	Invertebrates: Salinity is an important parameter influencing the type of community present. Salinity values below about 5 ppt favour brackish/freshwater types, while estuarine types become established at higher values. If seawater/estuarine water (salinity above ca 5 ppt) enters backwater areas because of tidal action, trapped water may persist for varying lengths of time (a saltmarsh community is present under natural conditions on the south bank). This may allow typical estuarine communities to develop and survive, depending on the salinity of the trapped water. **Confidence:** High
Salinities	**Fish:** The fish community is typical of a temporarily open / closed system, tolerant of low salinities and often venturing far upstream into the freshwater reaches. The distribution and abundance of these species in the system will ultimately depend on the extent of the estuarine area covered by their preferred, as opposed to tolerable, salinity ranges. The estuarine breeder G. aestuaria and the facultative catadromous M. cephalus prefer the 0-10 ppt salinities of the REI zone. Shrinking of the REI zone through either low flows and saline intrusion or high flows and freshwater dilution, could lead to a number of responses. Fish densities within the remaining REI zone could increase as the existing population is compacted into a smaller area. Alternatively, there could be increased migration upstream as the freshwater reaches provide the next best option. An increase in salinity levels is likely to see an increase in the number of non-estuarine-dependent marine species e.g. Diplodus cervinus that enter the system. Flocculation and lower turbidity may favour visual predators such as L. amia but discourage A. inodorous, which prefers murky waters. In turn, an increase in the extent of estuarine area under a 10-20 ppt salinity range may see an increase in the numbers of partially estuarine dependent species such as elf P. saltatrix and harder L. richardsonii. Depending on the persistence of different salinity "states" and the life-history characteristics of the species concerned, changes in species composition and abundance may be either short-term or permanent. **Confidence:** Low
	Birds: The estuary's waterbird community is influenced by water salinity levels. Certain species, such as Yellow-billed Duck, other waterfowl, rails, Reed Cormorant, etc., are freshwater-dependent. Other species, such as Cape Teal, Cape Shoveller, South African Shelduck, Avocet, Lesser Flamingo, Curlew Sandpiper, Little Stint and several other wading birds are more tolerant of high salinities. The collapse of the saltmarsh and subsequent opening of the road embankment to allow tidal interchange of water into the saltmarsh area has resulted in the establishment of a saline "lake" at the eastern edge of the saltmarsh. This new habitat is frequented by a community of waterbirds that are tolerant of water, which has a high salinity. Tidal interchange and the resultant flooding of the low-lying mudflat areas near the mouth is important for the maintenance of a specific community of wading birds which feed on invertebrates that use this specialised habitat. The maintenance of a high diversity of waterbirds at the estuary is important from conservation, ecotourism and ecosystem functioning perspectives. Areas with different salinities would support a greater diversity of waterbird species. **Confidence**: Medium
Other water quality variables	**Microalgae:** Low nutrient concentrations and short water retention times reported for the Orange River estuary would limit microalgal growth. **Confidence:** Low

ABIOTIC COMPONENT OR PROCESS	BIOLOGICAL RESPONSE
	Macrophytes: Diamond mining activities contributed to the decline of the desertified saltmarsh area and unless these are controlled in the future, successful rehabilitation of the saltmarsh will not take place. There has been leakage of diamond-mining process plant water into the saltmarsh and dust from the dried slimes dam. According to Raal (1996), the trigger event for the final collapse of the marsh in 1984 was the introduction of North Sieve process water and slimes dam dust into the marsh along its southwestern perimeter. **Confidence:** Medium
	Invertebrates: A high silt load in the water is detrimental to benthic invertebrates particularly, since smothering may clog sensitive organs (e.g., breathing apparatus). This can induce stress and organisms can die from the effects. **Confidence**: Medium
	Fish: High turbidity and higher temperatures than the marine environment during upwelling events are the likely reasons for A. inodorus being common in the Orange River Estuary. The higher temperatures during the summer are also likely to attract other marine species. Occasional low oxygen events in the marine environment may also influence the movement of estuarine associated species into the system. High detrital loads from upstream suggest that food may not be a limiting factor for detritivores e.g. L. richardsonii. **Confidence:** Low
	Birds: For a wetland of its size, the Orange River estuary supports relatively low numbers of waterbirds (Anderson et al. 2003). This can be attributed to various factors, including low nutrient concentrations in the water and a resultant limited availability of food. Any unnatural water quality issues that effect the birds' food (algae, invertebrates, fish, etc.) will be detrimental to the estuary's waterbird population. An unnaturally high silt load and resultant turbidity will affect the ability of piscivorous birds, such as terns, to locate and catch their prey in the estuary. The diamond mine water leakage into salt marsh (adjacent to the security fence at the eastern end of the marsh) has resulted in the establishment of various aquatic plants (such as Phragmites) and resulted in the use of this new wetland by various fresh-water dependent waterbird species. It is not known what negative effect the polluted water in the Alexander Bay oxidation dams has on the estuary's waterbirds. Toxins that are present in the water (and which often bioaccumulate in for example fish) could have negative effects on birds, especially reproduction. **Confidence:** Low
Other biotic components	**Microalgae:** Zooplankton grazing influences microalgal biomass and community composition. Confidence: High
	Macrophytes: The macrophytes provide a diversity of habitats for other biota. Braided islands and channels create sheltered shallow water areas frequented by herons, ducks, egrets and waders. Reed beds provide habitat for warblers and other roosting or reedbed-dwelling passerines. Fringing reeds also provide perches for the variety of kingfishers (Anon. 2002). **Confidence:** High
	Invertebrates: The invertebrates are an important food source for foraging fish and birds. The relatively high number of birds at times presents an anomaly in this respect – the presence of birds would suggest that invertebrates attain a much higher biomass than that indicated by the two surveys undertaken. **Confidence:** Medium
	Fish: The fish community is dominated by the small-bodied L. richardsonii which suggests ample food for piscivorous birds, mammals and fish. The indigenous freshwater Cyprinidae are also an abundant food source. Introduced carp Cyprinus carpio are likely to be competing with the indigenous freshwater species whereas adults of the translocated Oreochromis mossambicus may displace some estuarine species such as L. lithognathus through aggressive territorial behaviour. O. mossambicus is also known to be tolerant of extremely high salinities and poor water quality often-colonising river or estuarine reaches when conditions deteriorate. **Confidence:** Low
	Birds: The waterbirds that inhabit the Orange River estuary are dependent on macrophytes (for food, and roosting and breeding habitat), invertebrates, and fish for food. **Confidence**: Medium

b. Non-flow related anthropogenic influences that are presently directly affecting biotic characteristics in the estuary:

ANTHROPOGENIC INFLUENCES	BIOLOGICAL RESPONSE
Structures (e.g. weirs, bridges, jetties)	**Microalgae:** Unknown **Confidence:**
	Macrophytes: Agricultural developments at Alexander Bay, the levees protecting these developments and the oxidation pond system near the village of Alexander Bay cut off freshwater flow into the lower floodplain and saltmarsh area, which occurred via the Dunvlei river and flood channel system. The beach access road and embankment near the river mouth restricted tidal exchange and flooding of the desertified marsh area. Both freshwater and tidal inputs were cut off to the marsh area and as a result of this it started to die. Marsh decline was accelerated by dust and seepages from saline slimes dams that inundated the saltmarsh for extended periods of time (CSIR 1991). Thus, there was a sequence of development events that were responsible for the loss of the saltmarsh. **Confidence:** Medium
	Invertebrates: The presence of any man-made barrier that cuts off water exchange between sectors of the lower Orange River area and the main water body is likely to be detrimental for the existence of estuarine invertebrates. For example, the saltmarsh area on the south bank was previously cut off from the main channel by an embankment. These sheltered backwaters were probable important enclaves where estuarine invertebrate communities survived. The establishment of a barrier across the floodplain curtailed water exchange and the area lost its natural function. **Confidence:** Medium
	Fish: The floodplain and saltmarsh have been altered by various dykes, causeways and other structures. The saltmarsh refuge during high flows has been drastically reduced, as has the inundated foraging area during times of mouth closure and back flooding. Species associated with the channels and marginal areas of the saltmarshes such as C. nudiceps are also likely to occur in much lower numbers. **Confidence:** Low
	Birds: The levees that protect the Dunvlei lucerne fields closed the channels that supplied water to the saltmarsh, an area that was previously frequented by a wide variety and number of waterbirds. The north bank levee probably reduced the area of low-lying mudflats and other habitats that would have been favoured by wading birds. A reduced river flow rate, due to water abstraction, development of impoundments, etc., has effected the ecological functioning of the estuary, with probable impacts on its waterbirds. The oxidation ponds are used by waterbirds and the island in the middle of the largest pond has at times been used for breeding purposes by, for example, Hartlaub's Gulls. **Confidence:** Medium
Human exploitation (consumptive and non-consumptive)	**Microalgae:** Unknown **Confidence:-**
	Macrophytes: Agricultural activities along the river and in the catchment result in erosion and an increase in silt load to the estuary, which would smother submerged macrophytes and cause dieback. Confidence: **Low**
	Invertebrates: Unknown **Confidence: -**
	Fish: Recreational angling accounts for approximately 1 t per annum of linefish species mostly A. inodorus, A. coronus, L. lithognathus and L. aureti. Additional 100-500 kg of L. richardsonii is caught by recreational castnetters. Illegal gillnetting catches amount to approximately 10 t, mostly L. richardsonii and M. cephalus but also the four linefish species mentioned above. No information exists as to the species or extent of bait collection in the estuary. **Confidence:** Low
	Birds: Reduced hunting in the Ramsar site may be the reason for the increase in waterfowl (ducks and geese) numbers (Anderson *et al.* 2003). Angling in the estuary and in the vicinity of the mouth probably has a minimal impact on birds, in terms of a reduction in available food. An indirect effect is the disturbance of roosting terns and cormorants by anglers and breeding Cape Cormorants (on the berm) and other birds by anglers and boaters (on islands). **Confidence:** High
Flood plain developments	**Microalgae:** Unknown **Confidence: -**

ANTHROPOGENIC INFLUENCES	BIOLOGICAL RESPONSE
	Macrophytes: See structures above **Confidence:**
	Invertebrates: Unknown **Confidence:**
	Fish: As with structures. The floodplain and saltmarsh have been altered by various dykes, causeways and other structures. The saltmarsh refuge during high flows has been drastically reduced, as has the inundated foraging area during times of mouth closure and backflooding. Species associated with the channels and marginal areas of the saltmarshes such as C. nudiceps are also likely to occur in much lower numbers. **Confidence: Low**
	Birds: The levees that protect the Dunvlei lucerne fields closed the channels that supplied water to the saltmarsh, an area that was previously frequented by a wide variety and number of waterbirds. The north bank levee probably reduced the area of low-lying mudflats and other habitats that would have been favoured by wading birds. The oxidation ponds are used by waterbirds and the island in the middle of the largest has at times been used for breeding purposes by, for example, Hartlaub's Gulls. **Confidence:** Medium
Other…	**Micro-algae: N/A** **Confidence: -**
	Macrophytes: N/A **Confidence: -**
	Invertebrates: N/A **Confidence: -**
	Fish: No information on the possible toxicity of effluent from mining operations and adjacent town and developments or agricultural pesticide use e.g. oil from the golf course, fate of floodplain sewage ponds during flood events and pond overflow. **Confidence:** Low
	Birds: During the mid-1980s Ryan & Cooper (1985) wrote that the Orange River estuary is "…little disturbed at present; access is strictly controlled by mining companies and human disturbance is limited to angling at the mouth and some recreational activities along the north bank. However, further development of the land around the estuary and its adjoining pans should not be allowed". The situation is very different today. There are several major ecological problems at the estuary, most of which relate to the Orange River's altered flow regime, manifested through lower summer flows, higher winter flows and buffering of small and medium floods. Other factors which have probably impacted the birds at the estuary include (1) recreational activities (fishing, off-road vehicles on the beach) at or in the vicinity of sensitive breeding and roosting sites (see above), (2) disturbance by aircraft (Velasquez 1996), (3) disturbance by cattle and possibly by feral cats and dogs, (4) the hunting of ducks and geese within the Ramsar site and (5) the possible hybridisation of the alien Mallards with the indigenous Yellow-billed Duck. **Confidence:** Medium

3.2 Reference Condition

3.2.1 Abiotic Components

a. Seasonal variability in river inflow

Monthly-simulated runoff data for Present State, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 3.1**. The MAR under the Reference Condition was 10 833.01 10^6 m^3. A statistical analysis of the monthly-simulated runoff data in m^3/s for the Reference Condition is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	481.32	848.82	898.24	1325.20	**2200.29**	1535.03	1012.32	365.10	201.33	144.40	153.06	253.77
80%ile	330.52	666.85	683.45	861.52	1351.05	934.41	638.10	260.25	140.07	102.45	109.94	119.36
70%ile	239.41	439.10	521.36	583.63	853.36	726.03	423.60	177.35	88.95	69.25	82.51	84.27
60%ile	162.75	344.89	403.28	498.60	607.14	543.41	324.58	136.83	66.82	53.20	52.59	62.67
50%ile	116.12	251.96	328.85	375.02	480.03	481.30	295.75	110.39	59.44	44.21	39.83	42.49
40%ile	76.03	208.61	279.49	284.90	358.70	381.47	256.78	85.29	52.27	33.82	27.67	31.95
30%ile	65.64	176.65	202.51	214.36	285.06	275.13	178.81	67.87	41.94	28.25	21.53	20.04
20%ile	32.03	133.00	107.10	160.98	215.19	195.05	133.79	39.69	30.30	22.64	14.64	10.62
10%ile	16.78	69.62	63.86	111.66	141.58	140.95	67.33	25.74	20.34	15.30	11.72	3.05
1%ile	0.00	8.80	29.92	21.71	35.32	30.88	28.22	13.53	11.92	11.45	7.60	0.17

Confidence: Low

b. Flood regime for the Reference Condition

There where no detailed analyses done on the reduction in the magnitude and frequency of floods for the Orange River System. Preliminary analyses, provided by Ninham Shand Consulting Engineers, indicate that the smaller floods have been significantly larger, by as much as 85% (1:2) and 74% (1:5), respectively.

Larger floods (indicated by months with average flows greater than 5000 x $10^6 m^3$), which play an important role in resetting the habitat of the estuary, occurred much more frequently under the Reference Condition. An evaluation of the Present state simulated runoff scenario indicates that there has been a marked reduction in the occurrence of monthly flows greater than 5000 x $10^6 m^3$ (reprehensive of major flood events), from 20 under the Reference condition to 9 at present. On average, the highest monthly flow under the Reference Condition would have been 29% more than under the Present State.

Confidence: Low

c. Present sediment processes and characteristics

Under the Reference Condition, the system would have been reset more frequently, thus increasing overall variability in morphology, sediment processes and characteristics. The residence period and average extent of marine sediments (carried into the tidal basin during flood tides) would also have been less.

Available information indicates that in general present depth and bed morphology are probably relatively similar to that of the Reference Condition over most of the estuary. Under the Reference Condition, the channels in upper estuary were probably less stable, wider and/or deeper.

Present State sediment composition is estimated to very similar to that of the Reference Condition.

Confidence: Low

Table 3.2: Monthly Runoff Data (in m³/s) for the Reference Condition, Simulated over a 68-year Period

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Closed
1920	482.99	216.34	74.80	172.62	606.80	1456.40	683.62	117.64	52.54	28.25	14.97	61.65	0
1921	69.33	715.17	1056.46	503.62	209.47	106.21	40.10	32.89	79.02	58.18	61.35	27.57	0
1922	279.55	1000.08	384.83	1198.95	1735.01	713.37	268.89	86.11	133.78	117.30	52.47	23.78	0
1923	16.14	132.38	71.11	254.53	335.46	1725.65	594.95	31.73	21.22	15.59	10.09	103.26	0
1924	145.96	657.32	737.38	456.07	808.13	3856.44	1978.94	781.31	221.42	79.28	37.80	76.09	0
1925	130.24	190.14	96.53	227.77	263.97	506.61	190.19	25.55	32.34	20.46	9.01	85.05	1
1926	73.14	133.91	160.58	144.47	284.60	950.68	378.54	36.52	16.51	27.90	45.62	10.31	0
1927	134.40	176.19	273.92	649.74	358.71	529.35	137.13	28.74	18.61	13.23	11.38	12.15	0
1928	68.84	252.38	200.75	299.05	209.64	727.44	176.11	75.12	205.50	184.25	85.32	952.42	0
1929	480.60	398.40	814.45	518.18	289.24	340.23	289.77	77.33	37.89	25.36	70.32	40.46	0
1930	74.13	25.57	43.93	479.19	463.36	422.52	907.79	247.83	30.49	263.27	113.22	8.11	1
1931	81.71	366.92	144.99	88.91	486.39	310.98	67.94	24.71	17.22	14.52	6.73	36.59	1
1932	37.02	107.26	109.79	63.31	129.06	147.60	55.78	19.71	16.31	14.61	8.03	0.00	2
1933	0.00	1196.66	1308.27	3137.29	1537.10	931.15	352.41	238.92	139.24	109.20	174.78	32.91	1
1934	177.67	1088.41	1005.47	180.57	223.50	653.76	310.19	268.53	113.89	38.16	146.21	62.08	0
1935	17.05	68.17	86.31	285.38	307.40	582.65	276.96	379.34	140.63	49.44	25.69	5.35	1
1936	165.10	2146.08	651.38	1350.07	1653.92	470.00	131.55	40.01	30.17	24.75	14.42	0.25	1
1937	20.99	11.92	338.46	583.78	861.69	232.54	314.02	128.30	115.65	74.34	84.77	43.92	0
1938	331.09	255.86	449.06	860.18	2169.17	533.59	76.71	101.08	57.27	105.84	127.21	71.57	0
1939	335.30	673.38	304.97	149.85	358.65	680.15	482.04	348.92	127.97	49.45	25.55	295.20	0
1940	119.71	327.76	481.63	673.44	1291.22	342.93	314.51	79.76	26.26	35.89	25.70	32.04	0
1941	190.71	43.46	38.42	497.34	858.38	684.84	317.63	81.05	38.38	28.28	105.03	58.07	0
1942	249.26	418.95	1198.89	545.18	141.84	261.02	1287.17	1295.20	328.65	518.58	294.51	248.58	0
1943	818.64	2085.06	1750.13	873.63	2299.03	765.91	152.10	67.07	199.54	84.52	36.45	225.00	0
1944	329.67	205.45	33.37	34.70	253.43	936.59	263.14	75.86	56.06	30.66	12.88	0.54	1
1945	0.00	2.46	34.49	619.10	547.09	468.36	262.31	358.99	142.46	32.77	12.36	2.29	3
1946	275.25	219.40	109.42	163.29	327.37	217.41	228.13	118.91	50.38	33.94	19.93	149.81	0
1947	248.51	176.50	536.85	528.94	447.17	2257.05	844.85	108.77	40.59	22.78	12.43	3.48	1
1948	55.78	70.24	22.92	173.33	205.05	322.94	105.44	82.03	42.68	24.01	13.64	3.38	1
1949	47.08	407.31	667.78	322.43	644.35	1471.35	1394.81	785.76	197.05	139.61	384.68	151.99	0
1950	43.19	23.64	522.70	568.90	283.60	222.49	206.49	88.69	59.63	45.50	34.29	31.57	0
1951	665.96	209.41	81.13	173.71	798.21	233.00	119.56	46.83	44.38	208.92	127.15	74.37	0
1952	40.59	261.99	267.19	121.41	1376.55	442.19	406.05	139.05	46.93	22.55	21.47	13.67	0
1953	194.16	229.72	347.89	219.38	473.66	1611.34	424.38	105.57	68.34	38.15	11.86	1.60	1
1954	14.31	148.40	210.76	1314.54	2675.86	690.68	302.07	169.29	76.06	51.21	28.16	5.32	1
1955	54.58	235.84	486.87	282.97	1193.45	1502.33	666.87	178.17	68.72	38.79	20.56	11.08	0
1956	112.53	426.35	1765.47	862.42	411.16	384.43	179.37	40.81	39.14	155.56	169.06	1880.98	0
1957	1898.52	679.04	487.92	1400.17	487.22	139.17	289.04	358.87	144.09	37.80	20.32	47.79	0
1958	26.49	343.68	509.30	277.33	317.58	178.04	406.66	640.58	145.35	184.89	84.92	19.63	0
1959	162.16	349.71	604.39	329.85	514.23	523.56	302.51	137.65	62.30	45.03	83.17	59.22	0
1960	154.56	301.88	693.89	412.51	183.83	914.75	999.98	295.60	344.04	91.97	132.17	26.22	0
1961	13.21	469.19	724.74	213.81	1646.09	492.60	160.58	153.66	41.90	23.14	13.55	15.25	0
1962	12.77	503.77	243.97	1782.60	608.51	893.93	1041.13	136.63	59.25	187.92	91.08	41.06	0
1963	69.95	663.12	409.05	388.62	187.58	450.85	416.51	61.35	59.26	62.53	53.09	52.79	0
1964	918.54	711.77	314.80	390.22	205.87	60.60	359.71	102.28	80.19	62.46	58.37	106.43	0
1965	97.65	121.01	46.57	1060.72	1143.71	118.45	45.08	25.65	20.14	11.38	8.63	2.17	2
1966	11.99	98.46	326.45	1674.61	2272.91	747.60	1295.57	536.82	409.00	103.58	55.96	37.80	0
1967	28.70	266.09	201.60	50.29	24.22	271.15	234.66	288.34	65.83	50.65	21.23	40.36	0
1968	17.55	26.56	280.89	64.98	125.80	522.55	451.87	170.00	88.97	28.69	25.18	4.83	1
1969	336.57	164.64	315.79	145.39	241.68	29.10	6.17	6.57	9.43	13.74	15.62	65.03	3
1970	313.23	181.93	401.84	418.62	548.46	180.14	550.04	229.55	51.18	31.12	22.09	24.42	0
1971	24.03	178.02	323.83	1208.36	1363.07	1882.70	433.60	231.62	66.44	33.36	22.77	15.62	0
1972	65.29	113.84	46.95	5.24	425.69	220.93	192.83	39.48	24.05	11.48	114.44	77.25	1
1973	90.17	138.23	392.10	2383.34	4592.43	2555.56	846.70	341.61	180.09	69.32	438.42	113.97	0
1974	22.65	753.39	701.28	766.64	2337.51	1216.29	301.72	112.01	65.68	100.74	52.00	108.52	0
1975	201.02	611.88	1247.86	2430.54	3296.37	3029.99	1123.72	677.76	271.49	133.68	76.55	151.94	0
1976	1529.92	915.22	222.62	326.98	1333.02	1059.14	271.22	93.01	57.73	43.40	29.48	113.04	0
1977	355.03	224.54	240.59	1263.78	651.68	499.62	1299.41	218.03	88.75	68.58	50.06	185.56	0
1978	243.68	95.67	746.78	159.44	238.40	169.41	39.08	45.37	42.26	96.30	436.07	265.88	0
1979	378.84	251.54	307.43	260.20	539.38	358.32	65.90	22.38	20.43	21.12	42.48	106.97	0
1980	96.65	197.19	331.25	837.44	1082.51	806.64	172.75	131.24	209.54	51.95	294.60	269.83	0
1981	71.82	179.71	359.94	175.76	124.46	118.76	533.67	167.39	65.02	65.93	41.85	29.94	0
1982	165.23	669.34	80.27	29.82	40.79	31.75	45.78	44.21	52.91	68.09	48.07	15.41	0
1983	102.43	440.52	547.03	582.22	114.81	141.72	144.21	135.80	28.51	20.56	30.35	75.85	0
1984	76.51	158.39	105.54	141.25	649.62	369.64	87.27	16.95	27.58	16.11	9.68	1.93	2
1985	121.08	514.39	852.28	361.42	358.80	161.62	91.97	31.31	63.42	20.14	31.74	122.95	0
1986	369.04	1171.47	197.82	134.88	140.97	144.37	178.75	25.78	13.14	13.41	102.48	1306.45	0
1987	1336.62	820.37	624.23	302.76	4052.27	435.36	791.85	206.77	134.16	116.02	116.30	574.34	0

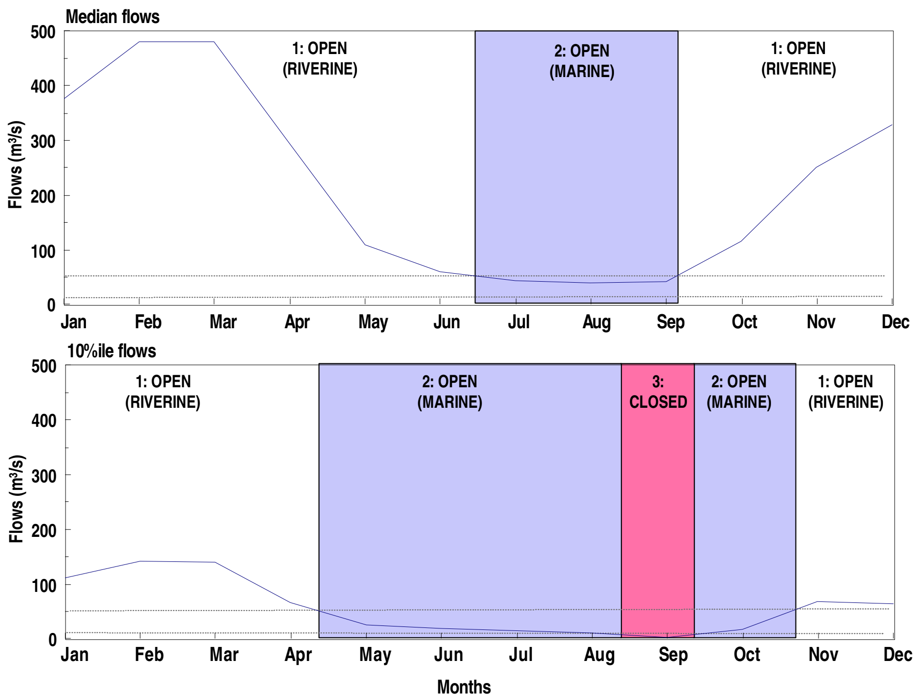
1: Open (River)	>50.0	2: Open (Marine)	10.0-50.0	3: Closed	< 10.0	Floods	> 2000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
< 10.0	2	1	0	1	0	0	1	1	1	0	5	13
10.0-50.0	16	5	7	2	2	2	4	18	24	38	33	23
>50.0	50	62	61	65	66	66	63	49	43	30	30	32

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

The occurrence and duration of the different Abiotic States during the Reference Condition are illustrated in the simulated monthly river flow table (**Table 3.2**).

To provide a conceptual overview of the annual distribution of Abiotic States under the Reference Condition, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Changes in the abiotic characteristics from Reference Condition to Present State, resulting from non-flow related anthropogenic influences other than modification of river inflow

Structures (e.g. weirs, bridges, mouth stabilization): Habitat within the estuary would not have been altered through, the levees protecting these developments and the oxidation pond system near the village of Alexander Bay. Without the road across, the salt marsh to the river mouth on the south bank and the golf course, protected by a dyke on the north bank, habitat for the salt marsh would have been available.

Confidence: Medium

Human exploitation (e.g. sand mining): N/A

Confidence: -

Waste discharges affecting water quality (e.g. dump sites, storm water, sewage discharges, etc): Without agricultural activities in the catchment no nutrient enrichment of the river and possibly, also the estuary would have occurred, pH levels would have remained in the typical ranges and occasional anoxic conditions would not have occurred.

Confidence: Low

Input of toxic substances from catchment: Without mining operations and the adjacent town and developments or agricultural (e.g., pesticide use) possible toxic contamination of the estuary would be eliminated.

Confidence: Low

Other: N/A

Confidence: -

3.2.2 Biotic Components

a. Change in biotic characteristics from the Reference Condition to the Present State

MICROALGAE

Because of the increase in low flow and reduction in floods, there will be longer water retention time, which would allow the development of phytoplankton. The stable channels would allow for benthic microalgal colonisation. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from the sea particularly during upwelling events. The increase in the marine state would promote the growth of marine microalgal species.

Confidence: Low

MACROPHYTES

Main channel: Large floods would have reset the estuary more frequently. Smaller floods (1:2 and 1:5) would have occurred more frequently resulting in sediment mobilization and reworking of the channels and islands. Macrophyte growth and cover on the islands would have been lower. The river mouth would have been more dynamic resulting in diverse macrophyte communities characterized by both primary colonizers and climax species at any one time.

The estuary has changed from being freshwater dominated for 9 months (Oct-Jun) of the year under the Reference Condition, the system is now only freshwater dominated for 5 months (Feb-Apr, Jun-Jul). This may restrict the distribution and growth of certain brackish species. Under reference conditions, higher flows would have occurred in the summer months when evaporation was high.

Desertified marsh: The current desertified saltmarsh area on the south bank would have functioned like a brackish wetland with some halophytic salt marsh species. Typical intertidal saltmarsh would have occurred near the mouth and in the elevated areas, there would have been supratidal marsh represented by Sarcocornia pillansii and Suaeda spp. Water would enter this area from the main channel, as there would be no road embankment blocking tidal flow. Old channels would have been active during floods (1:2 and 1:5 year floods) feeding water into this area. This was probably important in maintaining brackish conditions in this area. The occurrence and magnitude of these small floods particularly during the summer months has been reduced. When the mouth closed, this area would have been inundated as a result of an increase in water level and backflooding. This event would have been important in flushing out accumulated salts. It is important to note that mouth closure decreased from 3% in the Reference Conditions to 0% under the Present State and therefore this backflooding is not as important as previously thought (refer to **Appendix B**).

Confidence: Medium

INVERTEBRATES (INCLUDING ZOOPLANKTON)

Under the reference condition, more frequent flooding of the river would have resulted in a more channel-like configuration (less braided pattern of channels) of the lower Orange River Mouth area. Coupled to being freshwater dominated for 9 months of the year (Oct-Jun), estuarine invertebrates (benthos and plankton) are unlikely to have established themselves at any time in channel areas. The relatively short period when marine influence increased (3 months in winter) was probably too short to allow them to become established.

The lens of seawater presently encountered inside the mouth in deeper areas persists for a longer period (greater marine influence from Sept/October to Jan/Feb) under current conditions and this possibly allows for a benthic community to establish itself temporarily.

Under the reference condition the wetland on the south bank was possibly larger (maintained by more frequent floods coming through). The area would likely have provided habitat for estuarine/brackish water communities because of their relative isolation from the main channel and tidal action, particularly at high tide. Water retention time was probably longer and coupled to the leaching of salts from the substrate and evaporation (greater surface area if the wetland was larger), allowed these communities to become established to a greater degree compared to the present state.

Confidence: Low

FISH

The species composition under reference conditions is likely to have been similar to present with the exception that there may have been more species associated with the margins and channels of saltmarsh areas such as those of the Gobidae and pipefishes Syngnathidae. The population size of the latter would have fluctuated drastically on a seasonal and annual basis depending on the extent of inundation of the saltmarsh and the presence, absence or persistence of ephemeral growth of macrophytes such as Enteromorpha in the shallow areas.

Depending on the stock recruitment relationships, Lithognathus lithognathus and L. richardsonii are both likely to have been more abundant under reference conditions. Since then they have both been subject to overexploitation, L. lithognathus being in a collapsed state with a spawner biomass per recruit ratio (reproductive potential) of 6% of pristine. A decline in stock status leads to range shrinkage, L. lithognathus shrinking eastwards, resulting in a decline in numbers on the west coast. L. amia and L. lithognathus both have to survive the life-history "bottleneck" of estuarine dependence and therefore degraded estuaries and loss of nursery function have contributed to their decline.

Under reference conditions, these estuarine dependent species would have responded to various seasonal flow-rated cues, and recruitment, depending on environmental variables, would have occurred on a regular basis, unlike present day conditions where there has been an almost seasonal reversal in flow. Low flows during the winter months would have provided an estuarine refuge for marine species to escape rough sea conditions and a lack of food whereas high, and probably warmer, summer flows would have provided the cues for marine species to enter the estuary and escape upwelling events in the marine environment.

The fish community would have been dominated by estuarine and marine species tolerant of low salinities for extended periods. Some, namely M. cephalus, L.richardsonii and L. amia would have "migrated" far, 100 km or more, into the freshwater reaches. Gilchristella aestuaria is likely to have had (and probably still does) freshwater breeding populations. Freshwater species such as L. kimberleyensis would also have been abundant in the estuary but perhaps in slightly lower numbers due to competition with the estuarine species. The introduction of O. mossambicus and its territorial behaviour is also likely to have had an impact on the estuarine fish assemblage.

Confidence: Low

BIRDS

Despite the early anecdotal records (see above), there are no detailed data prior to 1980 to provide an indication of the waterbird species diversity and abundance of the ORE when it was in a pristine or near pristine state. It therefore has to be assumed that the early survey data provide a reasonable indication of the ORE's during reference conditions (i.e. in terms of bird numbers and diversity). A possible problem is that waterbird populations may undergo cyclical fluctuations (relating to, for example, changes in food availability in the Atlantic Ocean) and a limited number of waterbird surveys may not provide an accurate reflection of reference conditions. For the purpose of this study, however, reference conditions are assumed to be similar to that recorded during the initial surveys.

The number of waterbirds recorded at the estuary has declined considerably from early 1980s to the early 2000s (see above, Anderson et al. 2003). Despite this drop in the numbers of birds present, the waterbird species richness has remained relatively constant from 1980 to 2000, with an average of 52 species being recorded during 20 surveys. This ±74% decline in the number of waterbirds is primarily accounted for by the virtual absence of Cape Cormorants and Common Terns during the latter surveys. Cape Cormorants have declined from an average of 6400 (±3861) individuals from January 1980 – January 1994 to 212 (±612) individuals during 16 surveys conducted from April 1994 to August 2001. During this same period, Common Terns have declined from an average of 3928 (±3678) individuals to 425 (±731) individuals. The collapse in the population of these two species is due to both onsite and offsite factors (Anderson *et al.* 2003), including: (1) depletion of food reserves (Crawford & Dyer 1995; Crawford 1997, 1999, 2000; Schwartzlose *et al.* 1999), (2) increased disturbance by humans (Cooper *et al.* 1982; Crawford 1997, 2000), (3) disturbance and trampling by livestock (K. van Zyl pers. comm.), (4) predation and disturbance by feral dogs and cats, (5) change in the architecture of the mouth and islands (Swart *et al.* 1988; Morant & O'Callaghan 1990) with a consequent effect on roost site availability, (6) more suitable roosting sites elsewhere (R.E. Simmons pers. comm.), (7) disease (avian cholera Pasteurella multocida) (Crawford *et al.* 1992; Crawford & Dyer 1995), and (8) oiling.

Several other waterbird species that were particularly numerous in January 1980 (Ryan & Cooper 1985) have not subsequently attained their original numbers. These include Black-necked Grebe, Great Cormorant and Redknobbed Coot, both freshwater and saline species. Several waders too have shown this pattern, with lower numbers of Common Ringed Plover, Common Greenshank and others being recorded during the subsequent 19 surveys. The reason for this is unclear, but it could be related to the deterioration of the saltmarsh and the corresponding decrease in available mud-flat habitat for many of these species. Subsequent to 1980 there has, however, not been a significant decline in the numbers of the three main wader groups. During the 20 waterbird surveys, 12 different waterfowl species (ducks and geese) have been recorded, with from 7-10 different species being recorded during a specific count. Since January 1995, there has been an increase in the numbers of ducks and geese utilising the estuary. There are two possible reasons for this observation: (1) an increase in the area under irrigated agriculture, such as at Beauvallon (K. van Zyl pers. comm.) and (2) a halt in the hunting of these birds within the estuary and surrounding area (P. Laubscher pers. comm.). What is noticeable too, is the seasonal change in usage of the estuary by ducks and geese. Fewer waterfowl are present during the winter months, the time of year in this winter-rainfall area when they probably disperse to smaller, ephemeral wetlands.

Confidence: High

3.3 Present Ecological Status of the Orange River Estuary

The PES is determined using the EHI described in detail in Appendix E3 of the methodology for estuaries as set out in *DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component (Version 1.0)* and subsequent revisions of the methods of which the documentation in currently in preparation (B Weston, RDM Directorate, DWAF, pers. comm.). Details regarding the individual scoring systems are included in those reports.

The EHI is sub-divided into:

- The Habitat Health score determined by Abiotic variables (*hydrology, hydrodynamics and mouth condition, water quality, physical habitat alteration and human disturbance of habitat and biota*).
- The Biological Health score determined by Biotic variables (*microalgae, macrophytes, invertebrates, fish and birds – due to budgetary constraints, birds were not included in this assessment*).

The scores are 'percentage deviation' of the Present State from the Reference Condition, e.g. if the Present State is still the same as the Reference Condition, then the score is 100.

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	67	For the Orange River Estuary low flows are defined as flows associated with the *State 3: Closed* (i.e. <10.0 m^3/s) and *State 2: Open (brackish)* (between 10.0 and 50.0 m^3/s). Months with median low flows of less than 50.0 m^3/s increased form 3 (Jul – Sep) under the Reference Condition to 7 (Aug – Jan, May) under the Present State.	Low
b. % similarity in the magnitude of major floods (e.g., 1:20, 1:50 and 1:100) in comparison with the reference condition	45	For the Orange River floods greater than 5000 x $10^6 m^3$ were judged to be resetting events. These have been significantly reduced from 20 under the Reference conditions to 9 under the Present state.	Low
	58		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 68 year period	50	For the Orange River Estuary mouth closure occurs at flows less than 10 m^3/s**.** Under the Reference Condition, the estuary mouth used to close 18 out of the 68 years (26%) for about 1 month at a time, while under the Present State mouth closure does not occur for an extended period, i.e. more than a few days at a time. Alternatively, out of a total of 816 months (68 years), mouth closure decreased from 3% in the Reference Conditions to 0% under the Present State. *Note: Following a precautionary approach, and in view of the importance of mouth closure and the related back flooding to estuarine health, the mouth closures were score severely.*	Low
	50		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	60	There has been modification in the salinity distribution due to an increase of *State 2: Open (Marine*) and a decrease in *State 1: Open (Riverine)*. From being freshwater dominated for 9 months (Oct-Jun) of the year under the Reference Condition, the system is now only freshwater dominated for 5 months (Feb-Apr, Jun-Jul) with strong marine influence in the lower reaches for about 7 months (Aug-Jan, May).	Low
2a. Nitrate and phosphate concentration in the estuary	80	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. Allow for 10% change. With an increase in State 2, (i.e. stronger marine influence) during Aug-Jan and May, it is possible that nutrient concentrations in the bottom waters of the deeper basin near the mouth may at time be slightly higher than for the Reference Conditions (in particular during Oct to Apr when upwelling occurs at sea). Allow for an additional 10% change.	Low
2b. Suspended solids present in inflowing freshwater	90	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in State 1 (i.e. strong river influence).	Low
2c. Dissolved oxygen (DO) in the estuary	80	It is expected that the estuary will, at large, remain well-oxygenated as was the case under the Reference Condition. However, occasional events of low oxygen river water inflow has been reported, associated with algal blooms developing upstream (e.g. April 2003)	Low
2d. Levels of toxins	90	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Allow for 10%.	Low
	72		

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	Currently the braided/meandering channels in the upper estuary are more <u>stable</u> than under the Reference Conditions. The estuary bank adjacent to the golf course has been artificially stabilised. Similarly, the salt marsh area has also been cut off from the main estuary through the fixing of the southeastern estuary bank (road, oxidation pond protected). This has also resulted in a reduction of the estuary mouth-location envelope.	Low
1b	% similarity in sand fraction relative to total sand and mud	90	Although the river flow volumes and sediment carrying capacity were reduced from Reference to Present State, and the major dams are now trapping much sediment, the sand/mud ratio is still very similar in the river load. Also, riverine sediment is still mostly dominant over marine sediment intrusion.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	90	The depth and bed morphology are very similar to Reference Condition over most of the estuary. Presently the channels in upper estuary are more stable, probably slightly narrower and/or shallower. The average extent of the marine sediment (non-cohesive and coarser than riverine) intrusion is slightly further upstream.	Low
		86		

Influence of anthropogenic activities (other than river inflow) on present health of physical habitat:

VARIABLE	*SCORE*	*MOTIVATION*	*CONFIDENCE*
*Percentage of overall change in <u>intertidal habitat</u> caused by **anthropogenic** activity as opposed to modifications to water flow into estuary*	*75*	*Impacts of roads and bank protection for golf course and oxidation ponds are much larger than impacts of more stable braided channels and mouth excursion reduction.*	*High*
*Percentage of overall change which in sub<u>tidal habitat</u> caused by **anthropogenic** modifications (e.g., bridges, weirs, bulkheads, training walls, jetties, marinas) rather than modifications to water flow into estuary*	*10*	*Most change is due to reduced river flows and reduced smaller floods (1 in 2 to 1 in 10 year).*	*Low*

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	70	50	It is estimated that approximately 70 % of the original species remain. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species.	Low
2a. Abundance	50		Increase in low flow and reduction in floods, there will be longer water retention time, which would allow the development of phytoplankton. The stable channels would allow for benthic microalgal colonisation. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from agricultural activities and from the sea particularly during upwelling events. Biomass is expected to be 50% higher than it was under reference conditions.	Low
2b. Community composition	60		Because of the greater water retention, time flagellates would dominate the phytoplankton rather than diatoms.	Low
	50			

Macrophytes

VARIABLE	SCORE %	SCORE Score	MOTIVATION	CONFIDENCE
1. Species richness	70	50	The river channels and islands are more stable. The estuary is no longer reset as frequently as it was under reference conditions. As a result of this, there may be a loss of opportunistic species and an increase in reed growth at the expense of other species. Stable water levels would also have contributed to the increase in reeds. Brackish species may have been lost as a result of an increase in saline conditions.	Low
2a. Abundance	58		In 1986, 90% of the large salt marsh area on the southern bank was lost and became desertified. However, recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. The desertified marsh area represents approximately 20% of the total estuarine area. In the main channel there has been an increase in reed abundance due to sediment stablization. Approximately 30 % of previously exposed sandbank has been colonized. Overall, about 58% of the total biomass remains of the original species. These changes could be measured more accurately using GIS mapping which was not provided for in this study.	Low
2b. Community composition	60		Brackish communities have been lost from the desertified salt marsh area, but are still represented in the main river channel. Exotic weeds have been found in the river mouth area. These would have been absent under reference conditions and thus community composition has changed. After the 1998 flood, (Morant and O'Callaghan 1990) reported that the bare sand on the islands and banks were colonized by exotic species, mainly *Paspalum paspaloides*, *Nicotiana* spp and *Datura stramonium.* The persistence of these species is unknown. As salinity increased the brackish wetland species, i.e., *Phragmites australis* and *Sporobolus virginicus* could have outcompeted these weeds. As a result of these, changes the current community composition is 60% similar to the original composition.	Low
	50			

Invertebrates

VARIABLE	SCORE %	SCORE Score	MOTIVATION	CONFIDENCE
1. Species richness	70	50	It is estimated that there has been an **increase** in estuarine benthic species richness in the deeper section inside the mouth because of the lens of seawater that persists for longer. Zooplankton species richness in the main channel is also likely to have **increased** in this pocket. However, there has probably been a **decrease** in species richness in the main backwater system on the south bank (both the benthos and zooplankton). This is due to shrinking of the saltmarsh because of fewer floods that maintained the former saltmarsh. Water volume in larger pools etc would also have been greater. The construction of the embankment in 1986 and other anthropogenic effects caused further shrinking and drying out of the saltmarsh. Tidal linkage with the main channel is now restored, leading to some recovery of the saltmarsh. Overall, it is estimated that only about 70% of species remain (all groups considered for the main channel area and backwater system). The value may be an over-estimation, but species that survive here are probably very hardy and opportunistic.	Low
2a. Abundance	40		Although abundance probably increased in the lower Orange River Mouth area (the lens of estuarine water persists for 5-6 months compared to only three months under natural conditions), populations on the south bank have probably decreased significantly. Although some recovery is likely since the link with the main channel has been restored, the total area on the wetland on the south bank is probably considerably smaller because of flood reduction that possibly maintained the system.	Low
2b. Community composition	60		Only hardy species are likely to survive here, and it is likely that composition of the community is relatively unchanged.	Low
	40			

Fish

VARIABLE	SCORE %	SCORE Score	MOTIVATION	CONFIDENCE
1. Species richness	80	65	Probable loss of one or two of the Gobidae e.g., *Caffrogobius* spp. and *Psammogobius knysnaensis* and perhaps the Syngnathidae due to loss of the marginal areas and channels of the saltnarsh.	Low
2a. Abundance	60		Countrywide decline in stock status of *L. Lithognathus*, *L. amia* and *L. richardsonii* the latter which provides over 80 % of the fish biomass of most west coast estuaries. A decline in stock status can be attributed to overexploitation and estuarine habitat loss. In general, of species experiencing similar levels of exploitation, those that are estuarine dependent are those that have experienced the most declines. With the Orange, seasonal flow reversals are likely to have led to confusing recruitment cues for estuarine dependent fish. The freshwater component of the Orange fish fauna has also experienced a decline, mostly due to the introduction of alien species, loss of habitat and water quality problems in the catchment. Mouth closure extending into the summer months may be a barrier to *Caffrogobius* spp. re-entering the estuary after the marine larval stage.	Low
2b. Community composition	60		Although always dominated by the detritivorous *L. richardsonii*, there has been a decline in the number of piscivores such as *L.amia, A. inodorus* and *P. saltatrix* and to a lesser extent *L. lithognathus* and *L. aureti*. *G. aestuaria* are likely to have been impacted by unseasonal flows (flushed out at unexpected times) and the freshwater populations may be more abundant and robust than the estuarine. The community associated with the channels and marginal areas of the saltmarsh has become almost non-existent.	Low
	60			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%*	*Score*	Species richness from 1980-2001 remained relatively constant and an average of 52 species (±5.1SD) was recorded (Anderson *et al.* 2003).	Medium
	100	100		
2a. Abundance	26		Waterbird numbers have declined from 21,512 waterbirds (January 1980; Ryan & Cooper 1985) and 20,563-26,653 waterbirds (December 1985; Williams 1986) to an average of 6873 (±1719SD; n=6) and 5547 (±2039SD; n=7) waterbirds during summer and winter 1995-2001 (Anderson *et al.* 2003). The 74% reduction in abundance reflects a decline in the number of individual waterbirds and not biomass. The decrease in biomass will be more than 74% because the species that have declined in numbers (Cape Cormorant and Common Tern) have heavy body masses, relative to many of the other waterbird species that use the ORE.	Medium
2b. Community composition	40		The two major groups of birds that are present in lower numbers are terns and cormorants. Fewer Black-necked Grebe, Great Cormorant, Red-knobbed Coot and some waders are present. There has been no significant change in the numbers of the three main wader groups. There has been an Increase in waterfowl numbers. Although, it is difficult to determine the change in species composition, for the purpose of this study, the change is estimated to be about 60%.	Medium
	26			

Effect of non-flow related anthropogenic activities on present health of biotic components

COMPONENT	*DEGREE (%) TO WHICH ABOVE CHANGE IS CAUSED BY ANTHROPOGENIC ACTIVITY (other than modification of river inflow)**	*MOTIVATION*	*CONFIDENCE*
Microalgae	*10*	*The changes described for the microalgae from the reference to present condition are related to flow. Without data on the present state of the microalgae, it is difficult to predict the extent of anthropogenic influences. Microalgal species composition would indicate if there were water quality problems.*	*Low*
Macrophytes	*50*	*50 % of the changes described are due to anthropogenic activity. Agricultural developments, levees, the oxidation pond, beach access road and embankment cut off freshwater flow and tidal inputs to the salt marsh, which led to its dieback. Marsh decline was accelerated by dust and seepages from diamond mining. 50 % of the changes described are due to changes in river inflow. There has been a reduction in the frequency of large floods, which reset the system. 1:2 and 1:5 year floods, which were important in flooding the desertified marsh area in summer rarely, occur. Low flow in winter, mouth closure and backflooding of the desertified marsh area no longer occurs, although even under reference conditions this was an infrequent event.* *The opinion expressed here is different to that expressed in previous reports. According to Raal (1996) the process of artificially breaching the mouth of the river and the modifications to the natural hydrology are considered to have caused the most serious impacts to the marsh environment. Backflooding under closed mouth conditions was considered the only mechanism through which extensive areas of the elevated marshland could become inundated. It has been shown that the mouth only closed during drought conditions and that the small floods together with high spring tides were more important in flooding the marsh (refer to Appendix C). These have substantially been reduced.*	*Low*
Invertebrates	*70*	*The arguments set out above (macrophytes) also apply to the invertebrates, although the higher value (70%) excludes any consideration of the reduction in freshwater flow, including floods*	*Low*
Fish	*40*	*Ditto to the arguments above, developments on the saltmarsh and floodplain have removed much of the temporary shallow water habitat available to fish. Exploitation is a contributing factor, but levels within the estuary itself are low compared to that for the rest of the SA coastline. In turn, mining activities in the adjacent surf-zone may interfere with the long-shore movement of fish, reduce the chance of encountering the estuarine plume or mouth and reduce recruitment into the estuary.*	*Low*

COMPONENT	DEGREE (%) TO WHICH ABOVE CHANGE IS CAUSED BY ANTHROPOGENIC ACTIVITY (other than modification of river inflow)*	MOTIVATION	CONFIDENCE
Birds	*50*	*It is difficult to quantify the relative importance of the different anthropogenic factors that have contributed to the decline of waterbird species at the Orange River Estuary* *There are two bird species that have undergone significant population declines during the past two decades, the Cape Cormorant and the Common Tern. Various factors are responsible for the decline, probably all of which are anthropogenic (see above for detail).* *The collapse in the population of these two species is probably due to (1) depletion of food reserves, (2) increased disturbance by humans, (3) disturbance and trampling by livestock, (4) predation and disturbance by feral dogs and cats, (5) change in the architecture of the mouth and islands with a consequent effect on roost site availability, (6) more suitable roosting sites elsewhere, (7) disease (avian cholera* Pasteurella multocida*), and (8) oiling (see above for more details).*	*Low*

The PES is determined using the EHI. The Health Index consists of a Habitat health score and a Biological health score. The average of these two scores provides the Estuarine Health score (**Table 3.3**).

Table 3.3: Estuarine Health Score Results for the Present State of the Orange River Estuary

VARIABLE	WEIGHT	SCORES FOR PRESENT STATE
Hydrology	25	58
Hydrodynamics and mouth condition	25	50
Water quality	25	72
Physical habitat alteration	25	86
Habitat health score		**67**
Microalgae	20	50
Macrophytes	20	50
Invertebrates	20	40
Fish	20	60
Birds	20	26
Biotic health score		**45**
ESTUARINE HEALTH SCORE		**56**

The EHI score for the Orange River Estuary, based on its Present State, is 56, translating into a **Present Ecological Status of D+** (**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-/A+	Unmodified, natural
76 – 90	B-/B+	Largely natural with few modifications
61 – 75	C-/C+	Moderately modified
41 – 60	**D-/D+**	**Largely modified**
21 – 40	E	Highly degraded
0 – 20	F	Extremely degraded

3.4 Estuarine Importance of Orange River Estuary

The Orange River Mouth Wetland was designated a Ramsar status, i.e., a wetland of international importance, on 28/06/1991 (Cowan 1995). In September 1995, the Ramsar site was placed on the Montreux Record as a result of a belated recognition of the severely degraded state of the salt marsh on the south bank (CSIR, 2001). (The Montreux Record is a list of Ramsar sites around the world that are in a degraded state). This implies that the Orange River mouth may lose its status as a Ramsar site unless the condition of the salt marsh can be restored.

Turpie *et al.* (2002) nationally ranked the Orange River Estuary as the 7th most important system in South African in terms of conservation importance. The prioritisation study calculated conservation importance on the basis of size, habitat diversity, zonal type rarity and biodiversity importance.

Estuarine 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 E4 of the methodology for estuaries as set out in *DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component (Version 1.0)* and subsequent revisions of the methods of which the documentation in currently in preparation (B Weston, DWAF, pers. comm.).

For this study, the Ecological importance determination of the Orange River Estuary was obtained from the *Estuarine Prioritisation for RDM* project (Turpie *et al.* 2002). The *Functional Importance* score, however, was derived at the Specialist Workshop held in Stellenbosch in September 2003.

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

Estuary Size

SCORE	MOTIVATION
100	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 of greater than 200 ha, the Orange River Estuary is assigned a score of 100.

Zonal Type Rarity

SCORE	MOTIVATION
90	The estuary is one of two river mouths within the cool temperate biogeographical zone. The Zonal Type Rarity index is thus 50 - the score assigned is 90.

Habitat Diversity

SCORE	MOTIVATION
90	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 (Turpie *et al*, 2002).

Biodiversity Importance

SUB-COMPONENTS	SCORE	MOTIVATION
Plants	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 2de 10% percentile for the scores generated from all South African estuaries and is thus assigned a score of 90
Invertebrates	10	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 lowest 10% percentile for the scores generated from all South African estuaries and is thus assigned a score of 10.
Fish	60	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 5th 10% percentile for the scores generated from all South African estuaries and is thus assigned a score of 60.
Bird	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 actual records of presence). 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.
Biodiversity score	**88**	

Functional Importance

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

*** Using the maximum score of the above**

The individual scores obtained above are incorporated into the final Estuarine Importance Score (**Table 3.5**).

Table 3.5: Estuarine Importance Scores for the Orange River Estuary

CRITERION	SCORE	WEIGHT	WEIGHTED SCORE
Estuary Size	100	15	15
Zonal Rarity Type	90	10	10
Habitat Diversity	90	25	23
Biodiversity Importance	88	25	22
Functional Importance	100	25	25
ESTUARINE IMPORTANCE SCORE			**95**

The Estuarine Importance Score for the Orange River Estuary, based on its Present State, is 95, indicating that the estuary is considered as 'Highly Important' (**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

3.5 Recommended Ecological Category for the Orange River Estuary

The recommended EC represents the level of protection assigned to an estuary. In turn, it is again used to determine the Ecological Water Requirement Flow Scenario.

For estuaries, the first step is to determine the 'minimum' EC of an estuary, equivalent to PES. The relationship between EHI Score, PES and EC is set out in **Table 3.7**.

Table 3.7: Relationship between Present Ecological Status and Minimum Ecological Category

ESTUARINE HEALTH INDEX SCORE	PRESENT ECOLOGICAL STATUS	DESCRIPTION	ECOLOGICAL CATEGORY	CORRESPONDING MANAGEMENT CLASS
91 – 100	A	Unmodified, natural	A-/A+	Natural (Class I)
76 – 90	B	Largely natural with few modifications	B-/B+	Good (Class II)
61 – 75	C	Moderately modified	C-/C+	Fair (Class III)
41 – 60	D	Largely modified	D-/D+	
21 – 40	E	Highly degraded	E	Poor (unacceptable)
0 – 20	F	Extremely degraded	F	

NOTE: Should the present ecological status of an estuary be either a Category 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).

The degree to which the 'minimum' EC (based on its PES) needs to be modified to assign a recommended EC depends on:

- Importance of the estuary (determined in **Section 3.4** above)
- Modifying determinants, i.e., protected area status and desired protected area status - a status of 'area requiring high protection' should be assigned to estuaries that are identified as vital for the full and most efficient representation of estuarine biodiversity.

The proposed rules for allocation of the recommended EC are set out in **Table 3.8**.

Table 3.8: Proposed Rules for Allocation of Recommended Ecological Category

CURRENT/DESIRED PROTECTION STATUS AND ESTUARINE IMPORTANCE	ECOLOGICAL 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)	A or BAS	
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.

The Orange River Estuary is considered to be an estuary of 'high importance'. In addition, it is also a Ramsar site (i.e., protected area in particular for water birds). According to the guidelines the recommended EC should therefore be a Category A - if not possible then the Best Attainable State (BAS).

At the workshop, the following was concluded:

- With major dam developments in the catchment that have reduced river inflow to the estuary by more than 50% (considered irreversible), it is unlikely that the estuary could be returned to a Category A.

- Anthropogenic developments along the banks of the estuary (i.e. non-flow related modifications), such as the road across the salt marsh area, seepage of saline water from mining developments and human disturbance (of birds) also contribute largely to the PES of a Category D. It is therefore impossible to reverse modifications and to improve the EC to a Category B, through river flow adjustments only.

- The BAS for the estuary is therefore considered to be an **Ecological Category C**, with a strong recommendation that mitigating actions to reverse modifications caused by the non-flow related activities and developments in the estuary be investigated by the responsible authorities.

Thus, the recommended Ecological Category for the Orange River Estuary is estimated as Category C. (Confidence = Low)

4. QUANTIFICATION OF ECOLOGICAL WATER REQUIREMENT SCENARIOS

4.1 Simulated Future Runoff Scenarios

A summary of the simulated future runoff scenarios (in comparison to the Present State flows) is provided in **Table 4.1**.

4.2 Ecological Water Requirement Assessment Process

4.2.1 Scenario 1: Present State 2005

a. Described seasonal variability in river inflow (based on simulated runoff data for this scenario)

Monthly-simulated runoff data for Scenario 1, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 3.3**. The MAR under Scenario 1 is 4 423.46 x 10^6 m^3 (40.83% remaining of the natural MAR). A statistical analysis of the monthly-simulated runoff data in m^3/s for Scenario 1 is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	28.64	252.38	259.27	563.92	1439.88	771.99	715.57	223.63	91.46	19.67	24.23	17.06
80%ile	23.24	32.38	140.43	185.04	524.90	477.87	231.91	92.71	25.97	16.63	14.13	14.81
70%ile	22.82	26.62	53.56	105.54	300.10	279.17	138.37	47.54	20.90	15.65	13.47	14.48
60%ile	22.25	23.88	30.20	40.01	123.75	200.03	73.68	31.46	19.13	15.41	13.29	13.94
50%ile	21.69	22.65	25.35	28.94	57.69	112.18	60.04	27.48	18.67	15.18	13.20	13.61
40%ile	21.47	21.82	23.39	24.83	39.43	58.42	50.62	26.64	18.41	15.14	13.17	13.53
30%ile	21.42	21.59	21.71	22.93	29.43	43.40	41.72	26.01	18.37	15.08	13.12	13.48
20%ile	21.36	21.47	21.45	21.68	22.69	36.97	37.12	25.89	18.28	15.04	13.10	13.47
10%ile	21.36	21.37	21.36	21.47	21.75	31.02	36.08	25.57	18.22	15.00	13.08	13.46
1%ile	21.36	21.35	21.36	21.36	21.56	28.26	34.99	25.45	18.16	14.93	13.01	13.46

Confidence: Low

b. Flood regime for the Scenario 1

Similar to the Present State.

Confidence: Low

c. Changes in sediment processes and characteristics for Scenario 1

Similar to the Present State, because the lack of hydropower releases will not have a noticeable affect on the sediment processes and characteristics.

Confidence: Low

Table 4.1: Summary of the Simulated Future Runoff Scenarios for the Orange River Estuary

FUTURE SCENARIO:	MAR (x10^6 m^3)	% REMAINING	LARGER FLOODS	FLOWS AT AUGRABIES	FLOWS AT ESTUARY
Reference Condition	10 833.01	100	Natural	Natural	Natural
Present State (with hydropower water releases as up to 2000)	4 743.46	43.79	Spills from Vanderkloof and inflows from the Vaal.	As at present with no specific requirement imposed on the system as ORRS indicated that the flow released to supply current demands is sufficient. Higher flows in winter months due to additional hydropower releases	As at present with ORRS environmental flow requirement imposed on the system of 289mcm/a. Higher flows in winter months due to additional hydropower releases
Scenario 1: Present State (2005) with out hydropower releases	4 423.46	40.83	Spills from Vanderkloof and inflows from the Vaal.	As at present with no specific IFR imposed on the system as ORRS indicated that the flow released to supply current demands is sufficient. Relatively low flows in winter months as no additional releases are made for hydropower generation	As at present with ORRS environmental flow requirement imposed on the system of 289mcm/a. Low flows in winter months as no additional releases are made for hydropower.
Scenario 2: Vanderkloof lower level storage	4 296.43	39.66	Spills from Vanderkloof and inflows from the Vaal.	As for this scenario with no specific IFR imposed on the system as ORRS indicated that the flow released to supply current demands is sufficient. Relatively low flows in winter months as no additional releases are made for hydropower generation	As for this scenario with ORRS environmental flow requirement imposed on the system of 289mcm/a. Low flows in winter months as no additional releases are made for hydropower.
Scenario 3: Vioolsdrift re-regulating dam	4 082.1	37.68	Spills from Vanderkloof and inflows from the Vaal.	As for this scenario with no specific IFR imposed on the system as ORRS indicated that the flow released to supply current demands is sufficient. Relatively low flows in winter months as no additional releases are made for hydropower generation	As for this scenario with ORRS environmental flow requirement imposed on the system of 289mcm/a. Low flows in winter months as no additional releases are made for hydropower.
Scenario 4: Large Vioolsdrift	3 369.92	31.11	Spills from Vanderkloof and inflows from the Vaal.	As for this scenario with no specific IFR imposed on the system as ORRS indicated that the flow released to supply current demands is sufficient. Relatively low flows in winter months as no additional releases are made for hydropower generation	As for this scenario with ORRS environmental flow requirement imposed on the system of 289mcm/a. Low flows in winter months as no additional releases are made for hydropower.
Scenario 5: River Class C	1 969.50	18.18	Only as required by the Desktop Class C environmental requirement. (None; dam spills excluded: only upto the 1:2 year floods provided)	River Desktop C only as determined from flows at Augrabies. (Other flows over and above that required by the desktop requirement are flowing past this site but is not included in the monthly flow values provided)	River Desktop C only as determined from flows at river mouth. (Other flows over and above that required by the desktop requirement are flowing past this site but is not included in the monthly flow values provided)
Scenario 6: River Class D	1 558.10	14.38	Only as required by the Desktop Class D environmental requirement. (None; dam spills excluded: only upto the 1:2 year floods provided)	River Desktop D only as determined from flows at Augrabies. (Other flows over and above that required by the desktop requirement are flowing past this site but is not included in the monthly flow values provided)	River Desktop D only as determined from flows at river mouth. (Other flows over and above that required by the desktop requirement are flowing past this site but is not included in the monthly flow values provided)

FUTURE SCENARIO:	MAR (x10^6 m^3)	% REMAINING	LARGER FLOODS	FLOWS AT AUGRABIES	FLOWS AT ESTUARY
Scenario 7: Modified River Class D	4 529.93	41.73	Spills from Vanderkloof and inflows from the Vaal.	Desktop D low flow requirement and Desktop D high flow in February. Flows at this site from Vaal and Vanderkloof spills and local inflows, over and above that required by the modified Class D requirement are also included.	Desktop D low flow requirement and Desktop D high flow in February. Flows at this site from Vaal, Fish and Vanderkloof spills and local inflows, over and above that required by the modified Class D requirement are also included.
Scenario 8: Modified River class D with Natural losses	4 345.67	40.12	Spills from Vanderkloof and inflows from the Vaal.	Desktop D low flow requirement and Desktop D high flow in February. Flows at this site from Vaal and Vanderkloof spills and local inflows, over and above that required by the modified Class D requirement are also included.	Flows provided at Augrabies, reduced by natural losses down to the mouth, as well as flows at this site from Vaal, Fish and Vanderkloof spills and local inflows, over and above that required by the modified Class D requirement at Augrabies, are also included.
Scenario 9: River class C with floods	4 979.99	45.97	Spills from Vanderkloof and inflows from the Vaal.	River Desktop C and other flows over and above that required by the desktop requirement that are flowing past this site.	River Desktop C and other flows over and above that required by the desktop requirement that are flowing past this site.
Scenario 10: River Class D with floods	4 758.93	43.93	Spills from Vanderkloof and inflows from the Vaal.	River Desktop D and other flows over and above that required by the desktop requirement that are flowing past this site.	River Desktop D and other flows over and above that required by the desktop requirement that are flowing past this site.

Table 4.2: Monthly Runoff data (in m³/s) for Scenario 1, Simulated over a 68-year Period

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Closed
1920	22.89	21.37	22.00	21.57	170.97	80.08	117.53	69.46	26.05	17.28	13.11	14.72	0
1921	23.24	173.97	487.38	140.91	21.71	28.22	34.96	25.44	18.20	14.90	13.49	13.62	0
1922	21.36	434.75	145.17	560.23	624.27	375.53	200.76	27.87	20.30	15.53	13.12	14.71	0
1923	21.36	21.59	21.36	21.59	22.14	170.57	70.91	25.98	18.27	15.02	13.10	13.72	0
1924	21.36	23.11	40.34	34.15	365.78	3509.65	1851.69	693.52	108.23	29.29	16.51	14.72	0
1925	22.63	21.36	21.43	23.65	21.63	47.29	50.29	26.60	19.93	15.17	13.13	13.46	0
1926	21.47	22.46	22.17	21.51	21.60	37.11	40.61	25.53	18.20	15.13	13.19	13.48	0
1927	21.83	21.69	22.72	39.00	37.33	259.74	62.61	25.70	18.28	15.04	13.15	14.17	0
1928	21.50	24.14	22.11	24.87	22.65	124.17	54.12	25.99	18.67	15.54	14.99	22.93	0
1929	23.93	22.85	327.48	170.24	55.98	36.68	35.64	25.53	18.24	14.97	14.35	13.91	0
1930	21.42	22.04	21.58	52.37	55.90	159.23	40.53	26.25	18.37	15.27	13.15	13.46	0
1931	21.61	24.56	22.78	21.52	39.96	37.35	36.20	25.99	18.90	15.14	13.08	13.94	0
1932	30.13	21.37	21.39	21.39	21.82	28.44	35.29	25.47	18.27	15.18	13.02	13.46	0
1933	21.36	27.50	116.26	1136.89	923.27	476.01	55.10	80.70	22.61	15.17	29.54	14.70	0
1934	22.46	405.94	695.38	23.81	24.45	202.23	136.68	197.44	49.53	15.07	13.12	13.46	0
1935	21.36	23.99	21.67	23.57	26.41	199.48	65.93	180.27	51.44	15.14	13.18	13.83	0
1936	21.46	950.23	231.61	626.08	1370.26	246.10	35.80	25.76	18.31	15.05	13.15	13.48	0
1937	21.36	21.35	24.91	186.84	59.40	35.27	52.09	27.53	18.53	16.57	13.48	13.49	0
1938	21.93	87.13	23.72	35.39	1434.65	327.48	36.68	25.87	18.39	16.17	21.95	15.33	0
1939	23.23	186.57	145.17	27.11	90.62	64.93	242.72	208.87	19.13	15.05	13.08	14.38	0
1940	21.53	25.01	133.32	311.19	685.31	115.25	157.53	26.46	18.78	15.12	13.07	13.51	0
1941	21.37	21.38	21.36	21.50	354.21	41.62	69.89	30.95	18.62	15.15	13.28	13.46	0
1942	28.63	23.60	219.59	182.33	21.76	29.41	903.33	1158.49	195.09	385.36	140.28	54.68	0
1943	503.65	1830.62	1494.52	572.53	2112.78	551.75	36.66	25.91	24.90	15.51	13.35	14.92	0
1944	100.81	60.02	21.47	22.80	22.56	302.06	84.75	25.63	18.28	17.45	13.12	13.51	0
1945	21.76	21.50	21.36	23.92	28.94	44.87	67.73	37.79	20.36	15.15	13.17	13.70	0
1946	21.54	21.42	21.37	21.95	22.52	59.60	37.12	25.96	18.34	15.01	13.09	13.57	0
1947	23.81	21.47	25.77	26.82	55.68	703.54	367.43	28.88	18.41	15.15	13.12	13.46	0
1948	21.47	21.71	21.39	33.50	29.46	109.11	41.71	25.47	18.31	14.96	13.04	13.46	0
1949	21.36	21.40	23.79	22.87	340.88	479.11	232.27	290.95	84.70	44.20	213.90	14.87	0
1950	22.20	21.59	49.42	44.06	23.44	29.94	36.75	26.59	19.69	15.49	13.15	13.46	0
1951	23.08	21.55	21.36	21.40	314.37	43.24	35.00	25.46	18.19	27.53	15.29	13.48	0
1952	21.44	21.45	21.48	21.38	228.67	100.04	114.60	26.97	18.23	15.03	13.35	13.55	0
1953	21.46	21.90	61.56	27.34	32.56	530.18	231.37	43.69	19.00	15.66	13.38	13.60	0
1954	21.41	21.35	21.42	103.83	1849.41	461.28	145.19	72.26	18.53	15.10	13.53	13.60	0
1955	21.36	23.85	26.37	50.34	354.66	1041.29	466.25	75.08	18.37	15.11	13.18	13.52	0
1956	21.36	22.04	834.13	514.97	144.34	179.33	36.71	25.59	21.08	16.08	13.80	1373.53	0
1957	1621.29	407.02	206.57	1056.43	190.58	31.13	59.52	244.71	63.56	15.04	13.10	13.55	0
1958	21.36	21.82	28.98	29.49	28.85	31.10	35.49	214.59	46.84	73.69	13.13	13.46	0
1959	21.36	21.65	23.09	21.97	121.31	254.96	138.55	43.21	18.34	15.14	13.40	13.47	0
1960	21.42	21.55	172.64	123.08	22.75	279.60	769.64	185.23	230.56	17.25	89.16	16.50	0
1961	21.54	28.87	94.45	21.52	1056.27	275.26	44.08	47.97	18.22	14.98	13.58	13.65	0
1962	21.36	26.80	24.81	613.06	297.76	724.73	891.15	69.45	18.68	15.26	13.26	13.48	0
1963	22.94	32.79	54.02	21.67	21.56	32.26	259.59	25.58	18.44	14.99	13.00	13.46	0
1964	82.38	441.50	157.77	165.88	45.88	50.37	52.38	26.83	18.16	15.43	13.17	13.55	0
1965	21.36	21.37	21.62	47.54	300.36	38.32	50.70	25.88	18.27	14.96	13.03	13.46	0
1966	21.59	21.65	21.68	131.47	1452.10	521.07	1138.35	445.87	303.18	16.66	13.32	14.72	0
1967	22.46	28.36	21.42	21.36	21.56	122.48	88.09	82.76	25.85	15.20	13.23	13.53	0
1968	21.44	24.77	30.55	21.69	30.55	53.71	60.56	33.51	22.70	15.41	13.23	13.53	0
1969	21.90	21.45	21.36	21.37	33.61	30.82	36.49	25.97	20.96	17.87	13.09	13.48	0
1970	28.67	21.96	23.47	34.54	97.35	39.67	37.29	26.65	18.38	15.10	13.27	13.50	0
1971	22.04	21.52	21.43	309.67	77.01	718.18	151.83	27.42	18.39	15.07	13.11	13.97	0
1972	21.39	21.37	21.36	21.36	90.18	70.10	64.90	28.08	18.33	15.04	13.09	14.19	0
1973	21.40	21.48	31.06	762.49	2698.52	2369.15	692.40	274.57	107.24	23.87	328.69	14.88	0
1974	22.19	24.35	323.81	460.98	1979.92	922.75	174.19	28.52	19.16	15.18	13.22	14.70	0
1975	21.36	23.13	666.19	2009.81	2981.03	2865.58	976.40	567.78	146.23	28.41	16.10	15.41	0
1976	1047.64	658.75	60.62	105.73	849.67	882.27	103.51	36.84	19.92	15.91	13.81	14.44	0
1977	22.94	31.77	26.44	430.20	375.84	270.83	1113.07	99.34	18.43	15.51	13.67	14.48	0
1978	21.39	21.35	42.80	23.48	40.47	36.88	37.13	26.74	19.10	15.74	18.68	15.18	0
1979	23.11	22.94	21.48	22.03	69.43	107.89	41.76	26.18	18.40	15.04	38.81	38.77	0
1980	26.43	33.40	30.11	28.39	133.47	373.35	43.28	42.26	113.85	15.03	98.26	58.37	0
1981	23.70	23.41	27.20	24.67	21.93	30.32	49.42	30.44	18.26	16.76	13.20	13.46	0
1982	22.77	21.81	26.67	22.73	21.56	28.28	42.41	26.94	18.98	15.24	13.10	13.48	0
1983	21.42	37.23	41.83	25.83	21.59	46.20	52.28	26.31	18.39	15.04	13.19	13.46	0
1984	22.47	21.52	21.36	26.42	29.43	49.87	35.20	25.56	18.18	14.94	13.01	13.46	0
1985	24.87	27.57	63.97	33.71	34.79	38.06	40.33	26.71	25.19	17.13	13.19	14.14	0
1986	22.54	22.10	24.48	21.36	42.49	33.74	37.26	25.89	18.15	15.07	13.07	18.36	0
1987	22.82	30.94	24.94	44.30	3180.71	3733.57	609.83	99.65	52.96	15.92	13.33	316.98	0

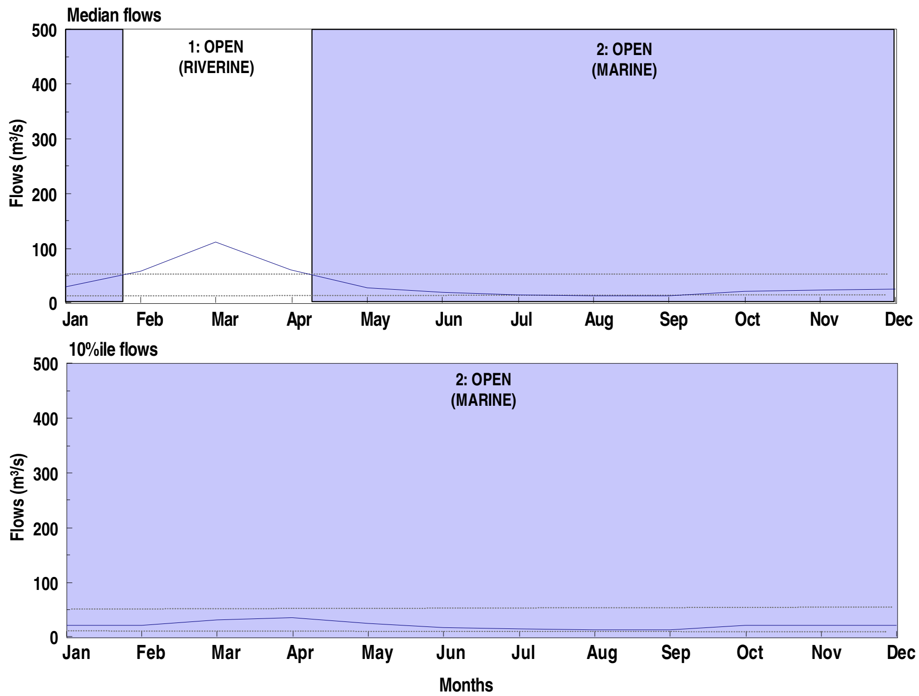
1: Open (River)	>50.0	2: Open (Brackish)	10.0-50.0	3: Closed	< 10.0	Floods	> 2000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
< 10.0	0	0	0	0	0	0	0	0	0	0	0	0
10.0-50.0	63	57	47	44	31	25	26	48	57	66	63	64
>50.0	5	11	21	24	37	43	42	20	11	2	5	4

d. Occurrence and duration of different Abiotic states for Scenario 1

The occurrence and duration of the different Abiotic States under Scenario 1 are illustrated in the simulated monthly river flow table (**Table 3.3**).

To provide a conceptual overview of the annual distribution of Abiotic States under Scenario 1, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Predicted change in biotic characteristics of Scenario 1 compared with the Reference Condition

MICROALGAE

There is a further increase in low flow compared to the Present State, which would result in longer water retention time and the development of phytoplankton. The stable channels would allow for benthic microalgal colonisation. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from agricultural activities and from the sea particularly during upwelling events. The reduction in the occurrence of the freshwater state would also reduce the suspended solid load which would increase light available for microalgal growth.

Confidence: Low

MACROPHYTES

The same changes as described for the present state apply. However, for Scenario 1 there is an increase in the period of low flows and as a result of this the estuary is only freshwater dominated for 3 months (Feb-Apr) with strong marine influence in the lower reaches for about 9 months (May-Jan). This may decrease the diversity of brackish species in the mouth region and decrease the growth of the reeds and sedges.

Confidence: Low

INVERTEBRATES (INCLUDING ZOOPLANKTON)

This scenario would likely benefit the **estuarine** benthic community in the lower Orange River Mouth area in that the lens of estuarine water will persist for 9 months of the year without interruption. Under the present scenario, this lens also breaks down for three months in winter. The persistence of the lens for a longer period without interruption will allow the community to become better established and not disappear in winter (freshwater will induce a shift towards a freshwater type community in this area – extension of upstream conditions towards the mouth). Species richness is also likely to increase.

Similarly, an estuarine zooplankton community is likely to become more prevalent in the estuarine water lens.

Invertebrates colonizing the wetland on the south bank are also likely to benefit, in that salinity is likely to increase because of tidal penetration from the main channel area, particularly around spring tides. This assumes that surface freshwater will be pushed further upstream with the tide. Greater input of nutrients with the tides will also lead to benefits for invertebrates through increased food availability.

Confidence: Low

FISH

This scenario is closer to the reference state than present day in that the winter flows are no longer elevated through hydro releases. Estuarine conditions persist throughout winter but may extend into the summer months as the first summer high flows or floods are captured by the upstream dams. Although the estuarine fish assemblage is likely to become more stable, the cues provided by spring and early summer freshettes will be close to non-existent, leading to a reduction in recruitment, and depending on mortality levels, may lead to an overall decline in abundance of fish such as L. lithognathus and L. amia. An increase in benthic microalga would provide a foodsource for L. richardsonii to compensate for a decrease in the detrital load from upstream. An increase in the estuarine small invertebrate community would favour juvenile L. lithognathus and Caffrogobius spp.

Confidence: Low

BIRDS

For the avifauna, the diversity and abundance of birds will be similar to the Present State. The estuary will however become more marine dominated, with a greater tidal influence. The more established invertebrate community would benefit waders. A permanently open mouth and relatively low river flow will not allow for the natural revegetation of the saltmarsh.

Confidence: Low

f. EHI Tables for Scenario 1

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	50	For the Orange River Estuary low flows are defined as flows associated with the *State 3: Closed* (i.e. <10.0 m^3/s) and *State 2: Open (Marine*) (between 10.0 and 50.0 m^3/s). Months with median low flows of less than 50.0 m^3/s increased form 3 (Jul – Sep) under the Reference Condition to 9 (May - Jan) under the Scenario 1.	Low
b. % similarity in the magnitude of major floods (e.g. 1:20, 1:50 and 1:100) in comparison with the reference condition	45	For the Orange River floods greater than 5000 x $10^6 m^3$ were judged to be resetting events. These have been significantly reduced from 20 under the Reference conditions to 9 under Scenario 1.	Low
	48		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 68 year period	50	For the Orange River Estuary mouth closure occurs at flows less than 10 m^3/s. Under the Reference condition the estuary mouth use to close 18 out of the 68 years (26%) for about 1 month at a time, while under Scenario 1 mouth closure does not occur for an extended period, i.e. more than a few days at a time. Alternatively, out of a total of 816 months (68 years), mouth closure decreased from 3% in the Reference Conditions to 0.0 % under Scenario 1. *Note: Following a precautionary approach, and in view of the importance of mouth closure and related back flooding to estuarine health, the mouth closures were scored severely.*	Low
	50		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	50	There has been modification in the salinity distribution due to an increase of *State 2: Open (Marine*) and a decrease in *State 1: Open (Riverine)*. From being freshwater dominated for 9 months (Oct-Jun) of the year under the Reference Condition, the system is now only freshwater dominated for 3 months (Feb-Apr) with strong marine influence in the lower reaches for about 9 months (May-Jan).	Low
2a. Nitrate and phosphate concentration in the estuary	80	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. Allow for 10% change. With an increase in State 2, (i.e. stronger marine influence) during Aug-Jan and May, it is possible that nutrient concentrations in the bottom waters of the deeper basin near the mouth may at time be slightly higher than for the Reference Conditions (in particular during Oct to Apr when upwelling occurs at sea). Allow for an additional 10% change.	Low
2b. Suspended solids present in inflowing freshwater	85	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in State 1 (i.e. strong river influence), slightly less compared with the Present State.	Low

2c. Dissolved oxygen (DO) in the estuary	80	It is expected that the estuary will, at large, remain well-oxygenated as was the case under the Reference Condition. However, occasional events of low oxygen river water inflow may still occur, associated with algal blooms developing upstream.	Low
2d. Levels of toxins	90	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Allow for 10%.	Low
	68		

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	Similar to the present status, because the lack of hydropower releases, will not have a noticeable effect on the sediment processes and characteristics.	Low
1b	% similarity in sand fraction relative to total sand and mud	90	Similar to the present status, because the lack of hydropower releases, will not have a noticeable effect on the sediment processes and characteristics.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	90	Similar to the present status, because the lack of hydropower releases, will not have a noticeable effect on the sediment processes and characteristics.	Low
		86		

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	65	40	It is estimated that approximately 65% of the original species remain. The increase in the marine state would promote the growth of marine species at the expense of freshwater/ brackish species.	Low
2a. Abundance	40		Increase in low flow and reduction in floods, there will be longer water retention time compared to the Present State, which would allow the development of phytoplankton. The stable channels would allow for benthic microalgal colonisation. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from agricultural activities and from the sea particularly during upwelling events. Biomass is expected to be 60 % higher than it was under reference conditions. The reduction in suspended solids would increase light available for microalgal growth.	Low
2b. Community composition	50		Because of the greater water retention time flagellates would dominate the phytoplankton rather than diatoms.	Low
	40			

Macrophytes

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	65	40	Loss of opportunistic species due to reduction in resetting floods and an increase in reed growth at the expense of other species. Stable water levels would also have contributed to the increase in reeds. Increase in salinity may result in loss of some freshwater / brackish species.	Low
2a. Abundance	50		In 1986, 90% of the large salt marsh area on the southern bank was lost and became desertified. This desertified marsh area represents approximately 20% of the total estuarine area. However, recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. A reduction in freshwater conditions to only 3 months would increase salinity and reduce macrophyte growth. For this scenario, the mouth can close for days at a time. This would be beneficial to the desertified marsh area if this event reduced saline sediment conditions. Overall, about 50% of the total biomass remains of the original species.	Low
2b. Community composition	58		Brackish communities have been lost from the desertified salt marsh area, but are still represented in the main river channel. The increase in saline conditions may change the community composition in the main channel. As a result of these changes, the current community composition is 58 % similar to the original composition.	Low
	40			

Invertebrates

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	50	40	In the main channel area, an estuarine benthic community has probably become more established in the lower part of the system (presence of a temporary lens of estuarine water) at the expense of a freshwater community. Reduced flood effects would also favour an estuarine type community. The stability and species number of this community (persist for 9 months of the year) is likely to increase under this scenario. A similar argument applies to the zooplankton. The species richness of the freshwater associated community is unlikely to attain maximum potential because of the short time interval (3 months) available to them to colonize. Since an estuarine type community probably existed in the wetland on the southern bank under natural conditions, it is likely that species richness will be restored in part. Overall, the change from natural is collectively considered to be about 50%.	Low
2a. Abundance	40		Abundance of the estuarine 'invasive' species is likely to increase in the main channel area (at the expense of freshwater species), but also increase in the wetland. Reasons are given in the species richness category.	Low
2b. Community composition	50		The greater persistence of the lens of estuarine water in the main channel area is likely to alter community composition since less hardy species will begin to colonize the area. This argument will also apply to the wetland on the southern shore, thus restoring the community composition to some level it was in the past. Reasons are given in the species richness category.	Low
	40			

Fish

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	80	65	Low flows extend into early summer, more favourable conditions for survival of estuarine fish and for marine species to enter the estuary. Freshwater fish, which under present-day conditions provide 50% of the species complement, will tend to avoid the saline estuarine waters.	Low
2a. Abundance	60		Increase in abundance of estuarine species due to more favourable conditions but decline in abundance of freshwater species. Numbers of estuarine dependent species such as *L. lithognathus* & *L. amia* could increase but ultimately abundance driven by overall stock status and the relationships between stock size and recruitment.	Low
2b. Community composition	40		Saltmarsh channel & marginal areas still largely unavailable to genera such as *Caffrogobius*. Freshwater fish component reduced. Trend towards a more salt loving estuarine fish community for a large part of the year as opposed to a freshwater tolerant community under natural and present day conditions.	Low
	40			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	100	100	Overall, there will probably be no change in species richness.	Low
2a. Abundance	26		The marine dominated system with tidal influences will benefit wading birds, such as Curlew Sandpiper and Little Stint. Less water will also increase the area of open habitat used by waders. Loss of *Phragmites* habitat reedbeds because of salinity changes will decrease the feeding and roosting habitat of rails (such as Purple Gallinule), passerines (such as Cape Reed Warbler) and roosting habitat of herons and egrets (such as Black-crowned Night Heron). An increase in the abundance of estuarine fish may benefit terns and cormorants. With no mouth closure and therefore no back flooding; the saltmarsh habitat will remain in its degraded state and therefore unavailable to certain bird species, such as Ethiopian Snipe. In conclusion, some species may increase in numbers (such as certain species of waders), while others may decrease slightly (such as rails).	Low
2b. Community composition	40		The population of waders and terns may increase, while species dependent on reedbed habitats may decrease.	Low
	26			

4.2.2 Scenario 2: Vanderkloof Lower Level Storage

a. Described seasonal variability in river inflow (based on simulated runoff data for this scenario)

Monthly-simulated runoff data for Scenario 2, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 4.3**. The MAR under Scenario 2 is 4 296.43 x 10^6 m^3 (39.66% remaining of the natural MAR). A statistical analysis of the monthly-simulated runoff data in m^3/s for Scenario 2 is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	28.64	251.20	253.83	558.86	1364.30	767.29	710.88	212.16	61.88	17.57	24.23	17.06
80%ile	23.24	32.38	140.43	180.20	516.42	477.87	194.03	89.89	25.97	16.41	14.13	14.81
70%ile	22.82	26.62	48.66	105.54	257.34	270.07	117.24	38.73	20.26	15.65	13.47	14.48
60%ile	22.25	23.88	27.56	40.01	104.58	179.61	71.47	29.19	19.02	15.41	13.29	13.94
50%ile	21.69	22.65	24.92	28.94	57.69	108.50	60.04	27.20	18.58	15.18	13.20	13.61
40%ile	21.47	21.82	23.03	24.83	39.43	58.42	50.62	26.60	18.40	15.14	13.17	13.53
30%ile	21.42	21.59	21.69	22.93	29.43	43.40	41.72	25.99	18.34	15.08	13.12	13.48
20%ile	21.36	21.47	21.45	21.68	22.69	36.97	37.12	25.89	18.27	15.04	13.10	13.47
10%ile	21.36	21.37	21.36	21.47	21.75	30.67	36.08	25.57	18.22	15.00	13.08	13.46
1%ile	21.36	21.35	21.36	21.36	21.56	28.26	34.99	25.45	18.16	14.93	13.01	13.46

Confidence: Low

b. Flood regime for the Scenario 2

There where no detailed analysis done on the reduction in the magnitude and frequency of floods for the Orange River System for Scenario 2.

Larger floods (represented by months with average flows greater than 5000 x $10^6$$m^3$) in turned played an important role in resetting the habitat of the estuary. An evaluation of the Present State simulated runoff scenario indicates that there has been a marked reduction in the occurrence of monthly flows greater than 5000 x $10^6$$m^3$ (reprehensive of major flood events), from 20 under the Reference Condition to 9 at present. On average the highest monthly flow under Scenario 2 has been reduce to 69% of its Reference Condition flows.

Confidence: Low

c. Changes in sediment processes and characteristics for Scenario 2

Similar to the Present State, because the river flow and flood regime and coastal processes/dynamics are very similar to the Present State.

Confidence: Low

Table 4.3: Monthly Runoff Data (in m³/s) for Scenario 2, Simulated over a 68-year Period

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Closed
1920	22.89	21.37	22.00	21.57	170.97	80.08	117.53	69.46	26.05	17.28	13.11	14.72	0
1921	23.24	173.97	487.38	140.91	21.71	28.22	34.96	25.44	18.20	14.90	13.49	13.62	0
1922	21.36	434.75	145.17	560.23	624.27	375.53	200.76	27.87	20.30	15.53	13.12	14.71	0
1923	21.36	21.59	21.36	21.59	22.14	164.82	66.22	25.98	18.27	15.02	13.10	13.72	0
1924	21.36	23.11	40.34	34.15	260.52	**3406.56**	1846.99	688.83	103.53	29.29	16.51	14.72	0
1925	22.63	21.36	21.43	23.65	21.63	47.29	50.29	26.60	19.93	15.17	13.13	13.46	0
1926	21.47	22.46	22.17	21.51	21.60	37.11	40.61	25.53	18.20	15.13	13.19	13.48	0
1927	21.83	21.69	22.72	39.00	37.33	259.74	62.61	25.70	18.28	15.04	13.15	14.17	0
1928	21.50	24.14	22.11	24.87	22.65	124.17	54.12	25.99	18.67	15.54	14.99	22.93	0
1929	23.93	22.85	327.48	170.24	55.98	36.68	35.64	25.53	18.24	14.97	14.35	13.91	0
1930	21.42	22.04	21.58	52.37	55.90	159.23	40.53	26.25	18.37	15.27	13.15	13.46	0
1931	21.61	24.56	22.78	21.52	39.96	37.35	36.20	25.99	18.90	15.14	13.08	13.94	0
1932	30.13	21.37	21.39	21.39	21.82	28.44	35.29	25.47	18.27	15.18	13.02	13.46	0
1933	21.36	27.50	116.26	1136.89	923.27	476.01	55.10	48.46	18.52	15.17	29.54	14.70	0
1934	22.46	401.99	542.28	23.81	24.45	75.49	79.85	192.74	44.83	15.07	13.12	13.46	0
1935	21.36	23.99	21.67	23.57	26.41	199.48	65.93	180.27	51.44	15.14	13.18	13.83	0
1936	21.46	950.23	231.61	558.27	1351.58	241.41	35.80	25.76	18.31	15.05	13.15	13.48	0
1937	21.36	21.35	24.91	186.84	59.40	35.27	52.09	27.53	18.53	16.57	13.48	13.49	0
1938	21.93	87.13	23.72	35.39	1328.47	322.78	36.68	25.87	18.39	16.17	21.95	15.33	0
1939	23.23	186.57	145.17	27.11	90.62	64.93	183.94	204.17	18.26	15.05	13.08	14.38	0
1940	21.53	25.01	133.32	311.19	642.18	110.55	152.83	26.46	18.78	15.12	13.07	13.51	0
1941	21.37	21.38	21.36	21.50	354.21	41.62	69.89	30.95	18.62	15.15	13.28	13.46	0
1942	28.63	23.60	219.59	109.71	21.76	29.41	873.46	1153.79	190.39	380.66	135.58	54.68	0
1943	494.45	1825.93	1489.82	567.83	**2108.04**	547.06	36.66	25.91	19.81	15.51	13.35	14.92	0
1944	100.81	60.02	21.47	22.80	22.56	302.06	84.75	25.63	18.28	17.45	13.12	13.51	0
1945	21.76	21.50	21.36	23.92	28.94	44.87	67.73	37.79	20.36	15.15	13.17	13.70	0
1946	21.54	21.42	21.37	21.95	22.52	59.60	37.12	25.96	18.34	15.01	13.09	13.57	0
1947	23.81	21.47	25.77	26.82	55.68	633.36	362.80	28.88	18.41	15.15	13.12	13.46	0
1948	21.47	21.71	21.39	33.50	29.46	109.11	41.71	25.47	18.31	14.96	13.04	13.46	0
1949	21.36	21.40	23.79	22.87	340.88	479.11	232.27	290.95	60.68	15.85	51.26	14.87	0
1950	22.20	21.59	49.42	44.06	23.44	29.94	36.75	26.59	19.69	15.49	13.15	13.46	0
1951	23.08	21.55	21.36	21.40	314.37	43.24	35.00	25.46	18.19	27.53	15.29	13.48	0
1952	21.44	21.45	21.48	21.38	228.67	100.04	114.60	26.97	18.23	15.03	13.35	13.55	0
1953	21.46	21.90	61.56	27.34	32.56	530.18	77.76	27.82	19.00	15.66	13.38	13.60	0
1954	21.41	21.35	21.42	103.83	1795.22	456.58	140.49	67.57	18.53	15.10	13.53	13.60	0
1955	21.36	23.85	26.37	50.34	354.66	997.23	461.56	70.39	18.37	15.11	13.18	13.52	0
1956	21.36	22.04	802.65	510.27	139.60	174.64	36.71	25.59	21.08	16.08	13.80	1345.20	0
1957	1616.59	402.32	201.87	1051.73	185.85	31.13	59.52	230.81	58.87	15.04	13.10	13.55	0
1958	21.36	21.82	28.98	29.49	28.85	31.10	35.49	165.79	42.15	68.99	13.13	13.46	0
1959	21.36	21.65	23.09	21.97	86.91	250.27	133.86	38.51	18.34	15.14	13.40	13.47	0
1960	21.42	21.55	172.64	123.08	22.75	235.45	764.94	180.53	225.86	17.25	89.16	16.50	0
1961	21.54	28.87	94.45	21.52	1016.91	270.56	44.08	38.75	18.22	14.98	13.58	13.65	0
1962	21.36	26.80	24.81	577.20	293.02	720.03	886.45	64.75	18.68	15.26	13.26	13.48	0
1963	22.94	32.79	26.33	21.67	21.56	29.63	240.64	25.58	18.44	14.99	13.00	13.46	0
1964	55.00	436.80	157.77	165.88	45.88	50.37	52.38	26.83	18.16	15.43	13.17	13.55	0
1965	21.36	21.37	21.62	47.54	228.69	38.32	50.70	25.88	18.27	14.96	13.03	13.46	0
1966	21.59	21.65	21.68	131.47	1393.99	516.37	1133.65	441.18	298.48	16.66	13.32	14.72	0
1967	22.46	28.36	21.42	21.36	21.56	122.48	88.09	82.76	25.85	15.20	13.23	13.53	0
1968	21.44	24.77	30.55	21.69	30.55	53.71	60.56	33.51	22.70	15.41	13.23	13.53	0
1969	21.90	21.45	21.36	21.37	33.61	30.82	36.49	25.97	20.96	17.87	13.09	13.48	0
1970	28.67	21.96	23.47	34.54	97.35	39.67	37.29	26.65	18.38	15.10	13.27	13.50	0
1971	22.04	21.52	21.43	309.67	77.01	718.17	151.83	27.42	18.39	15.07	13.11	13.97	0
1972	21.39	21.37	21.36	21.36	90.18	70.10	64.90	28.08	18.33	15.04	13.09	14.19	0
1973	21.40	21.48	31.06	762.49	**2378.76**	**2364.45**	687.71	269.87	102.55	23.87	319.29	14.88	0
1974	22.19	24.35	305.68	460.98	1970.03	918.06	174.19	28.52	19.16	15.18	13.22	14.70	0
1975	21.36	23.13	626.01	**2005.11**	**2976.29**	**2860.89**	971.71	563.08	141.53	23.71	16.10	15.41	0
1976	1033.81	654.05	60.62	105.73	834.69	877.57	98.82	36.84	19.92	15.91	13.81	14.44	0
1977	22.94	31.77	26.44	430.20	327.86	265.61	1108.37	94.64	18.43	15.51	13.67	14.48	0
1978	21.39	21.35	21.77	23.48	40.47	36.88	37.13	26.74	19.10	15.74	18.68	15.18	0
1979	23.11	22.94	21.48	22.03	69.43	107.89	41.76	26.18	18.40	15.04	38.81	38.77	0
1980	26.43	33.40	30.11	28.39	133.47	304.98	43.28	26.03	64.69	15.03	88.36	53.67	0
1981	23.70	23.41	27.20	24.67	21.93	30.32	49.42	30.44	18.26	16.76	13.20	13.46	0
1982	22.77	21.81	26.67	22.73	21.56	28.28	42.41	26.94	18.98	15.24	13.10	13.48	0
1983	21.42	37.23	41.83	25.83	21.59	46.20	52.28	26.31	18.39	15.04	13.19	13.46	0
1984	22.47	21.52	21.36	26.42	29.43	49.87	35.20	25.56	18.18	14.94	13.01	13.46	0
1985	24.87	27.57	63.97	33.71	34.79	38.06	40.33	26.71	25.19	17.13	13.19	14.14	0
1986	22.54	22.10	24.48	21.36	42.49	33.74	37.26	25.89	18.15	15.07	13.07	18.36	0
1987	22.82	30.94	24.94	44.30	**2868.70**	**3733.57**	605.13	94.95	48.26	15.92	13.33	302.66	0

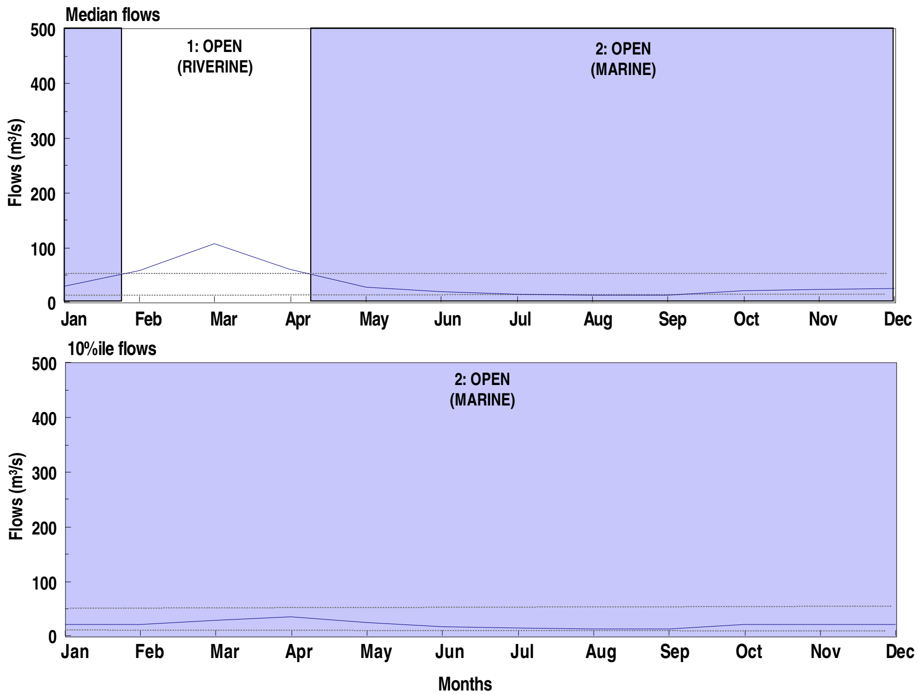
1: Open (River)	>50.0	2: Open (Marine)	10.0-50.0	3: Closed	< 10.0	Floods	> 2000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
< 10.0	0	0	0	0	0	0	0	0	0	0	0	0
10.0-50.0	63	57	48	44	31	25	26	49	58	66	63	64
>50.0	5	11	20	24	37	43	42	19	10	2	5	4

d. Occurrence and duration of different abiotic states for Scenario 2

The occurrence and duration of the different Abiotic States under Scenario 2 are illustrated in the simulated monthly river flow table (**Table 4.3**).

To provide a conceptual overview of the annual distribution of Abiotic States under Scenario 2, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Predicted change in biotic characteristics of Scenario 2 compared with the Reference Condition

MICROALGAE

The same conditions as described for Scenario 1 apply. There is a further increase in low flow compared to the Present State, which would result in longer water retention time and the development of phytoplankton. The stable channels would allow for benthic microalgal colonisation. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from agricultural activities and from the sea particularly during upwelling events. The reduction in the occurrence of the freshwater state would also reduce the suspended solid load which would increase light available for microalgal growth.

Confidence: Low

MACROPHYTES

The same changes as described for the present state apply. However, for Scenario 2 there is an increase in the period of low flows and as a result of this the estuary is only freshwater dominated for 3 months (Feb-Apr) with strong marine influence in the lower reaches for about 9 months (May-Jan). This may decrease the diversity of brackish species in the mouth region and decrease the growth of the reeds and sedges.

Confidence: Low

INVERTEBRATES (INCLUDING ZOOPLANKTON)

The same changes as described for Scenario 1 apply. This scenario would likely benefit the estuarine benthic community in the LOR Mouth area in that the lens of estuarine water will persist for 9 months of the year without interruption. Under the present scenario, this lens also breaks down for three months in winter. The persistence of the lens for a longer period without interruption will allow the community to become better established and not disappear in winter (freshwater will induce a shift to a freshwater type community in this area – extension of upstream conditions towards the mouth). Species richness is also likely to increase.

Similarly, an estuarine zooplankton community is likely to become more prevalent in the estuarine water lens.

Invertebrates colonizing the wetland on the south bank are also likely to benefit, in that salinity is likely to increase because of tidal penetration from the main channel area, particularly around spring tides. This assumes that surface freshwater will be pushed further upstream with the tide and that salinity does not increase above 35 in the wetland area.

Confidence: Low

FISH

As with Scenario 1. This scenario is closer to the reference state than present day in that the winter flows are no longer elevated through hydro releases. Estuarine conditions persist throughout winter but may extend into the summer months as the first summer high flows or floods are captured by the upstream dams. Although the estuarine fish assemblage is likely to become more stable, the cues provided by spring and early summer freshettes will be close to non-existent, leading to a reduction in recruitment, and depending on mortality levels, may lead to an overall decline in abundance of fish such as L. lithognathus and L. amia. An increase in benthic microalga would provide a foodsource for L. richardsonii to compensate for a decrease in the detrital load from upstream. An increase in the estuarine small invertebrate community would favour juvenile L. lithognathus and Caffrogobius spp.

Confidence: Low

BIRDS

Similar to Scenario 1.

Confidence: Low

f. EHI Tables for Scenario 2

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	50	For the Orange River Estuary low flows is defined as flows associated with the *State 3: Closed* (i.e. <10.0 m^3/s) and *State 2: Open (Marine)* (between 10.0 and 50.0 m^3/s). Months with median low flows of less than 50.0 m^3/s increased form 3 (Jul – Sep) under the Reference Condition to 9 (May - Jan) under the Scenario 2.	Low
b. % similarity in the magnitude of major floods (e.g. 1:20, 1:50 and 1:100) in comparison with the reference condition	45	For the Orange River floods greater than 5000 x $10^6 m^3$ were judged to be resetting events. These have been significantly reduced from 20 under the Reference conditions to 9 under the Present state.	Low
	48		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 68 year period	50	For the Orange River Estuary mouth closure occurs at flows less than 10 m^3/s. Under the Reference condition the estuary mouth use to close 18 out of the 68 years (26%) for about 1 month at a time, while under Scenario 2 mouth closure do not occur for an extended period, i.e. more than a few days at a time. Alternatively, out of a total of 816 months (68 years), mouth closure decreased from 3% in the Reference Conditions to 0.0 % under Scenario 1. *Note: Following a precautionary approach, and in view of the importance of mouth closure and related back flooding to estuarine health, the mouth closures were score severely.*	Low
	50		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	50	There has been modification in the salinity distribution due to an increase of *State 2: Open (Marine*) and a decrease in *State 1: Open (Riverine).* From being freshwater dominated for 9 months (Oct-Jun) of the year under the Reference Condition, the system is now only freshwater dominated for 3 months (Feb-Apr) with strong marine influence in the lower reaches for about 9 months (May-Jan).	Low
2a. Nitrate and phosphate concentration in the estuary	80	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. Allow for 10% change. With an increase in State 2, (i.e. stronger marine influence) during Aug-Jan and May, it is possible that nutrient concentrations in the bottom waters of the deeper basin near the mouth may at time be slightly higher than for the Reference Conditions (in particular during Oct to Apr when upwelling occurs at sea). Allow for an additional 10% change.	Low
2b. Suspended solids present in inflowing freshwater	85	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in State 1 (i.e. strong river influence), slightly less compared with the Present State.	Low
2c. Dissolved oxygen (DO) in the estuary	80	It is expected that the estuary will, at large, remain well-oxygenated as was the case under the Reference Condition. However, occasional events of low oxygen river water inflow may still occur, associated with algal blooms developing upstream.	Low
2d. Levels of toxins	90	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Allow for 10%.	Low
	68		

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	Similar to the present status, because river flow regime and coastal processes/dynamics are very similar to the present state.	Low
1b	% similarity in sand fraction relative to total sand and mud	90	Similar to the present status, because river flow regime and coastal processes/dynamics are very similar to the present state.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	90	Similar to the present status, because river flow regime and coastal processes/dynamics are very similar to the present state.	Low
		86		

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%*	*Score*	It is estimated that approximately 65 % of the original species remain. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species.	Low
	65	40		
2a. Abundance	40		Increase in low flow and reduction in floods, there will be longer water retention time compared to the Present State, which would allow the development of phytoplankton. The stable channels would allow for benthic microalgal colonisation. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from agricultural activities and from the sea particularly during upwelling events. Biomass is expected to be 60 % higher than it was under reference conditions. The reduction in suspended solids would increase light available for microalgal growth.	Low
2b. Community composition	50		Because of the greater water retention, time flagellates would dominate the phytoplankton rather than diatoms.	Low
	40			

Macrophytes

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%*	*Score*	Loss of opportunistic species due to reduction in resetting floods and an increase in reed growth at the expense of other species. Stable water levels would also have contributed to the increase in reeds. Increase in salinity may result in loss of some freshwater / brackish species.	Low
	65	40		
2a. Abundance	50		In 1986, 90% of the large salt marsh area on the southern bank was lost and became desertified. The desertified marsh area represents approximately 20% of the total estuarine area. However, recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. A reduction in freshwater conditions to only 3 months would increase salinity and reduce macrophyte growth. For this scenario, the mouth can close for days at a time. This would be beneficial to the desertified marsh area if this event reduced saline sediment conditions. Overall, about 50% of the total biomass remains of the original species.	Low

2b. Community composition	58	Brackish communities have been lost from the desertified salt marsh area but are still represented in the main river channel. The increase in saline conditions may change the community composition in the main channel. As a result of these changes the current community composition is 58 % similar to the original composition.	Low
	40		

Invertebrates

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	50	40	In the main channel area, an estuarine benthic community has probably become more established in the lower part of the system at the expense of the freshwater community (presence of a temporary lens of estuarine water) at the expense of a freshwater community. The stability and species number of this community (persist for 9 months of the year) is likely to increase under this scenario. A similar argument applies to the zooplankton. Since an estuarine type community probably existed in the wetland on the southern bank under natural conditions, it is likely that species richness will be restored in part. Overall, the change from natural is collectively considered to be about 50%.	Low
2a. Abundance	40		Abundance of the 'invasive' estuarine species is likely to increase in the main channel area (at the expense of freshwater species), but also increase in the wetland. Reasons are given in the species richness category.	Low
2b. Community composition	50		The greater persistence of the lens of estuarine water in the main channel area is likely to alter community composition since less hardy species will begin to colonize the area. This argument will also apply to the wetland on the southern shore, thus restoring the community composition to some level it was in the past. Reasons are given in the species richness category.	Low
	40			

Fish

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	80	65	Low flows extends into early summer, more favourable conditions for survival of estuarine fish and for marine species to enter the estuary. Freshwater fish, which under present day conditions, provide 50% of the species complement will tend to avoid the saline estuarine waters.	Low
2a. Abundance	60		Increase in abundance of estuarine species due to more favourable conditions but decline in abundance of freshwater species. Numbers of estuarine dependent species such as *L. lithognathus* & *L. amia* could increase but ultimately abundance driven by overall stock status and the relationships between stock size and recruitment.	Low
2b. Community composition	40		Saltmarsh channel & marginal areas still largely unavailable to genera such as *Caffrogobius*. Freshwater fish component reduced. Trend towards a more salt loving estuarine fish community for a large part of the year as opposed to a freshwater tolerant community under natural and present day conditions.	Low
	40			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	100	100	Overall, there will probably be no change in species richness.	Low
2a. Abundance	26		The marine dominated system with tidal influences will benefit wading birds, such as Curlew Sandpiper and Little Stint. Less water will also increase the area of open habitat used by waders. Loss of *Phragmites* habitat reedbeds because of salinity changes will decrease the feeding and roosting habitat of rails (such as Purple Gallinule), passerines (such as Cape Reed Warbler) and roosting habitat of herons and egrets (such as Black-crowned Night Heron). An increase in the abundance of estuarine fish species may benefit terns and cormorants. Possible short periods of closure and therefore, back flooding (however, it is unknown whether this will result in improvements in the saltmarsh habitat). Backflooding would temporarily decrease low-lying areas, used as feeding areas by waders and roosting areas by terns and cormorants. In conclusion, some species may increase in numbers (such as certain species of waders), while others may decrease slightly (such as rails).	Low
2b. Community composition	40		The population of waders and terns may increase, while species dependent on reedbed habitats may decrease.	Low
	26			

4.2.3 Scenario 3: Vioolsdrift Re-regulating Dam

a. Described seasonal variability in river inflow (based on simulated runoff data for this scenario)

Monthly-simulated runoff data for Scenario 3, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 4.4**. The MAR under Scenario 3 is 4 082.1 x 10^6 m^3 (37.68% remaining of natural MAR). A statistical analysis of the monthly-simulated runoff data in m^3/s for Scenario 3 is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	23.59	245.62	246.06	553.80	1356.40	761.31	704.09	208.89	58.91	11.14	19.17	11.92
80%ile	18.18	27.33	135.37	175.15	511.31	467.01	182.37	81.39	18.84	9.98	9.08	9.67
70%ile	17.76	21.56	43.60	100.49	253.30	262.64	100.59	37.00	13.23	9.21	8.42	9.33
60%ile	17.20	18.83	22.50	34.96	99.46	171.67	60.99	19.68	11.90	8.98	8.23	8.80
50%ile	16.63	17.60	19.87	23.88	52.57	97.63	43.39	16.33	11.46	8.74	8.14	8.47
40%ile	16.41	16.76	17.97	19.77	34.31	47.55	33.97	15.73	11.28	8.70	8.11	8.39
30%ile	16.37	16.54	16.63	17.87	24.31	32.54	25.07	15.13	11.22	8.64	8.07	8.34
20%ile	16.31	16.42	16.39	16.62	17.57	26.11	20.48	15.02	11.15	8.61	8.04	8.32
10%ile	16.30	16.32	16.31	16.42	16.63	19.81	19.44	14.71	11.10	8.57	8.02	8.31
1%ile	16.30	16.30	16.30	16.30	16.45	17.39	18.34	14.59	11.04	8.49	7.95	8.31

Confidence: Low

b. Flood regime for the Scenario 3

There was no detailed analysis done on the reduction in the magnitude and frequency of floods for the Orange River System for Scenario 3.

Larger floods (represented by months with average flows greater than 5000 x $10^6 m^3$) played an important role in resetting the habitat of the estuary. An evaluation of the Present State simulated runoff scenario indicates that there has been a marked reduction in the occurrence of monthly flows greater than 5000 x $10^6 m^3$ (representative of major flood events), from 20 under the Reference Condition to 9 at present. On average, the highest monthly flows under Scenario 3 have been reduced to 69% of the Reference Condition.

Confidence: Low

c. Changes in sediment processes and characteristics for Scenario 3

Despite the possibility of prolonged mouth closure, the estuarine sediment dynamics are still very similar to that of the present state, because the river flow and flood regime and coastal processes/dynamics are still similar. However, due to mouth closure for ~1/4 of year and continued inflow into estuary, the water level in the estuary will rise when the mouth is closed. Thus, the water depth in the estuary will increase (~1 – 2m) and intertidal areas will be inundated for part of the time that the mouth is closed.

Confidence: Low

Table 4.4: Monthly Runoff Data (in m³/s) for Scenario 3, Simulated over a 68-year Period

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Closed
1920	17.83	16.32	16.95	16.51	165.85	69.21	100.89	58.59	18.92	10.85	8.05	9.58	2
1921	18.19	168.92	482.32	135.85	16.59	17.36	18.31	14.58	11.08	8.46	8.43	8.48	3
1922	16.30	429.70	140.11	555.17	619.15	364.66	184.11	17.01	13.18	9.09	8.07	9.57	3
1923	16.30	16.54	16.30	16.53	17.02	164.38	60.96	15.11	11.15	8.59	8.05	8.57	3
1924	16.30	18.06	35.28	29.09	255.40	3400.44	1844.71	681.38	96.04	22.85	11.45	9.58	1
1925	17.58	16.31	16.38	18.60	16.51	36.43	33.65	15.74	12.81	8.74	8.08	8.32	3
1926	16.41	17.41	17.11	16.45	16.48	26.24	23.96	14.66	11.08	8.69	8.13	8.34	3
1927	16.78	16.64	17.66	33.94	32.21	248.88	45.96	14.83	11.16	8.60	8.09	9.03	3
1928	16.45	19.08	17.05	19.81	17.53	113.31	37.48	15.12	11.55	9.11	9.94	17.79	2
1929	18.87	17.79	322.42	165.18	50.86	25.81	18.99	14.67	11.12	8.53	9.29	8.77	3
1930	16.36	16.98	16.53	47.32	50.78	148.36	23.89	15.39	11.25	8.84	8.10	8.31	3
1931	16.56	19.51	17.72	16.47	34.84	26.49	19.56	15.12	11.78	8.70	8.03	8.79	3
1932	25.07	16.32	16.34	16.34	16.70	17.58	18.64	14.61	11.15	8.74	7.97	8.31	3
1933	16.30	22.45	111.20	1131.84	918.15	465.15	38.45	37.60	11.40	8.74	24.48	9.55	2
1934	17.40	396.93	537.23	18.76	19.33	64.63	87.02	185.79	37.72	8.64	8.06	8.31	3
1935	16.30	18.94	16.61	18.51	21.30	188.62	49.28	169.40	44.32	8.70	8.12	8.68	3
1936	16.41	945.18	226.56	553.22	1338.74	234.69	19.16	14.90	11.19	8.61	8.09	8.34	3
1937	16.31	16.30	19.86	181.79	54.28	24.41	35.44	16.67	11.41	10.14	8.43	8.34	2
1938	16.87	82.08	18.67	30.34	1321.90	316.17	20.03	15.01	11.27	9.73	16.90	10.19	1
1939	18.18	181.52	140.12	22.06	85.50	54.06	179.76	197.04	11.14	8.61	8.02	9.23	3
1940	16.47	19.95	128.27	306.13	625.20	104.15	145.48	15.60	11.66	8.68	8.02	8.37	3
1941	16.31	16.32	16.30	16.45	349.09	30.76	53.24	20.09	11.50	8.71	8.23	8.31	3
1942	23.58	18.55	214.54	104.66	16.65	18.55	871.59	1151.79	184.15	373.57	128.33	49.54	0
1943	484.84	1825.57	1485.66	560.31	2100.34	539.83	20.01	15.04	16.71	9.07	8.30	9.78	3
1944	95.75	54.97	16.42	17.74	17.44	291.20	68.11	14.77	11.16	11.01	8.07	8.36	2
1945	16.71	16.45	16.30	18.87	23.83	34.01	51.08	26.93	13.24	8.72	8.11	8.56	3
1946	16.49	16.37	16.31	16.89	17.41	48.73	20.47	15.09	11.22	8.58	8.03	8.43	3
1947	18.75	16.42	20.71	21.76	50.57	629.56	361.05	18.01	11.29	8.71	8.07	8.31	3
1948	16.41	16.66	16.33	28.45	24.34	98.25	25.07	14.60	11.18	8.52	7.99	8.31	3
1949	16.30	16.35	18.73	17.81	335.76	468.25	215.63	272.93	53.55	9.41	65.48	9.73	2
1950	17.15	16.54	44.36	39.01	18.32	19.07	20.10	15.72	12.57	9.06	8.09	8.31	3
1951	18.03	16.49	16.30	16.34	309.25	32.37	18.36	14.59	11.07	21.09	10.23	8.34	1
1952	16.39	16.40	16.43	16.33	223.56	89.18	97.95	16.11	11.10	8.59	8.30	8.41	3
1953	16.40	16.85	56.50	22.28	27.45	519.31	61.11	23.10	11.88	9.23	8.32	8.46	3
1954	16.35	16.30	16.36	98.78	1783.04	449.57	133.48	60.48	11.41	8.66	8.47	8.46	3
1955	16.30	18.80	21.31	45.28	349.54	988.29	454.80	63.30	11.25	8.67	8.12	8.38	3
1956	16.31	16.99	786.00	502.87	131.87	167.43	20.06	14.72	13.96	9.64	8.75	1349.66	2
1957	1609.91	395.19	194.25	1044.35	178.62	20.26	42.87	236.56	51.86	8.61	8.04	8.41	3
1958	16.30	16.77	23.92	24.43	23.74	20.24	18.84	160.50	35.02	62.05	8.08	8.31	2
1959	16.31	16.59	18.03	16.92	64.55	246.92	127.62	31.60	11.22	8.71	8.35	8.33	3
1960	16.37	16.50	167.59	118.03	17.63	212.39	757.68	173.53	220.47	10.82	84.11	11.36	0
1961	16.48	23.81	89.39	16.46	994.51	263.10	27.43	40.63	11.10	8.54	8.52	8.51	3
1962	16.30	21.74	19.75	567.03	287.90	713.68	879.25	58.21	11.55	8.82	8.20	8.33	3
1963	17.89	27.73	21.27	16.61	16.45	18.76	229.18	14.71	11.32	8.55	7.95	8.32	3
1964	46.49	429.12	152.72	160.82	40.77	39.51	35.73	15.96	11.04	8.99	8.12	8.41	3
1965	16.30	16.31	16.57	42.48	234.39	27.45	34.05	15.02	11.15	8.52	7.97	8.31	3
1966	16.54	16.59	16.62	126.42	1397.61	510.31	1127.74	435.08	291.25	10.23	8.27	9.58	2
1967	17.41	23.31	16.37	16.30	16.45	111.62	71.44	71.90	18.73	8.76	8.18	8.39	3
1968	16.39	19.72	25.49	16.63	25.43	42.84	43.91	22.65	15.58	8.97	8.17	8.38	3
1969	16.84	16.40	16.30	16.32	28.49	19.96	19.85	15.10	13.83	11.43	8.03	8.34	2
1970	23.61	16.91	18.41	29.48	92.23	28.81	20.64	15.79	11.25	8.66	8.21	8.36	3
1971	16.99	16.47	16.38	304.61	71.90	703.60	135.19	16.56	11.27	8.64	8.06	8.83	3
1972	16.33	16.31	16.30	16.30	85.07	59.23	48.25	17.22	11.21	8.61	8.04	9.05	3
1973	16.35	16.42	26.00	757.44	2413.30	2358.85	681.12	262.90	95.49	17.43	311.62	9.74	1
1974	17.14	19.29	291.57	455.93	1965.73	912.22	157.55	17.66	12.03	8.75	8.16	9.56	3
1975	16.30	18.08	621.56	2005.49	2982.31	2857.07	965.23	556.00	134.34	16.58	11.04	10.27	0
1976	1022.92	647.16	55.57	100.68	822.59	872.43	92.16	25.97	12.80	9.48	8.76	9.30	3
1977	17.88	26.72	21.39	425.14	309.42	258.54	1103.94	87.72	11.31	9.08	8.61	9.34	3
1978	16.33	16.30	16.71	18.43	35.35	26.02	20.48	15.88	11.98	9.30	13.63	10.04	1
1979	18.05	17.88	16.42	16.97	64.31	97.02	25.11	15.32	11.28	8.61	33.76	33.62	1
1980	21.38	28.34	25.06	23.33	128.36	294.12	26.63	15.17	71.42	8.59	82.10	46.28	1
1981	18.65	18.36	22.15	19.61	16.82	19.46	32.77	19.58	11.14	10.33	8.14	8.31	2
1982	17.71	16.76	21.62	17.67	16.45	17.41	25.76	16.07	11.86	8.80	8.04	8.33	3
1983	16.37	32.18	36.78	20.78	16.47	35.33	35.63	15.44	11.27	8.61	8.14	8.32	3
1984	17.41	16.46	16.30	21.37	24.31	39.00	18.55	14.70	11.06	8.51	7.96	8.31	3
1985	19.81	22.52	58.92	28.66	29.68	27.19	23.68	15.85	18.07	10.69	8.14	9.00	2
1986	17.48	17.04	19.43	16.30	37.37	22.87	20.61	15.03	11.03	8.64	8.02	13.22	2
1987	17.77	25.88	19.88	39.24	2893.51	3733.57	603.34	88.82	41.50	9.48	8.27	292.93	2

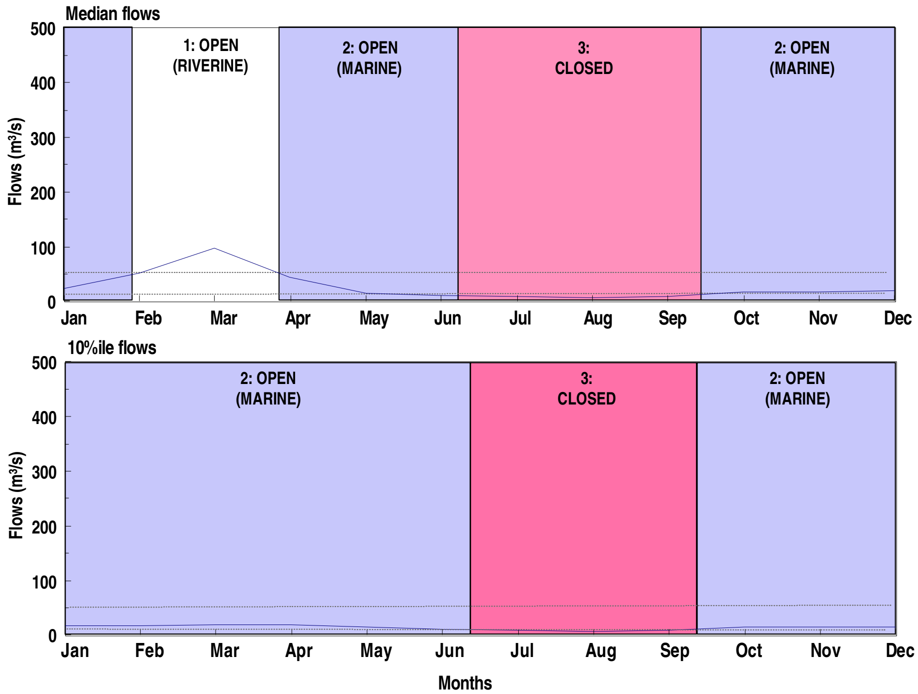
1: Open (River)	>50.0	2: Open (Brackish)	10.0-50.0	3: Closed	< 10.0	Floods	> 2000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
< 10.0	0	0	0	0	0	0	0	0	0	54	56	57
10.0-50.0	64	57	48	46	31	28	38	49	59	12	7	9
>50.0	4	11	20	22	37	40	30	19	9	2	5	2

d. Occurrence and duration of different Abiotic states for Scenario 3

The occurrence and duration of the different Abiotic States under Scenario 3 are illustrated in the simulated monthly river flow table.

To provide a conceptual overview of the annual distribution of Abiotic States under Scenario 3, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Predicted change in biotic characteristics of Scenario 3 compared with the Reference Condition

MICROALGAE

The mouth of the estuary could close for 2-3 months at a time. Due to inundation, the intertidal habitat for benthic microalgae will be lost. There may be an increase in subtidal benthic microalgae but this would depend on the suspended solid load and availability of light. Nutrients are also expected to be low during the closed phase. There is an increase in low flow and the estuary is in an open marine state for 7 months of the year. The brackish / freshwater species will be lost.

Confidence: Low

MACROPHYTES

This scenario differs from Scenario 1 and 2 in that the mouth could close most years (95 %) for 2-3 months at a time. The open riverine state occurs for only 2 months of the year. The estuary is mostly (7 months) in an open marine state and the fundamental characteristics of this system as a freshwater river mouth is altered. This may decrease the diversity of brackish species in the mouth region and decrease the growth of the reeds and sedges.

When the mouth is closed, the intertidal areas will be flooded and the intertidal salt marsh plants submerged. However, in the desertified marsh area mouth closure and associated back flooding may have a beneficial influence in removing salts and promoting germination. This will only be the case if the water is below 35 ppt. The groundwater in that area is probably hypersaline and back flooding with freshwater would be preferable. Because the estuary is mostly in an open marine state, the standing water currently in the desertified marsh area may become hypersaline. This would reduce salt marsh growth and distribution.

Confidence: Low

INVERTEBRATES (INCLUDING ZOOPLANKTON)

The subtidal benthic community present in the deeper channel areas inside the mouth and described under previous scenarios (excluding the natural condition) is likely to respond very negatively to Scenario 3. Changes are relatively rapid, the abiotic environment switching from those associated with river dominance (no estuarine water lens present) to an open mouth scenario having a lens of estuarine water in deeper holes, to a state of mouth closure when the lens develops low oxygen concentrations (predicted after mouth closure) and back to an open mouth where the oxygen concentrations are again restored in the lens. Each of these time frames spans 2-4 months and this will not allow any community (estuarine, brackish or freshwater) to establish itself before changes become unfavourable for them. This situation will persist for 65 out of every 68 years (95% of the time).

The zooplankton will respond quicker to prevailing conditions, although low oxygen concentrations at times (mouth closure) will negatively impact any community. Zooplankton abundance is also likely to decrease at times of mouth closure, because of reduced food availability (low nutrients).

Invertebrates associated with the wetland on the southern bank near the mouth are also likely to respond positively to mouth closure and as water floods the wetland, provided salinity values remain within an estuarine range (5 – 35 ppt). Composition of the benthic community may change, with deposit feeders becoming more dominant at times of mouth closure.

Confidence: Low

FISH

Although these conditions may allow the estuarine fish assemblage to become more stable, the advantages may be negated by increased mouth closure during spring and summer reducing the frequency and magnitude of recruitment. In turn, all small and juvenile fish, especially the estuarine residents & breeders e.g. G.aestuaria will benefit from backflooding and inundation of the saltmarsh during mouth closure. Non estuarine dependent marine species e.g. L. aureti will occur more frequently but only freshwater species tolerant of high salinities e.g. O. mossambicus will still occur in any numbers. The likelihood that estuarine, brackish or freshwater invertebrate communities will struggle to become established suggests that prey availability may become more important in defining the fish community / assemblage. Low oxygen conditions in the deeper areas during mouth closure may exclude some species from a deepwater refuge. In turn, depending on the extent of these low O_2 areas, some fish may be “trapped” either above or below these with some moving further upstream into the freshwater reaches.

The current fish assemblage is dominated by those species tolerant of low salinities. The majority of these are typical of arid west coast systems whether they be open or closed, and, with the exception of a limited pool of non-estuarine-dependent marine species, there is little to replace them if lost. Consequently, the system becoming marine dominated for much of the year is unlikely to see the establishment of a “more estuarine” fish assemblage. The current fish assemblage will either disappear completely or move into the “extended REI zone” in the freshwater reaches, the latter being the more likely option.

The above argument is best explained by comparing west coast estuarine fish assemblages with those on the south and east coasts of SA. On the eastern seaboard there are a variety of permanently open and temporarily open / closed estuaries of different sizes and characteristics. If one system changes state, there is a good chance that it will be “seeded” with a new fish assemblage more typical of it’s new character from a similar estuary nearby. The limited estuaries on the west coast and the distances between them do not provide much of a chance for this to occur.

Confidence: Low

BIRDS

Mouth closure will allow back flooding and inundation of the saltmarsh. If salinity conditions were suitable and re-vegetation took place, this wetland habitat could again become available to various bird species. Back flooding would however inundate intertidal areas and these open habitats would then be unavailable to waders. A decrease in the invertebrate communities would result in less food for waders. If the brackish environment reduces the area covered by reeds and sedges, the bird species dependent on these habitats would be negatively affected. Back flooding would also inundate islands and other low-lying areas, which are the breeding areas of several species. However, as many species, including Cape Cormorant, breed during the summer months, the effects will be limited. The stronger marine influence may effect fresh-water-dependent species, but these could merely be displaced to areas further upstream/

Confidence: Low

f. EHI Tables for Scenario 3

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	42	For the Orange River Estuary low flows is defined as flows associated with the *State 3: Closed* (i.e. <10.0 m³/s) and *State 2: Open (Marine*) (between 10.0 and 50.0 m³/s). Months with median low flows of less than 50.0 m³/s increased form 3 (Jul – Sep) under the Reference Condition to 10 (May - Jan) under Scenario 3.	Low
b. % similarity in the magnitude of major floods (e.g. 1:20, 1:50 and 1:100) in comparison with the reference condition	45	For the Orange River floods greater than 5000 x $10^6 m^3$ were judged to be resetting events. These have been significantly reduced from 20 under the Reference conditions to 9 under the Present state.	Low
	43		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 68 year period	0	For the Orange River Estuary mouth closure occurs at flows less than 10 m³/s. Under the Reference condition the estuary mouth use to close 18 out of the 68 years (26%) for about 1 month at a time, while under Scenario 3 mouth closure occur 65 out of 68 years (95%) for 2 - 3 months at a time. Alternatively, out of a total of 816 months (68 years), mouth closure increased from ~3% in the Reference Conditions to ~20.0 % under the Scenario 3. *Note: Following a precautionary approach, and in view of the importance of mouth closure and related back flooding to estuarine health, the mouth closures were score severely.*	Low
	0		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	30	There has been significant modification in the salinity distribution. Where *State 3: Closed* seldom occurred under the Reference Condition it is now present for 3 months (Jul –Sep) of the year. *State 1: Open (Riverine)* has decreased to only 2 months (Feb-Mar) with *State 2: Open (Marine*) occurring for 7 months (Oct – Jan, Apr - Jun) of the year.	Low
2a. Nitrate and phosphate concentration in the estuary	75	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. This would be slightly less compared with the Present State due to lower river inflow thus allow for 5% change. With an increase in State 2, (i.e. stronger marine influence) during Aug-Jan and May, it is possible that nutrient concentrations in the bottom waters of the deeper basin near the mouth may at time be slightly higher than for the Reference Conditions (in particular during Oct to Apr when upwelling occurs at sea). Allow for an additional 10% change. In addition, State 3 now occurs for 3 months (Jul-Sep) of the year when the system is expected to become nutrient depleted (under the Reference Condition it still had some nutrient supply albeit low during these months). Allow a further 10% change.	Low
2b. Suspended solids present in inflowing freshwater	80	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in State 1 (i.e. strong river influence), slightly less compared with the Scenarios 1 and 2.	Low
2c. Dissolved oxygen (DO) in the estuary	70	Although it is expected for the estuary to remain well-oxygenated during States 1 and 2, a decrease in dissolved oxygen in the bottom waters of the deeper basin could be expected under State 3, which under Scenario 3 could occur for 3 months of the year. Occasional events of low oxygen, river water inflow may also still occur, associated with algal blooms developing upstream.	Low
2d. Levels of toxins	90	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Allow 10%.	Low
	54		

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	60	Despite mouth possibly closed for three months, the sediment dynamics are still very similar to the present status, because the river flow regime and coastal processes/dynamics are still similar. However, due to mouth closure for ~1/4 of year and continued inflow into estuary, water level in estuary will rise when mouth closed. Thus, intertidal areas will be inundated for period of mouth closure.	Low
1b	% similarity in sand fraction relative to total sand and mud	90	Despite mouth possibly closed for three months, the sediment dynamics are still very similar to the present status, because the river flow regime and coastal processes/dynamics are still similar.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	75	Despite mouth possibly closed for three months, the sediment dynamics are still very similar to the present status, because the river flow regime and coastal processes/dynamics are still similar. However, due to mouth closure for ~1/4 of year and continued inflow into estuary, water level in estuary will rise when mouth closed. Thus, water depth in estuary will increase (~1 – 2m) for period of mouth closure.	Low
		75		

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	60	35	It is estimated that approximately 60% of the original species remain. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species.	Low
2a. Abundance	40		The mouth of the estuary could close for 2-3 months at a time. Under these conditions, there will be a loss in intertidal habitat for benthic microalgae. There may be an increase in subtidal benthic microalgae but this would depend on the suspended solid load and availability of light. Nutrients are also expected to be low during the closed phase. Because of the increase in low flow and reduction in floods, there will be longer water retention time compared to the present state, which would allow the development of phytoplankton. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from the sea particularly during upwelling events. Biomass is expected to be 60 % higher than it was under reference conditions. This is the same score as that for Scenario 1 and 2. There is an increase in low flow and therefore an increase in biomass compared to Scenarios 1 and 2. However, the closed mouth condition would reduce biomass and overall there is no increase compared to Scenarios 1 and 2.	Low
2b. Community composition	40		Because of the greater water retention, time flagellates would dominate the phytoplankton rather than diatoms. Subtidal benthic microalgae would replace intertidal communities during closed mouth conditions. This would be 40 % similar to the reference condition where benthic microalgae were probably an unimportant component of the estuary during to the high flows and shifting sandbanks.	Low
	35			

Macrophytes

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	60	35	Loss of opportunistic species due to reduction in resetting floods. Increase in salinity may result in loss of some freshwater / brackish species and would reduce the growth and distribution of salt marsh species in the desertified marsh area. Submergence with saline water for 3 months may result in the loss of some sensitive intertidal species.	Low
2a. Abundance	40		In 1986, 90% of the large salt marsh area on the southern bank was lost and became desertified. However, recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. A reduction in freshwater conditions to only 2 months would increase salinity and reduce macrophyte growth. However, back flooding as a result of mouth closure may improve conditions in the desertified salt marsh area as long as the salinity is less than 35 ppt. Overall, about 40% of the total biomass remains of the original species.	Low
2b. Community composition	55		Brackish communities have been lost from the desertified salt marsh area, but are still represented in the main river channel. The increase in saline conditions may change the community composition in the main channel. As a result of these changes, the current community composition is 55% similar to the original composition.	Low
	35			

Invertebrates

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	50	25	The temporary presence of the estuarine/brackish water lens inside the mouth and low oxygen concentrations that develop at times (three months), will negatively affect invertebrate benthic species that might occur here under the natural state. The net effect is a reduction in species richness. For most of the year (9 months), conditions will not favour the fresh/brackish water benthic group that would occur here under natural conditions. Although suitable conditions will prevail for three months approximately, the interval will be too short for freshwater species richness to develop and only hardy or mobile forms will establish themselves. By contrast, species richness is likely to increase in the wetland along the southern shore because of the longer persistence of estuarine abiotic conditions (reduced freshwater flooding).	Low
2a. Abundance	35		Because of the relatively rapid shift in the abiotic environment (every three months approx), subtidal benthic abundance levels are likely not to attain maximum levels. Under natural conditions, abundance levels will mainly focus on the fresh/brackish water group. Under this scenario, there has been a marked reduction in the larger floods that played an important role in flushing the wetland and leaching out salts, preventing excessive saline built up. A high salt content in the sediment would reduce abundance levels. However, backwashing could assume part of the role in removing excessive salts.	Low
2b. Community composition	35		The composition of the sub-tidal benthic community is likely to reduce under this scenario, primarily because of the rapid shift (measured in months) between abiotic states. The impact of reduced oxygen levels will exacerbate the situation. Feeding guilds are also likely to shift during closed mouth conditions, with deposit feeders becoming more common. Inter-tidal invertebrates in the wetland area will also change towards a more sub-tidal type, because of inundation of the area for three months of the year.	Low
	25			

Fish

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	50	25	Non estuarine-dependent marine species likely to occur more frequently but almost entire complement of freshwater species (50 % of current fish assemblage) that were common during summer high flows will be excluded from the estuary. Back flooding may help re-establish the saltmarsh channel habitat favourable to *Caffrogobius* spp. and other species. May be a slight reduction of freshwater tolerant estuarine dependent species during the marine dominated states but this will largely be due to migration into the freshwater reaches upstream.	Low
2a. Abundance	40		Freshwater species that contributed much of the biomass unlikely to be abundant in a marine dominated system. In terms of fish, the system is changing from high productivity, low diversity to high diversity, low productivity (assuming that a few freshwater stragglers remain, estuarine species take advantage of the back flooded saltmarsh and more marine stragglers enter the system). Unstable invertebrate communities suggest that food may be a limiting factor. *Liza richardsonii* likely to dominate the fish assemblage in terms of numbers and biomass.	Low
2b. Community composition	40		Reference community of a relatively small number of species tolerant of low salinities and able to survive extended mouth closure replaced by a less defined assemblage of a mixture of estuarine, marine and freshwater species that "recruited" opportunistically.	Low
	25			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	100	100	Probably no change in species composition, as even species that are negatively effected will be present in low numbers.	Low
2a. Abundance	20		With back flooding and the inundation of low-lying areas, less open habitat will be available to waders and their numbers could be reduced. A reduction in reedbeds may affect the bird species that are dependent on these habitats. Species dependent on the saltmarsh habitat may be present in larger numbers, but those birds currently using the saltmarsh "lake" will be negatively influenced. Back flooding may flood low-lying roosting and breeding areas.	Low
2b. Community composition	30		When back flooding occurs during winter and spring, there will be less habitat available for wading birds and this group will therefore be present in lower numbers. Flooding of low-lying areas will affect tern and cormorant roosting habitat.	Low
	20			

4.2.4 Scenario 4: Large Vioolsdrift Development

a. Described seasonal variability in river inflow (based on simulated runoff data for this scenario)

Monthly-simulated runoff data for Scenario 4, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 4.5**. The MAR under Scenario 4 is 3 369.92 x 10^6 m^3 (31.11% of natural MAR remaining). A statistical analysis of the monthly-simulated runoff data in m^3/s for Scenario 4 State is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	12.90	85.51	172.67	408.91	1243.34	738.58	664.68	185.11	44.64	4.85	4.43	4.89
80%ile	12.88	12.98	32.14	125.31	486.12	363.26	125.80	40.59	7.24	4.61	4.38	4.89
70%ile	12.88	12.88	13.12	31.26	231.80	205.26	69.39	12.64	7.24	4.61	4.38	4.89
60%ile	12.88	12.88	12.88	15.94	61.83	90.15	29.59	11.15	7.24	4.61	4.38	4.89
50%ile	12.88	12.88	12.88	13.80	26.44	38.69	21.26	10.89	7.24	4.61	4.38	4.89
40%ile	12.88	12.88	12.88	12.88	15.77	22.85	16.09	10.89	7.24	4.61	4.38	4.89
30%ile	12.88	12.88	12.88	12.88	13.01	18.11	14.89	10.89	7.24	4.61	4.38	4.89
20%ile	12.88	12.88	12.88	12.88	13.00	14.15	14.89	10.89	7.24	4.61	4.38	4.89
10%ile	12.88	12.88	12.88	12.88	13.00	13.89	14.89	10.89	7.24	4.61	4.38	4.89
1%ile	12.88	12.88	12.88	12.88	13.00	13.89	14.89	10.89	7.24	4.61	4.38	4.89

Confidence: Low

b. Flood regime for the Scenario 4

There where no detailed analysis done on the reduction in the magnitude and frequency of floods for the Orange River System for Scenario 4.

Larger floods (represented by months with average flows greater than 5000 x $10^6 m^3$) in turn played an important role in resetting the habitat of the estuary. An evaluation of the Present State simulated runoff scenario indicates that there has been a marked reduction in the occurrence of monthly flows greater than 5000 x $10^6 m^3$ (reprehensive of major flood events), from 20 under the Reference Condition to 8 at present. On average, the highest monthly flows under Scenario 4 have been reduced to 60% of its Reference Condition flows.

Confidence: Low

c. Changes in sediment processes and characteristics for Scenario 4

Because the river flows and floods are reduced slightly more compared to the previous scenarios (1, 2 and 3), Scenario 4 could cause a further slight increase in stability of the braided/meandering channels in the upper estuary, slight reduction in transport of fluvial material to the tidal basin, as well as slightly reduced overall flushing of sediments from the estuary. However, the largest changes from the Reference Conditions, would still be due to other anthropogenic impacts.

The overall sediment regime is much the same as the previous three scenarios, but in terms of sediment composition there will be a further small reduction in the riverine components. Also, due to prolonged mouth closure, marine sediment intrusion (through the open mouth) will also be slightly reduced.

The sediment regime is much the same as the previous three scenarios, but the further small reduction in the riverine components has an additional small impact on the sub-tidal habitats. The changes in terms of physical habitat alteration due to prolonged mouth closure are localised and small in relation to overall sub-tidal estuary domain. However, due to mouth closure for ~1/4 of year and continued inflow into estuary, water level in estuary will rise when mouth closed. Thus, water depth in estuary will increase (~1 – 2m) and inter-tidal areas will be inundated for part of the time that the mouth is closed.

Confidence: Low

Table 4.5: Monthly Runoff Data (in m³/s) for Scenario 4, Simulated over a 68-year Period

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Closed
1920	12.88	12.88	12.88	12.88	96.92	28.43	74.02	15.61	7.24	4.61	4.38	4.89	4
1921	12.88	12.88	293.86	86.62	13.00	13.89	14.89	10.89	7.24	4.61	4.38	4.89	4
1922	12.88	103.09	94.90	513.65	581.93	328.40	179.44	11.39	7.24	4.61	4.38	4.89	4
1923	12.88	12.88	12.88	12.88	13.00	14.63	107.28	10.89	7.24	4.61	4.38	4.89	4
1924	12.88	12.88	12.88	16.33	236.49	**3433.81**	1827.20	662.77	75.76	4.61	4.38	4.89	3
1925	12.88	12.88	12.88	15.17	13.00	18.13	14.89	10.89	8.65	4.61	4.38	4.89	4
1926	12.88	12.88	12.88	12.88	13.00	15.88	15.39	10.89	7.24	4.61	4.38	4.89	4
1927	12.88	12.88	12.88	18.91	13.00	166.38	14.89	10.89	7.24	4.61	4.38	4.89	4
1928	12.88	12.88	12.88	12.88	13.00	70.43	14.89	10.89	7.24	4.61	4.38	4.89	4
1929	12.88	12.88	12.88	12.88	15.32	13.89	14.89	10.89	7.24	4.61	4.38	4.89	4
1930	12.88	12.88	12.88	22.95	30.63	138.14	14.89	10.89	7.24	4.61	4.38	4.89	4
1931	12.88	12.88	12.88	12.88	21.21	16.16	14.89	10.89	7.24	4.61	4.38	4.89	4
1932	21.60	12.88	12.88	12.88	13.12	13.89	14.89	10.89	7.24	4.61	4.38	4.89	4
1933	12.88	12.88	99.53	312.27	748.93	432.15	27.84	10.89	7.24	4.61	4.38	4.89	4
1934	12.88	191.71	493.34	14.59	13.00	103.91	102.09	167.18	17.37	4.61	4.38	4.89	3
1935	12.88	12.88	12.88	12.88	13.00	136.96	14.89	10.89	7.24	4.61	4.38	4.89	4
1936	12.88	661.10	185.92	729.78	1334.45	209.58	14.89	10.89	7.24	4.61	4.38	4.89	4
1937	12.88	12.88	12.88	133.96	13.00	13.89	31.52	12.75	7.24	4.61	4.38	4.89	4
1938	12.88	77.98	12.88	12.88	945.89	288.60	14.89	10.89	7.24	4.61	4.38	4.89	4
1939	12.88	12.88	28.05	12.88	81.12	13.89	249.05	176.33	7.24	4.61	4.38	4.89	4
1940	12.88	12.88	12.88	162.43	710.16	77.64	121.78	10.89	7.24	4.61	4.38	4.89	4
1941	12.88	12.88	12.88	12.88	342.40	18.42	46.39	16.07	7.24	4.61	4.38	4.89	4
1942	12.88	12.88	44.74	12.88	13.00	13.89	678.55	1134.08	163.60	353.16	108.29	13.93	0
1943	470.81	1807.27	1459.10	534.30	**2072.52**	516.53	14.89	10.89	7.24	4.61	4.38	4.89	4
1944	12.88	12.88	12.88	12.88	13.00	54.85	29.41	10.89	7.24	4.61	4.38	4.89	4
1945	12.88	12.88	12.88	12.88	13.00	13.89	14.89	10.89	7.24	4.61	4.38	4.89	4
1946	12.88	12.88	12.88	13.45	13.00	42.49	14.89	10.89	7.24	4.61	4.38	4.89	4
1947	12.88	12.88	12.88	14.03	28.31	14.76	128.47	10.89	7.24	4.61	4.38	4.89	4
1948	12.88	12.88	12.88	24.64	20.86	88.10	19.44	10.89	7.24	4.61	4.38	4.89	4
1949	12.88	12.88	12.88	12.88	319.59	326.43	35.42	230.64	82.33	12.87	182.43	4.89	1
1950	12.88	12.88	12.88	12.88	13.79	13.89	14.89	10.89	7.24	4.61	4.38	4.89	4
1951	12.88	12.88	12.88	12.88	260.83	13.89	14.89	10.89	7.24	4.61	4.38	4.89	4
1952	12.88	12.88	12.88	12.88	189.66	14.93	20.95	10.89	7.24	4.61	4.38	4.89	4
1953	12.88	12.88	34.86	12.88	22.73	386.50	14.89	10.89	7.24	4.61	4.38	4.89	4
1954	12.88	12.88	12.88	35.45	1272.56	426.61	111.47	39.62	7.24	4.61	4.38	4.89	4
1955	12.88	12.88	12.88	37.82	301.87	839.48	433.08	43.19	7.24	4.61	4.38	4.89	4
1956	12.88	12.88	652.74	478.46	103.74	145.73	14.89	10.89	7.24	4.61	4.38	1248.99	3
1957	1588.63	374.56	166.99	1020.29	149.65	13.89	14.89	205.61	31.30	4.61	4.38	4.89	3
1958	12.88	12.88	12.88	12.88	13.00	14.55	14.89	10.89	7.24	8.36	4.38	4.89	4
1959	12.88	12.88	12.88	12.88	38.48	98.37	105.67	11.63	7.24	4.61	4.38	4.89	4
1960	12.88	12.88	12.88	15.84	13.11	266.99	735.26	154.57	202.02	4.61	34.68	4.89	2
1961	12.88	12.88	82.15	12.88	889.15	237.92	22.80	10.89	7.24	4.61	4.38	4.89	4
1962	12.88	12.88	12.88	414.29	259.42	695.33	857.68	36.40	7.24	4.61	4.38	4.89	4
1963	12.88	12.88	12.88	12.88	13.00	13.89	24.66	10.89	7.24	4.61	4.38	4.89	4
1964	12.88	323.94	107.91	112.35	18.73	18.10	20.90	10.89	7.24	4.61	4.38	4.89	4
1965	12.88	12.88	13.14	31.83	58.08	20.56	30.30	11.29	7.24	4.61	4.38	4.89	4
1966	13.06	13.16	12.88	26.09	1230.82	487.55	1110.08	417.54	271.15	4.61	4.38	4.89	3
1967	12.88	19.36	12.88	12.88	13.00	60.22	32.76	41.24	7.24	4.61	4.38	4.89	4
1968	12.88	16.27	21.88	12.88	16.76	34.89	19.96	13.77	7.24	4.61	4.38	4.89	4
1969	12.88	12.88	12.88	12.88	14.89	13.89	16.01	11.20	7.24	4.61	4.38	4.89	4
1970	20.18	12.88	12.88	16.42	76.82	22.99	14.89	10.89	7.24	4.61	4.38	4.89	4
1971	12.88	12.88	12.88	166.16	14.01	492.00	67.08	11.36	7.24	4.61	4.38	4.89	4
1972	12.88	12.88	12.88	12.88	52.51	32.50	21.57	10.89	7.24	4.61	4.38	4.89	4
1973	12.88	12.88	12.88	381.11	**2088.49**	**2342.35**	658.73	244.12	75.85	8.10	281.88	5.57	2
1974	12.88	12.88	209.35	406.60	1962.15	887.53	134.09	10.89	7.24	4.61	4.38	4.89	4
1975	12.88	12.88	479.26	1980.42	**2960.83**	**2839.51**	944.80	535.36	114.21	9.07	7.27	6.57	3
1976	956.29	620.03	15.15	53.18	838.51	852.09	69.65	13.12	8.43	5.39	4.79	5.05	4
1977	12.90	12.88	12.88	227.34	338.40	239.11	1083.89	66.00	7.24	4.61	4.38	4.89	4
1978	12.88	12.88	12.88	13.57	26.98	21.05	16.11	11.19	7.24	4.61	4.38	4.89	4
1979	12.88	12.88	12.88	12.88	13.00	55.44	16.39	10.93	7.24	4.61	4.38	4.89	4
1980	12.88	12.88	12.88	12.88	13.00	24.43	15.44	10.89	7.24	4.61	4.38	4.89	4
1981	12.88	12.88	12.88	12.88	13.00	13.89	14.89	10.89	7.24	4.61	4.38	4.89	4
1982	12.88	12.88	15.91	12.88	13.00	13.89	22.20	10.89	7.24	4.61	4.38	4.89	4
1983	12.88	19.22	25.80	15.26	13.00	29.36	29.00	11.10	7.24	4.61	4.38	4.89	4
1984	12.91	12.88	12.88	14.24	15.89	32.78	14.96	10.89	7.24	4.61	4.38	4.89	4
1985	12.88	13.06	25.63	14.98	25.89	22.30	15.83	10.98	7.29	4.61	4.38	4.89	4
1986	12.88	12.88	12.88	12.88	32.11	18.38	16.39	11.14	7.24	4.61	4.38	4.89	4
1987	12.88	18.65	12.99	35.78	1670.08	**3733.57**	584.05	67.98	21.76	5.45	4.56	237.09	2

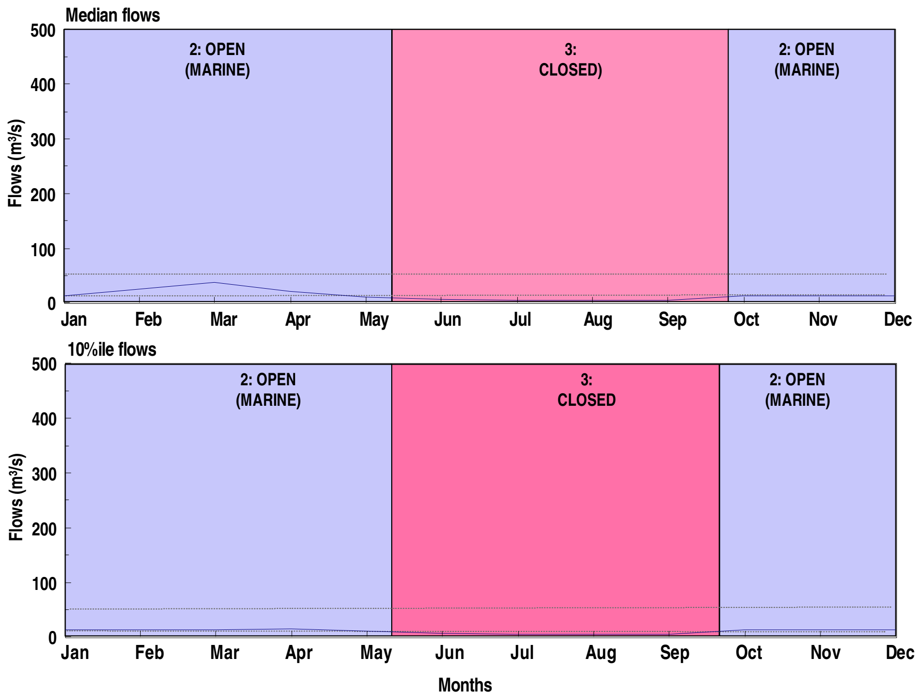
1: Open (River)	>50.0	2: Open (Marine)	10.0-50.0	3: Closed	< 10.0	**Floods**	> 2000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
< 10.0	0	0	0	0	0	0	0	0	58	66	64	65
10.0-50.0	65	60	56	51	39	35	46	56	3	1	1	1
>50.0	3	8	12	17	29	33	22	12	7	1	3	2

d. Occurrence and duration of different Abiotic states for Scenario 4

The occurrence and duration of the different Abiotic States under Scenario 4 are illustrated in the simulated monthly river flow table (**Table 4.5**).

To provide a conceptual overview of the annual distribution of Abiotic States under Scenario 4, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Predicted change in biotic characteristics of Scenario 4 compared with the Reference Condition

MICROALGAE

There is a further reduction in low flows and floods compared to Scenario 3. This would result in longer water retention time and the development of phytoplankton. The stable channels would allow for benthic microalgal colonisation. The mouth of the estuary could close for 4 months at a time. Due to inundation, the intertidal habitat for benthic microalgae will be lost. There may be an increase in subtidal benthic microalgae but this would depend on the suspended solid load and availability of light. Nutrients are also expected to be low during the closed phase. There is an increase in low flow and the estuary is in an open marine state for 8 months of the year. The freshwater state will no longer occur and the brackish / freshwater species will be lost.

Confidence: Low

MACROPHYTES

River flow and floods are reduced slightly more compared to the previous scenarios and therefore there is an increase in sediment stability and a loss of opportunistic, primary colonizers.

The mouth would close annually for 4 months at a time. For the rest of the time the estuary would be open and marine. The fundamental characteristics of this system as a freshwater river mouth is altered and changes in the macrophytes can be expected in response to salinity changes. When the mouth is closed, the intertidal areas will be flooded and the intertidal salt marsh plants submerged. In the desertified marsh area mouth closure and associated backflooding may have a beneficial influence in removing salts and promoting germination. This will only be the case if the water is below 35 ppt. Because the estuary is mostly in an open marine state, the water currently in the desertified marsh area may become hypersaline. This would reduce salt marsh growth and distribution.

Confidence: Low

INVERTEBRATES (INCLUDING ZOOPLANKTON)

The subtidal benthic community present in the deeper channel areas inside the mouth and described under previous scenarios (excluding the natural condition) is likely to change compared to Scenario 3. Riverine influence under this scenario no longer occurs and a more typical estuarine community will develop. Because of mouth closure for about 4 months of the year, oxygen depletion will prevail for longer, and the benthic community will probably consist of hardy types that are predominantly deposit feeders (benthic microalgae will also increase) and able to survive reduced oxygen concentrations.

The zooplankton will also consist of typical estuarine forms, but is expected to decrease during periods of mouth closure (food availability). It will increase again under open mouth conditions (remaining 7-8 months of the year) when suspended food availability increases, (nutrients will also enter the system from the sea). Because of the relatively long period under this situation, populations are likely to remain more stable compared to Scenario 3 where river dominance was also prevalent for part of the year (induce a shift in population composition). This situation will occur every year.

Invertebrates associated with the wetland on the southern bank near the mouth are also likely to respond positively to mouth closure and as water floods the wetland, provided salinity values remain within an estuarine range (5 – 35). It is possible that salinity concentrations will be higher in the wetland because of the longer residence time when the mouth is closed, larger surface area and consequent higher evaporation rates. Composition of the benthic community may also change, with deposit feeders becoming more dominant at times of mouth closure.

Confidence: Low

FISH

Similar to, but more extreme than Scenario 3. Although these conditions may allow the estuarine fish assemblage to become more stable, the advantages may be negated by mouth closure extending into spring and early summer therefore preventing any significant recruitment of estuarine dependent species. In turn, Caffrogobius spp. are unlikely to be able to return to the estuary after their marine larval stage. As with Scenario 3, all small and juvenile fish, especially the estuarine residents & breeders e.g. G.aestuaria, Caffrogobius spp. will benefit from backflooding and inundation of the saltmarsh during mouth closure. Non estuarine dependent marine species e.g., L. aureti will occur more frequently when the estuary is open and marine dominated but only freshwater species tolerant of high salinities e.g., O. mossambicus will still occur in any numbers. The likelihood of a more stable estuarine invertebrate community compared to Scenario 3 may mean prey availability not as limiting in Scenario 4. Extended mouth closure will probably greatly reduce the winter occurrence of A. inodorus in the estuary. The consequences for the stock status of this species are unknown and would be extremely difficult to identify or quantify.

As with Scenario 3 the lack of an alternative estuarine fish assemblage to that of the current freshwater tolerant one may result in an overall loss of species diversity. Low O_2 and the response of the fish assemblage are the same as for Scenario 3.

Confidence:

BIRDS

The situation for the estuary's birds will be similar to Scenario 3. Further concerns are that reduced river flow, a reduction in the transport of fluvial material and reduced overall flushing of the system will result in further stability of the braided channels and islands, which may affect the availability of suitable islets for breeding and roosting cormorants and terns. With the mouth being closed for a longer period, areas of open habitat (and the intertidal area) will be unavailable to waders. As the mouth will be closed during spring, these habitats will be unavailable to Palearctic waders that use west coast wetlands as stepping-stones on their way to final austral summer destinations, such as Langebaan Lagoon. The system will become marine-dominated which may reduce the area covered by certain macrophytes, resulting in more available habitat for waders. Negative influences on the estuary's fish (especially on recruitment) would affect piscivorous bird species. Although the saltmarsh will be inundated for a longer period, the system may become hypersaline and thus vegetation recruitment may not take place. Consequently, this area may not be restored to its near natural state. The backflooding of the estuary into the early summer months may result in low-lying areas (such as islands) being unavailable for breeding during this period.

Confidence: Low

f. EHI Tables for Scenario 4

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	25	For the Orange River Estuary low flows is defined as flows associated with the *State 3: Closed* (i.e. <10.0 m^3/s) and *State 2: Open (Marine*) (between 10.0 and 50.0 m^3/s). Months with median low flows of less than 50.0 m^3/s increased form 3 (Jul – Sep) under the Reference Condition to 12 under the Scenario 4.	Low
b. % similarity in the magnitude of major floods (e.g. 1:20, 1:50 and 1:100) in comparison with the Reference Condition	40	For the Orange River floods greater than 5000 x $10^6 m^3$ were judged to be resetting events. These have been significantly reduced from 20 under the Reference Conditions to 8 under the Scenario 4.	Low
	31		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 68 year period	0	For the Orange River Estuary mouth closure occurs at flows less than 10 m³/s. Under the Reference Condition the estuary mouth use to close 18 out of the 68 years (26%) for about 1 month at a time, while under Scenario 4 mouth closure occur annually (100%) for 3 – 4 months at a time. Alternatively, out of a total of 816 months (68 years), mouth closure increased from ~3% in the Reference Conditions to ~31.0 % under the Scenario 4. *Note: Following a precautionary approach, and in view of the importance of mouth closure and related back flooding to estuarine health, the mouth closures were score severely.*	Low
	0		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	10	There has been severe modification in the salinity distribution. Where *State 3: Closed* seldom occurred under the Reference Condition it is now present for 4 months (Jun–Sep) of the year. *State 1: Open (riverine)* no longer occurs while *State 2: Open (Marine*) occurs for 8 months (Oct -May) of the year.	Low
2a. Nitrate and phosphate concentration in the estuary	70	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. This would be slightly less compared with the Present State due to lower river inflow thus allow for 5% change. With an increase in State 2, (i.e. stronger marine influence) during Aug-Jan and May, it is possible that nutrient concentrations in the bottom waters of the deeper basin near the mouth may at time be slightly higher than for the Reference Conditions (in particular during Oct to Apr when upwelling occurs at sea). Allow for an additional 10% change. In addition, State 3 now occurs for 4 months (Jun-Sep) of the year when the system is expected to become nutrient depleted (under the Reference Condition it still had some nutrient supply albeit low during these months). Allow for a further 10% change.	Low
2b. Suspended solids present in inflowing freshwater	70	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in State 1 (i.e. strong river influence), less compared to Scenario 3.	Low
2c. Dissolved oxygen (DO) in the estuary	65	Although the estuary is expected to remain well-oxygenated during States 2, a decrease in dissolved oxygen in the bottom waters of the deeper basin could be expected under State 3, which under Scenario 4 could occur for 4 months of the year. Occasional events of low oxygen, river water inflow may also still occur, associated with algal blooms developing upstream.	Low
2d. Levels of toxins	90	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Allow for a 10% change.	Low
	43		

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	60	Under Scenario 4 the river flows and floods are reduced slightly more compared to the previous scenarios (1, 2 and 3). In addition, due to mouth closure for ~1/4-1/3 of year and continued inflow into estuary, water level in estuary will rise when mouth closed. Thus, intertidal areas will be inundated for period of mouth closure. However, the largest changes were due to other anthropogenic impacts. Thus, the score is less than for the previous three scenarios.	Low
1b	% similarity in sand fraction relative to total sand and mud	85	The sediment regime is much the same as the previous three scenarios, but the further small reduction in the riverine components has an additional small impact. Also, due to prolonged mouth closure, marine sediment intrusion (through the open mouth) will also be slightly reduced.	Low
2	Resemblance of subtidal estuary to Reference Condition: depth, bed or channel morphology	70	The sediment regime is much the same as the previous three scenarios, but the further small reduction in the riverine components has an additional small impact. Also, the changes in terms of physical habitat alteration due to prolonged mouth closure, are localised and small in relation to overall sub-tidal estuary domain. However, due to mouth closure for ~1/4 of year and continued inflow into estuary, water level in estuary will rise when mouth closed. Thus, water depth in estuary will increase (~1 – 2m) for period of mouth closure.	Low
		71		

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%* 60	*Score* 17	It is estimated that approximately 40 % of the original species remain. The freshwater state will no longer occur and there will be a loss of freshwater / brackish species.	Low
2a. Abundance	60		The mouth of the estuary could close for 4 months at a time. Under these conditions, there will be a loss of intertidal habitat for benthic microalgae. There may be an increase in subtidal benthic microalgae but this would depend on the suspended solid load and availability of light. Nutrients are also expected to be low during the closed phase. Longer water retention time would allow the development of phytoplankton.when the mouth is open, however, the reduction in freshwater inflow would reduce the extent of the river-estuary interface zone. The biomass is expected to be 40 % higher than what it was under Reference Conditions.	Low
2b. Community composition	20		Because of the greater water retention, time flagellates would dominate the phytoplankton rather than diatoms. Marine communities would displace brackish and fresh communities. Subtidal benthic microalgae would replace intertidal communities during closed mouth conditions.	Low
	17			

Macrophytes

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%* 50	*Score* 25	Loss of opportunistic species due to reduction in resetting floods. Increase in salinity may result in loss of freshwater / brackish species and would reduce the growth and distribution of salt marsh species in the desertified marsh area. Submergence with saline water for 3-4 months may result in the loss of some sensitive intertidal species.	Low
2a. Abundance	20		In 1986, 90% of the large salt marsh area on the southern bank was lost and became desertified. However, recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. A complete loss of freshwater conditions would increase salinity and reduce macrophyte growth and biomass.	Low
2b. Community composition	35		The increase in saline conditions may change the community composition in the main channel and desertified marsh area. There would be a loss of the freshwater / brackish community. As a result of these changes, the current community composition is 35% similar to the original composition.	Low
	20			

Invertebrates

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%* 30	*Score* 10	The presence of the estuarine/brachish water lens inside the mouth for most of the year and low oxygen concentrations that develop for about 4 months, will severely affect invertebrate benthic species that might occur here under the natural state. The riverine influence prevalent under the reference condition is no longer applicable under this scenario. Species richness is therefore likely to change by about 80% compared to the natural state. By contrast, species richness is likely to increase in the wetland along the southern shore because of the longer persistence of estuarine abiotic conditions (reduced freshwater flushing). The net change (benthos and zooplankton) will be about 70% compared to the natural state.	Low
2a. Abundance	30		Abundance levels of fresh or brackish water benthic animals will decline significantly because of the absence of a riverine influence. Under this scenario, there has been a marked reduction in the larger floods that played an important role in flushing the wetland and leaching out salts, preventing excessive saline built up. A high salt content in the sediment would reduce abundance levels. However, backwashing could assume part of the role in removing excessive salts. Under this scenario, it is possible that salt concentrations will build up over time because of the lack of freshwater flooding that removes salts.	Low
2b. Community composition	30		The composition of the sub-tidal benthic community is likely to change significantly under this scenario. The community will shift towards an estuarine type with some change induced by low oxygen levels. Some species will disappear because of reduced O_2 levels. Feeding guilds are also likely to shift during closed mouth conditions, with deposit feeders becoming more common. Inter-tidal invertebrates in the wetland area will also change towards a more sub-tidal type, because of inundation of the area for three months of the year.	Low
	10			

Fish

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	Score		
1. Species richness	40	17	Only remnants of freshwater community remaining, only the introduced *O. mossambicus* in any certainty. Possible recruitment failure of estuarine dependent species e.g., *L. lithognathus, L. amia* & *Caffrogobius* spp. due to mouth closure during the main recruitment period. More marine species present but not part of original assemblage.	Low
2a. Abundance	60		Freshwater fish biomass loss but *L. richardsonii* may increase in numbers due to lack of competition with, and predation by, species that failed to recruit. This species, an estuarine and surf-zone resident, does recruit opportunistically during open mouth periods.	Low
2b. Community composition	30		Probable loss of estuarine dependent species that have a short recruitment window e.g. *L. lithognathus* & *L.amia*. System dominated numerically and by mass, by partially estuarine dependent *L. richardsonii* tthat recruits opportunistically and the estuarine breeder *G. aestuaria*. Freshwater species absent and non-estuarine dependent species more common during the open phase in response to higher salinities.	Low
	17			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	Score		
1. Species richness	100	100	Probably no change in species composition, as even species that are negatively affected will be present in low numbers.	Low
2a. Abundance	15		With an extended period of backflooding and the inundation of low-lying areas, less open habitat will be available to waders and their numbers could be reduced. A reduction in reedbeds may affect the bird species that are dependent on these habitats, but more open habitat areas would become available to waders. Species dependent on the saltmarsh habitat may be present in larger numbers, but with hypersaline conditions expected, it is possible that the saltmarsh will not be revegetated by saltmarsh vegetation. An extended period of backflooding will mean that breeding habitats (such as islands) may be inundated during early summer. Further stability of the braided channels and islands will mean that the cormorant and tern breeding islets may not be established and maintained. Roost and breeding areas will be flooded, with an effect on cormorants, terns and gulls. Changes in fish populations may affect piscivorous birds.	Low
2b. Community composition	25		When back flooding occurs during winter and spring, there will be less habitat available for wading birds and this group will therefore be present in lower numbers. Conditions will not be suitable for the establishment and maintenance of the tern and cormorant roosting and breeding islands and low-lying breeding/roosting areas will be flooded during winter and early summer.	Low
	15			

4.2.5 Scenario 5: River Class C

a. Described seasonal variability in river inflow (based on simulated runoff data for this scenario)

Monthly-simulated runoff data for Scenario 5, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 4.6**. The MAR under Scenario 5 is 1 969.5 x 10^6 m^3 (18.18% of natural MAR remaining). A statistical analysis of the monthly-simulated runoff data in m^3/s for Scenario 5 is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	56.29	93.79	160.41	138.97	456.39	180.54	121.32	55.10	34.12	25.53	25.42	21.62
80%ile	54.82	91.37	140.18	123.85	378.45	175.23	117.89	53.77	33.47	25.12	24.95	20.62
70%ile	51.18	81.77	113.88	102.11	306.16	160.29	111.23	49.87	30.79	23.62	23.92	19.36
60%ile	45.97	72.47	90.25	88.45	239.59	130.33	93.38	47.24	29.07	21.46	22.15	17.93
50%ile	37.84	58.01	60.54	64.03	151.07	112.00	83.70	40.84	26.04	19.65	19.20	15.55
40%ile	29.19	42.52	45.29	50.62	111.61	86.46	67.40	33.78	21.80	16.72	16.32	13.57
30%ile	21.53	30.92	33.87	39.60	80.88	66.09	52.10	27.64	17.85	13.79	13.58	10.78
20%ile	14.88	23.89	27.16	33.47	63.13	51.19	40.53	22.56	14.78	11.48	11.20	8.49
10%ile	12.59	20.94	24.80	31.22	57.22	47.37	35.27	20.19	13.16	10.19	10.04	2.93
1%ile	0.00	8.80	22.14	21.71	35.32	30.88	24.73	13.53	11.48	9.74	7.60	0.08

Confidence: Low

b. Flood regime for the Scenario 5

There where no detailed analysis done on the reduction in the magnitude and frequency of floods for the Orange River System for Scenario 5.

Larger floods (represented by months with average flows greater than 5000 x $10^6 m^3$) in turned played an important role in resetting the habitat of the estuary. An evaluation of the Present State simulated runoff scenario indicates that there has been a marked reduction in the occurrence of monthly flows greater than 5000 x 10^6m^3 (reprehensive of major flood events), from 20 under the Reference Condition to 0 at present. On average, the highest monthly flows under Scenario 5 have been reduce to 10% of its Reference Condition flows.

Confidence: Low

c. Changes in sediment processes and characteristics for Scenario 5

Under Scenario 5, there are no large/resetting floods to scour out estuarine sediments. Thus, there will probably be a net accumulation of sediments, both riverine and marine. The mainly braided channels in the upper estuary could change to a mostly meandering nature. More permanent and larger sandbanks will occur throughout the estuary. Due to the net sediment build-up, the estuary (and inter-tidal areas) could eventually reduce significantly in size.

Due to the significantly reduced riverine sediment inputs, with some amount of ongoing marine sediment intrusion (and in the absence of major flushing), marine sediments (coarser and non-cohesive) will constitute a much larger proportion of estuarine sediments than during reference or present conditions.

The sub-tidal area, e.g. basin and lower channels, will become smaller and shallower. The morphological character of the braided channels is also likely to change substantially.

Confidence: Low

Table 4.6: Monthly Runoff Data (in m³/s) for Scenario 5, Simulated over a 68-year Period

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Closed
1920	56.31	45.29	25.07	34.68	239.35	179.85	118.77	42.64	21.91	13.78	11.33	17.83	0
1921	24.25	92.05	170.15	89.47	62.67	42.40	34.29	21.41	30.26	22.42	22.73	12.38	0
1922	52.92	94.66	82.83	134.87	414.03	158.70	71.48	34.07	33.14	25.28	22.13	11.34	0
1923	12.12	23.87	24.83	45.87	101.91	181.19	116.76	21.21	13.29	10.22	9.15	20.21	1
1924	43.09	91.04	145.80	79.79	294.05	181.19	121.55	55.25	34.17	24.33	18.74	18.99	0
1925	40.40	35.81	26.47	41.69	74.98	119.16	54.33	20.12	15.30	11.09	8.56	19.39	1
1926	27.06	23.94	30.87	32.61	80.68	175.49	105.29	22.02	12.89	13.64	20.54	8.27	1
1927	41.11	30.81	44.46	109.76	111.62	126.07	40.79	20.71	13.04	9.96	9.85	9.58	3
1928	23.89	58.16	33.67	52.72	62.68	160.47	51.37	30.20	34.17	25.64	24.07	21.68	0
1929	56.28	77.87	152.80	91.77	82.62	78.56	80.98	30.98	16.77	12.58	23.24	15.19	0
1930	27.79	14.05	24.73	84.50	145.65	96.85	120.51	53.28	14.81	25.64	25.07	6.70	1
1931	30.63	74.86	29.79	30.83	153.15	72.96	35.29	19.81	12.94	10.10	6.73	14.49	1
1932	15.57	22.72	27.33	30.39	55.18	47.89	34.85	17.97	12.87	10.11	8.03	0.00	2
1933	0.00	94.66	170.15	139.78	396.02	175.01	101.85	52.93	33.43	25.21	25.56	13.83	1
1934	47.18	94.66	170.15	35.62	63.79	151.20	89.00	54.09	32.12	17.96	25.36	17.87	0
1935	12.80	20.71	25.81	50.69	90.20	142.25	75.15	55.25	33.50	20.73	15.44	4.72	1
1936	46.37	94.66	135.07	139.78	406.65	109.08	40.35	22.61	14.76	12.32	11.11	0.12	1
1937	13.35	11.92	64.19	102.14	308.40	56.29	90.17	45.19	32.21	24.16	24.05	15.81	0
1938	54.84	58.70	100.16	123.76	453.56	127.36	35.99	38.24	24.74	25.18	25.19	18.78	0
1939	54.88	91.50	53.05	32.89	111.59	154.52	113.81	54.93	32.84	20.73	15.38	21.68	0
1940	38.59	69.82	106.34	111.34	369.88	79.07	90.32	31.83	14.12	17.33	15.44	13.60	0
1941	48.03	16.85	24.71	88.19	307.51	155.11	91.27	32.28	16.91	13.80	24.78	17.49	0
1942	51.80	79.84	170.15	96.04	57.26	62.96	121.55	55.25	34.17	25.64	25.56	21.60	0
1943	56.31	94.66	170.15	124.28	463.01	164.20	44.85	27.36	34.10	24.51	18.43	21.52	0
1944	54.79	41.37	24.70	29.90	72.07	175.37	68.86	30.46	24.01	15.05	10.51	0.25	1
1945	0.00	2.46	24.70	107.72	196.60	108.66	68.48	55.03	33.52	16.17	10.31	2.11	3
1946	52.76	46.38	27.31	33.59	98.53	52.74	61.77	42.94	21.08	16.79	13.02	21.25	0
1947	51.77	30.86	116.82	93.47	140.39	181.19	120.02	40.39	17.49	11.50	10.34	3.38	1
1948	19.35	21.04	16.96	34.77	62.31	75.25	38.28	32.63	18.13	12.02	10.81	3.28	1
1949	17.60	78.72	137.69	56.20	250.17	179.98	121.55	55.25	34.08	25.49	25.56	21.26	0
1950	16.82	13.75	114.14	99.78	80.41	53.94	57.53	34.79	26.15	19.96	17.94	13.46	0
1951	56.31	42.81	25.47	34.82	291.39	56.40	39.40	23.81	18.78	25.64	25.19	18.91	0
1952	16.29	59.65	43.47	31.39	381.39	101.92	108.92	47.52	19.76	11.46	13.55	9.81	1
1953	48.25	50.07	67.98	40.38	149.00	181.19	111.33	39.49	29.70	17.96	10.12	1.38	1
1954	10.74	26.29	35.09	138.63	463.01	155.84	86.53	49.38	30.10	21.07	16.54	4.70	1
1955	19.11	52.26	107.34	50.31	355.89	180.25	118.65	49.92	29.71	18.14	13.24	8.82	1
1956	37.09	80.55	170.15	123.91	128.67	87.02	52.21	22.75	17.10	25.64	25.56	21.68	0
1957	56.31	91.57	107.53	139.78	153.74	47.12	80.65	55.03	33.53	17.86	13.16	16.50	0
1958	14.11	72.28	111.59	49.43	94.44	50.01	109.00	55.25	33.55	25.64	24.06	10.72	0
1959	45.87	73.21	127.58	57.31	173.07	124.31	86.66	47.44	27.24	19.87	23.96	17.60	0
1960	44.56	65.82	141.85	70.92	60.62	173.94	121.23	54.37	34.17	24.76	25.24	12.01	0
1961	9.92	84.65	144.65	39.51	405.94	114.91	47.16	48.42	17.84	11.65	10.78	10.05	1
1962	9.59	85.82	40.02	139.78	240.57	172.58	121.55	47.19	25.92	25.64	24.28	15.30	1
1963	24.71	91.24	92.57	66.05	60.92	104.15	110.29	26.36	25.93	22.89	22.27	16.99	0
1964	56.31	92.00	56.13	66.38	62.38	35.88	102.81	38.58	30.32	22.89	22.57	20.35	0
1965	33.97	23.35	24.74	130.37	348.77	44.15	34.47	20.16	13.14	9.67	8.36	1.99	3
1966	9.00	22.32	59.79	139.78	463.01	163.01	121.55	55.25	34.17	25.16	22.43	14.71	1
1967	14.42	60.29	33.73	30.17	24.22	65.33	63.06	54.30	28.67	20.96	13.47	15.17	0
1968	12.87	14.21	45.50	30.42	54.65	124.00	113.02	49.42	30.79	14.02	15.21	4.35	1
1969	54.89	28.94	56.44	32.65	68.82	29.10	5.41	6.57	9.08	10.01	11.55	18.16	3
1970	54.18	32.84	89.67	72.16	197.58	50.15	115.59	52.56	21.39	15.30	13.83	11.52	0
1971	13.77	31.42	58.96	135.17	380.17	181.19	112.55	52.65	28.92	16.48	14.14	10.11	0
1972	21.27	23.02	24.74	5.24	133.40	53.57	54.85	22.52	13.76	9.77	25.08	19.04	2
1973	32.40	24.64	85.75	139.78	463.01	181.19	120.04	54.85	33.90	23.63	25.56	20.51	0
1974	13.58	92.55	142.52	117.54	463.01	177.78	86.42	41.29	28.61	25.06	22.02	20.40	0
1975	48.69	89.49	170.15	139.78	463.01	181.19	121.55	55.25	34.17	25.44	23.59	21.26	0
1976	56.31	94.66	36.85	56.88	375.87	176.43	72.54	36.00	25.02	19.42	16.85	20.49	0
1977	55.07	48.22	39.52	136.97	252.14	117.04	121.55	52.11	30.78	23.54	21.57	21.38	0
1978	51.45	22.20	146.65	33.39	67.91	49.41	34.25	23.55	17.97	24.91	25.56	21.66	0
1979	55.30	57.86	53.82	46.76	191.08	82.02	35.22	18.95	13.16	11.20	19.81	20.37	0
1980	33.76	38.38	61.29	122.25	340.00	166.87	50.46	45.90	34.17	21.21	25.56	21.68	0
1981	26.09	32.03	72.82	35.05	54.43	44.20	115.16	49.26	28.34	23.26	19.66	13.02	0
1982	46.38	91.45	25.42	29.82	40.79	31.75	34.49	23.35	22.13	23.49	21.11	10.08	0
1983	34.97	81.90	118.44	101.89	52.86	47.48	42.71	46.99	14.49	11.10	17.04	18.98	0
1984	29.54	27.92	27.06	32.43	251.58	84.19	36.83	16.95	14.34	10.31	8.93	1.73	2
1985	38.83	86.18	156.24	62.01	111.64	48.86	37.20	21.14	27.69	11.03	17.36	20.69	0
1986	55.21	94.66	33.47	32.10	57.12	47.67	52.09	20.21	12.65	9.98	24.68	21.68	1
1987	56.31	93.42	130.75	53.27	463.01	100.15	119.61	51.67	33.16	25.27	25.09	21.68	0

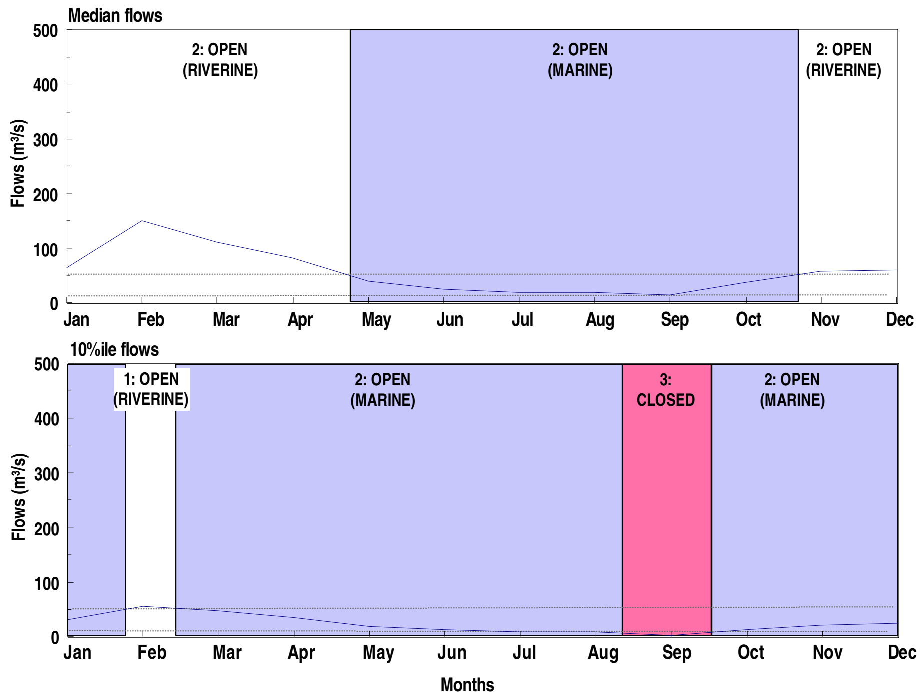
1: Open (River)	>50.0	2: Open (Marine)	10.0-50.0	3: Closed	< 10.0	Floods	> 2000

< 10.0	5	1	0	1	0	0	1	1	1	4	7	17
10.0-50.0	42	30	28	25	2	12	17	47	67	64	61	51
>50.0	21	37	40	42	66	56	50	20	0	0	0	0

d. Occurrence and duration of different Abiotic states for Scenario 5

The occurrence and duration of the different Abiotic States under Scenario 5 are illustrated in the simulated monthly river flow table (**Table 4.6**).

To provide a conceptual overview of the annual distribution of Abiotic States under Scenario 5, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Predicted change in biotic characteristics of Scenario 5 compared with the Reference Condition

MICROALGAE

The river channels and islands are more stable. The estuary is no longer reset as there are no large floods. As a result of this there may be a loss of opportunistic benthic microalgal species. Successional community changes in the phytoplankton in response to flooding will no longer occur. The stable channels would allow for benthic microalgal colonisation. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be higher than the natural condition due to reduced flow and increased residence time.

Confidence: Low

MACROPHYTES

Large floods don't occur, the estuary no longer resets and is in a permanent stable state. More permanent and larger sandbanks will occur throughout the estuary and macrophytes will colonize these. There will be a loss of open surface water area. There will be a loss of opportunistic primary colonizers and a decrease in diversity. In the desertified marsh area flushing by large freshwater floods will no longer occur. A long-term increase in salinity would favour salt marsh communities over brackish reeds and sedges. However, these would still be represented in the main river channel.

Confidence: Low

INVERTEBRATES (INCLUDING ZOOPLANKTON)

The subtidal benthic community present in the deeper channel areas inside the mouth will change from an estuarine type community (6 months – May to November) to a more brackish-freshwater type community during the summer. The time interval should be sufficient to allow each type to establish itself. Because of the greater intrusion of marine sand at the expense of muds, species associated with sand will extend further upstream.

The zooplankton will respond in a similar way to the subtidal benthos, although response will be much quicker. Some estuarine types will probably survive for longer in protected backwaters where suitable salinity conditions (>5 ppt) persist because of the braided nature of channels and sandbanks.

Invertebrates associated with the wetland on the southern bank near the mouth are also likely to be dominated by an estuarine community. Since floods no longer come through to flush out excess salts, salinity values could increase progressively over time and possibly become problematic (hypersaline).

Confidence: Low

FISH

If freshwater tolerant estuarine dependent species (e.g. Mugil cephalus) are swimming upstream during the summer high flows then a reduction in floods may result in a shrinking of their range within the system. This would be enhanced by the formation of a larger more persistent REI zone within the estuary. Depending on the cueing effect of flood events, recruitment of larvae and juvenile fish may be greatly reduced despite the mouth being open for most of the time. Backflooding and inundation of the saltmarsh and associated channels no longer occur resulting in almost complete loss of habitat and foraging area for Caffrogobius spp. However, alternative habitat may be available in the predicted shallow meandering channels, even more so if saltmarsh and alga growth become established within them. Saltwater penetration in the lower reaches may be beneficial to marine and estuarine predators (e.g. L. amia & P. saltatrix) and benthic feeders (e.g. L. lithognathus) that forage visually. Similarly, flocculation could lead to a slight loss of refuge from piscivorous predators in the shallows. In the absence of other anthropogenic influences, marine species are likely to occur more frequently in the saline lower estuary whereas freshwater species (with the exception of O. mossambicus) are likely to be confined to the head of the estuary and river reaches.

Confidence: Low

BIRDS

No resetting floods to scour out estuarine sediments and maintain islands, therefore roosting, breeding cormorant, and tern habitat would not be established and maintained. Fewer intertidal areas will result in less foraging habitat for waders. The larger area of sandbanks may provide habitats for roosting birds, especially at low tide, but over time these may eventually become colonised by reedbeds and this habitat will then become unavailable to waterbirds that use open habitats for foraging, roosting and breeding. A loss of open surface water area may reduce the feeding area of several species, including Great Cormorant and White Pelican. It is believed that the rehabilitation of the saltmarsh is complex, including a dependence on occasional inflow of freshwater via river channels. As this will no longer take place, the saltmarsh will remain in its degraded state, thus unavailable to waterbirds. A change in the invertebrate community could negatively influence waders.

Confidence: Low

f. EHI Tables for Scenario 5

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	75	For the Orange River Estuary low flows are defined as flows associated with the *State 3: Closed* (i.e. <10.0 m^3/s) and *State 2: Open (Marine)* (between 10.0 and 50.0 m^3/s). Months with median low flows of less than 50.0 m^3/s increased form 3 (Jul – Sep) under the Reference Condition to 6 (May - Oct) under Scenario 5.	Low
b. % similarity in the magnitude of major floods (e.g. 1:20, 1:50 and 1:100) in comparison with the reference condition	0	For the Orange River floods greater than 5000 x $10^6 m^3$ were judged to be resetting events. These have been significantly reduced from 20 under the Reference Conditions to 0 under the Scenario 5.	Low
	45		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 70 year period	55	For the Orange River Estuary mouth closure occurs at flows less than 10 m^3/s. Under the Reference condition the estuary mouth use to close 18 out of the 68 years (26%) for about 1 month at a time, while under the Scenario 5 mouth closure occurs for 27 out of 68 years (40 %) for about 1 month at a time. Alternatively, out of a total of 816 months (68 years), mouth closure decreased from 3% in the Reference Conditions to 4.7 % under the Scenario 5. *Note: Following a precautionary approach, and in view of the importance of mouth closure and related back flooding to estuarine health, the mouth closures were scored severely.*	Low
	55		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	70	There has been modification in the salinity distribution due to an increase of *State 2: Open (Marine)* and a decrease in *State 1: Open (Riverine)*. From being freshwater dominated for 9 months (Oct-Jun) of the year under the Reference Condition, the system is now only freshwater dominated for 6 months (Nov-Apr) with strong marine influence in the lower reaches for about 6 months (May-Oct).	Low
2a. Nitrate and phosphate concentration in the estuary	90	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. Allow for 10% change. Although State 2 increased, (i.e. stronger marine influence) compared to the Reference Conditions, the 'new' months in which this occurs is during winter when upwelling is not that regular along the west coast. Therefore, nutrient levels in the marine dominated waters in the estuary are expected to remain low throughout the year, similar to the Reference Condition.	Low
2b. Suspended solids present in inflowing freshwater	90	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in State 1 (i.e. strong river influence) – similar to the Present State	Low
2c. Dissolved oxygen (DO) in the estuary	80	It is expected that the system will remain well-oxygenated as was the case under the Reference Condition. However, occasional events of low oxygen, river water inflow may still occur, associated with algal blooms developing upstream.	Low
2d. Levels of toxins	80	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Furthermore, a marked reduction in floods could prevent period flushing of contaminated sediments, thus allow 20%.	Low
	76		

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	10	Under Scenario 5, there are no large/resetting floods to scour out estuarine sediments. Thus, there will probably be a net accumulation of sediments, both riverine and marine. The mainly braided channels in the upper estuary could change to a mostly meandering nature. More permanent and larger sandbanks will occur. Due to the net sediment build-up, the estuary (and inter-tidal areas) could eventually reduce significantly in size.	Low
1b	% similarity in sand fraction relative to total sand and mud	10	Due to the significantly reduced riverine sediment inputs, with some amount of ongoing marine sediment intrusion (and in the absence of major flushing), marine sediments (coarser and non-cohesive) will constitute a much larger proportion than during reference or present conditions.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	10	Similar to 1a and 1b above. This zone will become smaller and shallower. The morphological character of the channels is likely to change substantially.	Low
		10		

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	70	50	The river channels and islands are more stable. The estuary is no longer reset as there are no large floods. As a result of this there may be a loss of opportunistic benthic microalgal species. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species but to a lesser extent than it currently occurs.	Low
2a. Abundance	70		The stable channels would allow for benthic microalgal colonisation. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be higher than the natural condition. Biomass is expected to be 30 % higher than it was under reference conditions	Low
2b. Community composition	50		Because of the greater water retention, time flagellates would dominate the phytoplankton rather than diatoms. Successional community changes in response to floods will be lost.	Low
	50			

Macrophytes

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	50	25	The river channels and islands are stable. The estuary is no longer reset. As a result of this there will a loss of opportunistic species.	Low
2a. Abundance	30		In 1986, 90% of the large salt marsh area on the southern bank was lost and became desertified. However, recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. There will be an increase in macrophyte distribution and growth in the main channel as a result of the stable conditions due to the lack of floods.	Low
2b. Community composition	40		Stable conditions would promote the growth of both salt marsh and reeds in the main channel and it is difficult to say whether there will be a change in community composition. In the desertified marsh area flushing by large freshwater floods will no longer occur. An increase in salinity would favour salt marsh communities over brackish reeds and sedges. However, these would still be represented in the main river channel.	Low
	25			

Invertebrates

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	Score		
1. Species richness	60	35	Species richness associated with fresh or brackish water in the lower Orange River Mouth area will decline during part of the year (May to November) when marine influence is prevalent. The shift between states could also influence. Species richness, with relatively hardy species dominating.	Low
2a. Abundance	50		Adundance levels of species in the main channel will shift according to changes in the abiotic environment, with high variation in abundance in each group (successional pattern). Invertebrate abundance in the wetland area is unlikely to change significantly.	Low
2b. Community composition	50		There will be a significant shift in community composition between the two states, and will be driven by salinity changes.	Low
	35			

Fish

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	Score		
1. Species richness	40	17	Few of the original freshwater fish left in the estuary where previously they provided 50 % of the species. Probable loss of the Gobidae and less chance of the Syngnathidae occurring. More frequent occurrence of marine species in the system.	Low
2a. Abundance	60		Loss of freshwater species that provided 50 % of the biomass. Decrease in abundance of the Gobidae and probably *G. aestuaria* the latter, depending on the size of the REI zone, probably with the bulk of it's population in the freshwater reaches. Possible increase in abundance of L .richardsonii in response to reduced competition with other species. Overall decline in recruitment of estuarine dependent species due to reduced freshwater inflow and intensity of recruitment cues.	Low
2b. Community composition	40		Few freshwater species, mostly translocated *O .mossambicus*. Few Gobidae and other species associated with margins and channels of the saltmarsh. Increase in the numbers of marine piscivorous predators in addition to *L. amia* & *A. inodorus* that are already in the system. Detritivorous *L. richardsonii* and dominant whence under reference conditions and the presence of freshwater species the community was largely omnivorous.	Low
	17			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	Score		
1. Species richness	100	100	Probably no change in species composition, as even species that are negatively affected will be present in low numbers.	Low
2a. Abundance	24		Close to reference, but no floods. A larger area of sandbanks will in the short-term result in more roosting habitat for some species. As the sandbanks may eventually become colonised by reedbeds, this habitat will then become unavailable to waterbirds that use open habitats for foraging, roosting and breeding. Fewer intertidal areas will result in less foraging habitat for waders and their numbers will be reduced. Some species, such as rails and several passerines, will benefit from the increased area covered by reedbeds. A loss of open surface water area would reduce the feeding area available to several species, including Great Cormorant and White Pelican.	Low
2b. Community composition	35		Scenario 5 will reduce the availability of habitat for species dependent on open habitats. Less open water will result in a smaller feeding area for larger piscivorous bird species.	Low
	24			

4.2.6 Scenario 6: River Class D

a. Described seasonal variability in river inflow (based on simulated runoff data for this scenario)

Monthly-simulated runoff data for Scenario 6, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 4.7**. The MAR under Scenario 6 is 1 558.1 x 10^6 m^3 (14.38% of natural MAR remaining). A statistical analysis of the monthly-simulated runoff data in m^3/s for Scenario 6 is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	49.02	77.59	126.88	99.37	367.63	132.59	87.06	34.61	22.32	17.21	17.14	14.97
80%ile	47.78	75.68	109.65	87.21	300.59	129.15	84.96	34.04	22.03	17.01	16.92	14.47
70%ile	44.71	68.13	88.33	72.03	240.80	119.47	80.88	32.38	20.81	16.29	16.43	13.84
60%ile	40.32	60.81	70.19	63.29	188.43	100.04	69.95	31.26	20.03	15.27	15.59	13.14
50%ile	33.47	49.44	47.48	47.91	119.05	88.14	64.02	28.54	18.65	14.41	14.19	11.96
40%ile	26.18	37.25	37.49	40.92	92.17	71.58	54.03	25.53	16.73	13.02	12.82	10.97
30%ile	19.72	28.12	30.00	35.17	71.23	58.37	44.66	22.92	14.94	11.62	11.51	9.58
20%ile	14.11	22.59	25.60	31.98	59.14	48.70	37.57	20.76	13.54	10.52	10.38	8.00
10%ile	12.16	20.26	24.06	30.78	55.11	46.20	34.35	19.75	12.81	9.91	9.80	2.93
1%ile	0.00	8.80	21.51	21.71	35.32	30.88	24.36	13.53	11.41	9.68	7.60	0.08

Confidence: Low

b. Flood regime for the Scenario 6

There where no detailed analysis done on the reduction in the magnitude and frequency of floods for the Orange River System for Scenario 6.

Larger floods (represented by months with average flows greater than 5000 x $10^6 m^3$) in turned played an important role in resetting the habitat of the estuary. An evaluation of the Present State simulated runoff scenario indicates that there has been a marked reduction in the occurrence of monthly flows greater than 5000 x $10^6 m^3$ (reprehensive of major flood events), from 20 under the Reference Condition to 0 at present. On average the highest monthly flows under Scenario 6 have been reduce to 8% of its Reference Condition flows.

Confidence: Low

c. Changes in sediment processes and characteristics for Scenario 6

Similar to Scenario 5, because the river flow regime (e.g. no large/resetting floods to scour out estuarine sediments) and coastal processes/dynamics are very similar to Scenario 5.

Confidence: Low

Table 4.7: Monthly Runoff Data (in m³/s) for Scenario 6, Simulated over a 68-year Period

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	CLOSED
1920	49.04	39.43	24.23	32.62	188.24	132.15	85.50	29.30	16.78	11.62	10.44	13.09	0
1921	22.01	76.22	135.21	63.94	58.83	41.60	33.75	20.27	20.57	15.73	15.87	10.38	0
1922	46.18	78.27	64.50	96.06	331.17	118.43	56.53	25.66	21.88	17.08	15.58	9.86	1
1923	11.70	22.57	24.08	38.44	85.56	133.02	84.27	20.19	12.87	9.93	9.02	14.27	2
1924	37.90	75.42	114.38	57.75	231.27	133.02	87.20	34.67	22.34	16.64	13.97	13.66	0
1925	35.62	31.97	25.16	36.26	67.22	92.79	46.03	19.68	13.78	10.34	8.50	13.86	1
1926	24.38	22.63	28.04	31.53	71.10	129.32	77.24	20.53	12.69	11.55	14.82	7.80	1
1927	36.22	28.04	36.95	77.08	92.18	97.27	37.74	19.97	12.75	9.80	9.63	8.99	3
1928	21.71	49.56	29.88	42.02	58.84	119.58	44.22	24.01	22.34	17.25	16.50	15.00	0
1929	49.01	65.06	120.37	65.42	72.42	66.45	62.35	24.34	14.45	11.05	16.11	11.77	0
1930	25.00	13.89	24.01	60.76	115.36	78.32	86.57	33.83	13.56	17.25	16.98	6.38	1
1931	27.39	62.69	27.33	30.51	120.46	62.82	34.37	19.42	12.71	9.87	6.73	11.43	2
1932	14.70	21.67	25.72	30.21	53.33	46.57	34.10	17.83	12.68	9.88	8.03	0.00	3
1933	0.00	78.27	135.21	100.02	315.66	129.01	75.14	33.68	22.01	17.05	17.21	11.10	1
1934	41.35	78.27	135.21	33.10	59.59	113.57	67.26	34.18	21.41	13.61	17.11	13.11	0
1935	12.36	20.05	24.72	40.96	77.59	107.76	58.78	34.67	22.04	14.92	12.40	4.59	1
1936	40.66	78.27	105.48	100.02	324.81	86.25	37.47	20.78	13.53	10.93	10.34	0.12	1
1937	12.82	11.92	50.20	72.05	242.56	52.01	67.98	30.39	21.45	16.55	16.49	12.08	0
1938	47.80	49.98	77.80	87.15	365.20	98.10	34.80	27.43	18.06	17.04	17.03	13.56	0
1939	47.83	75.79	42.57	31.68	92.15	115.72	82.46	34.54	21.74	14.92	12.37	15.00	0
1940	34.10	58.73	82.54	78.21	293.50	66.79	68.07	24.71	13.24	13.31	12.40	10.98	0
1941	42.05	16.48	24.00	63.13	241.86	116.10	68.65	24.90	14.51	11.63	16.83	12.92	0
1942	45.23	66.61	135.21	68.15	55.15	56.34	87.20	34.67	22.34	17.25	17.21	14.96	0
1943	49.04	78.27	135.21	87.54	373.33	122.01	40.22	22.80	22.31	16.72	13.82	14.92	0
1944	47.76	36.35	23.99	29.87	65.23	129.25	54.93	24.12	17.74	12.23	10.05	0.25	1
1945	0.00	2.46	23.99	75.62	154.63	85.98	54.70	34.58	22.05	12.76	9.96	2.11	4
1946	46.05	40.29	25.71	32.05	83.26	49.71	50.59	29.44	16.40	13.05	11.25	14.79	0
1947	45.21	28.08	90.58	66.50	111.77	133.02	86.27	28.35	14.77	10.54	9.97	3.38	2
1948	17.89	20.35	16.48	32.66	58.59	64.31	36.19	25.04	15.07	10.78	10.20	3.28	1
1949	16.41	65.73	107.61	43.83	196.75	132.24	87.20	34.67	22.30	17.19	17.21	14.79	0
1950	15.75	13.61	88.52	70.54	70.92	50.49	47.99	25.96	18.70	14.56	13.59	10.92	0
1951	49.04	37.48	24.50	32.68	229.17	52.08	36.88	21.29	15.36	17.25	17.03	13.62	0
1952	15.30	50.73	36.29	30.90	303.08	81.60	79.46	31.38	15.80	10.52	11.50	9.10	1
1953	42.25	43.19	53.11	35.58	117.64	133.02	80.94	27.96	20.31	13.61	9.87	1.38	2
1954	10.38	24.48	30.81	99.09	373.33	116.58	65.75	32.17	20.50	15.08	12.92	4.57	1
1955	17.68	44.91	83.30	40.76	281.90	132.41	85.42	32.40	20.32	13.69	11.35	8.29	1
1956	32.83	67.16	135.21	87.25	103.79	71.95	44.73	20.84	14.60	17.25	17.21	15.00	0
1957	49.04	75.84	83.46	100.02	120.93	45.96	62.15	34.58	22.06	13.56	11.31	12.43	0
1958	13.47	60.66	86.57	40.30	80.48	47.94	79.51	34.67	22.06	17.25	16.49	9.55	1
1959	40.24	61.40	99.37	44.41	136.13	96.13	65.83	31.34	19.20	14.52	16.45	12.97	0
1960	39.14	55.58	111.00	52.08	57.44	128.32	87.00	34.30	22.34	16.84	17.05	10.20	0
1961	9.58	70.39	113.40	35.13	324.20	90.03	41.64	31.76	14.93	10.61	10.18	9.22	2
1962	9.26	71.32	34.04	100.02	189.20	127.43	87.20	31.24	18.60	17.25	16.60	11.83	1
1963	22.40	75.58	71.97	48.97	57.64	83.05	80.30	22.38	18.60	15.95	15.64	12.67	0
1964	49.04	76.18	44.60	49.17	58.64	35.57	75.72	27.58	20.60	15.95	15.79	14.34	0
1965	30.20	22.16	24.02	92.44	276.00	43.22	33.86	19.72	12.80	9.62	8.31	1.99	3
1966	8.69	21.36	46.99	100.02	373.33	121.23	87.20	34.67	22.34	17.03	15.72	11.54	1
1967	13.72	51.22	29.91	30.06	24.22	57.87	51.37	34.27	19.85	15.04	11.46	11.77	0
1968	12.42	14.04	37.62	30.23	52.87	95.93	81.98	32.19	20.81	11.73	12.29	4.26	1
1969	47.85	26.56	44.80	31.56	63.02	29.10	5.33	6.57	9.03	9.83	10.55	13.25	4
1970	47.24	29.63	69.74	52.87	155.40	48.03	83.55	33.53	16.54	12.34	11.63	9.95	1
1971	13.18	28.51	46.45	96.31	302.02	133.02	81.69	33.56	19.96	12.90	11.78	9.25	1
1972	19.50	21.91	24.02	5.24	107.01	50.25	46.35	20.74	13.08	9.71	16.98	13.69	2
1973	28.88	23.18	66.74	100.02	373.33	133.02	86.27	34.50	22.22	16.30	17.21	14.42	0
1974	13.02	76.60	111.58	82.67	373.33	130.81	65.69	28.73	19.82	16.98	15.52	14.36	0
1975	42.62	74.21	135.21	100.02	373.33	133.02	87.20	34.67	22.34	17.16	16.27	14.79	0
1976	49.04	78.27	31.96	44.18	298.45	129.93	57.18	26.47	18.19	14.30	13.06	14.41	0
1977	48.00	41.73	33.71	97.76	198.30	91.42	87.20	33.34	20.81	16.26	15.31	14.85	0
1978	44.94	21.26	115.11	31.94	62.40	47.55	33.73	21.18	14.99	16.91	17.21	14.99	0
1979	48.19	49.32	43.08	38.90	150.29	68.70	34.32	18.68	12.81	10.40	14.48	14.35	0
1980	30.03	33.99	47.98	86.06	268.74	123.73	43.66	30.69	22.34	15.15	17.21	15.00	0
1981	23.56	28.99	56.82	32.81	52.68	43.26	83.29	32.12	19.70	16.13	14.41	10.70	0
1982	40.67	75.74	24.47	29.82	40.79	31.75	33.88	21.09	16.88	16.23	15.09	9.24	1
1983	31.05	68.23	91.91	71.89	51.31	46.30	38.91	31.16	13.41	10.35	13.16	13.66	0
1984	26.47	25.76	25.54	31.44	197.86	70.11	35.31	16.95	13.34	9.97	8.82	1.73	3
1985	34.30	71.60	123.31	46.86	92.19	47.20	35.54	20.15	19.41	10.31	13.31	14.51	0
1986	48.11	78.27	29.74	31.27	55.03	46.42	44.66	19.76	12.58	9.82	16.79	15.00	1
1987	49.04	77.30	101.95	42.31	373.33	80.46	86.01	33.15	21.89	17.08	16.99	15.00	0

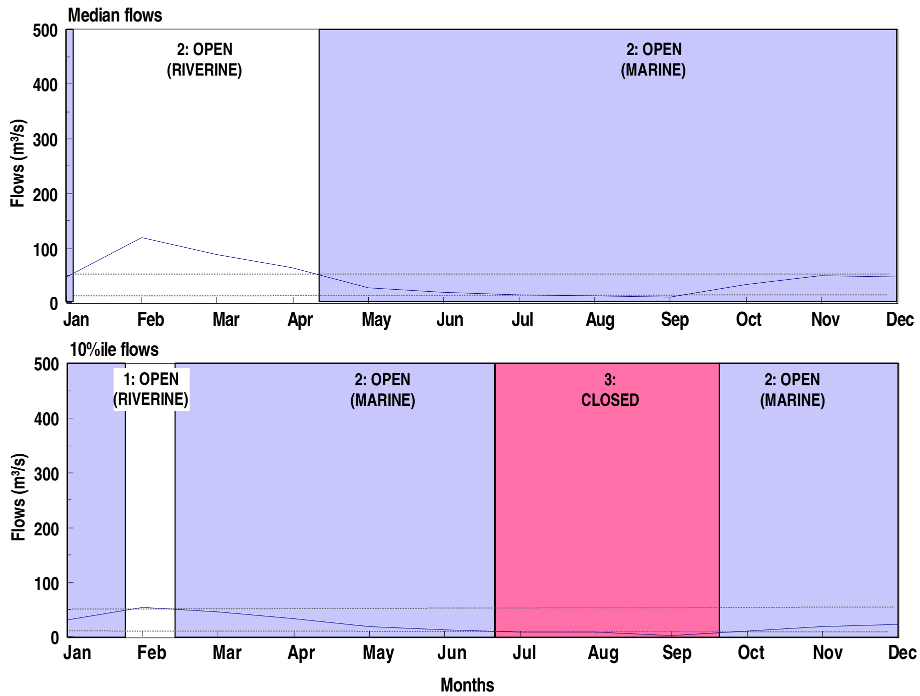
1: Open (River)	>50.0	2: Open (Marine)	10.0-50.0	3: Closed	< 10.0	Floods	> 2000	32.00				

< 10.0	5	1	0	1	0	0	1	1	1	9	10	23	52
10.0-50.0	63	35	35	35	2	15	24	67	67	59	58	45	505
>50.0	0	32	33	32	66	53	43	0	0	0	0	0	259

d. Occurrence and duration of different Abiotic states for Scenario 6

The occurrence and duration of the different Abiotic States under Scenario 6 are illustrated in the simulated monthly river flow table (**Table 4.7**).

To provide a conceptual overview of the annual distribution of Abiotic States under Scenario 6, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Predicted change in biotic characteristics of Scenario 6 compared with the Reference Condition:

MICROALGAE

This scenario differs from that of Scenario 5, in that there is a possibility of mouth closure and there is a decrease in the freshwater state, the estuary is now more marine. The river channels and islands are stable as there are no large floods. . As a result of this there may be a loss of opportunistic benthic microalgal species. Successional community changes in the phytoplankton in response to flooding will no longer occur. The stable channels would allow for benthic microalgal colonisation. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from the sea particularly during upwelling events.

Confidence: Low

MACROPHYTES

If large floods do not occur, the estuary no longer resets and is in a permanent stable state. More permanent and larger sandbanks will occur throughout the estuary and macrophytes will colonize these. There will be a loss of open surface water area. There will be a loss of opportunistic primary colonizers and a decrease in diversity. In the desertified marsh area flushing by large freshwater floods wil no longer occur. A long term increase in salinity would favour salt marsh communities over brackish reeds and sedges. There is an increase in the period of low flows and as a result of this the estuary is only freshwater dominated for 3 months (Feb-Apr) with strong marine influence in the lower reaches for about 9 months (May-Jan). This may decrease the diversity of brackish species in the mouth region and decrease the growth of the reeds and sedges.

Confidence: Low

INVERTEBRATES (INCLUDING ZOOPLANKTON)

The subtidal benthic community present in the deeper channel areas inside the mouth will consist of an estuarine type community most of the time (9 months). A freshwater associated community will only persist for 3 months of the year, but the time interval is probably too short to allow the community to establish itself. Because of the possibility of mouth closure for 1-2 months at a time, low oxygen concentrations may cause high mortality of benthic animals in winter.

Zooplankton succession will respond in a similar way to the subtidal benthos, although response will be much quicker. Three months spent under freshwater dominance should allow for the zooplankton to establish itself, but flushing of organisms out of the estuary will counter this. Some estuarine types will probably survive for longer in protected backwaters where suitable salinity conditions (>5 ppt) persist because of the braided nature of channels and sandbanks.

Invertebrates associated with the wetland on the southern bank near the mouth are also likely to be dominated by an estuarine community. Since floods no longer come through to flush out excess salts, salinity values could increase progressively over time and become problematic (hypersaline).

Confidence: Low

FISH

Scenario 6 differs from 5 in that the system is marine dominated for 3 months longer and closed phases occur more frequently and are of longer duration. Possible mouth closure through the main recruitment periods of spring and early summer may result in recruitment failure of some species (e.g. L. lithognathus). Juveniles of species such as L. richardsonii, that recruit opportunistically throughout most of the year, will not be as negatively impacted as those with short recruitment windows. With more frequent and extended mouth closure, backflooding of the saltmarsh areas may allow some rudimentary populations of species such as Caffrogobius to persist. On the whole however, there is unlikely to be much difference in species composition & abundance between scenarios 5 & 6.

If freshwater tolerant estuarine dependent species (e.g. Mugil cephalus) are swimming upstream during the summer high flows then a reduction in floods may result in a shrinking of their range within the system. This would be enhanced by the formation of a larger more persistent REI zone within the estuary. Depending on the cueing effect of flood events, recruitment of larvae and juvenile fish may be greatly reduced despite the mouth being open. Limited backflooding and inundation of the saltmarsh and associated channels coupled with an alternative habitat that may be available in the predicted shallow meandering channels may allow small populations of the Gobidae & Syngnathidae to exist. Saltwater penetration in the lower reaches may be beneficial to marine and estuarine predators (e.g. L. amia & P. saltatrix) and benthic feeders (e.g. L. lithognathus) that forage visually. Similarly, flocculation could lead to a slight loss of refuge from piscivorous predators in the shallows. In the absence of other anthropogenic influences, marine species are likely to occur more frequently in the saline lower estuary whereas freshwater species (with the exception of O. mossambicus) are likely to be confined to the head of the estuary and river reaches.

Confidence: Low

BIRDS

A larger area of sandbanks may, in the short term, result in more roosting habitat for certain bird species. These may, however, become colonized by macrophytes and then unavailable to these bird species (but increased salinity may negate this). Tern and cormorant breeding islands not established and maintained because of absence of floods and therefore no scouring of channels. Fewer intertidal areas will result in less foraging habitat for waders. There will be an estuarine dominated invertebrate community for most of the time, which could be beneficial to waders. A loss of open surface water area would reduce the feeding area of several species, including Great Cormorant and White Pelican. It is believed that the rehabilitation of the saltmarsh is complex, including a dependence on occasional inflow of freshwater via river channels. As this will no longer take place, the saltmarsh will remain in its degraded state, thus unavailable to waterbirds.

Confidence: Low

f. EHI Tables for Scenario 6

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	50	For the Orange River Estuary low flows is defined as flows associated with the *State 3: Closed* (i.e. <10.0 m^3/s) and *State 2: Open (Marine)* (between 10.0 and 50.0 m^3/s). Months with median low flows of less than 50.0 m^3/s increased form 3 (Jul – Sep) under the Reference Condition to 9 (May - Jan) under Scenario 6.	Low
b. % similarity in the magnitude of major floods (e.g. 1:20, 1:50 and 1:100) in comparison with the reference condition	0	For the Orange River floods greater than 5000 x $10^6 m^3$ were judged to be resetting events. These have been significantly reduced from 20 under the Reference conditions to 0 under the Scenario 6.	Low
	30		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 70 year period	25	For the Orange River Estuary mouth closure occurs at flows less than 10 m^3/s. Under the Reference condition, the estuary mouth used to close 18 out of the 68 years (26%) for about 1 month at a time, while under Scenario 6 mouth closure occurs for 32 out of 68 years (47 %) for about 1 – 2 months at a time. Alternatively, out of a total of 816 months (68 years), mouth closure decreased from 3% in the Reference Conditions to 6.4 % under Scenario 6. *Note: Following a precautionary approach, and in view of the importance of mouth closure and related back flooding to estuarine health, the mouth closures were scored severely.*	Low
	25		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	50	There has been modification in the salinity distribution due to an increase of *State 2: Open (Marine*) and a decrease in *State 1: Open (Riverine).* From being, freshwater dominated for 9 months (Oct-Jun) of the year under the Reference Condition; the system is now only freshwater dominated for 3 months (Feb-Apr) with strong marine influence in the lower reaches for about 9 months (May-Jan).	Low
2a. Nitrate and phosphate concentration in the estuary	80	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. Allow for 10% change. With an increase in State 2, (i.e. stronger marine influence) during Aug-Jan and May, it is possible that nutrient concentrations in the bottom waters of the deeper basin near the mouth may at time be slightly higher than for the Reference Conditions (in particular during Oct to Apr when upwelling occurs at sea). Allow for an additional 10% change.	Low
2b. Suspended solids present in inflowing freshwater	85	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in State 1 (i.e. strong river influence), slightly less compared with the Present State.	Low
2c. Dissolved oxygen (DO) in the estuary	80	It is expected that the estuary will remain well-oxygenated as was the case under the Reference Condition. However, occasional events of low oxygen, river water inflow may also still occur, associated with algal blooms developing upstream.	Low
2d. Levels of toxins	80	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Furthermore, a marked reduction in floods could prevent period flushing of contaminated sediments, thus allow 20%.	Low
	68		

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	10	Similar to Scenario 5 as the river flow regime (e.g. no large/resetting floods to scour out estuarine sediments) and coastal processes/dynamics are very similar to Scenario 5.	Low
1b	% similarity in sand fraction relative to total sand and mud	10	Similar to Scenario 5 as the river flow regime (e.g. no large/resetting floods to scour out estuarine sediments) and coastal processes/dynamics are very similar to Scenario 5.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	10	Similar to Scenario 5 as the river flow regime (e.g. no large/resetting floods to scour out estuarine sediments) and coastal processes/dynamics are very similar to Scenario 5.	Low
		10		

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	65	40	The river channels and islands are more stable. The estuary is no longer reset, as there are no large floods. As a result of this there may be a loss of opportunistic benthic microalgal species. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species similar to that of scenario 1 and 2.	Low
2a. Abundance	50		The stable channels would allow for benthic microalgal colonisation. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from the sea particularly during upwelling events. Biomass is expected to be 50 % higher than it was under reference conditions	Low
2b. Community composition	45		Because of the greater water retention, time flagellates would dominate the phytoplankton rather than diatoms. This effect will be greater than that for Scenario 5 due to the increase in low flow conditions. Successional community changes in response to floods will be lost.	Low
	40			

Macrophytes

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	45	20	The river channels and islands are stable. The estuary is no longer reset. As a result of this there will a loss of opportunistic species. Increase in salinity will reduce number of freshwater/brackwater species.	Low
2a. Abundance	40		In 1986 90% of the large salt marsh area on the southern bank was lost and became desertified. However recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. There will be an increase in macrophyte distribution and growth in the main channel as a result of the stable conditions. There will be an increase in salt marsh at the expense of reeds and sedges as a result of the increase in salinity.	Low
2b. Community composition	30		Stable, saline conditions would promote the growth of salt marsh at the expense of brackish communities (reeds and sedges). In the desertified marsh area flushing by large freshwater floods will no longer occur. An increase in salinity would favour salt marsh communities over brackish reeds and sedges.	Low
	20			

Invertebrates

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	50	25	Species richness of the subtidal benthos and associated with fresh or brackish water in the lower Orange River Mouth area will decline compared to the natural state. The 3 months window is relatively short for the commuity to fully establish itself.	Low
2a. Abundance	40		Adundance levels of brackish/freshwater associated species in the main channel will also decline because of the narrow window when suitable conditions prevail. Invertebrate abundance in the wetland area is unlikely to change significantly.	Low
2b. Community composition	35		The community composition is unlikely to restore itself tin comparison to the natural state, given the narrow window of time when conditions become suitable. Because of mouth closure on occasion, feeding guilds will probably shift towards more deposit feeding.	Low
	25			

Fish

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	30	10	Mouth closure over the recruitment window of some species (e.g. *L. lithognathus*) could result in recruitment failure and their loss from the system. Few of the original freshwater fish left in the estuary where previously they provided 50% of the species. Possible loss of the Gobidae and less chance of the Syngnathidae occurring. More frequent occurrence of marine species in the system.	Low
2a. Abundance	50		Loss of freshwater species that provided 50% of the biomass. Decrease in abundance of the Gobidae and probably *G. aestuaria* the latter, depending on the size of the REI zone, probably with the bulk of it's population in the freshwater reaches. Possible increase in abundance of *L .richardsonii* in response to reduced competition with other species. Overall decline in recruitment of estuarine dependent species due to reduced freshwater inflow and intensity of recruitment cues and mouth closure over the main recruitment window.	Low
2b. Community composition	30		Few freshwater species, mostly translocated *O .mossambicus*. Few Gobidae and other species associated with margins and channels of the saltmarsh. Increase in the numbers of marine piscivorous predators in addition to *L. amia* & *A. inodorus* that are already in the system. Detritivorous *L. richardsonii* and dominant whence under reference conditions and the presence of freshwater species the community was largely omnivorous. Recruitment failure and possible loss of *L. lithognathus* & *L. amia* from the system.	Low
	10			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	100	100	Probably no change in species composition, as even species that are negatively affected will be present in low numbers.	
2a. Abundance	24		Similar to Scenario 5. A larger area of sandbanks will in the short-term result in more roosting habitat for some species. As the sandbanks may eventually become colonised by reedbeds, this habitat will then become unavailable to waterbirds that use open habitats for foraging, roosting and breeding. Fewer intertidal areas will result in less foraging habitat for waders and their numbers will be reduced. Some species, such as rails and several passerine species will benefit from the increased area covered by reedbeds. A loss of open surface water may reduce the feeding area available to several species, including Great Cormorant and White Pelican.	
2b. Community composition	35		Scenario 6 will reduce the availability of habitat for species dependent on open habitats. Less open water will result in a smaller feeding area for larger piscivorous bird species.	
	24			

4.2.7 Scenario 7: Revised River Class D

a. Described seasonal variability in river inflow (based on simulated runoff data for this scenario)

Monthly-simulated runoff data for Scenario 7, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 4.8**. The MAR under Scenario 7 is 4 529.93 x 10^6 m^3 (41.73% of natural MAR remaining). A statistical analysis of the monthly-simulated runoff data in m^3/s for Scenario 7 is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	28.17	229.69	236.25	545.17	1373.57	790.16	713.61	213.14	63.03	26.40	23.21	24.42
80%ile	27.63	35.27	113.03	148.81	607.65	469.72	206.18	102.63	33.68	26.13	22.98	23.35
70%ile	26.25	33.68	38.42	74.47	381.22	278.09	139.12	54.34	31.69	25.35	22.49	22.06
60%ile	24.30	31.45	36.78	42.26	218.67	174.22	76.90	43.68	30.69	24.23	21.66	20.60
50%ile	21.25	28.45	32.51	37.73	145.99	93.14	62.42	37.87	29.11	23.29	20.18	18.17
40%ile	18.00	25.55	30.18	31.13	94.69	62.56	47.61	33.01	26.51	21.77	18.80	16.14
30%ile	15.13	22.70	26.85	27.47	70.18	52.26	38.31	28.79	24.08	20.24	17.49	13.28
20%ile	12.64	21.26	25.63	25.71	58.39	44.27	34.94	25.29	22.28	19.05	16.35	11.90
10%ile	11.85	20.68	25.20	25.10	54.85	43.10	30.17	23.67	21.32	18.38	15.83	11.12
1%ile	11.66	16.75	23.19	19.89	46.62	42.13	26.65	21.16	19.85	18.13	15.14	7.58

Confidence: Low

b. Flood regime for the Scenario 7

There was no detailed analysis done on the reduction in the magnitude and frequency of floods for the Orange River System for Scenario 7 - Similar to the Present State.

Confidence: Low

c. Changes in sediment processes and characteristics for Scenario 7

This scenario will have a similar effect on the sediment processes and characteristics and morphology as Scenario 1.

Confidence: Low

Table 4.8: Monthly Runoff Data (in m³/s) for Scenario 7, Simulated over a 68-year Period

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	CLOSED
1920	28.17	25.66	25.25	26.05	256.75	70.20	119.64	55.09	29.26	20.24	16.42	20.50	0
1921	16.15	143.14	457.39	109.89	57.06	43.04	29.40	24.50	31.38	24.73	21.86	14.92	0
1922	26.90	401.44	115.09	531.95	653.22	364.25	189.22	33.21	33.08	26.21	21.57	13.86	0
1923	11.84	21.26	25.21	29.27	85.33	86.78	204.82	24.36	21.40	18.40	15.76	22.93	0
1924	23.22	35.05	38.41	37.75	436.34	**3473.02**	1835.22	696.77	111.27	25.72	19.96	21.68	0
1925	22.21	23.71	25.50	28.07	65.93	54.60	38.09	23.66	22.58	18.85	15.70	22.09	0
1926	17.20	21.27	26.30	25.46	70.04	63.66	60.19	24.92	21.17	20.17	20.81	11.87	0
1927	22.47	22.69	28.78	43.43	92.32	236.71	42.52	24.01	21.25	18.26	15.82	12.06	0
1928	16.01	28.30	26.81	31.25	57.06	108.35	36.81	30.54	33.68	26.40	22.50	24.43	0
1929	28.17	32.34	297.52	139.29	71.43	48.07	49.65	31.08	23.45	19.62	22.10	17.79	0
1930	17.48	20.61	25.19	38.66	122.15	162.30	66.79	46.43	22.30	26.40	22.98	11.64	0
1931	18.54	31.72	26.11	25.10	138.28	47.17	29.84	23.63	21.20	18.33	14.08	17.08	0
1932	12.90	21.02	25.66	25.10	53.13	43.14	29.65	23.41	21.16	18.34	15.66	6.03	1
1933	11.66	35.79	109.98	1118.79	907.44	471.36	97.07	102.66	33.24	26.17	23.21	16.40	0
1934	24.75	419.49	691.39	26.32	57.86	173.94	137.38	200.71	52.75	22.41	23.11	20.54	0
1935	11.85	20.68	25.38	30.66	76.89	177.03	47.13	165.98	40.25	23.85	18.38	11.35	0
1936	24.45	917.48	201.62	749.34	1300.02	222.19	32.03	25.32	22.26	19.49	16.31	8.35	1
1937	12.06	20.59	32.11	155.16	257.35	44.49	62.02	40.86	32.53	25.63	22.49	18.43	0
1938	27.62	72.79	35.44	45.27	1287.99	333.87	30.14	36.08	28.13	26.16	23.04	21.47	0
1939	27.64	156.09	115.06	25.54	125.42	60.29	298.09	188.94	32.90	23.85	18.35	24.43	0
1940	21.53	30.69	100.71	280.54	699.89	121.27	155.29	31.67	21.89	22.08	18.38	16.17	0
1941	25.07	20.64	25.18	39.38	477.12	60.38	76.35	31.98	23.53	20.25	22.83	20.15	0
1942	26.48	32.75	189.03	78.73	53.16	45.56	819.89	1125.77	198.22	346.43	123.25	42.66	0
1943	482.09	1833.70	1497.60	576.00	**2116.16**	556.39	33.99	28.59	36.85	25.81	19.81	24.27	0
1944	70.43	30.98	25.18	25.10	63.82	278.80	64.57	30.72	27.70	20.90	16.03	10.94	0
1945	11.66	8.95	25.18	43.16	189.54	52.92	47.74	47.63	33.30	21.48	15.93	11.06	1
1946	26.84	25.88	25.66	25.74	82.90	63.11	41.32	39.31	25.98	21.80	17.23	24.00	0
1947	26.47	22.69	36.98	40.40	116.84	669.17	385.84	37.56	23.87	19.06	15.94	11.15	0
1948	14.31	20.68	19.15	26.08	56.80	110.60	31.13	32.22	24.25	19.33	16.17	11.14	0
1949	13.66	32.52	38.10	32.25	384.26	456.65	237.84	298.70	61.42	26.32	204.78	24.00	0
1950	13.36	20.61	36.73	41.63	69.84	44.12	39.48	33.70	28.97	23.45	19.58	16.03	0
1951	28.17	25.15	25.32	26.09	433.29	44.51	31.62	26.15	24.63	26.98	23.03	21.60	0
1952	13.16	28.60	28.60	25.10	470.83	76.77	95.94	42.47	25.20	19.04	17.48	12.30	0
1953	25.15	26.64	49.38	27.70	122.37	507.56	62.81	36.94	31.05	22.41	15.84	11.01	0
1954	11.82	21.76	27.07	71.76	1858.46	467.25	151.06	75.57	31.29	24.03	18.91	11.34	0
1955	14.22	27.09	36.10	38.58	539.31	912.13	471.96	78.38	31.06	22.50	17.33	11.95	0
1956	20.96	32.89	836.45	510.02	153.70	175.33	37.18	25.42	23.64	26.40	23.21	1372.55	0
1957	1538.05	410.86	209.99	1001.95	195.44	43.07	49.51	242.15	66.79	22.36	17.29	19.14	0
1958	12.35	31.20	36.50	30.30	79.95	43.48	61.80	158.51	50.05	76.87	22.49	13.22	0
1959	24.26	31.39	37.56	32.57	155.49	114.37	139.31	46.51	29.60	23.41	22.45	20.26	0
1960	23.77	29.87	140.16	92.12	55.58	318.56	749.74	180.48	233.75	25.94	76.17	14.54	0
1961	11.81	33.73	91.69	27.45	1065.96	261.36	36.38	63.25	24.07	19.14	16.16	12.54	0
1962	11.81	33.97	27.97	642.36	306.84	730.50	851.27	72.69	28.83	26.40	22.60	17.91	0
1963	16.32	35.08	53.57	35.09	55.80	52.19	207.09	27.90	28.83	24.97	21.64	19.63	0
1964	68.59	455.33	127.75	134.94	56.85	42.99	59.12	36.31	31.42	24.97	21.78	23.08	0
1965	19.80	21.15	25.19	48.95	353.86	43.05	38.18	23.66	21.32	18.06	15.69	11.05	0
1966	11.79	20.94	31.57	108.80	1545.17	509.79	1131.26	449.11	296.95	26.15	21.72	17.31	0
1967	12.46	28.73	26.83	25.10	33.85	99.50	79.07	78.15	30.45	23.97	17.44	17.77	0
1968	11.88	20.62	28.97	25.10	53.12	70.08	63.55	43.77	31.69	20.37	18.27	11.29	0
1969	27.64	22.30	30.96	25.47	61.48	40.44	21.10	16.84	17.45	18.29	16.52	20.83	0
1970	27.37	23.10	34.47	36.28	173.03	43.56	64.66	45.93	26.16	21.03	17.61	14.04	0
1971	12.22	22.81	31.42	277.74	324.09	749.32	162.96	45.99	30.59	21.64	17.76	12.60	0
1972	15.03	21.08	25.19	9.30	129.99	54.89	45.43	25.26	21.67	18.16	22.98	21.73	1
1973	19.21	21.42	34.11	746.66	**2562.52**	**2375.13**	698.12	277.82	110.29	25.35	338.10	23.24	0
1974	12.15	35.35	337.03	431.00	**2028.82**	928.43	173.90	38.18	30.41	26.10	21.52	23.12	0
1975	25.32	34.73	646.91	1992.96	**2925.31**	**2815.63**	963.13	570.98	145.43	31.52	22.27	24.00	0
1976	969.16	644.52	30.58	74.77	926.72	885.44	109.23	37.48	28.29	23.17	19.05	23.22	0
1977	27.71	26.26	27.88	424.58	385.18	271.72	1115.03	102.58	31.69	25.31	21.31	24.12	0
1978	26.36	20.91	38.43	25.68	60.83	43.39	29.39	25.97	24.16	26.02	23.21	24.42	0
1979	27.80	28.24	30.48	29.53	188.49	84.69	29.81	23.53	21.33	18.91	25.85	23.09	0
1980	19.72	24.24	31.84	45.07	286.74	290.31	36.42	41.35	33.68	24.10	90.44	62.37	0
1981	16.84	22.93	32.91	26.16	53.12	43.05	64.48	43.66	30.25	25.16	20.40	15.58	0
1982	24.45	35.13	25.31	25.10	52.91	42.96	30.18	25.83	26.60	25.28	21.08	12.57	0
1983	20.17	33.17	37.07	42.04	53.09	49.11	39.71	42.10	22.11	18.85	19.15	21.67	0
1984	18.13	22.09	25.61	25.41	209.16	59.11	30.51	23.29	22.01	18.44	15.74	11.04	0
1985	21.62	34.05	38.65	33.93	95.28	43.30	30.67	24.31	29.87	18.82	19.30	23.43	0
1986	27.76	35.79	26.78	25.31	59.17	43.11	37.12	23.67	21.03	18.27	22.79	24.43	0
1987	28.17	35.54	37.72	37.70	**3047.79**	**3733.57**	615.47	102.88	56.13	26.21	22.99	311.78	0

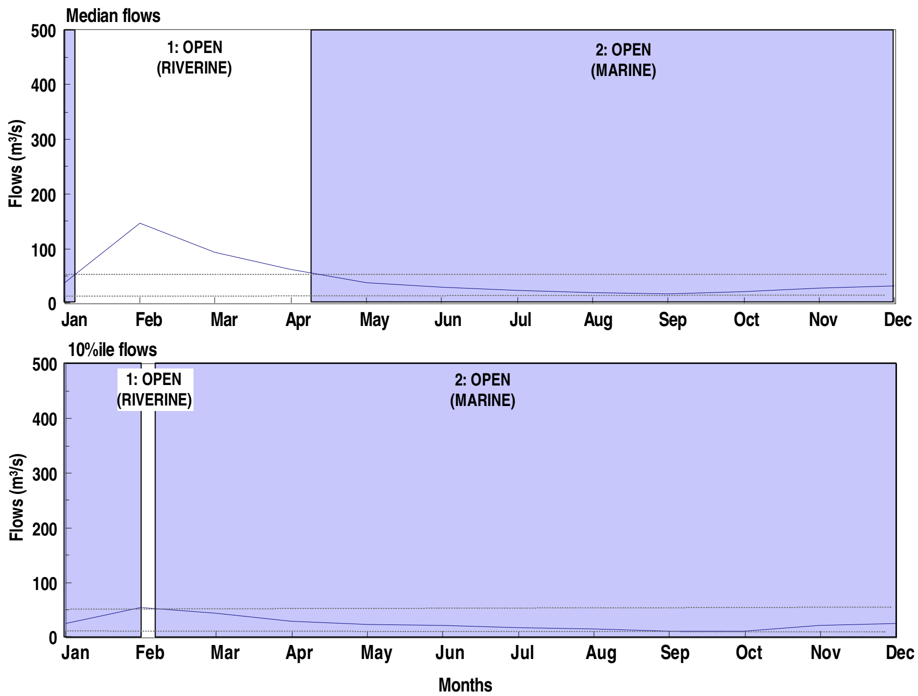
1: Open (River)	>50.0	2: Open (Marine)	10.0-50.0	3: Closed	< 10.0	**Floods**	> 2000

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
< 10.0	0	1	0	1	0	0	0	0	0	0	0	2
10.0-50.0	63	57	50	45	1	20	30	47	57	66	63	63
>50.0	5	10	18	22	67	48	38	21	11	2	5	3

d. Occurrence and duration of different Abiotic states for Scenario 7

The occurrence and duration of the different Abiotic States under Scenario 7 are illustrated in the simulated monthly river flow table (**Table 4.8**).

To provide a conceptual overview of the annual distribution of Abiotic States under Scenario 7, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Predicted change in biotic characteristics of Scenario 7 compared with the Reference Condition

MICROALGAE
This scenario is similar to that of Scenario 1 and 2. There is a further increase in low flow compared to the present state, which would result in longer water retention time and the development of phytoplankton. The stable channels would allow for benthic microalgal colonisation. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from the sea particularly during upwelling events. The reduction in the occurrence of the freshwater state would also reduce the suspended solid load which would increase light available for microalgal growth. **Confidence: Low**
MACROPHYTES
This scenario is similar to that of Scenario 1 and 2. There is an increase in the period of low flows and as a result of this the estuary is only freshwater dominated for 3 months (Feb-Apr) with strong marine influence in the lower reaches for about 9 months (May-Jan). This may decrease the diversity of brackish species in the mouth region and decrease the growth of the reeds and sedges. **Confidence:Low**

INVERTEBRATES (INCLUDING ZOOPLANKTON)

This scenario is similar to that of Scenario 1 and 2. This scenario would likely benefit the estuarine benthic community in the lower Orange River Mouth area in that the lens of estuarine water will persist for about 9 months of the year without interruption. Under the present scenario, this lens also breaks down for three months in winter. The persistence of the lens for a longer period without interruption will allow the community to become better established and not disappear in winter (freshwater will induce a shift towards a freshwater type community in this area – extension of upstream conditions towards the mouth). Species richness is also likely to increase.

Similarly, an estuarine zooplankton community is likely to become more prevalent in the estuarine water lens.

Invertebrates colonizing the wetland on the south bank are also likely to benefit, in that salinity is likely to increase because of tidal penetration from the main channel area, particularly around spring tides. This assumes that surface freshwater will be pushed further upstream with the tide. Greater input of nutrients with the tides will also lead to benefits for invertebrates through increased food availability.

Confidence: Low

FISH

Similar to Scenarios 1 & 2 and the same arguments apply. This scenario is closer to the reference state than present day in that the winter flows are no longer elevated through hydro releases. Estuarine conditions persist throughout winter but may extend into the summer months as the first summer high flows or floods are captured by the upstream dams. Although the estuarine fish assemblage is likely to become more stable, the cues provided by spring and early summer freshettes will be close to non-existent, leading to a reduction in recruitment, and depending on mortality levels, may lead to an overall decline in abundance of fish such as L. lithognathus and L. amia. An increase in benthic microalga would provide a foodsource for L. richardsonii to compensate for a decrease in the detrital load from upstream. An increase in the estuarine small invertebrate community would favour juvenile L. lithognathus and Caffrogobius spp.

Confidence: Low

BIRDS

Similar to Scenario 1 and 2. Estuary more marine dominated; decrease in brackish species and decrease in reeds and sedges. No mouth closure, besides for a few days at a time. Therefore, no back flooding. Physical habitat alteration similar to Scenario 1. The estuary will however become more marine dominated, with a greater tidal influence. The more established invertebrate community would benefit waders. A permanently open mouth and relatively low river flow will not allow for the natural revegetation of the saltmarsh.

Confidence: Low

f. EHI Tables for Scenario 7

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	50	For the Orange River Estuary low flows is defined as flows associated with the *State 3: Closed* (i.e. <10.0 m^3/s) and *State 2: Open (Marine*) (between 10.0 and 50.0 m^3/s). Months with median low flows of less than 50.0 m^3/s increased form 3 (Jul – Sep) under the Reference Condition to 9 (May - Jan) under the Scenario 7.	Low
b. % similarity in the magnitude of major floods (e.g. 1:20, 1:50 and 1:100) in comparison with the reference condition	45	For the Orange River floods greater than 5000 x $10^6 m^3$ were judged to be resetting events. These have significantly beem reduced from 20 under the Reference conditions to 9 under Scenario 7.	Low
	48		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 68 year period	55	For the Orange River Estuary mouth closure occurs at flows less than 10 m^3/s. Under the Reference condition the estuary mouth use to close 18 out of the 68 years (26%) for about 1 month at a time, while under Scenario 7 mouth closure do not occur for an extended period, i.e. more than a few days at a time. Alternatively, out of a total of 816 months (68 years), mouth closure decreased from 3% in the Reference Conditions to 0.5% under Scenario 7. *Note: Following a precautionary approach, and in view of the importance of mouth closure and related back flooding to estuarine health, the mouth closures were score severely.*	Low
	55		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	50	There has been modification in the salinity distribution due to an increase of *State 2: Open (Marine*) and a decrease in *State 1: Open (Riverine)*. From being, freshwater dominated for 9 months (Oct-Jun) of the year under the Reference Condition, the system is now only freshwater dominated for 3 months (Feb-Apr) with strong marine influence in the lower reaches for about 9 months (May-Jan).	Low
2a. Nitrate and phosphate concentration in the estuary	80	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. Allow for 10% change. With an increase in State 2, (i.e. stronger marine influence) during Aug-Jan and May, it is possible that nutrient concentrations in the bottom waters of the deeper basin near the mouth may at time be slightly higher than for the Reference Conditions (in particular during Oct to Apr when upwelling occurs at sea). Allow for an additional 10% change.	Low
2b. Suspended solids present in inflowing freshwater	85	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in State 1 (i.e. strong river influence), slightly less compared with Scenario 1.	Low
2c. Dissolved oxygen (DO) in the estuary	80	It is expected that the estuary will remain well-oxygenated as was the case under the Reference Condition. However, occasional events of low oxygen, river water inflow may occur, associated with algal blooms developing upstream.	Low
2d. Levels of toxins	90	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Allow for 10%.	Low
	68		

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	This scenario will have a similar effect on the sediment processes and characteristics and morphology as Scenario 1.	Low
1b	% similarity in sand fraction relative to total sand and mud	90	This scenario will have a similar effect on the sediment processes and characteristics and morphology as Scenario 1.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	90	This scenario will have a similar effect on the sediment processes and characteristics and morphology as Scenario 1.	Low
		86		

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	65	40	It is estimated that approximately 65% of the original species remain. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species.	Low
2a. Abundance	40		Increase in low flow and reduction in floods, there will be longer water retention time compared to the present state, which would allow the development of phytoplankton. The stable channels would allow for benthic microalgal colonisation. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from the sea particularly during upwelling events. Biomass is expected to be 60% higher than it was under reference conditions. The reduction in suspended solids would increase light available for microalgal growth.	Low
2b. Community composition	50		Because of the greater water retention, time flagellates would dominate the phytoplankton rather than diatoms.	Low
	40			

Macrophytes

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	65	40	Loss of opportunistic species due to reduction in resetting floods and an increase in reed growth at the expense of other species. Stable water levels would also have contributed to the increase in reeds. Increase in salinity may result in loss of some freshwater / brackish species.	Low
2a. Abundance	50		In 1986, 90% of the large salt marsh area on the southern bank was lost and became desertified. However, recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. A reduction in freshwater conditions to only 3 months would increase salinity and reduce macrophyte growth.	Low
2b. Community composition	58		Brackish communities have been lost from the desertified salt marsh area, but are still represented in the main river channel. The increase in saline conditions may change the community composition in the main channel. As a result of these changes the current community composition is 58% similar to the original composition.	Low
	40			

Invertebrates

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	Score		
1. Species richness	60	35	In the main channel area, an estuarine benthic community has probably invaded the lower part of the system (presence of a temporary lens of estuarine water) at the expense of a freswater community. The stability and species number of this community (persist for 9 months of the year) is likely to increase under this scenario. A similar argument applies to the zooplankton. The species richness of the freshwater associated community is unlikely to attain maximum potential because of the short time interval (3 months) available to them to colonize. Since an estuarine type community probably existed in the wetland on the southern bank under natural conditions, it is likely that species richness will be restored in part. Overall, the change from natural is collectively considered to be about 50%.	Low
2a. Abundance	50		Abundance of the estuarine 'invasive' species is likely to increase in the main channel area (at the expense of freshwater species), but also increase in the wetland. Reasons are given in the species richness category.	Low
2b. Community composition	50		The greater persistence of the lens of estuarine water in the main channel area is likely to alter community composition since typical estuarine species will also colonize the area (less hardy species will also occur). This argument will also apply to the wetland on the southern shore, thus restoring the community composition to some level it was in the past. Reasons are given in the species richness category.	Low
	35			

Fish

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	Score		
1. Species richness	80	65	Low flows extends into early summer, more favourable conditions for survival of estuarine fish and for marine species to enter the estuary. Freshwater fish, which under present day conditions provide 50% of the species complement, will tend to avoid the saline estuarine waters.	Low
2a. Abundance	60		Increase in abundance of estuarine species due to more favourable conditions but decline in abundance of freshwater species. Numbers of estuarine dependent species such as *L. lithognathus* & *L. amia* could increase but ultimately abundance driven by overall stock status and the relationships between stock size and recruitment.	Low
2b. Community composition	40		Saltmarsh channel & marginal areas still largely unavailable to genera such as *Caffrogobius*. Freshwater fish component reduced. Trend towards a more salt loving estuarine fish community for a large part of the year as opposed to a freshwater tolerant community under natural and present day conditions.	Low
	40			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	Score		
1. Species richness	100	100	Overall, there will probably be no change in species richness.	
2a. Abundance	30		The marine dominated system with tidal influences will benefit wading birds, such as Curlew Sandpiper and Little Stint. Less water will also increase the area of open habitat used by waders. Loss of *Phragmites* habitat reedbeds because of salinity changes will decrease the feeding and roosting habitat of rails (such as Purple Gallinule), passerines (such as Cape Reed Warbler) and roosting habitat of herons and egrets (such as Black-crowned Night Heron). An increase in the abundance of estuarine fish species may benefit terns and cormorants. The saltmarsh habitat will remain in its degraded state and therefore unavailable to certain bird species, such as Ethiopian Snipe. In conclusion, some species may increase in numbers (such as certain species of waders), while others may decrease slightly (such as rails).	
2b. Community composition	45		The population of waders and terns may increase, while species dependent on reedbed habitats may decrease.	
	30			

4.2.8 Scenario 8: Modified River Class D (allowing for natural river losses)

a. Described seasonal variability in river inflow (based on simulated runoff data for this scenario)

Monthly-simulated runoff data for Scenario 8, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 4.9**. The MAR under Scenario 8 is 4 345.67 x 10^6 m^3 (40.12% of natural MAR remaining). A statistical analysis of the monthly-simulated runoff data in m^3/s for Scenario 8 is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	16.43	231.64	232.86	544.25	1385.05	788.86	708.79	209.05	62.77	22.92	18.81	15.26
80%ile	15.86	21.55	113.03	149.10	610.57	468.98	193.58	99.12	30.56	22.28	17.22	14.91
70%ile	14.65	19.68	33.98	74.47	378.57	277.67	144.40	50.83	28.85	21.61	16.57	13.02
60%ile	12.69	17.48	21.96	34.80	216.41	174.31	77.94	39.26	27.72	20.21	15.71	11.95
50%ile	9.82	13.36	18.61	25.04	144.73	96.07	58.55	34.18	26.39	19.60	14.39	9.73
40%ile	6.69	10.73	15.42	16.57	93.46	58.81	45.51	29.35	23.41	18.11	13.05	7.16
30%ile	5.93	7.86	11.39	13.92	60.18	46.50	36.50	24.12	20.49	16.43	11.80	6.03
20%ile	5.93	6.34	9.87	10.57	49.96	40.03	30.71	20.44	18.78	15.13	10.52	6.03
10%ile	5.93	5.93	9.46	9.38	43.05	35.86	24.59	19.16	17.74	14.38	9.95	6.03
1%ile	5.93	5.93	8.76	8.24	35.07	32.89	22.16	16.77	16.47	14.13	9.41	6.03

Confidence: Low

b. Flood regime for the Scenario 8

There was no detailed analysis done on the reduction in the magnitude and frequency of floods for the Orange River System for Scenario 8 - Similar to the Present State.

Confidence: Low

c. Changes in sediment processes and characteristics for Scenario 8

Very similar effects are expected as for Scenario 3. Thus, despite the possibility of prolonged mouth closure, the estuarine sediment dynamics are still very similar to that of the present state, because the river flow and flood regime and coastal processes/dynamics are still similar. However, due to mouth closure for ~1/4 of year and continued inflow into estuary, water level in estuary will rise when mouth closed. Thus, water depth in estuary will increase (~1 – 2m) and intertidal areas will be inundated for part of the time that mouth is closed.

Confidence: Low

Table 4.9: Monthly Runoff Data (in m³/s) for Scenario 8, Simulated over a 68-year Period

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	CLOSED
1920	16.48	10.87	9.48	10.57	256.95	70.24	119.68	55.09	29.26	18.29	10.48	11.88	1
1921	5.93	143.14	459.36	109.89	44.28	33.61	22.90	19.54	27.80	20.72	16.41	6.42	2
1922	15.10	401.44	115.09	534.51	657.75	364.61	189.26	28.88	30.86	22.65	15.63	6.03	1
1923	5.93	6.25	9.41	13.88	77.41	92.64	146.56	19.53	17.80	14.38	9.81	13.86	4
1924	11.44	20.03	25.49	56.70	439.93	3470.60	1818.19	690.88	106.57	25.13	14.24	12.73	0
1925	10.39	9.09	9.67	14.34	54.53	53.28	32.42	18.80	19.93	14.94	9.79	13.04	3
1926	5.93	6.28	10.47	9.82	59.95	56.23	54.63	20.08	17.57	16.23	14.94	6.03	4
1927	10.78	7.51	13.18	34.07	86.17	237.88	42.52	19.19	17.65	14.24	9.88	6.03	3
1928	5.93	13.32	11.01	15.98	44.35	108.35	34.20	26.01	30.08	22.44	16.57	15.21	1
1929	16.38	17.36	297.52	139.29	62.33	39.86	45.51	26.70	19.93	15.69	17.40	9.54	1
1930	5.93	5.93	9.40	32.64	122.15	162.30	60.46	41.86	18.74	22.38	17.03	6.03	4
1931	6.77	16.61	10.32	9.38	138.28	41.03	23.24	18.76	17.59	14.32	8.76	8.23	4
1932	14.65	6.03	9.89	9.38	40.20	33.87	23.07	18.57	17.66	14.38	9.73	6.03	5
1933	5.93	20.78	109.98	1133.25	911.04	474.99	166.67	101.33	29.65	22.16	17.26	7.38	2
1934	12.97	425.88	686.91	12.29	44.82	185.90	132.31	194.73	46.80	18.43	17.19	11.86	0
1935	5.93	5.93	9.60	15.30	70.81	177.03	45.95	165.98	40.25	19.83	12.44	6.03	4
1936	12.73	917.48	201.62	744.24	1303.03	219.53	26.49	20.48	18.70	15.54	10.37	6.03	1
1937	5.93	5.93	16.25	155.64	245.44	36.90	62.03	37.32	28.92	21.64	16.55	9.92	3
1938	15.85	73.26	19.69	29.55	1315.65	328.21	23.55	31.53	24.56	22.15	17.90	12.80	0
1939	15.85	158.87	115.06	9.85	125.96	52.36	294.40	184.90	29.28	19.84	12.42	15.34	1
1940	9.79	17.47	100.71	280.54	701.19	114.83	148.97	27.80	18.83	18.19	12.46	7.18	2
1941	13.25	5.93	9.40	23.89	477.12	57.58	76.39	31.03	20.27	16.43	16.89	11.45	2
1942	14.82	17.80	189.03	88.49	40.12	37.26	857.07	1127.98	195.44	343.54	116.75	42.66	0
1943	448.50	1754.61	1451.39	566.96	2087.22	552.51	28.47	23.91	30.11	21.80	13.93	15.11	0
1944	70.43	30.98	9.39	9.38	52.24	278.80	64.57	26.28	24.34	17.00	10.11	6.03	3
1945	5.93	5.93	9.39	27.43	189.54	46.21	47.74	42.91	29.70	17.49	9.99	6.03	5
1946	15.12	11.31	9.86	10.56	79.28	63.11	37.62	34.70	22.42	17.79	11.30	14.86	1
1947	14.70	7.69	21.26	25.77	116.84	683.64	391.26	33.04	20.27	15.03	9.98	6.03	3
1948	5.93	5.93	7.47	21.96	50.86	110.63	30.35	27.99	20.67	15.37	10.17	6.03	4
1949	5.93	17.53	22.53	16.72	384.76	456.69	238.33	298.97	61.42	22.87	214.07	14.94	1
1950	5.93	5.93	21.00	51.27	57.64	36.16	34.77	29.46	26.68	19.83	13.63	7.08	3
1951	16.41	10.14	9.53	10.58	433.87	36.57	25.38	21.31	21.07	26.98	18.67	12.65	1
1952	5.93	13.41	13.05	9.38	471.40	76.85	98.33	37.75	21.73	15.09	11.80	6.03	3
1953	13.34	11.87	49.82	15.79	122.39	510.01	60.67	34.21	28.16	19.04	10.11	6.03	1
1954	5.93	6.68	11.30	71.76	1867.85	459.97	145.46	69.81	27.53	20.03	13.38	6.03	3
1955	5.93	12.37	20.44	38.58	539.79	923.00	465.49	72.32	27.48	18.47	11.40	6.03	2
1956	9.15	17.91	853.66	507.43	151.19	173.63	31.23	20.58	20.17	22.45	17.33	1371.80	1
1957	1539.24	405.52	205.14	1000.80	192.99	33.68	45.43	240.16	61.18	18.35	11.36	10.35	0
1958	5.93	16.22	20.92	14.98	72.55	35.17	55.78	195.72	44.36	71.45	16.55	6.03	2
1959	12.48	16.38	21.92	17.25	155.49	147.34	134.88	40.54	26.09	19.39	16.50	11.61	0
1960	11.99	14.89	140.16	92.12	42.97	321.36	746.72	175.23	229.95	21.98	76.17	6.03	1
1961	5.93	18.73	91.69	11.79	1069.67	254.04	36.38	51.71	20.49	15.18	10.74	6.03	2
1962	5.93	18.98	12.34	656.85	306.68	726.61	842.07	67.47	25.40	22.39	16.71	9.28	2
1963	5.93	22.06	62.10	19.77	43.09	44.49	196.47	23.09	25.38	20.96	15.70	10.91	1
1964	59.41	444.53	127.75	134.94	49.37	38.14	58.70	31.79	27.83	20.95	15.84	14.01	0
1965	8.02	6.15	9.66	58.56	339.77	40.30	38.18	19.21	17.71	14.07	9.74	6.03	5
1966	6.12	6.22	16.05	115.16	1546.99	506.76	1128.53	444.93	291.28	22.23	15.77	8.51	3
1967	5.93	20.00	11.04	9.38	25.33	99.50	84.14	80.16	28.29	19.96	11.51	9.10	3
1968	5.93	9.32	22.14	9.38	44.85	70.12	62.11	41.78	28.10	16.43	12.34	6.03	4
1969	15.86	7.30	15.50	9.86	48.51	31.59	20.66	13.37	14.54	14.27	10.58	12.25	2
1970	22.80	8.25	18.72	24.32	173.03	43.56	58.40	41.31	22.80	17.06	11.82	6.03	2
1971	5.93	7.85	15.92	278.92	318.99	753.23	162.11	41.83	27.10	17.64	11.84	6.03	3
1972	5.93	6.09	9.40	5.93	129.99	54.89	45.49	20.42	18.09	14.15	17.04	12.77	4
1973	7.43	6.42	18.51	756.21	2576.58	2368.50	692.54	271.56	103.71	24.63	324.59	15.04	2
1974	5.93	20.35	351.08	429.96	2033.77	929.58	167.79	34.14	27.13	22.08	15.58	14.10	1
1975	13.55	19.73	679.88	2006.36	2945.75	2819.13	960.20	567.98	143.02	27.03	19.14	16.54	0
1976	968.71	594.76	30.58	74.77	884.63	872.01	104.49	32.52	25.69	19.82	13.47	14.47	0
1977	15.95	11.61	12.23	437.85	382.88	267.48	1105.62	98.12	28.09	21.30	15.36	14.97	0
1978	14.59	5.93	32.86	10.70	59.31	41.39	24.09	21.40	20.56	22.31	17.36	15.21	1
1979	16.02	13.31	15.07	14.22	188.49	84.69	24.80	18.72	17.76	14.98	25.85	21.72	0
1980	7.94	9.82	16.22	29.37	278.93	292.79	32.02	36.54	65.93	20.09	92.57	58.18	2
1981	5.93	8.02	17.25	10.66	40.08	33.62	58.28	38.93	26.74	21.38	14.53	6.76	3
1982	12.68	20.13	12.53	9.38	39.87	33.52	30.18	21.70	23.56	21.27	15.14	6.03	2
1983	8.40	24.34	34.11	28.69	40.05	49.11	39.71	37.42	18.53	14.86	13.20	12.71	1
1984	6.38	7.08	9.84	11.02	209.16	59.11	24.09	18.44	18.44	14.43	9.79	6.03	5
1985	9.85	19.24	38.65	21.49	95.28	42.24	25.02	19.57	27.70	15.24	13.35	14.78	1
1986	15.97	20.78	10.99	9.66	59.17	38.22	32.00	19.08	17.43	14.36	16.89	15.22	1
1987	16.40	26.33	22.24	37.70	3189.79	3733.57	616.59	99.79	53.71	23.02	17.24	306.90	0

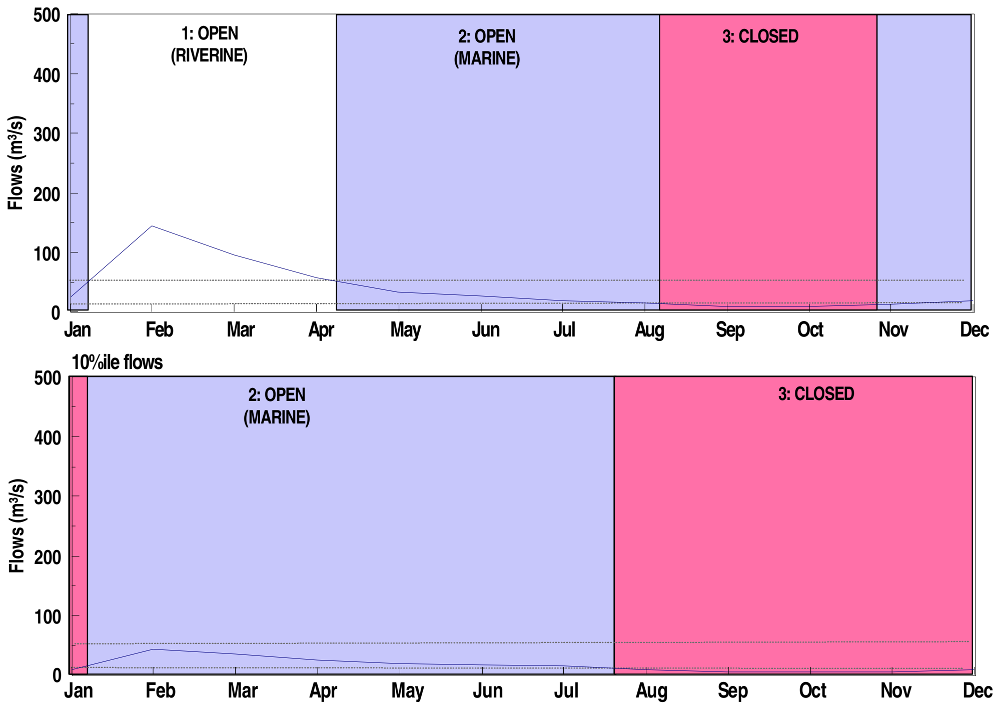
1: Open (River)	>50.0	2: Open (Marine)	10.0-50.0	3: Closed	< 10.0	Floods	> 2000

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
< 10.0	35	26	15	12	0	0	0	0	0	0	9	35
10.0-50.0	28	32	35	31	14	22	30	47	58	66	54	30
>50.0	5	10	18	25	54	46	38	21	10	2	5	3

d. Occurrence and duration of different Abiotic states for Scenario 8

The occurrence and duration of the different Abiotic States under Scenario 8 are illustrated in the simulated monthly river flow table (**Table 4.9**).

To provide a conceptual overview of the annual distribution of Abiotic States under Scenario 8, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Predicted change in biotic characteristics of Scenario 8 compared with the Reference Condition

MICROALGAE

Scenario 8 is similar to Scenario 3 in that the mouth will close 2-3 months at a time annually. . Due to inundation, the intertidal habitat for benthic microalgae will be lost. There may be an increase in subtidal benthic microalgae but this would depend on the suspended solid load and availability of light. Nutrients are also expected to be low during the closed phase. There is an increase in low flow and the estuary is in an open marine state for 7 months of the year. The brackish / freshwater species will be lost.

Confidence: Low

MACROPHYTES

The mouth could close most years (81 %) for 2-3 months at a time. The open riverine state occurs for only 3 months of the year. The estuary is mostly (7 months) in an open marine state and the fundamental characteristics of this system as a freshwater river mouth is altered. This may decrease the diversity of brackish species in the mouth region and decrease the growth of the reeds and sedges.

When the mouth is closed the intertidal areas will be flooded and the intertidal salt marsh plants submerged. However, in the desertified marsh area mouth closure and associated backflooding may have a beneficial influence in removing salts and promoting germination. This will only be the case if the water is below 35 ppt. The groundwater in that area is probably hypersaline and backflooding with freshwater would be preferable. Because the estuary is mostly in an open marine state, the standing water currently in the desertified marsh area may become hypersaline. This would reduce salt marsh growth and distribution.

Confidence: Low

INVERTEBRATES (INCLUDING ZOOPLANKTON)

Similar to scenario 2, benefiting the estuarine benthic community in the LOR Mouth area. The lens of estuarine water will persist for about 9 months of the year without interruption. The mouth is also likely to close more frequently (nearly every year for 2-3 months at a time), increasing residence time that will favour an estuarine type community. Under the present scenario, this lens also breaks down for three months in winter. The persistence of the lens for a longer period without interruption will allow the community to become better established and not disappear in winter (freshwater will induce a shift to a freshwater type community in this area – extension of upstream conditions towards the mouth). Species richness is also likely to increase. This is at the expense of a freshwater associated community that dominated for most of the year under the reference condition.

Similarly, an estuarine zooplankton community is likely to become more prevalent in the estuarine water lens at the expense of a freshwater type community.

Invertebrates colonizing the wetland on the south bank are also likely to benefit, in that salinity is likely to increase because of tidal penetration from the main channel area, particularly around spring tides. Increased water levels at times of mouth closure will also benefit the estuarine type community. This assumes that surface freshwater will be pushed further upstream with the tide and that salinity does not increase above 35 in the wetland area.

Confidence: Low

FISH

Similar to scenario 3 but more extreme with mouth closure likely to occur throughout the peak recruitment period of most estuarine species (spring & early summer). Although these conditions may allow the estuarine fish assemblage to become more stable, the advantages may be negated by increased mouth closure during spring and summer reducing the frequency and magnitude of recruitment. In turn, all small and juvenile fish, especially the estuarine residents & breeders e.g. G.aestuaria will benefit from backflooding and inundation of the saltmarsh during mouth closure. Non estuarine dependent marine species e.g. L. aureti will occur more frequently but only freshwater species tolerant of high salinities e.g. O. mossambicus will still occur in any numbers. The likelihood that estuarine, brackish or freshwater invertebrate communities will struggle to become established suggests that prey availability may become more important in defining the fish community / assemblage. Low oxygen conditions in the deeper areas during mouth closure may exclude some species from a deepwater refuge. In turn, depending on the extent of these low O_2 areas, some fish may be "trapped" either above or below these with some moving further upstream into the freshwater reaches.

The current fish assemblage is dominated by those species tolerant of low salinities. The majority of these are typical of arid west coast systems whether they be open or closed, and, with the exception of a limited pool of non-estuarine-dependent marine species, there is little to replace them if lost. Consequently, the system becoming marine dominated for much of the year is unlikely to see the establishment of a "more estuarine" fish assemblage. The current fish assemblage will either disappear completely or move into the "extended REI zone" in the freshwater reaches, the latter being the more likely option.

The above argument is best explained by comparing west coast estuarine fish assemblages with those on the south and east coasts of SA. On the eastern seaboard, there are a variety of permanently open and temporarily open / closed estuaries of different sizes and characteristics. If one system changes state, there is a good chance that it will be "seeded" with a new fish assemblage more typical of its new character from a similar estuary nearby. The limited estuaries on the west coast and the distances between them do not provide much of a chance for this to occur.

Confidence: Low

BIRDS

Similar to Scenario 3. However, mouth open for longer periods and estuary more marine dominated.

Confidence: Low

f. EHI Tables for Scenario 8

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	50	For the Orange Estuary low flows is defined as flows associated with the *State 3: Closed* (i.e. <10.0 m^3/s) and *State 2: Open (Marine*) (between 10.0 and 50.0 m^3/s). Months with median low flows of less than 50.0 m^3/s increased form 3 (Jul – Sep) under the Reference Condition to 9 (May - Jan) under the Scenario 8.	Low
b. % similarity in the magnitude of major floods (e.g. 1:20, 1:50 and 1:100) in comparison with the reference condition	45	For the Orange River floods greater than 5000 x $10^6 m^3$ were judged to be resetting events. These have been significantly reduced from 20 under the Reference conditions to 9 under Scenario 8.	Low
	48		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 68 year period	0	For the Orange Estuary mouth closure occurs at flows less than 10 m^3/s. Under the Reference condition the estuary mouth use to close 18 out of the 68 years (26%) for about 1 month at a time, while under Scenario 8 mouth closure occur nearly annually (81%) for 2 – 3 months at a time. Alternatively, out of a total of 816 months (68 years), mouth closure increased from ~3% in the Reference Conditions to ~16.2 % under the Scenario 8. *Note: Following a precautionary approach, and in view of the importance of mouth closure and related back flooding to estuarine health, the mouth closures were score severely.*	Low
	0		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	40	There has been modification in the salinity distribution due to an increase of *State 2: Open (Marine*) and *State 3: Closed* and a decrease in *State 1: Open (Riverine).* From being freshwater dominated for 9 months (Oct-Jun) of the year under the Reference Condition, the system is now only freshwater dominated for 3 months (Feb-Apr) with strong marine influence in the lower reaches for about 9 months (May-Jan). The extended period of mouth closure will also modify the horizontal salinity gradient to a more vertical gradient during the closed phase.	Low
2a. Nitrate and phosphate concentration in the estuary	75	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. This would be slightly less compared with the Present State due to lower river inflow thus allow for 5% change. With an increase in State 2, (i.e. stronger marine influence) during Jan, May & Nov-Dec, it is possible that nutrient concentrations in the bottom waters of the deeper basin near the mouth may at time be slightly higher than for the Reference Conditions (in particular during Oct to Apr when upwelling occurs at sea). Allow for an additional 10% change. In addition, State 3 now occurs for 2 months (Jul-Aug) of the year when the system is expected to become nutrient depleted (under the Reference Condition it still had some nutrient supply albeit low during these months). Allow a further 10% change.	Low
2b. Suspended solids present in inflowing freshwater	80	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in State 1 (i.e. strong river influence), slightly less compared with the Scenarios 1 and 2.	Low
2c. Dissolved oxygen (DO) in the estuary	70	Although it is expected for the estuary to remain well-oxygenated during States 1 and 2, a decrease in dissolved oxygen in the bottom waters of the deeper basin could be expected under State 3, which under Scenario 3 could occur for 3 months of the year. Occasional events of low oxygen, river water inflow may also occur, associated with algal blooms developing upstream.	Low
2d. Levels of toxins	90	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Allow 10%.	Low
	58		

Physical habitat alteration

	VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1	Resemblance of intertidal sediment structure and distribution to reference condition			
1a	% similarity in intertidal area exposed	60	Despite mouth possibly closed for three months, the sediment dynamics are still very similar to the present status, because the river flow regime and coastal processes/dynamics are still similar. However, due to mouth closure for ~1/4 of year and continued inflow into estuary, water level in estuary will rise when mouth closed. Thus, intertidal areas will be inundated for period of mouth closure.	Low
1b	% similarity in sand fraction relative to total sand and mud	90	Despite mouth possibly closed for three months, the sediment dynamics are still very similar to the present status, because the river flow regime and coastal processes/dynamics are still similar.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	75	Despite mouth possibly closed for three months, the sediment dynamics are still very similar to the present status, because the river flow regime and coastal processes/dynamics are still similar. However, due to mouth closure for ~1/4 of year and continued inflow into estuary, water level in estuary will rise when mouth closed. Thus, water depth in estuary will increase (~1 – 2m) for period of mouth closure.	Low
		75		

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	65	40	It is estimated that approximately 65 % of the original species remain. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species.	Low
2a. Abundance	40		The mouth of the estuary could close for 2-3 months at a time. Under these conditions there will be a loss in intertidal habitat for benthic microalgae. There may be an increase in subtidal benthic microalgae but this would depend on the suspended solid load and availability of light. Nutrients are also expected to be low during the closed phase. Because of the increase in low flow and reduction in floods, there will be longer water retention time compared to the present state, which would allow the development of phytoplankton. Strong marine influence in the lower reaches of the estuary would result in the establishment of a river-estuary interface zone where phytoplankton biomass is expected to be high due to the introduction of nutrients from the sea particularly during upwelling events. Biomass is expected to be 60 % higher than it was under reference conditions. Closed mouth conditions would reduce biomass.	Low
2b. Community composition	40		Because of the greater water retention, time flagellates would dominate the phytoplankton rather than diatoms. Subtidal benthic microalgae would replace intertidal communities during closed mouth conditions. This would be 40 % similar to the reference condition where benthic microalgae were probably an unimportant component of the estuary during to the high flows and shifting sandbanks.	Low
	40			

Macrophytes

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	60	35	Loss of opportunistic species due to reduction in resetting floods. Increase in salinity may result in loss of some freshwater / brackish species and would reduce the growth and distribution of salt marsh species in the desertified marsh area. Submergence with saline water for 2- 3 months may result in the loss of some sensitive intertidal species.	Low
2a. Abundance	50		In 1986 90% of the large salt marsh area on the southern bank was lost and became desertified. However, recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. A reduction in freshwater conditions to only 3 months would increase salinity and reduce macrophyte growth. However, backflooding as a result of mouth closure may improve conditions in the desertified salt marsh area as long as the salinity is less than 35 ppt. Overall, about 50% of the total biomass remains of the original species.	Low
2b. Community composition	56		Brackish communities have been lost from the desertified salt marsh area, but are still represented in the main river channel. The increase in saline conditions may change the community composition in the main channel. As a result of these changes the current community composition is 56 % similar to the original composition.	Low
	35			

Invertebrates

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	*Score*		
1. Species richness	60	35	Freshwater associated species will be lost compared to natural conditions because of the longer duration of estuarine type conditions that now persist under this scenario.	Low
2a. Abundance	35		Freshwater associated species are unlikely to attain maximum abundance because of the short time frame of suitable conditions compared to natural conditions because of the longer duration of estuarine type conditions that now persist under this scenario.	Low
2b. Community composition	35		Freshwater associated species will not be part of the mix for most of the time because of the prevalence of estuarine conditions.	Low
	35			

Fish

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	Score		
1. Species richness	50	25	Similar to scenario 3 & rationale remains the same. Non estuarine-dependent marine species likely to occur more frequently but almost entire complement of freshwater species (50 % of current fish assemblage) that were common during summer high flows will be excluded from the estuary. Backflooding may help re-establish the saltmarsh channel habitat favourable to *Caffrogobius* spp. and other species. May be a slight reduction of freshwater tolerant estuarine dependent species during the marine dominated states but this will largely be due to migration into the freshwater reaches upstream.	Low
2a. Abundance	40		Freshwater species that contributed much of the biomass is unlikely to be abundant in a marine dominated system. In terms of fish, the system is changing from high productivity, low diversity to high diversity, low productivity (assuming that a few freshwater stragglers remain, estuarine species take advantage of the backflooded saltmarsh and more marine stragglers enter the system). Unstable invertebrate communities suggest that food may be a limiting factor. *Liza richardsonii* likely to dominate the fish assemblage in terms of numbers and biomass.	Low
2b. Community composition	40		Reference community of a relatively small number of species tolerant of low salinities and able to survive extended mouth closure replaced by a less defined assemblage of a mixture of estuarine, marine and freshwater species that "recruited" opportunistically.	Low
	25			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
	%	Score		
1. Species richness	100	100	Probably no change in species composition, as even species that are negatively affected will be present in low numbers.	Low
2a. Abundance	20		With backflooding and the inundation of low-lying areas, less open habitat will be available to waders and their numbers could be reduced. A reduction in reedbeds may affect the bird species that are dependent on these habitats. Species dependent on the saltmarsh habitat may be present in larger numbers, but those birds currently using the saltmarsh "lake" will be negatively influenced. Backflooding may flood low-lying roosting and breeding areas during early to mid-summer.	Low
2b. Community composition	30		Wader community reduced because of less feeding habitat. Low-lying breeding areas inundated during summer, therefore no cormorant breeding areas. Tern roosting areas flooded.	Low
	20			

4.2.9 Scenario 9: River Class C (allowing for floods)

a. Described seasonal variability in river inflow (based on simulated runoff data for this scenario)

Monthly-simulated runoff data for Scenario 9, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 4.10**. The MAR under Scenario 9 is 4 979.99 x 10^6 m^3 (45.97% of natural MAR remaining). A statistical analysis of the monthly-simulated runoff data in m^3/s for Scenario 9 is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	62.22	178.06	252.50	552.66	1394.39	766.93	701.39	228.29	68.73	33.19	31.49	27.70
80%ile	60.75	97.30	152.24	176.17	652.35	519.87	207.69	94.90	41.90	32.67	30.88	26.65
70%ile	57.11	88.06	122.48	113.07	401.05	290.73	139.56	66.00	39.15	31.29	29.86	25.39
60%ile	51.90	79.48	96.18	94.38	266.72	203.68	130.06	60.21	37.44	29.01	28.09	23.96
50%ile	43.77	63.95	69.23	69.96	168.15	166.76	119.43	53.59	34.40	27.20	25.14	21.59
40%ile	35.12	48.46	51.22	58.25	118.99	121.12	91.93	46.54	30.34	24.28	22.26	19.60
30%ile	27.46	36.85	39.80	45.53	86.88	86.27	71.64	40.40	26.21	21.34	19.51	16.81
20%ile	20.81	29.83	33.09	39.41	69.13	64.42	60.89	35.31	23.14	19.03	17.13	14.52
10%ile	18.53	26.87	30.74	37.16	65.26	60.26	55.32	32.95	21.52	17.74	15.97	8.96
1%ile	5.93	14.73	28.08	27.64	41.33	43.63	44.27	26.28	19.84	17.29	13.53	6.11

Confidence: Low

b. Flood regime for the Scenario 9

There was no detailed analysis done on the reduction in the magnitude and frequency of floods for the Orange River System for Scenario 9 - Similar to the Present State.

Confidence: Low

c. Changes in sediment processes and characteristics for Scenario 9

Similar to the Present State, because the limiting of hydropower releases will not have a noticeable effect on the sediment processes and characteristics.

Confidence: Low

Table 4.10: Monthly Runoff Data (in m³/s) for Scenario 9, Simulated over a 68-year Period

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	CLOSED
1920	62.24	51.22	31.00	40.62	300.47	192.61	192.67	55.73	33.71	21.34	17.26	23.87	0
1921	30.19	100.85	410.95	95.40	68.68	55.16	53.83	34.16	38.62	29.98	28.67	18.41	0
1922	58.86	359.27	88.76	476.88	690.74	412.98	215.77	46.82	41.50	32.84	28.06	17.38	0
1923	18.05	29.80	30.76	51.80	107.92	193.95	187.80	33.96	21.66	17.77	15.08	26.25	0
1924	49.03	96.98	151.73	85.72	461.67	3351.11	1879.07	708.18	120.65	32.37	24.68	25.02	0
1925	46.33	41.75	32.41	47.62	80.99	142.92	73.87	32.87	23.67	18.64	14.49	25.42	0
1926	32.99	29.87	36.81	38.54	86.69	188.24	124.83	34.77	21.25	21.19	26.47	14.30	0
1927	47.04	36.75	50.40	115.69	117.62	243.62	60.34	33.46	21.40	17.51	15.79	15.62	0
1928	29.82	64.10	39.61	58.65	68.69	211.54	70.91	42.95	42.53	33.19	30.00	27.71	0
1929	62.22	83.80	250.97	97.70	88.62	91.31	100.52	43.73	25.14	20.13	29.17	21.22	0
1930	33.73	19.99	30.66	90.43	154.56	197.63	140.05	66.04	23.17	33.19	31.00	12.73	0
1931	36.56	80.79	35.72	36.76	175.67	85.71	54.83	32.57	21.30	17.65	12.66	20.53	0
1932	21.51	28.66	33.27	36.32	61.19	60.64	54.39	30.72	21.23	17.66	13.96	6.03	1
1933	5.93	100.59	256.07	1063.62	871.27	562.06	129.63	65.68	41.79	32.76	31.49	19.86	1
1934	53.12	328.23	465.85	41.55	69.80	163.95	133.35	212.14	62.13	25.52	31.29	23.91	0
1935	18.73	26.65	31.74	56.62	96.21	232.68	96.21	159.03	41.86	28.28	21.37	10.76	0
1936	52.30	875.32	155.15	855.49	1386.27	268.47	59.89	35.36	23.12	19.88	17.05	6.15	1
1937	19.28	17.85	70.12	190.32	314.40	69.04	116.31	57.95	40.57	31.72	29.98	21.84	0
1938	60.78	88.09	106.09	129.70	1069.69	350.09	55.53	50.99	33.10	32.73	31.12	24.82	0
1939	60.82	113.70	68.34	38.82	139.89	167.27	327.24	223.59	41.20	28.29	21.31	27.71	0
1940	44.52	75.75	112.27	225.09	815.64	137.48	185.07	44.59	22.48	24.88	21.37	19.63	0
1941	53.96	22.79	30.65	94.13	517.23	167.86	129.85	45.04	25.27	21.36	30.71	23.52	0
1942	57.73	85.77	201.11	101.97	63.27	75.71	693.51	1173.14	207.61	398.16	154.30	38.34	0
1943	555.60	1844.38	1509.33	592.96	2129.06	574.12	64.39	40.11	42.47	32.06	24.37	27.55	0
1944	60.72	47.31	30.63	35.83	78.07	255.79	92.05	43.21	32.37	22.61	16.45	6.29	1
1945	5.93	8.39	30.63	113.65	236.11	121.96	91.46	67.79	41.88	23.72	16.24	8.15	3
1946	58.70	52.31	33.24	39.53	104.54	81.26	81.51	55.70	29.44	24.34	18.96	27.28	0
1947	57.70	36.80	122.75	99.41	148.12	646.35	369.53	53.14	25.85	19.06	16.27	9.42	1
1948	25.29	26.97	22.89	40.70	68.32	138.13	57.82	45.39	26.49	19.57	16.75	9.31	1
1949	23.53	84.66	143.62	62.13	406.40	484.63	221.62	291.75	52.62	33.04	36.21	27.29	0
1950	22.75	19.69	120.07	105.72	86.41	66.69	77.07	47.54	34.51	27.52	23.87	19.50	0
1951	62.24	48.74	31.41	40.75	479.20	69.15	58.94	36.56	27.14	34.97	31.12	24.94	0
1952	22.23	65.58	49.40	37.32	529.96	114.67	129.30	60.27	28.12	19.02	19.48	15.85	0
1953	54.19	56.00	83.00	46.31	157.08	549.06	130.87	52.25	38.06	25.51	16.05	7.42	1
1954	16.67	32.23	41.02	154.95	1413.35	483.44	172.74	86.99	38.46	28.63	22.48	10.73	0
1955	25.04	58.19	113.27	59.71	594.77	813.71	493.64	89.80	38.07	25.69	19.18	14.85	0
1956	43.02	86.48	817.42	535.39	160.63	201.71	71.75	35.51	25.46	33.19	31.49	1384.39	0
1957	1644.13	420.78	221.62	1076.48	206.78	59.87	100.19	239.26	76.23	25.41	19.09	22.54	0
1958	20.04	78.21	117.53	55.37	100.45	62.76	128.54	68.00	41.91	63.58	29.99	16.75	0
1959	51.80	79.15	133.52	63.24	192.87	166.24	106.20	60.19	35.60	27.43	29.89	23.63	0
1960	50.50	71.75	147.78	76.85	66.63	303.64	797.13	199.95	243.16	32.32	72.07	18.04	0
1961	15.85	90.58	206.24	45.44	986.31	297.68	68.02	66.14	26.20	19.21	16.71	16.09	0
1962	15.52	91.76	45.95	639.44	313.77	746.89	918.54	84.11	34.28	33.19	30.21	21.33	0
1963	30.64	97.17	98.50	71.99	66.93	116.90	129.83	39.11	34.29	30.45	28.20	23.02	0
1964	68.47	460.17	81.06	79.51	68.39	48.63	122.55	51.33	38.68	30.44	28.50	26.39	0
1965	39.90	29.28	30.68	141.77	401.81	56.91	61.72	32.91	21.50	17.23	14.29	8.02	1
1966	14.93	28.26	65.72	145.72	1562.18	543.37	1165.74	460.53	315.73	32.71	28.36	20.74	0
1967	20.35	66.22	39.67	36.10	30.22	107.01	96.80	98.30	37.03	28.52	19.40	21.20	0
1968	18.80	20.14	51.43	36.35	60.66	158.98	132.57	62.17	39.15	21.57	21.14	10.38	0
1969	60.83	34.87	62.37	38.59	74.82	41.85	24.95	19.33	17.44	17.57	17.48	24.19	0
1970	60.11	38.77	95.60	78.10	207.20	62.91	135.13	65.32	29.75	22.85	19.76	17.55	0
1971	19.70	37.35	64.89	276.49	386.18	726.47	172.69	65.40	37.28	24.03	20.07	16.15	0
1972	27.20	28.96	30.68	11.17	156.89	76.83	74.93	35.27	22.12	17.32	31.01	25.07	0
1973	38.34	30.57	91.69	691.67	2446.30	2391.31	719.80	289.22	119.66	31.31	347.45	26.54	0
1974	19.51	98.48	308.54	445.11	2035.70	944.92	195.58	54.04	36.97	32.61	27.95	26.43	0
1975	54.63	95.43	601.14	2030.34	2997.04	2887.75	1003.79	582.43	158.64	40.98	29.52	27.29	0
1976	1068.62	677.36	42.78	62.81	970.90	904.52	130.90	48.89	33.38	26.97	22.78	26.52	0
1977	61.01	54.15	45.45	431.99	394.17	293.20	1140.52	113.99	39.14	31.10	27.50	27.41	0
1978	57.39	28.13	152.58	39.33	73.92	62.16	53.79	36.31	26.33	32.46	31.49	27.70	0
1979	61.23	63.80	59.75	52.69	234.89	117.73	54.76	31.71	21.52	18.76	25.74	26.40	0
1980	39.70	44.31	67.22	128.18	346.01	267.22	70.00	58.65	42.53	28.77	31.49	27.71	0
1981	32.02	37.96	78.76	40.99	60.44	56.95	134.70	62.01	36.70	30.81	25.60	19.06	0
1982	52.31	97.38	31.35	35.75	46.80	44.50	54.04	36.10	30.49	31.04	27.04	16.11	0
1983	40.91	87.84	125.56	107.82	58.86	62.09	67.53	59.74	22.85	18.66	22.98	25.01	0
1984	35.47	33.85	32.99	38.37	258.29	105.42	56.37	29.70	22.70	17.87	14.86	7.76	1
1985	44.76	92.11	170.03	67.94	119.33	61.62	56.74	33.89	36.05	18.58	23.29	26.73	0
1986	61.14	100.59	39.40	38.03	66.12	60.42	71.63	32.96	21.01	17.53	30.62	27.71	0
1987	62.24	99.35	136.68	62.66	2331.42	3733.57	637.21	114.30	65.52	32.83	31.03	326.23	0

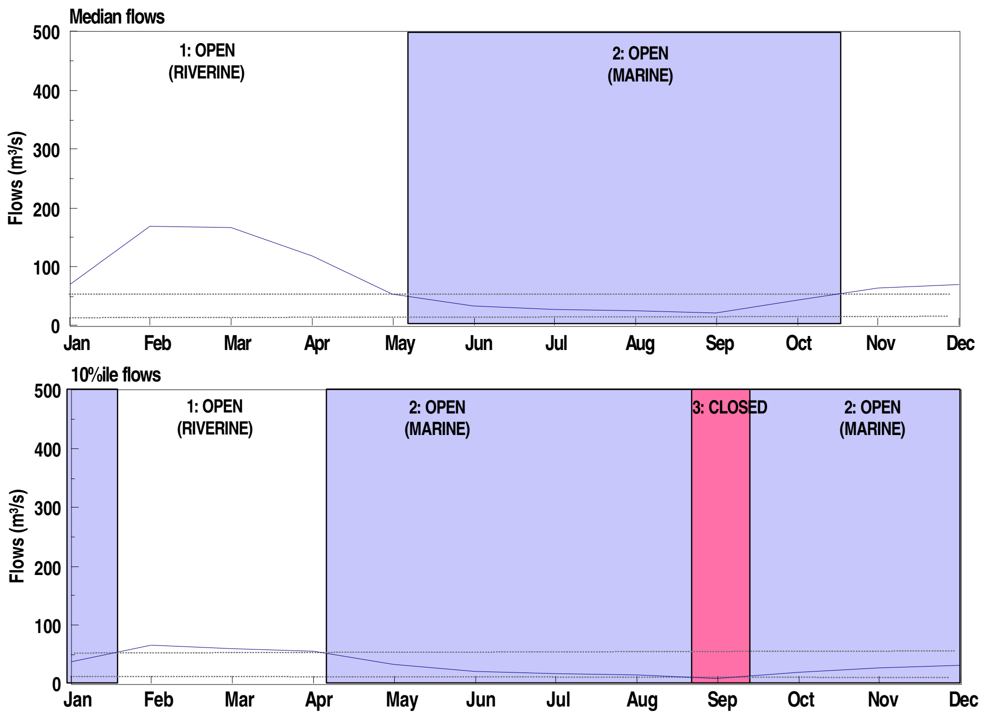
1: Open (River)	>50.0	2: Open (Marine)	10.0-50.0	3: Closed	< 10.0	Floods	> 2000

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
< 10.0	2	1	0	0	0	0	0	0	0	0	0	9
10.0-50.0	37	27	26	23	2	3	1	30	58	66	65	57
>50.0	29	40	42	45	66	65	67	38	10	2	3	2

d. Occurrence and duration of different Abiotic states for Scenario 9

The occurrence and duration of the different Abiotic States under Scenario 9 are illustrated in the simulated monthly river flow table (**Table 4.10**).

To provide a conceptual overview of the annual distribution of Abiotic States under Scenario 9`, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Predicted change in biotic characteristics of Scenario 9 compared with the Reference Condition

MICROALGAE

This scenario is similar to scenario 5 except that it does include floods. The period of low flows, similarity in mean duration of mouth closure and similarity in salinity gradients represents an improvement from present conditions. The state of the microalgae is close to reference conditions. The magnitude of major floods has been reduced. The stable channels would allow for benthic microalgal colonisation. A small increase in the marine influence in the lower reaches of the estuary would change microalgal species composition and increase phytoplankton biomass compared to reference conditions.

Confidence: Low

MACROPHYTES

Most of the changes are in response to the reduction in large floods would have reset the estuary more frequently. Stable conditions would increase the growth and distribution of macrophytes in the main channel. An increase in marine (saline) conditions could restrict the distribution and growth of certain brackish species.

Confidence: Low

INVERTEBRATES (INCLUDING ZOOPLANKTON)

The prevalence of floods and the greater persistence of freshwater type conditions in the lower Orange River area will favour a freshwater type community for about 6 months. This is probably sufficient time for the community to establish itself The Saltmarsh area on the southern shore is likely to be flushed more frequently and this will favour the estuarine type community that likely establishes itself there

Confidence: Low

FISH

Similar to reference conditions during the wet season and similar to scenario 5 during the dry season. A partial increase in floods may see the formation of a larger more persistent REI zone within the estuary favouring species such as G.aestuaria. Depending on the cueing effect of flood events, recruitment of larvae and juvenile fish may be slightly greater than scenario 5 especially if the mouth remains open for most of the time. Saltwater penetration in the lower reaches may be beneficial to marine and estuarine predators (e.g. L. amia & P. saltatrix) and benthic feeders (e.g. L. lithognathus) that forage visually. Similarly, flocculation could lead to a slight loss of refuge from piscivorous predators in the shallows. In the absence of other anthropogenic influences, marine species are likely to occur more frequently in the saline lower estuary whereas freshwater species (with the exception of O. mossambicus) are likely to be confined to the head of the estuary and river reaches.

Depending on recruitment from the "adjacent" estuaries and surf-zone some species such as Caffrogobius spp. and the Syngnathidae may recolonise the estuary and persist throughout the wet and dry season

Confidence: Low

BIRDS

Similar to Scenario 1 and 5, but with floods. Some flooding to scour out estuarine sediments and maintain islands, therefore roosting and breeding cormorant and tern habitat would be improved. Mouth closure for short periods, therefore suitable for birds that breed and roost in low-lying areas. Close to reference, except marine influence over a longer period.

Confidence: Low

f. EHI Tables for Scenario 9

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	83	For the Orange Estuary low flows is defined as flows associated with the *State 3: Closed* (i.e. <10.0 m³/s) and *State 2: Open (Marine)* (between 10.0 and 50.0 m³/s). Months with median low flows of less than 50.0 m³/s increased form 3 (Jul – Sep) under the Reference Condition to 5 (Jun - Oct) under the Scenario 9.	Low
b. % similarity in the magnitude of major floods (e.g. 1:20, 1:50 and 1:100) in comparison with the reference condition	45	For the Orange River floods greater than 5000 x 10^6m³ were judged to be resetting events. These have been significantly reduced from 20 under the Reference conditions to 9 under Scenario 9.	Low
	68		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 68 year period	70	For the Orange Estuary mouth closure occurs at flows less than 10 m³/s. Under the Reference condition the estuary mouth use to close 18 out of the 68 years (26%) for about 1 month at a time, while under Scenario 8 mouth closure occur 10 out of the 68 years (15%) for ~1 month at a time. Alternatively, out of a total of 816 months (68 years), mouth closure increased from ~3% in the Reference Conditions to ~1.5 % under the Scenario 9. *Note: Following a precautionary approach, and in view of the importance of mouth closure and related back flooding to estuarine health, the mouth closures were score severely.*	Low
	70		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	75	There has been modification in the salinity distribution due to an increase of *State 2: Open (Marine*) a decrease in *State 1: Open (Riverine).* From being freshwater dominated for 9 months (Oct-Jun) of the year under the Reference Condition, the system is now only freshwater dominated for 7 months (Nov-May) with strong marine influence in the lower reaches for about 5 months (Jun-Oct).	Low
2a. Nitrate and phosphate concentration in the estuary	90	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. Allow for 10% change. Occurrence of State 2, (i.e. stronger marine influence) only increased by 1 month from the Reference Condition and it is not expected to cause any marked difference in nutrient concentrations in the bottom waters of the deeper basin near the mouth.	Low
2b. Suspended solids present in inflowing freshwater	90	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in river inflow, in general.	Low
2c. Dissolved oxygen (DO) in the estuary	80	It is expected that the estuary will remain well-oxygenated as was the case under the Reference Condition. However, occasional events of low oxygen, river water inflow may occur, associated with algal blooms developing upstream.	Low
2d. Levels of toxins	90	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Allow for 10%.	Low
	78		

Physical habitat alteration

	VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1	Resemblance of intertidal sediment structure and distribution to reference condition			
1a	% similarity in intertidal area exposed	75	Similar to the present status, because the lack of hydropower releases, will not have a noticeable effect on the sediment processes and characteristics.	Low
1b	% similarity in sand fraction relative to total sand and mud	90	Similar to the present status, because the lack of hydropower releases, will not have a noticeable effect on the sediment processes and characteristics.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	90	Similar to the present status, because the lack of hydropower releases, will not have a noticeable effect on the sediment processes and characteristics.	Low
		86		

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%*	*Score*	It is estimated that approximately 90% of the original species remain. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species.	Low
	90	80		
2a. Abundance	80		Because of the increase in low flow and reduction in floods compared to reference conditions, there will be longer water retention time, which would allow the development of phytoplankton biomass. The stable channels would allow for benthic microalgal colonisation. Biomass is expected to be 20% higher than it was under reference conditions.	Low
2b. Community composition	90		Small change as a result of the greater water retention time flagellates would dominate the phytoplankton rather than diatoms.	Low
	80			

Macrophytes

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%*	*Score*	The river channels and islands are more stable. The estuary is no longer reset as frequently as it was under reference conditions. As a result of this there may be a loss of opportunistic species and an increase in reed growth at the expense of other species. Stable water levels would also have contributed to the increase in reeds. Brackish species may have been lost as a result of an increase in saline conditions.	Low
	90	80		
2a. Abundance	80		In 1986, 90% of the large salt marsh area on the southern bank was lost and became desertified. However, recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. Salinity conditions closer to that of the reference state would encourage the growth of macrophytes. In the main channel, there has been an increase in reed abundance due to sediment stablization.	Low
2b. Community composition	80		Brackish communities have been lost from the desertified salt marsh area but are still represented in the main river channel.	Low
	80			

Invertebrates

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%*	*Score*	The prevalence of freshwater type conditions for 6 months of the year will favour a freshwater type community, more similar to natural conditions. This is probably a sufficient time for the community to establish itself, although not to the same degree (freshwater type conditions persist for nine months of the year under natural conditions).	Low
	75	60		
2a. Abundance	60		The time during which freshwater type conditions persist is probably sufficient for abundance levels to attaining peak levels, although not to the same level for some rarer species (freshwater type conditions persist for nine months of the year under natural conditions).	Low
2b. Community composition	60		Similarly, the mix of species is likely to attain relatively high levels. Some 'rare' species may not establish themselves relatively close to the mouth for however, compared to natural conditions (when freshwater conditions persist for nine months of the year).	Low
	60			

Fish

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%*	*Score*	Similar to present day but closer to reference conditions. Probable loss of one or two of the Gobidae e.g. *Caffrogobius* spp. and *Psammogobius knysnaensis* and perhaps the Syngnathidae due to more stable conditions and loss of the marginal areas and channels of the saltnarsh.	Low
	90	80		
2a. Abundance	70		Decline in abundance of freshwater species in the estuary but probably compensated by an increase in abundance of some of the more "opportunistic" estuarine dependent species such as L. richardsonii during the winter months. Recruitment also likely to be greater due to a lessening of the confusing cues resulting from seasonal reversal of flows under present day conditions.	Low
2b. Community composition	60		Similar to present day but without seasonal flow reversal. Although always dominated by the detritivorous *L. richardsonii*, there has been a decline in the number of piscivores such as *L.amia, A. inodorus* and *P. saltatrix* and to a lesser extent *L. lithognathus* and *L. aureti. Freshwater tolerant estuarine species likely to be more "dominant" than freshwater species than they were under reference conditions.*	Low
	60			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%*	*Score*	Probably no change in species composition, as even species that are negatively affected will be present in low numbers.	Low
	100	100		
2a. Abundance	50		Similar to Scenario 1 and 5, but with flooding. Flooding may be beneficial as island roosting and breeding sites may be established and maintained. Limited backflooding with mean low-lying breeding/roosting areas will not be flooded.	Low
2b. Community composition	60		Scenario 5 may benefit roosting/breeding cormorants and roosting terns.	Low
	50			

4.2.10 Scenario 10: River Class D (allowing for floods)

a. Described seasonal variability in river inflow (based on simulated runoff data for this scenario)

Monthly-simulated runoff data for Scenario 10, over a 68-year period (1920-1987) were obtained from the Department of Water Affairs and are provided in **Table 4.11**. The MAR under Scenario 10 is 4 758.93 x 10^6 m^3 (44.93% of natural MAR remaining). A statistical analysis of the monthly-simulated runoff data in m^3/s for Scenario 10 is provided below.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
90%ile	54.95	178.06	228.73	545.82	1427.02	777.46	736.15	223.13	61.89	24.81	23.14	21.03
80%ile	53.72	82.19	120.75	147.26	581.97	493.45	218.39	81.83	30.69	24.56	22.85	20.51
70%ile	50.64	76.11	96.31	82.87	388.17	284.44	145.73	47.96	29.17	23.85	22.36	19.88
60%ile	46.25	67.59	78.53	70.39	212.81	189.07	103.03	44.89	28.44	22.82	21.59	19.17
50%ile	39.40	55.37	59.44	54.06	146.25	135.57	96.22	41.77	27.31	21.96	20.12	17.99
40%ile	32.11	43.18	43.42	47.74	98.86	105.94	74.42	38.29	25.17	20.57	18.75	17.00
30%ile	25.65	34.06	35.94	41.10	77.24	78.48	64.29	35.68	23.30	19.18	17.45	15.62
20%ile	20.05	28.53	31.54	37.92	65.15	61.99	58.27	33.51	21.90	18.08	16.31	14.03
10%ile	18.10	26.19	29.99	36.72	62.76	59.04	54.21	32.50	21.17	17.46	15.73	8.96
1%ile	5.93	14.73	27.44	27.64	41.33	43.63	43.90	26.28	19.77	17.24	13.53	6.11

Confidence: Low

b. Flood regime for the Scenario 10

There was no detailed analysis done on the reduction in the magnitude and frequency of floods for the Orange River System for Scenario 9 - Similar to the Present State.

Confidence: Low

c. Changes in sediment processes and characteristics for Scenario 10

Similar to the Present State, because the limiting of hydropower releases will not have a noticeable effect on the sediment processes and characteristics.

Confidence: Low

Table 4.11: Monthly Runoff Data (in m³/s) for Scenario 10, Simulated over a 68-year Period

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	CLOSED
1920	54.97	45.36	30.17	38.55	253.57	144.91	159.57	48.03	28.38	19.18	16.38	19.12	0
1921	27.95	100.85	410.95	69.88	64.84	54.35	53.29	33.02	28.93	23.28	21.80	16.41	0
1922	52.11	359.27	70.43	476.88	617.30	394.31	213.54	38.41	30.24	24.64	21.51	15.90	0
1923	17.64	28.51	30.01	44.38	91.57	145.78	326.69	32.94	21.23	17.48	14.95	20.30	0
1924	43.83	81.36	120.31	63.68	409.85	3406.34	1872.23	701.34	113.80	24.28	19.90	19.70	0
1925	41.55	37.91	31.09	42.20	73.22	110.35	65.57	32.44	22.14	17.90	14.43	19.90	0
1926	30.32	28.56	33.98	37.46	77.11	142.08	96.78	33.28	21.05	19.10	20.75	13.83	0
1927	42.16	33.97	42.88	83.02	98.18	228.04	57.28	32.72	21.11	17.36	15.57	15.02	0
1928	27.64	55.49	35.81	47.95	64.85	173.35	63.76	36.76	30.70	24.81	22.44	21.03	0
1929	54.95	71.00	250.97	83.87	78.43	79.21	81.89	37.09	22.81	18.60	22.04	17.81	0
1930	30.93	19.83	29.95	66.70	124.75	187.62	106.11	46.59	21.92	24.81	22.91	12.41	0
1931	33.32	68.63	33.26	36.45	138.77	75.57	53.91	32.17	21.07	17.42	12.66	17.46	0
1932	20.63	27.61	31.65	36.14	59.34	59.32	53.64	30.58	21.04	17.43	13.96	6.03	1
1933	5.93	84.20	219.21	1063.63	871.27	529.05	103.01	46.44	30.37	24.60	23.14	17.13	1
1934	47.28	328.23	466.13	39.03	65.60	187.43	157.29	205.29	55.29	21.16	23.05	19.14	0
1935	18.29	25.98	30.66	46.89	83.59	210.25	78.32	159.03	31.41	22.47	18.33	10.63	0
1936	46.59	875.32	155.15	834.07	1379.36	261.62	57.01	33.53	21.89	18.48	16.27	6.15	1
1937	18.76	17.85	56.13	168.68	248.56	64.76	95.66	43.15	29.81	24.11	22.42	18.12	0
1938	53.73	85.13	83.73	93.08	1165.97	343.24	54.34	40.18	26.42	24.59	22.97	19.59	0
1939	53.77	113.70	68.34	37.61	130.47	131.64	332.83	216.75	30.10	22.48	18.30	21.03	0
1940	40.04	64.66	88.47	225.09	820.55	130.63	178.23	37.46	21.60	20.86	18.33	17.02	0
1941	47.99	22.41	29.93	69.06	476.03	128.86	109.73	37.81	22.87	19.18	22.77	18.95	0
1942	51.16	72.54	164.25	74.08	61.16	69.09	796.07	1166.30	200.76	391.32	147.45	31.50	0
1943	548.76	1837.53	1502.49	586.12	2122.16	567.27	59.76	35.55	30.68	24.27	19.75	20.95	0
1944	53.69	42.28	29.92	35.80	71.24	255.79	74.47	36.87	26.10	19.78	15.99	6.29	1
1945	5.93	8.39	29.92	81.55	184.71	98.73	74.24	47.33	30.41	20.31	15.89	8.15	3
1946	51.98	46.22	31.64	37.98	89.27	78.39	70.13	42.19	24.76	20.60	17.18	20.82	0
1947	51.14	34.01	96.52	72.44	119.60	646.35	369.53	41.10	23.13	18.09	15.90	9.42	1
1948	23.82	26.28	22.41	38.59	64.60	131.37	55.73	37.80	23.43	18.34	16.13	9.31	1
1949	22.34	71.67	113.54	49.76	388.27	440.58	221.62	291.75	52.62	24.74	90.01	20.83	0
1950	21.68	19.55	94.46	76.47	76.92	63.24	67.53	38.72	27.06	22.11	19.52	16.95	0
1951	54.97	43.41	30.44	38.62	428.85	64.83	56.42	34.04	23.72	26.12	22.97	19.66	0
1952	21.24	56.66	42.23	36.83	456.11	94.36	99.83	44.13	24.16	18.07	17.43	15.14	0
1953	48.18	49.12	70.84	41.51	124.42	504.69	100.48	40.72	28.67	21.16	15.80	7.42	1
1954	16.31	30.41	36.74	115.14	1617.67	476.59	165.90	80.14	28.86	22.64	18.85	10.61	0
1955	23.61	50.84	89.24	52.78	528.97	864.78	486.80	82.96	28.68	21.24	17.29	14.33	0
1956	38.77	73.10	803.67	528.55	153.72	194.87	64.27	33.59	22.96	24.81	23.14	1371.97	0
1957	1637.28	413.94	214.77	1069.63	199.88	58.71	81.69	238.02	69.39	21.11	17.25	18.46	0
1958	19.40	66.60	92.50	46.23	86.48	60.69	99.05	53.79	52.61	79.66	22.43	15.59	0
1959	46.17	67.33	105.30	50.34	155.99	139.49	137.61	51.09	27.56	22.07	22.38	19.01	0
1960	45.07	61.51	116.94	58.01	63.44	364.24	790.29	193.10	236.32	24.39	72.07	16.23	0
1961	15.51	76.32	174.22	41.06	993.94	290.83	62.41	58.11	23.29	18.16	16.11	15.26	0
1962	15.19	77.25	39.97	612.15	306.86	740.04	911.69	77.26	26.96	24.81	22.53	17.86	0
1963	28.33	81.51	77.90	54.90	63.65	95.81	130.05	35.13	26.96	23.50	21.58	18.70	0
1964	87.75	453.32	81.06	79.51	64.64	48.32	95.55	40.33	28.96	23.50	21.72	20.37	0
1965	36.14	28.10	29.95	103.79	416.93	55.97	61.65	32.47	21.16	17.17	14.25	8.02	1
1966	14.62	27.29	52.92	105.95	1538.24	536.52	1158.90	453.69	308.89	24.58	21.65	17.57	0
1967	19.66	57.16	35.85	35.99	30.22	102.25	84.36	77.85	28.21	22.59	17.39	17.80	0
1968	18.35	19.97	43.56	36.16	58.87	126.72	101.52	44.94	29.17	19.29	18.22	10.29	0
1969	53.78	32.49	50.73	37.49	69.03	41.85	24.87	19.33	17.39	17.38	16.48	19.28	0
1970	53.17	35.56	75.68	58.80	175.39	60.79	103.09	46.28	24.90	19.90	17.56	15.98	0
1971	19.11	34.45	52.38	238.64	308.02	726.47	146.63	46.32	28.32	20.46	17.71	15.29	0
1972	25.43	27.84	29.95	11.17	133.34	72.39	66.33	33.50	21.44	17.27	22.91	19.72	0
1973	34.82	29.11	72.67	691.90	2527.02	2384.46	712.95	282.38	112.82	23.85	341.22	20.45	0
1974	18.95	82.54	303.59	438.27	2028.79	938.07	188.73	41.48	28.18	24.53	21.46	20.40	0
1975	48.55	80.14	609.10	2023.50	2990.13	2880.90	996.95	575.59	151.80	34.13	22.20	20.83	0
1976	1061.88	670.52	37.89	50.12	968.32	897.68	124.05	42.05	26.55	21.85	19.00	20.44	0
1977	53.93	47.67	39.64	418.71	387.26	286.36	1133.68	107.15	29.17	23.81	21.24	20.88	0
1978	50.88	27.19	121.05	37.87	68.41	60.30	53.27	33.93	23.35	24.46	23.14	21.03	0
1979	54.12	55.25	49.01	44.84	183.76	106.86	53.87	31.43	21.17	17.95	22.05	20.38	0
1980	35.96	39.92	53.91	91.99	274.75	267.22	63.20	43.44	30.70	22.71	23.14	21.03	0
1981	29.49	34.93	62.76	38.74	58.68	56.01	102.83	44.88	28.06	23.68	20.34	16.73	0
1982	46.60	81.68	30.40	35.75	46.80	44.50	53.70	33.85	25.24	23.79	21.02	15.27	0
1983	36.98	74.17	98.04	77.82	57.31	61.16	64.46	43.91	21.77	17.90	19.09	19.69	0
1984	32.40	31.69	31.47	37.37	203.87	90.86	54.85	29.70	21.70	17.53	14.75	7.76	1
1985	40.23	77.53	135.38	52.79	99.02	59.95	55.08	32.91	27.77	17.87	19.24	20.54	0
1986	54.04	84.20	35.67	37.20	64.49	59.17	64.20	32.51	20.94	17.37	22.73	21.03	0
1987	54.97	83.23	107.88	53.22	2427.18	3733.57	630.37	107.46	58.67	24.63	22.92	322.07	0

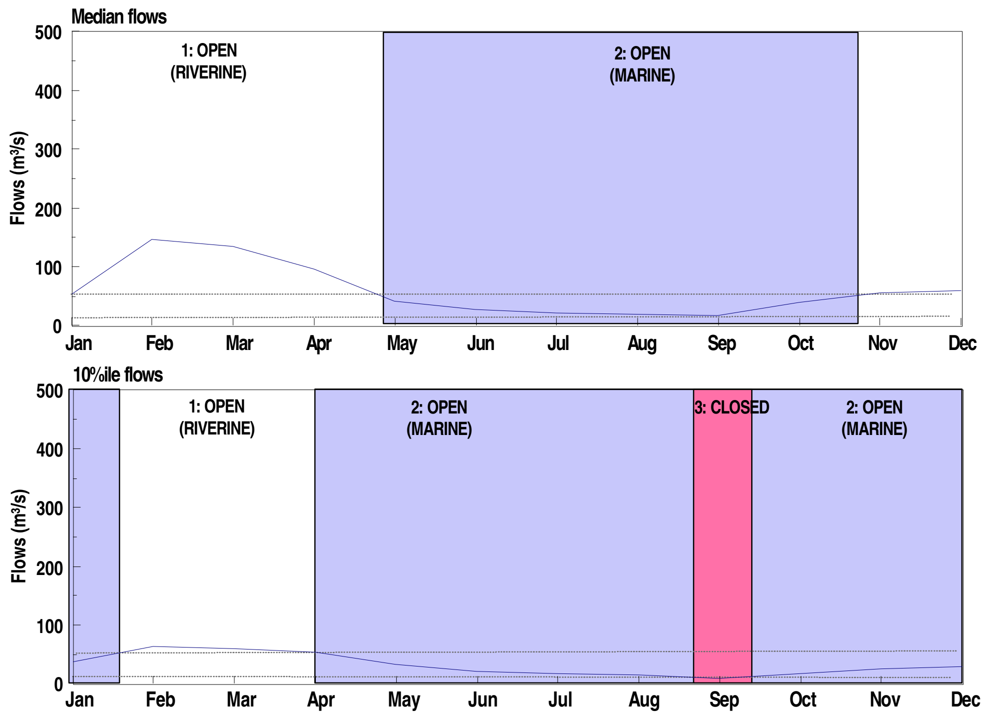
1: Open (River)	>50.0	2: Open (Marine)	10.0-50.0	3: Closed	< 10.0	Floods	> 2000

< 10.0	2	1	0	0	0	0	0	0	0	0	0	9
10.0-50.0	45	31	29	29	2	3	1	48	57	66	64	57
>50.0	21	36	39	39	66	65	67	20	11	2	4	2

d. Occurrence and duration of different Abiotic states for Scenario 10

The occurrence and duration of the different Abiotic States under Scenario 10 are illustrated in the simulated monthly river flow table (**Table 4.11**).

To provide a conceptual overview of the annual distribution of Abiotic States under Scenario 10, median monthly flows and 10%ile flows were used to depict the situation for normal and drought periods, respectively:



e. Predicted change in biotic characteristics of Scenario 10 compared with the Reference Condition

MICROALGAE

Scenario 10 differs from scenario 9 in that there has been an increase in the period of low flow. As a result of this the estuary is more saline but is still better than present conditions. The period of low flows, similarity in mean duration of mouth closure and similarity in salinity gradients represents an improvement from present conditions. The state of the microalgae is close to reference conditions. The magnitude of major floods has been reduced. The stable channels would allow for benthic microalgal colonisation. An increase in the marine influence in the lower reaches of the estuary would change microalgal species composition and increase phytoplankton biomass compared to reference conditions.

Confidence: Low

MACROPHYTES

Most of the changes are in response to the reduction in large floods would have reset the estuary more frequently. Stable conditions would increase the growth and distribution of macrophytes in the main channel. An increase in marine (saline) conditions could restrict the distribution and growth of certain brackish species.

Confidence: Low

INVERTEBRATES (INCLUDING ZOOPLANKTON)

Similar to previous scenario where freshwater conditions persist for about 6 months of the year. However, this is less than the 9 months reported for the reference condition. The subtidal benthic community present in the deeper channel areas inside the mouth will change from an estuarine type community (6 months – May to November) to a more freshwater type community during the summer. The time interval should be sufficient to allow each type to establish itself.

The zooplankton will respond in a similar way to the subtidal benthos, although response will be much quicker. Some estuarine types will probably survive for longer in protected backwaters where suitable salinity conditions (>5 ppt) persist because of the braided nature of channels and sandbanks.

Invertebrates associated with the wetland on the southern bank near the mouth are also likely to be dominated by an estuarine community.

Confidence: Low

FISH

Similar to scenario9 with the loss of the seasonal flow reversals making conditions better than the present day. The mouth remains open during most of the time facilitating recruitment of larvae and juvenile fish. However, depending on the cues provided by floods recruitment may also reduced. Saltwater penetration in the lower reaches may be beneficial to marine and estuarine predators (e.g. L. amia & P. saltatrix) and benthic feeders (e.g. L. lithognathus) that forage visually. Similarly, flocculation could lead to a slight loss of refuge from piscivorous predators in the shallows. In the absence of other anthropogenic influences, marine species are likely to occur more frequently in the saline lower estuary whereas freshwater species (with the exception of O. mossambicus) are likely to be confined to the head of the estuary and river reaches. Depending on recruitment from the "adjacent" estuaries and surf-zone some species such as Caffrogobius spp. and the Syngnathidae may recolonise the estuary and persist throughout the wet and dry season

Confidence: Low

BIRDS

Similar to Scenario 5 and 9. Slightly less river dominance than Scenario 9.

Confidence: Low

f. EHI Tables for Scenario 10

Hydrology

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
a. % similarity in period of low flows	75	For the Orange Estuary low flows is defined as flows associated with the *State 3: Closed* (i.e. <10.0 m^3/s) and *State 2: Open (Marine*) (between 10.0 and 50.0 m^3/s). Months with median low flows of less than 50.0 m^3/s increased form 3 (Jul – Sep) under the Reference Condition to 6 (May - Oct) under the Scenario 10.	Low
b. % similarity in the magnitude of major floods (e.g. 1:20, 1:50 and 1:100) in comparison with the reference condition	45	For the Orange River floods greater than 5000 x $10^6 m^3$ were judged to be resetting events. These have been significantly reduced from 20 under the Reference conditions to 9 under Scenario 10.	Low
	63		

Hydrodynamics and mouth condition

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
Change in mean duration of closure over a 68 year period	70	For the Orange Estuary mouth closure occurs at flows less than 10 m^3/s. Under the Reference condition the estuary mouth use to close 18 out of the 68 years (26%) for about 1 month at a time, while under Scenario 8 mouth closure occur 10 out of the 68 years (15%) for ~1 month at a time. Alternatively, out of a total of 816 months (68 years), mouth closure increased from ~3% in the Reference Conditions to ~1.5 % under the Scenario 10. *Note: Following a precautionary approach, and in view of the importance of mouth closure and related back flooding to estuarine health, the mouth closures were score severely.*	Low
	70		

Water quality

VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1. Change in the longitudinal salinity gradient (%) and vertical salinity stratification	70	There has been modification in the salinity distribution due to an increase of *State 2: Open (Marine*) a decrease in *State 1: Open (Riverine)*. From being freshwater dominated for 9 months (Oct-Jun) of the year under the Reference Condition, the system is now only freshwater dominated for 6 months (Nov-Apr) with strong marine influence in the lower reaches for about 6 months (May-Oct).	Low
2a. Nitrate and phosphate concentration in the estuary	90	Agricultural activities in the catchment could have resulted in inorganic nutrient enrichment to the estuary, although river vegetation probably acted as a 'filter'. Allow for 10% change. Occurrence of State 2, (i.e. stronger marine influence) increased by 3 months from the Reference Condition, but mostly in winter when upwelling is not expected to cause any marked difference in nutrient concentrations in the bottom waters of the deeper basin near the mouth.	Low
2b. Suspended solids present in inflowing freshwater	90	Although the suspended solid concentration in inflowing river water is not expected to change, the total load into the estuary will be less due to a decrease in river inflow, in general.	Low
2c. Dissolved oxygen (DO) in the estuary	80	It is expected that the estuary will remain well-oxygenated as was the case under the Reference Condition. However, occasional events of low oxygen, river water inflow may occur, associated with algal blooms developing upstream.	Low
2d. Levels of toxins	90	No data available, but agricultural activities (e.g. introduction of pesticides) may have resulted in some change. Allow for 10%.	Low
	76		

Physical habitat alteration

	VARIABLE	SCORE	MOTIVATION	CONFIDENCE
1	Resemblance of intertidal sediment structure and distribution to reference condition			
1a	% similarity in intertidal area exposed	75	Similar to the present status, because the lack of hydropower releases, will not have a noticeable effect on the sediment processes and characteristics.	Low
1b	% similarity in sand fraction relative to total sand and mud	90	Similar to the present status, because the lack of hydropower releases, will not have a noticeable effect on the sediment processes and characteristics.	Low
2	Resemblance of subtidal estuary to reference condition: depth, bed or channel morphology	90	Similar to the present status, because the lack of hydropower releases, will not have a noticeable effect on the sediment processes and characteristics.	Low
		86		

Microalgae

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	%	Score	It is estimated that approximately 80 % of the original species remain. The increase in the marine state would promote the growth of marine species at the expense of freshwater / brackish species.	Low
	80	65		
2a. Abundance	70		Because of the increase in low flow and reduction in floods compared to reference conditions, there will be longer water retention time which would allow the development of phytoplankton biomass. The stable channels would allow for benthic microalgal colonisation. Biomass is expected to be 30 % higher than it was under reference conditions.	Low
2b. Community composition	80		Small change as a result of the greater water retention time, flagellates would dominate the phytoplankton rather than diatoms.	Low
	65			

Macrophytes

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	%	Score	The river channels and islands are more stable. The estuary is no longer reset as frequently as it was under reference conditions. As a result of this there may be a loss of opportunistic species and an increase in reed growth at the expense of other species. Stable water levels would also have contributed to the increase in reeds. Brackish species may have been lost as a result of an increase in saline conditions.	Low
	80	65		
2a. Abundance	70		In 1986, 90% of the large salt marsh area on the southern bank was lost and became desertified. However, recent aerial photographs indicate that the removal of the causeway near the mouth and the introduction of tidal waters may have increased vegetation cover. Salinity conditions closer to that of the reference state would encourage the growth of macrophytes in this area. In the main channel there has been an increase in reed abundance due to sediment stablization. Increase in saline conditions in the main channel would however reduce the growth and distribution of brackish reeds and sedges.	Low
2b. Community composition	70		Brackish communities have been lost from the desertified salt marsh area, but are still represented in the main river channel. Saline conditions would displace some freshwater species in the main channel.	Low
	65			

Invertebrates

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	%	Score	Species richness is likely to be greater under this scenario compared to Scenario 6 (Rver Class D), because of fresh-water conditions persisting for longer each year.	Low
	60	35		
2a. Abundance	40		Abundance levels are probably similar to Scenario 6 or slightly higher.	Low
2b. Community composition	40		Because of the slightly longer duration of freshwater conditions, community composition is likely to increase marginally.	Low
	35			

Fish

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	%	Score	Similar to present day but closer to reference conditions with recruitment cues following the same patterns. Probable loss of one or two of the Gobidae e.g. *Caffrogobius* spp. and *Psammogobius knysnaensis* and perhaps the Syngnathidae due to more stable conditions and loss of the marginal areas and channels of the saltnarsh.	Low
	90	80		
2a. Abundance	70		Decline in abundance of freshwater species in the estuary but probably compensated by an increase in abundance of some of the more "opportunistic" estuarine dependent species such as L. richardsonii during the winter months. Recruitment also likely to be greater due to a lessening of the confusing cues resulting from seasonal reversal of flows under present day conditions.	Low
2b. Community composition	70		Similar to present day but without seasonal flow reversal. Although always dominated by the detritivorous *L. richardsonii*, there has been a decline in the number of piscivores such as *L.amia, A. inodorus* and *P. saltatrix* and to a lesser extent *L. lithognathus* and *L. aureti. Freshwater tolerant estuarine species likely to be more "dominant" than freshwater species than they were under reference conditions. Freshwater species excluded from the estuary for most of the year. Perhaps recolonization of species such as Caffrogobius.*	Low
	70			

Birds

VARIABLE	SCORE		MOTIVATION	CONFIDENCE
1. Species richness	*%*	*Score*	Probably no change in species composition, as even species that are negatively affected will be present in low numbers.	Low
	100	100		
2a. Abundance	50		Similar to Scenarios 5 and 9. Flooding may however be beneficial as island roosting and breeding sites may be established and maintained. Limited backflooding with mean low-lying breeding/roosting areas will not be flooded.	Low
2b. Community composition	60		May benefit roosting/breeding cormorants and roosting terns.	Low
	50			

4.3 Ecological Categories associated with different Scenarios

The individual EHI scores, as well as the corresponding EC for the different scenarios are provided in **Table 4.12.**

Table 4.12: Summary of Estuarine Health Index (EHI) Scoring and Ecological Category (EC) associated with Different Future Scenarios

VARIABLE	WEIGHT	Present State	FUTURE SCENARIOS									
			1	2	3	4	5	6	7	8	9	10
Hydrology	25	58	48	48	43	31	45	30	48	48	68	63
Hydrodynamics	25	50	50	50	0	0	55	25	60	0	70	70
Water quality	25	72	68	68	54	43	76	68	68	58	78	76
Physical habitat	25	86	86	86	75	71	10	10	86	75	86	86
Habitat Score	**50**	**67**	**63**	**63**	**43**	**36**	**47**	**33**	**66**	**45**	**76**	**74**
Microalgae	20	50	40	40	35	17	50	40	40	40	80	65
Macrophytes	20	50	40	40	35	20	25	20	40	35	80	65
Invertebrates	20	40	40	40	25	10	35	25	35	35	60	35
Fish	20	60	40	40	25	17	17	10	40	25	60	70
Birds	20	26	26	26	20	15	24	24	30	20	50	50
Biological Score	**50**	**45**	37	**37**	**28**	**16**	**30**	**24**	**37**	**31**	**66**	**57**
EHI INDEX SCORE		**56**	**50**	**50**	**36**	**26**	**38**	**29**	**51**	**39**	**71**	**65**
EC		**D+**	**D-**	**D-**	**E**	**E**	**E**	**E**	**D+**	**E**	**C+**	**C-**

To select the recommended 'Ecological Water Requirement Scenario', the guideline for estuaries states that, the simulated runoff scenario representing the largest modification in flow, but that which would still keep the estuary in the recommended EC (in this case a **Category C)** should be the recommended 'Ecological Water Requirement Scenario'.

For the purposes of this rapid assessment, a preliminary estimate of the **recommended 'Ecological Water Requirement Scenario'** for the Orange River Estuary (to meet the recommended **Ecological Category of C**) is estimated at a MAR of 4 758.93 x 10^6 m^3 (equivalent to Scenario 10) with the following distribution:

MONTH	FLOW (m^3/s) – flow should ≥ % in given month									
	90%ile	80%ile	70%ile	60%ile	50%ile	40%ile	30%ile	20%ile	10%ile	1%ile
OCT	54.95	53.72	50.64	46.25	39.4	32.11	25.65	20.05	18.1	5.93
NOV	178.06	82.19	76.11	67.59	55.37	43.18	34.06	28.53	26.19	14.73
DEC	228.73	120.75	96.31	78.53	59.44	43.42	35.94	31.54	29.99	27.44
JAN	545.82	147.26	82.87	70.39	54.06	47.74	41.1	37.92	36.72	27.64
FEB	1427.02	581.97	388.17	212.81	146.25	98.86	77.24	65.15	62.76	41.33
MAR	777.46	493.45	284.44	189.07	135.57	105.94	78.48	61.99	59.04	43.63
APR	736.15	218.39	145.73	103.03	96.22	74.42	64.29	58.27	54.21	43.9
MAY	223.13	81.83	47.96	44.89	41.77	38.29	35.68	33.51	32.5	26.28
JUN	61.89	30.69	29.17	28.44	27.31	25.17	23.3	21.9	21.17	19.77
JUL	24.81	24.56	23.85	22.82	21.96	20.57	19.18	18.08	17.46	17.24
AUG	23.14	22.85	22.36	21.59	20.12	18.75	17.45	16.31	15.73	13.53
SEP	21.03	20.51	19.88	19.17	17.99	17	15.62	14.03	8.96	6.11

White = State 1 (river dominated); Blue = State 2: Strong marine influence; Red = State 3: Mouth closure

Of particular significance is that the distribution of Abiotic States in this Scenario resembles that of the Reference Condition, namely a river dominated state (State 1) during the autumn/summer, with stronger marine influence (State 2) during late winter/spring and mouth closure (State 3) only occurring occasionally during spring. As a result, the predicted biotic response is closer to that of the Reference Conditions (presently, State 2 [i.e. stronger marine influence] is dominant during the spring/summer, while the river dominated state [State 1] dominates during autumn/winter – almost a reversal of Reference Conditions).

NOTE:

The recommended Ecological Flow scenario for an Ecological Category C can still be refined. It, however, is important that the revised flow scenario maintain the distribution of Abiotic States presented in the current recommended scenario (see above).

It is estimated, that to maintain the estuary in its **Present Ecological Status of a Category D+,** a flow (and abiotic State) distribution represented by **Scenario 7** (MAR = 4 529.73 x 10^6 m^3) would be required:

MONTH	FLOW (m^3/s) – flow should ≥ % in given month									
	90%ile	80%ile	70%ile	60%ile	50%ile	40%ile	30%ile	20%ile	10%ile	1%ile
OCT	28.17	27.63	26.25	24.3	21.25	18	15.13	12.64	11.85	11.66
NOV	229.69	35.27	33.68	31.45	28.45	25.55	22.7	21.26	20.68	16.75
DEC	236.25	113.03	38.42	36.78	32.51	30.18	26.85	25.63	25.2	23.19
JAN	545.17	148.81	74.47	42.26	37.73	31.13	27.47	25.71	25.1	19.89
FEB	1373.57	607.65	381.22	218.67	145.99	94.69	70.18	58.39	54.85	46.62
MAR	790.16	469.72	278.09	174.22	93.14	62.56	52.26	44.27	43.1	42.13
APR	713.61	206.18	139.12	76.9	62.42	47.61	38.31	34.94	30.17	26.65
MAY	213.14	102.63	54.34	43.68	37.87	33.01	28.79	25.29	23.67	21.16
JUN	63.03	33.68	31.69	30.69	29.11	26.51	24.08	22.28	21.32	19.85
JUL	26.4	26.13	25.35	24.23	23.29	21.77	20.24	19.05	18.38	18.13
AUG	23.21	22.98	22.49	21.66	20.18	18.8	17.49	16.35	15.83	15.14
SEP	24.42	23.35	22.06	20.6	18.17	16.14	13.28	11.9	11.12	7.58

White = State 1 (river dominated); Blue = State 2: Strong marine influence; Red = State 3: Mouth closure

5. RECOMMENDATIONS ON ADDITIONAL DATA REQUIREMENTS

Data requirements to improve the confidence of the preliminary Ecological Reserve determination are set out in the method for Estuaries. It is recommended that the following monitoring be conducted to improve the confidence of the Ecological Reserve determination on the Orange River Estuary (largely based on the recommended data requirements for a Comprehensive Ecological Reserve Determination).

NOTE:

It is strongly recommended that surveys to collect the additional data requirements on the different abiotic and biotic components (see below) in the Orange River Estuary be coordinated (i.e. undertaken simultaneously) to prevent duplication and to enable scientists to quantify linkage between different abiotic and biotic processes, a key requirements in predicting the effects of the modification in river inflow..

Abiotic components (hydrodynamics)

DATA REQUIREMENTS	MOTIVATION
Continuous river flow gauging at the head of the estuary	Such data are crucial for correlating river flow to the state of the mouth (as reflected by water level recordings); particularly in temporarily open/closed estuaries. The dataset duration required will depend on, for example, the frequency of mouth closure in the particular estuary, in the case of the Orange River Estuary at least 15 years (to provide data on about 3-5 mouth closures). For this purpose, it is recommended that the gauging station at Brandkaros be re-installed.
Continuous water level recordings near mouth of the estuary and in the salt marsh area near the beach.	To obtain long-term records of variations in tidal levels and mouth conditions. For representative data, recordings of between 5 and 15 years are required in the saltmarsh area near the mouth.
Daily observations on the state of the mouth	During the period just prior to mouth closure, results from the continuous water level recordings may not be accurate enough. Where possible, daily mouth observations should be logged when the mouth is nearly closed or closed. The time at which the observation was made and the state of the tide must also be recorded, ideally at low tide
Aerial photographs of estuary - colour, geo-referenced rectified aerial photographs at 1: 5 000 scale covering the entire estuary (based on the geographical boundary), and taken at low tide in summer, are required. These photographs must include the breaker zone near the mouth.	Repetitive, systematic and comparative oblique photographs taken of the mouth, tidal basin and upper estuary area provide valuable information on the dynamic of an estuary mouth, for example, to derive the effect of wave action on the mouth dynamics, in particular, the extent to which the mouth is exposed to direct wave action, and to determine the width of the breaker zone (indicative of the beach slope).

Abiotic components (sediment dynamics)

DATA REQUIREMENTS	MOTIVATION
Series of cross-section profiles along the beach, bar, mouth and lower basin region (at about 25 m intervals) as well as upstream along the entire estuary (at ~300 m intervals from the +5 m MSL contour on the left bank, trough the estuary to the +5 m MSL contour on the right bank), using D-GPS and echo-sounding). This should be done every 3 years (and immediately after a flood) to quantify the sediment deposition rate in the estuary.	These data are required to allow/enable the quantification of sediment transport processes, estuarine morphology and long-term evolution of estuarine topography resulting from significant changes in the hydraulic regime. It may not be possible to acquire these data sets in the short term, but long term monitoring programmes to collect such data must be considered if the dynamic sediment processes in the estuary and the holistic functioning of the river/estuary/nearshore system are to be better understood. As some of the critical processes/dynamics have decadal (or longer) time scales, a minimum record of typically 15 years would be required. Alternatively, numerical models could be used to simulate longer-term processes if sufficient shorter term data is available to adequately calibrate and verify such models.
Series of sediment grab samples for the analysis of particle size distribution (PSD), cohesive nature and organic content, taken every 3 years (and immediately after a flood) along the length of the estuary (at ~ 100 to 300 m intervals across the estuary including inter- and supratidal area). Representative samples should also be collected from the adjacent beach and sand bar.	
A series of sediment core samples for historical sediment characterisation taken once-off, but ideally just after a medium to large flood as well as a year (or two) later along the same grid as the grab samples (see above).	
Sediment load near the head of estuary (including grain size distribution and particulate carbon - detritus component): Daily intervals for a minimum 5 years. Ideally, both suspended- and bed-load should be monitored. The measurements could be done at Brandkaros, but ideally within a few kilometers upstream of the Oppenheimer Bridge.	

Abiotic components (water quality)

DATA REQUIREMENTS	MOTIVATION
At least monthly water quality measurements on system variables [conductivity, temperature, pH, dissolved oxygen, turbidity, suspended solids], inorganic nutrients [e.g. nitrate, ammonium and reactive phosphate] and, if possible, toxic substances in river water entering at the head of the estuary (Oppenheimer Bridge Ideally, particulate organic carbon input (see also sediment dynamics) should be recorded.	The water quality of river inflow and the temporal variability thereof is required to understand the present state of the estuary, as well as to predict the changes as a result of modification in flow. Usually this data is acquired from the river IFR site just upstream of the estuary. However in the case of the Orange River Estuary modifications to river water quality still occurs in the section just above the estuary where no data are available. It is recommended that this station be added to the DWAF's (SA) national water quality monitoring programme. To observe specific trends a minimum record of ~5 years is typically required.
Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: • low flow season (i.e. period of maximum seawater intrusion), but when the mouth is still open • during mouth closure (this may require a series of surveys to capture the dynamic nature of this state)	These measurements, together with the river inflow data (must be collected simultaneously) are used to estimate the correlation between salinity/temperature distribution patterns along the length of the estuary and river flow. Where only a limited amount of fieldwork is possible, this could best be achieved by measuring the 'extremes' such as the end of low flow season (marine dominated) and during mouth closure.
Water quality measurements on system variables [pH, dissolved oxygen, turbidity, suspended solids], inorganic nutrients [e.g. nitrate, ammonium and reactive phosphate] taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: • end of low flow season when the mouth is still open • during mouth closure (this may require a series of surveys to capture the dynamic nature of this state) Ideally organic nutrients (i.e. dissolved and particulate organic carbon should also be recorded)	The water quality field exercise must coincide with the salinity/temperature profiling. In this way a limited water quality data set (which is usually very expensive to acquire) can be used to derive water quality characteristics under different tidal conditions, using salinity data, expert opinion or appropriate assessment tools, e.g. numerical models
Measurements of toxic substances (e.g. trace metals) in sediments across the estuary, focussing on depositional areas, characterised by finer, often organic rich sediments.	To establish the spatial distribution and extent of toxic pollutant distribution in the estuary. In highly dynamic systems such as estuaries, it is considered more appropriate to sample environmental components which tend to integrate or accumulate change over time, such as sediments

Microalgae

DATA REQUIREMENTS	MOTIVATION
Chlorophyll-a measurements taken at 5 stations (at least) at the surface, 0.5 m and 1 m depths thereafter. Cell counts of dominant phytoplankton groups i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Measurements should be taken coinciding with the different Abiotic States, particularly State 2 (marine influence) and State 3 (closed mouth conditions).	To determine phytoplankton and biomass and dominant phytoplankton types. Phytoplankton biomass is an index of eutrophication while changes in the dominant phytoplankton groups indicate changes in response to water quality and quantity. A study of this nature is probably only necessary in large permanently open estuaries where phytoplankton are important primary producers. Measurements for different flow conditions are required to establish natural variability.
Intertidal and subtidal benthic chlorophyll-a measurements taken at 5 stations. Epipelic diatoms need to be collected for identification. Measurements should be taken coinciding with the different Abiotic States, particularly State 2 (marine influence) and State 3 (closed mouth conditions).	To determine benthic microalgal biomass and dominant epipelic diatom species. Benthic microalgae are important primary producers in shallow estuaries or those with large intertidal areas. Epipelic diatom composition can indicate changes in water quality. Measurements for different flow and mouth conditions are required to establish natural variability.
NOTE: 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.	

Macrophytes

DATA REQUIREMENTS	MOTIVATION
Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the present state, as well as the reference condition (if available)	To map the distribution of the different plant community types and to calculate the area covered by different plant community types (habitat types[1]). Aerial photographs can be used to monitor habitat change from reference to present day, e.g. reed encroachment.
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.	This information is required to determine the regional and national botanical importance of an estuary, and to set the ecological reserve category.
Permanent transects (a fix monitoring station that can be used to measure change in vegetation in response to changes in salinity and inundation patterns)[2]: Measurements of percentage plant cover along an elevation gradient Measurements of salinity, water level, sediment moisture content and turbidity	These measurements are used to relate changes in the flora to changes in salinity, water level, flooding and sedimentation. From these data the sensitivity of the flora to changes in freshwater input can be determined and reference conditions can be estimated. In addition the implications of future run-off scenarios can be predicted and used to set the Resource Quality Objectives for water quantity.

Invertebrates

DATA REQUIREMENTS	MOTIVATION
Compile a detailed sediment distribution map at ten sites of the estuary Obtain a detailed determination of the extent and distribution of shallows and tidally exposed substrates.	This is required to identify different habitat types, e.g. sand, mud, detritus distribution and interface area.
During each survey, collect sediment samples for analysis of grain size [1] and organic content [2] at the ten benthic sites.	These measurements are required to gain understanding of links between the abiotic parameters and biological components
During each survey determine the longitudinal distribution of salinity, as well as other system variables (e.g. temperature, pH and dissolved oxygen and turbidity)[3] at each of the ten benthic sampling sites	
Collect a set of benthic samples from ten sites, each consisting of six replicate grabs stored separately. Collect two of these from sandy areas, and the remainder spread between 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 (i.e. quarterly) data sets for at least one year are required, preferably collected at neap tides (weaker current velocities improve sampling efficiency).	To estimate biomass distribution and key species of the benthos. The richness of benthos determines the importance of the area for each species.
Collect replicated hyperbenthic samples.at the same benthic sites identified above (i.e. two replicates at each of the ten sites). 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 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 (i.e. quarterly) data sets for at least one year are required, preferably collected at neap tides (weaker current velocities improve sampling efficiency)..	To estimate biomass distribution and species of the macrocrustacea.
Collect replicated zooplankton samples at each of the ten benthic sites (i.e. two replicates at each of the ten sites) at night. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at neap tides (weaker current velocities improve sampling efficiency – zooplankton also moves into the water column more effectively, providing a better estimate of abundance).	To estimate biomass distribution and key species of the zooplankton.
Additional trip(s) may be required to gather data on the occurrence/recruitment and emigration of key that require a connection to the marine environment at specific times of the year.	

Fish

DATA REQUIREMENTS	MOTIVATION
The Orange Estuary needs to be sampled quarterly over at least one year to account for the seasons followed by another year covering summer and winter. Seine-nets to sample small and juvenile fish and gillnets to sample adults are the appropriate gear. Monofilament gill nets should comprise at least 3 different mesh sizes within the range of 40-150 mm stretched mesh. Seine nets should be 30 m long, 1.7 m deep with a 15 mm bar mesh in the wings and a 5 mm bar mesh in the purse. All species in the catch should be identified, counted and measured in total length. Given the uncertainty as to the dominant food sources and the possible seasonal changes in them, a representative sample should be retained for stomach content analysis. Salinity, temperature, turbidity and if possible oxygen need to be recorded at each sampling site. The Orange Estuary needs to be sampled from the mouth to Brandkaros 35 km upstream. Samples in the estuary proper up until the Ernst Oppenheimer Bridge (10 km) should be 1 km apart thereafter at 2 km intervals to Brandkaros covering all habitat types (sand, channel, saltmarsh etc). This gives 23 sites in total. Given the evident links between the estuary and adjacent surfzone, it would also be advisable to sample the surf-zone with the seine-net, to at least 1 km either side of the mouth. All the salinity regimes must be covered. These typically include: Fresh (representative of river), 0 – 10 ppt, 10 – 20 ppt and 20 – 35 ppt.	To estimate biomass distribution and species of the fish, as well as seasonal variability.

Birds

DATA REQUIREMENTS	MOTIVATION
Continue with full count of all water associated birds bi-annually, covering as much of the estuarine area as possible, (as part of the requirements of Ramsar). All birds should be identified to species level and the total number of each counted.	To estimate biomass distribution and species of the birds, as well as seasonal variability.

6. REFERENCES

ANDERSON, M D, KOLBERG, H, ANDERSON, P C, DINI, J & ABRAHAMS, A. 2003. Waterbird populations at the Orange River mouth from 1980-2001: a reassessment of its Ramsar status. *Ostrich* **74**(3&4): 159-172.

ANON. 2002. Orange River Mouth Transboundary Ramsar Site (ORMTRS). Conservation Area Management Plan. Northern Cape Directorate Environment and Conservation (Kimberley) and Ministry of Environment and Tourism (Windhoek). 3rd Draft. February 2002.

BARNARD, P (ed). 1998. Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force. 332 pp.

BARNES, K N. 2000. The Eskom Red Data Book of Birds of South Africa, Lesotho & Swaziland. Johannesburg: BirdLife South Africa.

BURNS, M E R. 1989. The vegetation of the Orange River mouth. Unpublished Paper. Orange River environmental workshop, Oranjemund.

BORNMAN, T G. 2002. Freshwater requirements of supratidal and floodplain salt marsh on the West Coast, South Africa. PhD Thesis, University of Port Elizabeth, Port Elizabeth, South Africa. 243 pp.

BIRDLIFE INTERNATIONAL**.** 2000. Threatened birds of the world. Barcelona and Cambridge: Lynx Editions and BirdLife International.

COOPER, J , BROOKE, R K, SHELTON. P A and CRAWFORD, R J M. 1982. Distribution, population size and conservation of the Cape Cormorant *Phalacrocorax capensis*. *Fish Bulletin of South Africa* **16**: 121-143.

CRAWFORD, R J M. 1997a. Cape Cormorant *Phalacrocorax capensis*. In: The atlas of southern African Birds. Vol 1: Non-passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. & Brown, C.J. (eds), pp 32-33. Johannesburg: BirdLife South Africa.

CRAWFORD, R J M. 1997b. Swift Tern *Sterna bergii*. In: The atlas of southern African Birds. Vol 1: Non-passerines. Harrison, J.A., Allan, D.G., Underhill, L.G., Herremans, M., Tree, A.J., Parker, V. & Brown, C.J. (eds), pp 470-471. Johannesburg: BirdLife South Africa.

CRAWFORD, R J M. 1999. Seabird responses to long-term changes of prey resources off southern Africa. In: Adams, L. & Slotow, R. (eds). Proceedings of 22nd International Ornithological Congress. Johannesburg: BirdLife South Africa.

CRAWFORD, R J M. 2000. Cape Cormorant *Phalacrocorax capensis.* In: The Eskom Red Data Book of Birds of South Africa, Lesotho & Swaziland. Barnes, K.N. (ed.). pp 32-33. Johannesburg: Bird Life South Africa.

CRAWFORD, R J M. and Dyer, B M. 1995. Responses by four seabird species to a fluctuating availability of Cape Anchovy *Engraulis capensis* off South Africa. *Ibis* **137**: 329-339.

CRAWFORD, R J M , ALLWRIGHT, D M and HËŸL, C.W. 1992. High mortality of Cape Cormorants (*Phalacrocorax capensis*) off western South Africa in 1991 caused by *Pasteurella multocida*. *Colonial Waterbirds* **15**(2): 236-238.

CSIR. 1991. Environmental rehabilitation: Orange River Saltmarshes. *CSIR Report* **EMA - C91165**.Stellenbosch.

CSIR, 2001. Orange River mouth. Conservation and development Plan: Intuitional Support Study. *CSIR Report* **ENV-S-C 2001-075**.

CSIR *in prep.* Orange (CW 1). In: Estuaries of the Cape. Part 2, Synopses of available information on individual systems. Morant, P. (ed).

COWAN G I. 1995. Wetlands of South Africa. Department of Environmental Affairs and Tourism, Pretoria

DWAF. 1999. *Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component (Version 1.0).* Department of Water Affairs and Forestry, Pretoria.

MORANT, P D and O'CALLAGHAN, M. 1990. Some observations on the impact of the March 1988 flood on the biota of the Orange River Mouth. *Transactions of the Royal Society of Southern Africa* **47**: 295-305.

O'CALLAGHAN, M. 1984. Some management recommendations for the Orange River near Alexander Bay. Unpublished Report. Submitted to State Alluvial Diggings, Alexander Bay.

RAAL, P. 1996. The vegetation of the Orange River Mouth. In: A. Venter and M van Veelen. Refinement of the instream flow requirements of the Orange River and Orange River Mouth. Department of Water Affairs and Forestry, Pretoria.

RYAN, P G & COOPER, J. 1985. Waders (Charadrii) and other coastal birds of the northwestern Cape Province, South Africa. *Bontebok* **4**: 1-8.

RAMSAR CONVENTION BUREAU. 1999. Information Sheet on Ramsar Wetlands (RIS). Gland, Switzerland: Ramsar Convention Bureau.

SCHWARTZLOSE, R A, ALHEIT, J, BAKUN, A, BAUMGARTNER, T R, CLOETE, R, CRAWFORD, R J M, FLETCHER, W J, GREEN-RUIZ, Y, HAGEN, E., KAWASAKI, T, LLUCH-BELDA, D, LLUCH-COTA, S E, MACCALL, A D, MATSUURA, Y, NEVAREZ-MARTINEZ, M O, PARRISH, R H, ROY, C, SHUST, K V, WARD, M N and ZUZUNAGA, J Z. 1999. Worldwide large-scale fluctuations of sardine and anchovy populations. *South African Journal of Marine Science* **21**: 289-347.

SIMMONS, R E, BROWN, C J & WILLIAMS, A J. (in prep). Birds to Watch in Namibia: a red list. National Biodiversity Programme, Ministry of Environment & Tourism.

SWART, D H, MORANT, P D, MÖLLER, J P, CROWLEY, J B and DE WET, A. 1988. A record of events at the Orange river mouth during the March 1988 flood. *South African Journal of Science* **84**: 881-889.

TURPIE, JK, ADAMS, JB, COLLOTY, BM, JOUBERT A, HARRISON, TD, MAREE, RC ,TALJAARD, S, VAN NIEKERK, L, WHITFIELD, AK, WOOLDRIDGE, TH, LAMBERTH, S J, TAYLOR, R, MORANT P, AWAD, A, WESTON, B and MACKAY, H. 2002. Classification and prioritization of South African estuaries on the basis of health and conservation priority status for determination of the estuarine water reserve. Department of Water Affairs and Forestry, Pretoria.

WILLIAMS, A J.1986. Wetland birds at the Orange River mouth and their conservation significance. *Bontebok* **5**: 17-23.

WILLIAMS, A J. 1990. Orange River Mouth Wetland. Directory of Wetlands of International Importance Data Sheet. Unpubl. Report. Pretoria: Department of Environmental Affairs and Tourism.