Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the INKOMATI WATER MANAGEMENT AREA, MPUMALANGA

PROJECT NO: WP 9133

EcoClassification Report

INKOMATI

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DEPARTMENT OF WATER AFFAIRS AND FORESTRY

CHIEF DIRECTORATE: RESOURCE DIRECTED MEASURES

COMPREHENSIVE RESERVE DETERMINATION STUDY FOR SELECTED WATER RESOURCES (RIVERS, GROUNDWATER AND WETLANDS) IN THE INKOMATI WATER MANAGEMENT AREA, MPUMALANGA.

SABIE AND CROCODILE SYSTEMS: ECOSPECS REPORT: FINAL

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Reports as part of this project:

Report no	Report title
26/8/3/10/12/001	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Inception report
26/8/3/10/12/002	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Desktop EcoClassification report
26/8/3/10/12/003	Newsletters
26/8/3/10/12/004	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Basic Human Needs Reserve report
26/8/3/10/12/005	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Groundwater report
26/8/3/10/12/006	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Resource Unit report
26/8/3/10/12/007	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Desktop Estimation report
26/8/3/10/12/008	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Wetland report
26/8/3/10/12/009	**Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: EcoClassification report**
26/8/3/10/12/010	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: EWR scenario report
26/8/3/10/12/011	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Operation scenarios and consequences report
26/8/3/10/12/012	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: EcoSpecs report
26/8/3/10/12/013	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Socio Economic Present State Evaluation Report
26/8/3/10/12/014	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Training audit and report
26/8/3/10/12/015	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Main report
26/8/3/10/12/016	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Electronic information and data
26/8/3/10/12/016	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Electronic information and data

Bold indicates this report

REFERENCES

This report is to be referred in bibliographies as:

Department of Water Affairs, South Africa. 2009. Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. Sabie and Crocodile Systems: EcoClassification Report - Volume 1. Prepared by Water for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/009.

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EXECUTIVE SUMMARY

BACKGROUND

The Reserve for the Komati River was determined at a Comprehensive level and approved in 2006. Subsequently the Chief Directorate Resource Directed Measures (CD: RDM) identified that the remaining catchments within WMA 5 also requires a high confidence Reserve. High confidence results are needed in light of the initiation of the Compulsory Licensing Process in the WMA and the proposed new developments.

STUDY AREA

The Inkomati WMA is largely located within the Mpumulanga Province. It can be considered to consist of three largely independent catchments, the Komati, Crocodile (East) and Sabie–Sand River catchments. All these rivers drain the WMA and confluence to form the Incomati River in Mozambique which flows into the Indian Ocean.

The focus of this study is on the determination of the Crocodile (X2) and Sabie-Sand (X3) River systems. The Reserve for these systems was previously determined using methodologies that are currently outdated and these Reserves were not implemented, resulting in significant changes in the system. The Department of Water Affairs and Forestry deemed it necessary to re-evaluate the Reserve using updated information and conduct the new Reserve studies at a Comprehensive level of assessment. The results of this study will thus replace those of any previous Reserve determinations for the Crocodile, Sabie and Sand Rivers. The sites at which the Ecological Reserve was determined (referred to as Ecological Water Requirement or EWR Sites) are described in the table below.

EWR site no	EWR site name	River	Coordinates		EcoRegion (Level 2)	Geomorphic Zone	Quat
			Latitude	Longitude			
CROCODILE SYSTEM							
EWR 1	Valeyspruit	Crocodile River	S25 29.647	E30 08.656	9.02	Upper Foothills	X21A
EWR 2	Goedehoop	Crocodile River	S25 24.555	E30 18.955	9.04	Upper Foothills	X21B
EWR 3	Poplar Creek	Crocodile River	S25 27.127	E30 40.865	10.02	Lower Foothills	X21E
EWR 4	KaNyamazane	Crocodile River	S25 30.146	E31 10.919	4.04	Lower Foothills	X22K
EWR 5	Malelane	Crocodile River	S25 28.972	E31 30.464	3.07	Lower Foothills	X24D
EWR 6	Nkongoma	Crocodile River	S25 23.430	E31 58.467	12.01	Lower Foothills	X24H
EWR 7	Honeybird	Kaap River	S25 38.968	E31 14.572	4.04	Upper Foothills	X23H
SABIE SYSTEM							
EWR 1	Upper Sabie	Sabie River	S25 04.424	E30 50.924	4.04	Upper Foothills	X31B
EWR 2	Aan de Vliet	Sabie River	S25 01.675	E31 03.099	4.04	Lower Foothills	X31D
EWR 3	Kidney	Sabie River	S24 59.256	E31 17.572	3.07	Lower Foothills	X31K
EWR 4	MacMac	Mac Mac River	S25 00.800	E31 00.243	4.04	Upper Foothills	X31C
EWR 5	Marite	Marite River	S25 01.077	E31 07.997	4.04	Upper Foothills	X31G
EWR 6	Mutlumuvi	Mutlumuvi River	S24 45.352	E31 07.923	3.07	Upper Foothills	X32F
EWR 7	Tlulandziteka	Tlulandziteka River	S24 40.829	E31 05.188	3.07	Lower Foothills	X32C
EWR 8	Sand	Sand River	S24 58.045	E31 37.641	3.07	Lower Foothills	X32J

THIS REPORT

This report describes the results of the EcoClassification assessments that were undertaken for each EWR Site as part of the Crocodile and Sabie-Sand Comprehensive Reserve Determination Study.

METHODOLOGY

The procedure for the EcoClassification of the rivers was according to the revised methods for rivers as outlined in Louw and Hughes (2002), and the EcoClassification manual version 2 (Kleynhans and Louw, 2007).

The physico-chemical assessment was according to Kleynhans (2005) and all subsequent updates which are still being documented (these updates will be included in the current RDM method Revision project that are being undertaken through the Water Research Commission). Different levels of EcoClassification exist and the Level 4 method, required for the Comprehensive Ecological Reserve Methodology, was applied. The EcoClassification steps are summarised as follows:

- Determine reference conditions for each component.
- Determine the Present Ecological State (PES) for each component as well as for the EcoStatus.
- Determine the trend for each component.
- Determine reasons for the PES and whether these are flow or non-flow related.
- Determine the Ecological Importance and Sensitivity (EIS) for the biota and habitat.
- Considering the PES and the EIS, suggest a realistic Recommended Ecological Category (REC) for each component as well as for the EcoStatus.
- Determine Alternative Ecological Categories (AECs) for each component as well as for the EcoStatus.

RESULTS: CROCODILE RIVER SYSTEM

The EcoClassification results for the Crocodile system are summarised below. The detailed explanations for each of the below summaries are provided in subsequent sections of this report as well as in the various specialist reports (EcoClassification Report: Volume 2).

EWR 1 Valeyspruit (Crocodile River)

EIS: Moderate
Highest scoring metric were diversity of sensitive habitat types present e.g. wetlands (including floodplains containing various oxbows).

PES: A/B
Minor impacts, mainly due to farming, exotic vegetation species and trout. Impacts are mostly non-flow related

REC: A/B
Maintain the PES as only moderate EIS.

AEC down: B/C
Scenario includes decreased low flows due to e.g. increased golf estates, trout farms and increased abstractions for Dullstroom. Growth of Dullstroom will also result in increased sewage. Increased grazing causing trampling and destabilisation of banks.

Driver Components	PES & REC Category	Trend	AEC↓
HYDROLOGY	A/B		B
WATER QUALITY	A		B
GEOMORPHOLOGY	B	Stable	C
Response Components	**PES & REC Category**	**Trend**	**AEC↓**
FISH	A	Stable	B/C
MACRO INVERTEBRATES	B	Stable	B/C
INSTREAM	A/B		B/C
RIPARIAN VEGETATION	A	Stable	B
ECOSTATUS	A/B		B/C

EWR 2 Goedehoop (Crocodile River)

EIS: High
Rare and endangered fish spp. which are sensitive to flow and quality changes. High species diversity.

PES: B
Impacts as for EWR 1 with increased agricultural activities and decreased flows. However, impacts mostly still non-flow related.

REC: B
Although the EIS is high, the PES is already a B and as the impacts are mostly non-flow related, it would not be realistic to improve the PES through flow related interventions.

AEC down: C
See EWR 1. Possible zero flow situations and additional impacts on moderate events.

Driver Components	PES & REC Category	Trend	AEC↓
HYDROLOGY	B		C
WATER QUALITY	B		C
GEOMORPHOLOGY	B	Stable	B/C
Response Components	**PES & REC Category**	**Trend**	**AEC↓**
FISH	B	Stable	C
MACRO INVERTEBRATES	B	Negative	C
INSTREAM	B		C
RIPARIAN VEGETATION	A/B	Negative	B
ECOSTATUS	B		C

EWR 3 Poplar Creek (Crocodile River)

EIS: High
Rare and endangered fish, vegetation and bird spp, some of which are sensitive to flow and quality changes.

PES: B/C
Major problems related to upstream Kwena Dam and its operation, e.g. migration, sedimentation, changed flow regime. The changed flow regime consists of higher than natural flows in the dry season and much lower low flows in the wet season.

REC: B
The EIS is high; therefore the REC is an improvement of the PES. This can be achieved by improving the flow regime (low flows) and removal of exotic vegetation species.

AEC down: C/D
Lower flows than natural in both the dry and wet season. Associated increase in temperature and oxygen.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C		B	D
WATER QUALITY	C		B/C	C/D
GEOMORPHOLOGY	C	Negative	C	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B	Stable	B	C
MACRO INVERTEBRATES	C	Negative	B	C/D
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	B/C		B	C/D

EWR 4 KaNyamazane (Crocodile River)

EIS: High
Rare and endangered species that are sensitive to flow and quality changes are present. There is also a high species taxon richness and a diversity of habitat types

PES: C
Combination of flow and non-flow related impacts. Changes mostly related to changes in flow regime due to upstream Kwena Dam and the operation of upstream system. Abstractions, return flows, landuse mismanagement, water quality issues, and sedimentation.

REC: B
The EIS is HIGH, therefore the REC is an improvement of the PES. Improvements to flow regime will be required. Only successful if combined with removal of exotic vegetation and if there are some improvement in grazing and browsing.

AEC down: C/D
Montrose Dam with decreased floods. Pools will fill in, bars will appear, riffles will be clogged and covered with sediment, reed growth will increase, the marginal zone will expand and vegetation will encroach.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C			
WATER QUALITY	C		B	C
GEOMORPHOLOGY	B/C	Stable	B	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B	Stable	B	C
MACRO INVERTEBRATES	C	Stable	B	D
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	C/D

EWR 5 Malelane (Crocodile River)

EIS: Very High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on LB.

PES: C
Change in low flows, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.

REC: B
The EIS is VERY HIGH, therefore the REC is an improvement of the PES. Changes mostly focussing on improving the low flow regime and some land use management.

AEC down: D
Decreased low flows and periods of zero flows in some stretches of the river which will result in increased algal growth, temperature and nutrient problems, loss of deeper channel sections, increased reed and vegetation growth.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C		B	D
WATER QUALITY	C		B	D
GEOMORPHOLOGY	C/D	Negative	C	D
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	C	Stable	B	D
INSTREAM	C		B	D
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	D

EWR 6 Nkongoma (Crocodile River)

EIS: Very High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on left bank.

PES: C
Change in low flows, even zero flows present, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.

REC: B
The EIS is VERY HIGH, therefore the REC is an improvement of the PES. Changes mostly focussing on improving the low flow regime and some land use management.

AEC down: D
Decreased low flows and periods of zero flows in some stretches of the river which will result in increased algal growth, temperature and nutrient problems, loss of deeper channel sections, increased reed and vegetation growth.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	D		B	D
WATER QUALITY	C		B	D
GEOMORPHOLOGY	C	Negative	C	C/D
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	C	Stable	B	C/D
INSTREAM	C		B	D
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	D

EWR 7 Kaap (Kaap River)

EIS: High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and habitat types sensitive to flow and quality changes.

PES: C
Changes are flow and non-flow related. Low to zero flows present due to upstream abstractions. Land-use activities related to agriculture and mining. Extensive exotic vegetation present.

REC B:
The EIS is high, therefore the REC is an improvement of the PES.
No zero flows, increased low flows, more moderate floods. This must happen in conjunction with exotic vegetation removal.

AEC D:
Mountain View Dam will be present which will result in much lower flows than present and decreased floods. The channel will be narrower, some riffles will be sandier and smaller in general which will result in more reeds and a narrower marginal zone.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	D		C	D
WATER QUALITY	B		B	C
GEOMORPHOLOGY	B	Negative	B	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	B	Stable	B	C
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	C/D	Negative	B/C	D
ECOSTATUS	C		B	D

RESULTS: SABIE-SAND SYSTEM

The EcoClassification results for the Sabie-Sand River system are summarised below.

EWR 1: Upper Sabie (Sabie River)

EIS: High
Rare and endangered fish and vegetation species. Fish species present that are intolerant to flow and flow related water quality changes. .

PES: B/C
Impacts due to forestry, exotic vegetation species, and abstraction. Impacts largely non-flow related.

REC: B
The EIS is high, therefore the REC is an improvement of the PES. Inactivity of picnic site and removal of aliens is required. Improved fish EC dependent on improved vegetation cover.

AEC down: C/D
Decreased low flows resulting in increased sediment with increased nutrients, turbidity, temperature, additional toxics. Increased vegetation exotics and reeds on bars.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	A/B		A/B	B/C
WATER QUALITY	A/B		A/B	B/C
GEOMORPHOLOGY	B	Stable	B	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Stable	B	C/D
MACRO INVERTEBRATES	B	Stable	A/B	C
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	B/C	Negative	B	C/D
ECOSTATUS	B/C		B	C/D

EWR 2: Aan de Vliet (Sabie River)

EIS: High
Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.

PES: C
Forestry and landuse activities, mostly non-flow related.

REC: B
Changes in flow are not required to improve the state.
Remove exotic vegetation and cease mowing in the riparian zone. Reduce recreational disturbances. The nutrient status must also be improved.

AEC down: C/D
Increased abstraction could lead to increased return flows that will cause problems due to pesticides, nutrient loading etc. Mismanagement of land use in terms of forestry and agriculture

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C		B/C	D
WATER QUALITY	B		A/B	C
GEOMORPHOLOGY	B	Negative	B	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Stable	B	C/D
MACRO INVERTEBRATES	B/C	Stable	B	C
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	C/D

EWR 3 Kidney (Sabie River)

EIS: Very High
Rare and endangered species, taxon richness and species intolerant to flow and flow related water quality changes. Refuge area for biota and an important migration corridor for birds and fish. Within KNP.

PES: A/B
Forestry, abstraction, Inyaka Dam and landuse activities. (Flow and non-flow related)

REC: A/B
As the PES is already an A/B, the REC = the PES.

AEC Down: B/C
Increased abstractions, no Reserve implementation, less floods. Increased nutrients, changes in temperature, oxygen etc. Riffles lost due to sedimentation, channel shallower and sandier. Vegetation exotics will increase.
More reeds will be present in sandier areas.

Driver Components	PES & REC Category	Trend	AEC↓
HYDROLOGY	C		C/D
WATER QUALITY	B		C
GEOMORPHOLOGY	B	Negative	C
Response Components	**PES & REC Category**	**Trend**	**AEC↓**
FISH	B	Stable	C
MACRO INVERTEBRATES	B	Stable	C
INSTREAM	B		C
RIPARIAN VEGETATION	A/B	Stable	B/C
ECOSTATUS	A/B		B/C

EWR 4 Mac Mac (Mac Mac River)

EIS: High
Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.

PES: B
Forestry, exotic vegetation and wastewater input. Impacts are flow and non-flow related.

REC: A/B
The EIS at EWR 4 is high and the REC is therefore to improve the PES by improving the fish. Improved water quality required.

AEC down: C
Decreased low flows due to e.g. a weir or small dam in the upper catchment. This will result in embedded cobbles. Nutrients and temperature will increase. Increased exotic vegetation in the riparian zone.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C		C	C
WATER QUALITY	A/B		A	B/C
GEOMORPHOLOGY	A	Stable	A	B
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Stable	B	C/D
MACRO INVERTEBRATES	A/B	Stable	A/B	B/C
INSTREAM	B		B	C
RIPARIAN VEGETATION	A/B	Negative	A/B	B/C
ECOSTATUS	B		A/B	C

EWR 5 Marite (Marite River)

EIS: High.
Rare, endangered and unique biota. Species richness high and species intolerant to flow and flow related water quality changes present.

PES: B/C
Increased low flows and landuse activities. Impacts mostly flow related

REC: B
The EIS is high; therefore the REC is an improvement of the PES. More natural distribution of flows required. Reduce grazing and trampling, remove exotic vegetation.

AEC down: C/D
No flow releases for the EWR, less dilution and less floods due to e.g. direct abstraction from the dam. More nutrients and toxics present. Sandier river, some riffles and bedrock areas in the reach will be lost, vegetation encroachment on bars and banks and embedded cobbles. Increased aliens, removal, grazing, and trampling.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C			D
WATER QUALITY	B		B	C
GEOMORPHOLOGY	C	Negative	C	D
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Negative	B	C/D
MACRO INVERTEBRATES	B/C	Stable	B	C
INSTREAM	B/C		B	C/D
RIPARIAN VEGETATION	B/C	Negative	B	C/D
ECOSTATUS	B/C		B	C/D

EWR 6 Mutlumuvi (Mutlumuvi River)

EIS: High
Rare, endangered and unique biota. Taxon species richness high and species intolerant to flow and flow related water quality changes present.

PES: C
Abstraction, forestry, informal settlements and landuse activities. Impacts flow and non-flow related.

REC: B
The EIS is high and improvement requires improved system operation which improves the low flow regime.

AEC down: C/D
Decreased low flows and longer periods of zero flows. Increased algal growth. Less moderate floods will cause some impact on sedimentation. The reedbeds will become less dense and Matumi will disappear.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C			
WATER QUALITY	B/C		B	C/D
GEOMORPHOLOGY	C	Stable	C	D
Response Components	**PES Category**	**Trend**	**AEC ↑**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	B/C	Negative	B	C
INSTREAM	C		B	C/D
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	C/D

EWR 7 Tlulandziteka (Tlulandziteka River)

EIS: Moderate
Rare and endangered species, high taxon richness, species intolerant to flow and flow related water quality changes.

PES: C
Forestry, abstraction, flow modification and poor landuse management. Impacts flow and non-flow related.

REC: C
Due to the moderate EIS, the REC = the PES.

AEC Up: B
Improved flows through fixing of canals, rehabilitation of forestry areas and improved management of canal system and landuse. Remove exotic vegetation, minimise agricultural disturbance and remove unused orchards.

AEC Down: D
Increased use of the dam with less spills, i.e. less floods. More abstraction and forestry. Nutrients, temperature, oxygen, and turbidity levels will change. Increase in bed height, more subsurface flows and sediment with resulting decrease in riffles and shallower pools. More reeds, alien vegetation and more removal.

Driver Components	PES & REC Category	Trend	AEC ↑	AEC↓
HYDROLOGY	A?			D
WATER QUALITY	C		B	D
GEOMORPHOLOGY	C/D	Stable	C	D
Response Components	**PES &REC Category**	**Trend**	**AEC ↑**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	B/C	Negative	B	C/D
INSTREAM	C		B	D
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	D

EWR 8 Lower Sand (Sand River)

EIS: High
Rare and endangered species, high taxon richness and species intolerant to flow and flow related water quality changes. Situated in KNP

PES: B
Abstraction, dams, weirs, poor landuse management. Impacts are flow and non-flow related.

REC: B
Although the EIS is High, the PES is already in a B therefore the REC = PES. Improve the macroinvertebrate EC by increasing low flows.

AEC down: C
More decreased low flows and longer periods of no flow.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C?		C	D?
WATER QUALITY	B		B	C
GEOMORPHOLOGY	C	Negative	C	Lower C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B	Stable	B	C
MACRO INVERTEBRATES	C	Negative	B	C/D
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	B	Stable	B	B/C
ECOSTATUS	B	Negative	B	C

CONCLUSIONS AND RECOMMENDATIONS: CROCODILE RIVER SYSTEM

A summary of data availability, the confidence in the available data as well as the confidence in the results of the EcoClassification assessment for each of the EWR sites is given below. Red cells indicate a low confidence, yellow cells indicate a medium confidence and green cells indicate a high confidence.

Summary of the confidence in the available data and EcoClassification results for each of the EWR Sites in the Crocodile River catchment

EWR site	EWR 1		EWR 2		EWR 3		EWR 4		EWR 5		EWR 6		EWR 7	
Confidence	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification
Hydrology	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Geomorphology	3	3	3	2.5	3	4	3	3	3	3.5	3	3	3	2.5
Physico-chemical	2	2	2	2	3	3	3	3	3	3	3	3	3	3
IHI (instream & riparian	4	3.75	4	3.75	4	3.75	4	3.3	4	3.25	4	3.3	4	2.9
Fish	4	5	4	4	4	4	4	4	4	4	4	4	4	3.5
Macroinvertebrates	4	4	4	4	4	4	4	3	4	4	4	3	4	3
Vegetation	4	4.1	3.5	3.7	4	3.7	4	3.6	3	3.4	4.5	3.6	3.5	3.1
Median	4	4	4	3.75	4	4	4	3.3	4	3.5	4	3.3	4	3

Conclusions

The results indicated that there was a lot of data available and therefore the confidence in data availability was rated as HIGH. This is due to the recent and historical information collected during national and provincial River Health Programme (RHP) surveys, research in the Kruger national Park (KNP), previous EWR studies and the detailed updated hydrological study recently undertaken. Historical information from surveys undertaken by the Transvaal Provincial Administration's Nature Conservation Department (Mpumalanga Department of Nature Conservation) also contributed to the data that used to undertake the EcoClassification assessments at each site.

Whereas a HIGH level of confidence in the EcoClassification results was obtained for EWR 1 and 3, a MEDIUM to HIGH level of confidence was obtained for EWR 2, 4, 5 and 6 and a MEDIUM level of confidence was obtained for EWR 7.

Medium levels of confidence in the EcoClassification results were attributed to the following:

- EWR 2: Lack of measured water quality data.
- EWR 4: Unsuitability of previously selected cross-section which makes interpretation difficult.
- EWR 5: Interpretation of vegetation is problematic and not necessarily representative of the rest of the reach.
- EWR 6: Problems with biological surveys (difficult habitats) and lack of critical habitats (e.g. riffles).
- EWR 7: Same problem as at EWR 6 as well as the presence of extensive alien vegetation which is increasing continuously, thus resulting in the lack of indigenous vegetation that can be used as indicators for flow requirements along the cross sections.

Recommendations

The amount and accuracy of the data available at each site was high and therefore no more detailed work is needed to improve data availability.

To improve the confidence in the EcoClassification results at EWR 2, 4, 6 and 7 the following is recommended as part of monitoring:

- Due to the lack of a nearby water quality monitoring station at EWR 2 diatom assessments as part of future monitoring is recommended. This will provide a good indication of the trend of the physico-chemical variables and if problems are indicated, a more detailed physico-chemical analysis can be undertaken. This is also relevant for EWR 1 as data availability is low for the physico-chemical component.
- A new cross section has been selected in the riffle immediately downstream of EWR 4 and future monitoring must focus on this area.
- An alien eradication programme is required at EWR 7.

More work has been undertaken at these sites than for most if not any river in South Africa and it is unlikely that further work will increase confidences. A Water Resources Monitoring Programme is recommended where some of the issues listed above can possibly be addressed. Some of the uncertainties are due to the natural nature of the site (which results in difficulties in surveying and interpretation) as well as a lack of measured water quality. This will be confirmed once the assessment of the adequacy of baseline information is undertaken as part of the Ecological Specifications assessment (the results of which will be provided in what report 26/8/3/10/12/012).

CONCLUSIONS AND RECOMMENDATIONS: SABIE – SAND SYSTEM

A summary of data availability, the confidence of the available data as well as the confidence in the results of the EcoClassification assessment for each of the EWR sites in the Sabie-Sand River catchments is given below. The red cells indicate a low level of confidence, yellow cells indicate a medium level of confidence and the green cells indicate a high level of confidence.

Summary of the data availability, confidence in this data as well as the confidence in the EcoClassification results for each of the EWR Sites in the Sabie-Sand River catchments

EWR site	EWR 1		EWR 2		EWR 3		EWR 4		EWR 5		EWR 6		EWR 7		EWR 8	
Confidence	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification
Hydrology	3	3	4	4	3	3	3	3	4	4	2	2	2.5	2.5	4	4
Geomorphology	3	3.5	3	3.5	5	4	3	3	3.5	3.5	3	3	2	2	3.5	3
Physico-chemical	3	3	3	3	2.5	2.5	3	3	3	3	2	2	2	2	3	2
IHI (instream & riparian	4	3.2	4	3.1	4	3.1	4	3.4	4	3.2	4	2.9	4	2.9	4	2.9
Fish	3	4	4	4	4	4	3	4	4	4	3	4	3	3	3	4
Macroinvertebrates	3	4	4	4	4	4	3	3	3	2.5	3	3.5	2.5	2	3	3.5
Vegetation	4	3.4	4	3.2	5	4	4	3.9	4	4	4	3.8	2	3.7	4.5	3.7
Median	3	3.4	4	3.5	4	4	3	3	4	3.5	3	3	2.5	2.5	3.5	3.5

Conclusions

The results indicated MEDIUM to HIGH confidence for data availability at all the sites except for EWR 7. The confidence at EWR 7 is LOW to MEDIUM as this site was only surveyed at a Rapid Level. There is also no hydrological gauge or water quality measuring station nearby. Although good biological response information was available for EWR sites 1, 4 and 6, information on the ecological drivers was not sufficient and therefore the confidence is MEDIUM. The MEDIUM-HIGH (EWR 8) and HIGH (EWR 2, 3 and 5) confidence are due to data collated during national and provincial RHP surveys, research that was conducted in the KNP as well as the 1996 and 1997 Reserve studies (previously referred to as 'IFR studies'). An updated hydrology study was also undertaken for the Sabie and Sand Rivers. However, confidence in the hydrology data for the Sand River will always be low due to the fact that there is only one gauge that represents the whole catchment.

MEDIUM to LOW levels of confidence in the EcoClassification results in the Sabie-Sand River catchments were attributed to the following:

- EWR 1: Apart from the instream biological surveys and one geomorphology survey, no other work had been undertaken at this site.
- EWR 2: This site is a complex site from a vegetation point of view which resulted in the site not having a HIGH EcoClassification confidence.
- EWR 4 and 7: EWR 7 was an additional site, and as such the EcoClassification assessment was only conducted at a Rapid level III. There was also no nearby hydrological or water quality measuring gauge for both EWR sites.
- EWR 5: There was a lack of macroinvertebrate information (probably due to the bedrock nature of the system), as well as lack of hydrological and water quality measuring data.
- EWR 8: The lack of confidence was a result of a lack of physico-chemical information, especially as this site dries up which means that temperature and oxygen information becomes crucial.

Recommendations

EWR 1, 4 and 7 should be included as RHP sites. More work has been undertaken on the Sabie River within the KNP and it is unlikely that further work will increase confidences on these sites. A Water Resources Monitoring Programme is recommended where most of the problems listed above can be addressed. Some of the uncertainties are due to the natural nature of the site (bedrock and alluvial), which results in problems with the interpretation of the results, especially in terms of the macroinvertebrate assessments. The lack of measured water quality and hydrology data should be addressed as it is crucial for monitoring as well as for improving confidences in the long term. More specifically, the following is recommended in terms of future monitoring requirements:

- Due to the lack of a nearby water quality monitoring stations, diatom assessments as part of future monitoring is recommended especially at EWR 3 and 8. This will provide a good indication of the trend of the physico-chemical variables and if problems are indicated, more detailed physico-chemical analysis can be undertaken; however only based on available data.
- Instream and riparian vegetation monitoring should take place at EWR 1, 2, 4 and 7 as this will bring the level of confidences for these sites to the same level as the other sites.
- Macroinvertebrates should be monitored at EWR 5 and 7 as part of the RHP. This will provide additional information and add further detail to the Ecological Category, and therefore the EcoSpecs.

In general it is recommended that the EWR sites become the RHP sites where in close proximity to one another. The other EWR sites should be included as RHP sites. Most of the problems above can be addressed within a monitoring programme, and it is not recommended that any specific additional work is undertaken to address the confidences. This will be confirmed once the assessment of the adequacy of the baseline information is undertaken as part of the EcoSpec assessment.

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APPENDIX H Riparian Vegetation Specialist Report (J Mackenzie)
APPENDIX I EcoStatus Models (Provided electronically)
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ABBREVIATIONS AND ACRONYMS

AEC	Alternative Ecological Category
ASPT	Average Score Per Taxon
CD: RDM	Chief Directorate: Resource Directed Measures
Conf	Confidence
D:RQS	Directorate: Resource Quality Services
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
F	Flow related
FRAI	Fish Response Assessment Index
FROC	Fish Frequency of occurrence
Geom	Geomorphology
GSM	Gravel, sand, mud habitat
Hydro	Hydrology
IIHI	Instream Index of Habitat Integrity
Inverts	Macroinvertebrates
KNP	Kruger National Park
MCM	Million Cubic Metres
MIRAI	Macro Invertebrate Response Assessment Index
MRU	Management Resource Unit
MV	Marginal Vegetation
NF	Non Flow related
NRHP	National River Health Programme
NRU	Natural Resource Unit
PES	Present Ecological State
Physico-chem	Physico chemical
Quat	Quaternary catchment
RAU	Resource Assessment Unit
RC	Reference Condition
REC	Recommended Ecological Category
RIHI	Riparian Index of Habitat Integrity
Rip Veg	Riparian vegetation
RU	Resource Unit
SAIAB	South African Institute of Aquatic Biodiversity
SANBI	South African National Biodiversity Institute
SASS5	South African Scoring System version 5
SIC	Stones-in-current habitat
SOOC	Stones-out-of-current habitat
SPI	Specific Pollution Index
SRP	Soluble Reactive Phosphate
TEACHA	Tool for Ecological Aquatic Chemical Habitat Assessment
TIN	Total Inorganic Nitrogen
VEGRAI	Riparian Vegetation Response Assessment Index
WMS	Water Management System
WWTW	Waste Water Treatment Works

1 BACKGROUND AND INTRODUCTION

1.1 BACKGROUND

The Chief Directorate Resource Directed Measures (CD: RDM) identified the Inkomati Water Management Area (WMA) as requiring a comprehensive Reserve assessment in light of the initiation of the Compulsory Licensing Process in the WMA and the proposed construction of the Montrose and Mountain View Dams. These studies require higher levels of confidence in the Reserve determination results as is currently available in certain catchments, such as the Sabie-Sand and Crocodile River catchments. The results of a Comprehensive Reserve study in these catchments would thus assist the Department of Water Affairs (DWA) to make informed decisions regarding the authorisation of future water use and the magnitude of the impacts of the present and proposed developments.

The Comprehensive Ecological Reserve Methodology was followed within the 8 - step Ecological Reserve process (Figure 1-1). This report summarizes step 3 of the Ecological Reserve process.

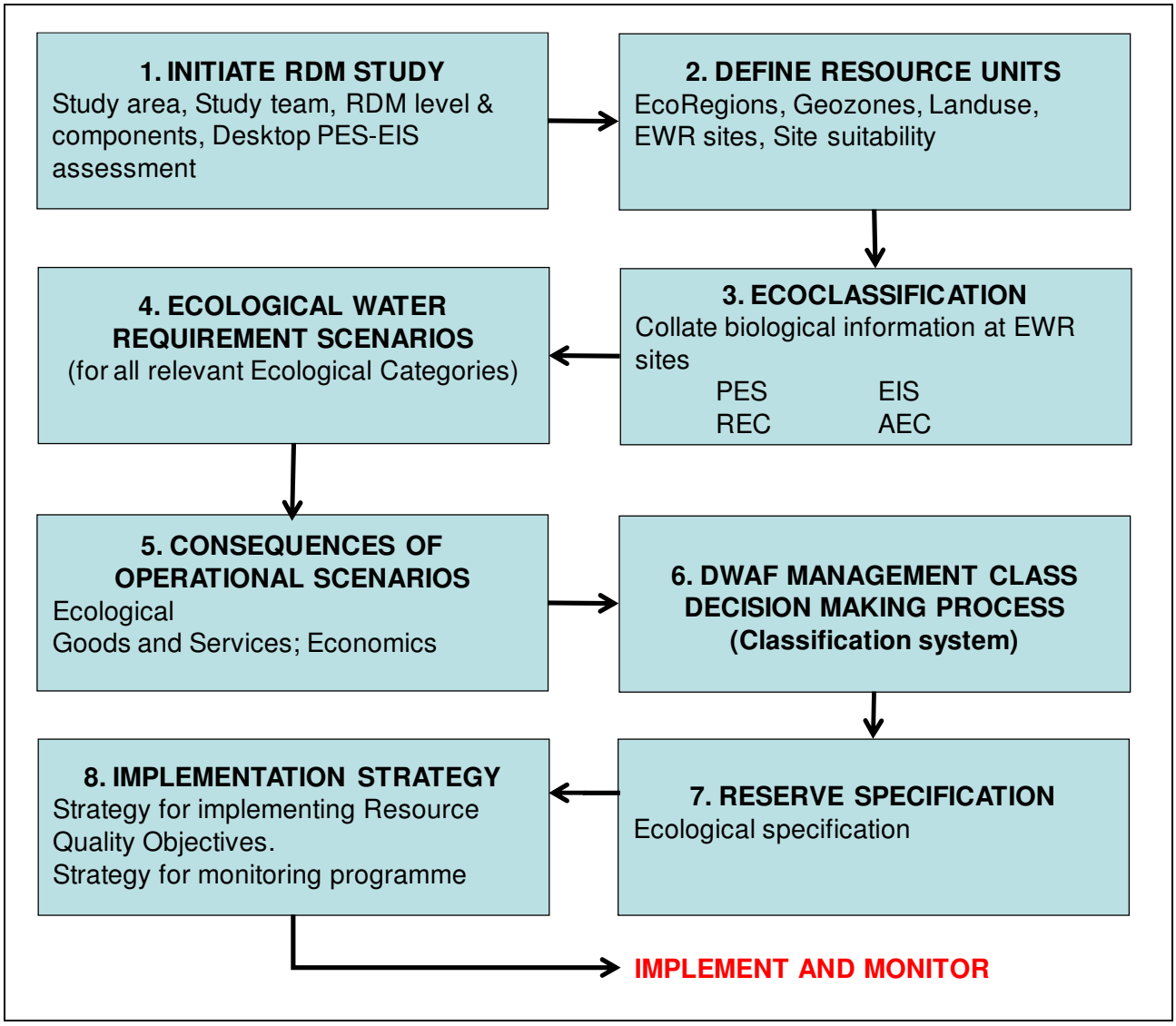


Figure 1-1 The 8-step Ecological Reserve procedure (adapted from DWAF, 1999)

The Reserve studies that were previously conducted for the Crocodile and Sabie-Sand river catchments consist of:

- An Intermediate Ecological Reserve study was undertaken during 2002 (Godfrey, 2002) for the Crocodile System. This study will update and refine the Intermediate Ecological Reserve study. The same study sites will be used, but more updated methodologies applied where necessary.
- An Intermediate Ecological Reserve was undertaken during 1996 (Tharme, 1997) for the Sabie-Sand system. Many of the methods now in place were not available at that stage and to complicate matters further, the large floods of 2001 (biggest floods on record) resulted in most of the physical site specific data not being applicable. Where applicable, the same study sites were used, but resurveyed and all historical information was also used within this updated study.

1.2 STUDY AREA AND STUDY SITES

The Inkomati WMA is largely located within the Mpumulanga Province. It can be considered to consist of three largely independent catchments, the Komati, Crocodile (East) and Sabie–Sand River catchments. All these rivers drain the WMA and confluence to form the Incomati River in Mozambique which flows into the Indian Ocean.

The Reserve requirements for the Komati River system (the remaining major river system in WMA 5) was determined and approved in 2003, the results of which are at a high confidence and are still relevant for use and implementation by the DWA. As such it was deemed unnecessary to include this system in the study area. The focus of this study therefore is only on the Crocodile (X2) and Sabie-Sand (X3) catchments. The locality and characteristics of the EWR sites are provided in Table 1.1 and Figure 1-2 and 1-3 for the Sabie-Sand and Crocodile River catchments respectively. Information on site selection and the Management Resource Units (MRUs) in which they fall are provided in RDM Report 26/8/3/10/12/006 (DWAF, 2008).

Table 1.1 Locality of EWR sites for the Inkomati River System

EWR site no	EWR site name	River	Coordinates		EcoRegion[1] (Level 2)	Geomorphic Zone	Quat[2]
			Latitude	Longitude			
CROCODILE SYSTEM							
EWR 1	Valeyspruit	Crocodile	S25 29.647	E30 08.656	9.02	Upper Foothills	X21A
EWR 2	Goedehoop	Crocodile	S25 24.555	E30 18.955	9.04	Upper Foothills	X21B
EWR 3	Poplar Creek	Crocodile	S25 27.127	E30 40.865	10.02	Lower Foothills	X21E
EWR 4	KaNyamazane	Crocodile	S25 30.146	E31 10.919	4.04	Lower Foothills	X22K
EWR 5	Malelane	Crocodile	S25 28.972	E31 30.464	3.07	Lower Foothills	X24D
EWR 6	Nkongoma	Crocodile	S25 23.430	E31 58.467	12.01	Lower Foothills	X24H
EWR 7	Honeybird	Kaap	S25 38.968	E31 14.572	4.04	Upper Foothills	X23H
SABIE SYSTEM							
EWR 1	Upper Sabie	Sabie	S25 04.424	E30 50.924	4.04	Upper Foothills	X31B
EWR 2	Aan de Vliet	Sabie	S25 01.675	E31 03.099	4.04	Lower Foothills	X31D
EWR 3	Kidney	Sabie	S24 59.256	E31 17.572	3.07	Lower Foothills	X31K
EWR 4	MacMac	Mac Mac	S25 00.800	E31 00.243	4.04	Upper Foothills	X31C
EWR 5	Marite	Marite	S25 01.077	E31 07.997	4.04	Upper Foothills	X31G
EWR 6	Mutlumuvi	Mutlumuvi	S24 45.352	E31 07.923	3.07	Upper Foothills	X32F
EWR 7	Tlulandziteka	Tlulandziteka	S24 40.829	E31 05.188	3.07	Lower Foothills	X32C
EWR 8	Sand	Sand	S24 58.045	E31 37.641	3.07	Lower Foothills	X32J

1 Refer to Kleynhans *et al.* (2007) for EcoRegion description 2 Quaternary catchment

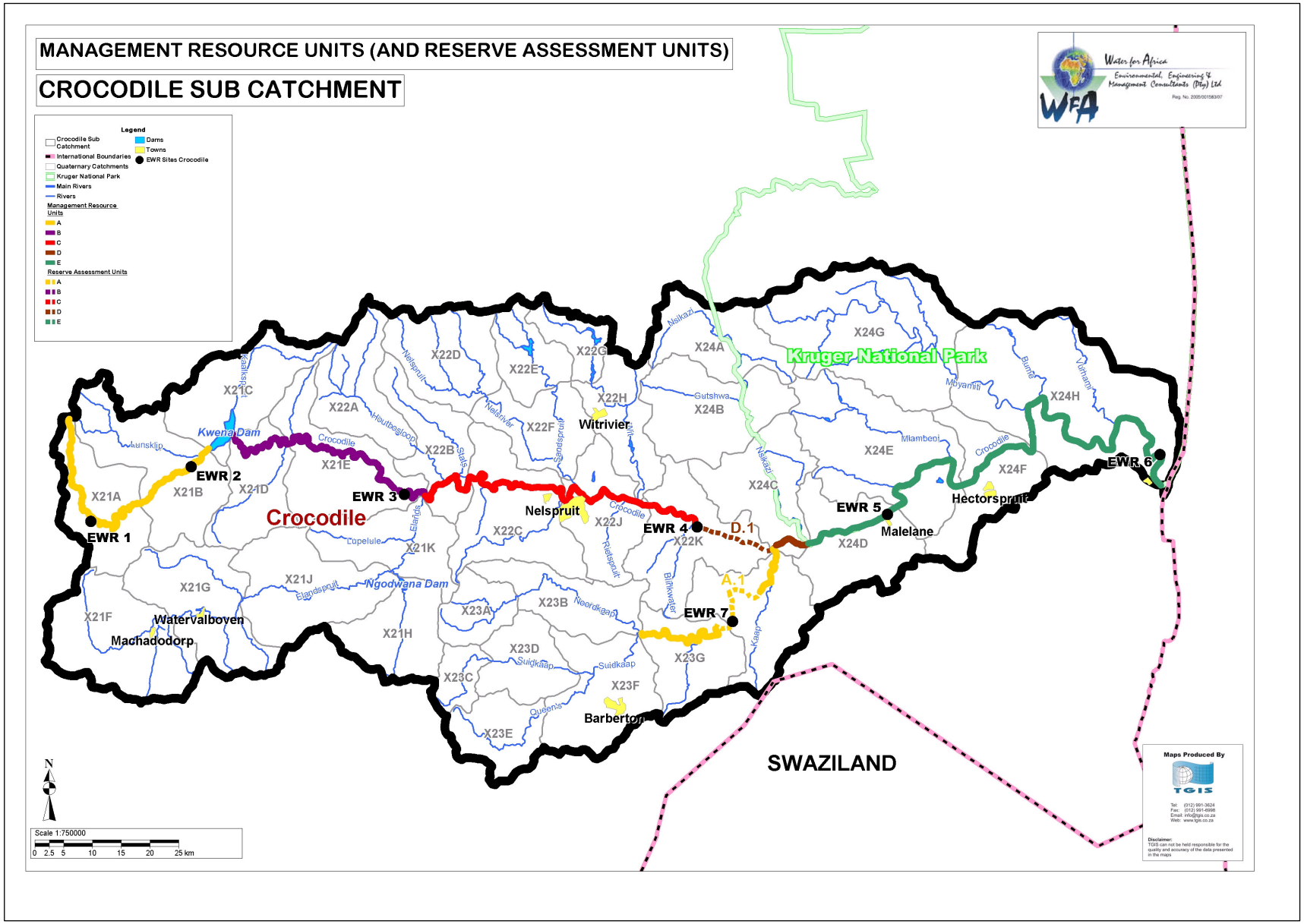


Figure 1-2 Crocodile River catchment and locality of EWR sites

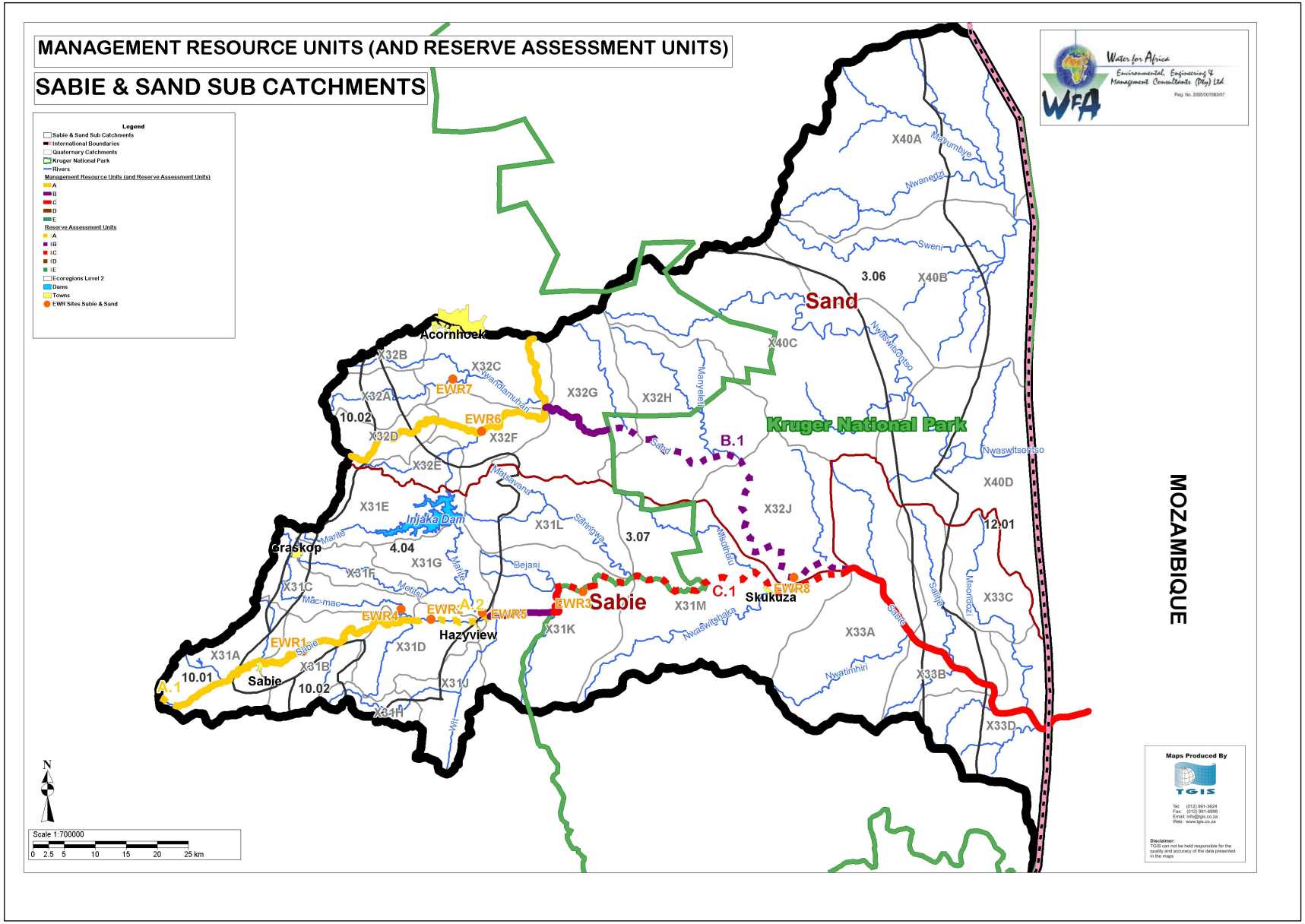


Figure 1-3 Sabie-Sand River catchment and locality of EWR sites

1.3 METHODOLOGY

EcoClassification forms step 3 of the 8-step Reserve process (Louw and Hughes, 2002) (Figure 1-1).

The procedure for the EcoClassification that was followed during the Crocodile, Sabie and Sand Comprehensive Reserve determination was according to the revised methods for rivers as outlined in the EcoClassification manual version 2 (Kleynhans and Louw, 2007). The physico-chemical assessment was according to Kleynhans (2005) and all subsequent updates which are still being documented (these updates will be included in the current RDM method Revision project that are being undertaken through the Water Research Commission). Different levels of EcoClassification exist and the Level 4 method, required for the Comprehensive Ecological Reserve Methodology, was applied. The EcoClassification steps are summarised as follows:

- Determine reference conditions for each component.
- Determine the Present Ecological State (PES) for each component[1] as well as for the EcoStatus[2].
- Determine the trend for each component.
- Determine reasons for PES and whether these are flow or non-flow related.
- Determine the Ecological Importance and Sensitivity (EIS) for the biota and habitat.
- Considering the PES and the EIS, suggest a realistic Recommended Ecological Category (REC) for each component as well as for the EcoStatus.
- Determine Alternative Ecological Categories (AECs) for each component as well as for the EcoStatus.

1.4 PURPOSE OF THE REPORT

This report serves thus to document the results of the EcoClassification process which were finalised at a specialist meeting held 18 – 22 February 2008. The final results consist of the following:

- EIS score
- Reference conditions
- PES for each component and the EcoStatus
- REC for each component and the EcoStatus
- AEC/s for each component and the EcoStatus
- Confidences for all of the above and conclusions and recommendations based on the confidences.

Note: The REC and AECs together form the range of EWR scenarios for which EWRs will be set in the latter part of this study. The final output of this report is therefore the range of EWR scenarios.

[1] **Components:** Driver components (Hydrology, Geomorphology, Physico-chemical variables) and Response components (Riparian vegetation, Fish, Macroinvertebrates)

[2] **EcoStatus:** *'The totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services'.*
In essence the EcoStatus represents an ecologically integrated state representing the driver and response components

1.5 OUTLINE OF THE REPORT

The report consists of the main EcoClassification report (this report) which is outlined below. Specialist appendices are provided in a separate (Volume 2) together with the suite of EcoStatus models and component assessment models applied to this study in electronic format (Report 26/8/3/10/12/016) which will accompany the main report (Report 26/8/3/10/12/015) of this study.

Chapter 1: Introduction and Background
This chapter.

Chapter 2-8: EcoClassification Crocodile River system
The results are provided for each EWR site.

Chapter 9: Summary of Results and Conclusions: Crocodile River system
The results are summarised and recommendations are made.

Chapter 10 – 17: EcoClassification Sabie-Sand River system
The results are provided for each EWR site.

Chapter 18: Summary of Results and Conclusions: Sabie-Sand River system
The results are summarised and recommendations are made.

Chapter 19: References

2 EWR 1 VALEYSPRUIT (CROCODILE RIVER)

2.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 2.1.

Table 2.1 EWR 1: Summary of data availability

Component	Data availability	Conf[1]
Hydrology	The nearest reliable gauge is downstream of Kwena Dam at the outlet of X21C.	4
Physico-chemical	No DWA monitoring data was available, and information was extrapolated from EWR 2. Limited phytoplankton, periphyton and diatom data available (no of data sets (n) = 1). A very poor data set exists for this site, so expert judgement and knowledge of the area was relied on.	2
Geomorphology	Historical aerial photography (1944, 1956, 1965, 1997). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points. Data collected from field assessment in October 2007. Previous VEGRAI[2] training site Historical aerial photography (1944, 1956, 1965, 1997). Available floristic data – biomes, bioregions and vegetation type etc. Water Research Commission (WRC) (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	3.5
Fish	Single site visit and fish sampling during October 2007. Kleynhans *et al.* (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. J. Engelbrecht)	4
Macroinvertebrates	Data and analysis from a single sampling trip during October 2007 (two sets of samples available). Historical macroinvertebrate data from the Rivers Database for sites X2LUNS-KRUIS, X2CROC-VALYS (the EWR site), and X2CROC-DONKE. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	4

1 Confidence 2 Vegetation Response Assessment Index

2.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 2.2) was rated as **MODERATE**. A variety of riparian and instream habitats are present and include pools, riffles, rapids and wetland areas (oxbows and floodplains).

Table 2.2 EWR 1: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	2	4	Amphipods, spotted neck otter, *Cliffortia* spp. Lydenburg Montane Grassland poorly protected and vulnerable.
Unique (endemic, isolated, etc.)	2	4	*Barbus anoplus.*
Intolerant (flow & flow related water quality)	2	4	Macroinvertebrates.
Species/taxon richness	2	4	Macroinvertebrates.
RIPARIAN & INSTREAM HABITATS			

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Diversity of types	3	4	Pools, riffles, rapids, wetland sponges, oxbows, floodplain pans.
Refugia	1	3	
Sensitivity to flow changes	2	2	
Sensitivity to flow related water quality changes	3	3	Small stream therefore sensitive.
Migration route/corridor (instream & riparian)	1	3	Birds.
Importance of conservation & natural areas	1	4	Some areas consist of natural grassland.
MEDIAN	2		
EIS EVALUATION	**MODERATE**		

2.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 2.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 2.3 EWR 1: Reference conditions

Component	Reference conditions	Conf
Hydrology	Gauge records for 1985 to 2008 are available. This record is calculated from stage measurements in the Kwena Dam and low flows are probably not accurate. Virgin MAR: 9.92 MCM	4
Physico-chemical	Benchmark tables were used according to Kleynhans *et al.,* 2005. Refer to Table 2.4.	1
Geomorphology	The site has typical meandering floodplain with ox-bow features on the floodplain. The floodplain consists of cut banks, advancing point bars and cut-off meanders. This site is classified as an alluvial meandering channel type and is representative of the macro-reach; being typical of eastern-draining rivers above the escarpment. Small wetlands are present on the floodplain.	3
Riparian vegetation	The site occurs in the Lydenburg Montane Grassland in the Grassland biome. The marginal zone will be incised into the grassland floodplain with meandering channels and backwater/oxbow lake non-woody plants. Non-woody vegetation dominate both on the marginal and non-marginal zones as well as the floodplains (*Miscanthus* is dominant), with a minor woody presence (*Cliffortia* and *Leucosidea* spp. mainly).	4
Fish	One species present. Refer to Table 2.5.	5
Macroinvertebrates	The reference total SASS 5 score is 240, with more than 35 taxa and an ASPT of 7.5. Additional information is provided below.	3

TEACHA[3] is an instrument to support decision-making in the Reserve process, and is a data manipulation tool. The primary output is the recommended water quality component of the Ecological Reserve with corresponding ion data (e.g. salt ionic data, i.e. Ca, Na, Mg, Cl, SO_4) to use in the setting of resource quality objectives. The use of this software presupposes that information is available and reliable. It is not an expert system and requires the availability of expertise to check that the outcome is correct and scientifically valid. It also has strict data input requirements, e.g. **all** salt ions have to be input or the model will not run. TEACHA was used for this assessment where possible, with data extracted from DWA's Water Management System (WMS). Where all ionic data was not available Electrical Conductivity (EC) was used as a surrogate for aggregated salts and standard statistical packages e.g. Excel or Statistica, were used to produce summary statistics (e.g. median, 5th percentile, 95th percentile).

Detailed physico-chemical reference conditions (RCs) are provided in Table 2.4.

[3] Tool for Ecological Aquatic Chemical Habitat Assessment

Table 2.4 EWR 1: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	< 0.005
	Total Inorganic Nitrogen (TIN)	< 0.25
Physical variables	pH (5^{th}+95^{th} percentiles)	6.5 + 8.0
	Electrical conductivity (mS/m)	≤ 30 mS/m
	Turbidity (NTU)	Pristine river, no known man-made modifications of the catchment, and no known concerns about turbidity. Changes in turbidity appear to be natural and related to natural catchment processes such as rainfall runoff.

1 milli Siemens/meter

Information on the expected reference conditions for fish at NRHP site X2CROC-VALYS, according to Kleynhans *et al*. (2007b), was used to determine the expected reference conditions. This reference condition for fish should be valid for the entire Natural Resource Unit (NRU) Croc A and the stretch of the Crocodile within EcoRegion 9.02. Only one indigenous fish species, namely *Barbus anoplus* (Chubbyhead barb) is expected at this site under reference conditions. This species is expected at more than 75% of sites in a reach and should be present in moderate abundance (Table 2.5).

Table 2.5 EWR 1: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 1 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Barbus anoplus	Chubbyhead barb	BANO	5	5
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%)		3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)		

Macroinvertebrate taxa expected under reference conditions include:
Aeshnidae, Ancylidae, Athericidae, Baetidae >2spp, Baetidae 2spp, Caenidae, Ceratopogonidae, Chironomidae, Chlorocyphidae, Coenagrionidae, Corbiculidae, Corixidae, Culicidae, Dixidae, Dytiscidae, Elmidae, Gerridae, Gomphidae, Gyrinidae, Helodidae, Heptageniidae, Hydracarina, Hydrophilidae, Hydropsychidae >2spp, Hydropsychidae 2spp, Hydroptilidae, Leptoceridae, Leptophlebiidae, Libellulidae, Muscidae, Naucoridae, Nepidae, Notonectidae, Oligochaeta, Perlidae, Philopotamidae, Physidae, Planorbinae, Pleidae, Polymitarcyidae, Porifera, Potamonautidae, Prosopistomatidae, Protoneuridae, Psephenidae, Simuliidae, Sphaeriidae, Tabanidae, Tipulidae, Tricorythidae, Turbellaria, and Veliidae

2.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

2.4.1 Hydrology

The present MAR is 9.22 MCM (93% of natural). There have not been significant changes in this catchment over the period of recorded flow (1985 – 2008). The only change has been the

construction of many trout dams which would reduce low flows and delay the first freshettes. Dullstroom's abstraction has increased somewhat over the past 5 to 10 years.

2.4.2 Geomorphology (B EC, 85.3%)

No good quality Google Earth imagery was available. The site is a typical meandering floodplain with ox-bow features on the floodplain. The floodplain consists of cut banks, advancing point bars and cut-off meanders. An oxbow lake is evident on the eastern flank of the floodplain. Aerial photograph analysis indicates that this predates 1956. No directional changes could be observed from the aerial photographs due to the large scale of the photographs and the narrow channel. The channel appears to have been straightened upstream of the site between 1956 and 1964. These changes are associated with agricultural activities which are evident at this time. Other localised impacts have arisen from the roads.

2.4.3 Physico-chemical variables (A EC, 93%)

Based on the diatom assessment, the site is in a B category based on the Specific Pollution Index (SPI[4]) score of 16.5. The presence of pollution tolerant species, although in very small numbers, indicates that upstream anthropogenic activities may be impacting slightly on this site and may be the source of slightly elevated concentrations of organically bound nitrogen.

Slight nutrient elevations are present as shown by periphyton, phytoplankton and diatoms (n = 1 for all indicators) and are due to farming and urban activities in area. Abstractions result in slight fluctuations in oxygen and temperature. PES values for the physico-chemical variables are provided in Table 2.6 and in Appendix C.

Table 2.6 EWR 1: Physico-chemical PES values

Water Quality Constituents		Value: PES
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.01
	Total Inorganic Nitrogen (TIN)	-
Physical variables	pH (5^{th}+95^{th} percentiles)	-
	Electrical conductivity (mS/m)	-
	Turbidity (NTU)	95^{th} percentile: 19.4

2.4.4 Instream and Riparian Habitat Integrity (IIHI: B EC, 84%; RIHI: B EC, 82.4%)

The Instream Index of Habitat Integrity (IIHI) score is mostly due to bed and bank modification, loss of channel connectivity and some changes in hydrology due to increased abstractions and land use activities in the reach. The Riparian Index of Habitat Integrity (RIHI) EC is a result of bank structure modification in the marginal and non marginal zone (aliens and erosion). The confidence of both the instream and riparian is medium.

[4] A diatom based water quality index. The index evaluates organic and inorganic pollution based on the sensitivity of each taxon, while taking into account the response of the whole diatom community (Almeida, 2001). The index is used to indicate general water quality.

2.4.5 Fish (A EC, 92.6%)

The fish population is still close to natural. Some stressors are present in low intensity, such as habitat alteration due to sedimentation and bank erosion, and the presence of the alien predatory rainbow trout (*Oncorhynchus mykiss*).

2.4.6 Macroinvertebrates (B EC, 87.1%)

SASS5 score: 215 No of Taxa: 34 ASPT: 6.3

The macroinvertebrate assemblage reflects slightly deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and sedimentation of instream habitats with coinciding water quality problems. This can be seen most clearly in the disappearance of the stoneflies (Perlidae) and the cobble dwelling Chlorocyphid mayflies. Many sensitive flow dependent taxa were collected in stones-in-current (SIC), stones-out-of-current (SOOC) and gravel-sand-mud (GSM) habitats, while vegetation harboured the more resilient taxa. High scoring taxa in the former biotopes include Heptageniidae, Polymitarcyidae, Prosopistomatidae, Psephenidae, and Athericidae.

2.4.7 Riparian vegetation (A EC, 92.5%)

Marginal zone: This zone is most important for year-round refuge habitat, and overhanging vegetation is important for habitat creation/variability.

Lower zone: Has high seasonal importance for breeding habitat, and shading of aquatic habitats.

Upper zone: Is not directly important for instream habitat, but bank stability is indirectly important as it provides possible shading. The site is very close to reference conditions, minor impacts include exotics on the non marginal zone and some bank slumping caused by livestock trampling.

2.4.8 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 2.7.

CAUSE: A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
SOURCE: A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the waterbody (EPA, 2000).

Table 2.7 EWR 1: Causes and sources

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
Hydro[3]	A/B	2.5	Reduction in base flows.	Abstraction and trout dams.	F	4
Physico-chem[4]	A	2	Elevated nutrients. Lower flows result in fluctuations in oxygen and temperature.	Farming activities. Dullstroom town.	NF	2
Geom[5]	B	3	Channel incision/confinement and straightening.	Land-use impacts from agriculture and roads.	NF	3

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
Rip veg[6]	A	4.1	Some reduction in non-woody cover and abundance in marginal and non-marginal zones.	Small amount of exotics on non-marginal zone, and some trampling which has caused bank destabilization (slumping has occurred).	NF	4
Fish	A	5	Sedimentation of substrates.	Increased erosion, grazing and bank instability.	NF	3.5
			Loss of overhanging vegetation as cover.	Bank erosion and instability.		
			Pressure on fish assemblage / predation.	Aliens (Trout).		
Inverts[7]	B	4	Alteration of low flows.	Abstraction.	F	2.5
			Increased sedimentation of instream habitat.	Land use.	NF	

1 Flow related 2 Non-flow related 3 Hydrology
4 Physico-chemical 5 Geomorphology 6 Riparian vegetation
7 Macroinvertebrates

2.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity are stable or still changing. The results are summarised in Table 2.8.

Table 2.8 EWR 1: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico chem	A	Stable	A	N/A		2
Geom	B	Stable	B	N/A	The current impacts are relatively small and the present state of the system is stable under these conditions.	3
Rip veg	A	Stable	A	N/A	Low impact of exotics, are unlikely to increase. Existing trampling pressure unlikely to cause a trend.	2
Fish	A	Stable	A	N/A	The fish assemblage in this section of the Crocodile River have adapted to the slightly altered water quality and flows, as well as the presence of alien rainbow trout for many years, and should remain fairly stable over the long term should current conditions prevail.	4
Inverts	B	Stable	B	N/A	The macroinvertebrates have already reacted to the current conditions.	2

2.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 2.9. The Instream EC is an A/B (90%).

Table 2.9 EWR 1: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	1	90		
2.What is the natural diversity of **fish** species with a preference for different cover types	1.5	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	1	90		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	1	90		
FISH ECOLOGICAL CATEGORY	4.5	370	**92.6**	**A**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	3	90		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	4	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	4	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	11	290	**87.1**	**B**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		660	**88.1**	**A/B**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.53	49.39	
Confidence rating for **macroinvertebrate** information	3.5	0.47	40.65	
	7.5	1.00	90.03	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**A/B**	

To determine the EcoStatus, the Vegetation Response Assessment Index (VEGRAI) EC and confidence is included in the EcoStatus assessment index (Table 2.10). The EcoStatus EC is an A/B (91.3%).

Table 2.10 EWR 1: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**92.5**	**A**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	3.76667	0.48	43.11
Confidence rating for riparian vegetation zone information	4.1	0.52	48.21
	7.86667	1.00	91.32
ECOSTATUS	**EC**		**A/B**

2.7 RECOMMENDED ECOLOGICAL CATEGORY (REC): A/B

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 1 is **MODERATE** and the REC is therefore to maintain the PES.

2.8 ALTERNATIVE ECOLOGICAL CATEGORY (AEC): B/C

A hypothetical scenario was designed by the specialist team that would result in a lower EC and included the following:

- Decreased low flows due to e.g. increased golf estates, trout farms and increased abstractions for Dullstroom.
- Increased sewage.
- Increased grazing causing trampling and destabilisation of banks.

Each component is adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models are available electronically and summarised in Table 2.11.

Table 2.11 EWR 1: Alternative B/C EC

	PES	AEC	Comments	Conf
Physico -chem	A	B	Overall nutrient levels and toxics would increase.	2
Geom	B	C	A reduction in the moderate floods. This would result in less frequent and shorter duration overtopping floods, which would result in partial desiccation of the floodplains and associated wetlands.	2
Rip veg	A	B	Increased trampling pressure will cause bank destabilization (slumping) and the subsequent change of marginal zone vegetation with a reduction in non-woody cover and abundance. This will allow exotics to increase on the non-marginal zone, but the impact will remain low.	2.1
Fish	A	B/C	Decreased flows and some moderate events will result in decreased flushing of sediment from the substrate, the primary cover available for *B. anoplus* (in the absence of overhanging vegetation as result of steep banks). The above mentioned scenario is therefore expected to decrease the FROC of *B. anoplus*.	4
Inverts	B	B/C	An increase in sedimentation and nutrient loading could be aggravated by a reduction in flow. The cumulative effect of these factors could reduce the quality of the cobble habitat due to increased sedimentation and increased algal growth, as well as the vegetation habitat due to reduced inundation. The fast flow and moderate flow habitats will also be affected. It is anticipated that the changes in habitat and flow will reduce the abundance and/or frequency of occurrence of rheophilics and taxa requiring inundated vegetation. Possible increased nutrients could increase the abundances and frequency of occurrences of more tolerant taxa.	3

2.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results for setting EWR scenarios are summarised in Table 2.12.

Table 2.12 EWR 1: Summary of EcoClassification results

IHI				Driver Components	PES & REC Category	Trend	AEC↓
INSTREAM	B	RIPARIAN	B	HYDROLOGY	A/B		B
				WATER QUALITY	A		B
				GEOMORPHOLOGY	B	Stable	C
				Response Components	**PES & REC Category**	**Trend**	**AEC↓**
				FISH	A	Stable	B/C
				MACRO INVERTEBRATES	B	Stable	B/C
				INSTREAM	A/B		B/C
				RIPARIAN VEGETATION	A	Stable	B
				ECOSTATUS	A/B		B/C

IHI Hydrology PES	A/B
Diatoms	B

Note: Applicable to all EcoClassification summary results:

- IHI hydrology is provided as it includes an ecological evaluation of the potential impact on habitat.
- Diatoms are provided as it provides information for the water quality assessment in terms of current pollution levels and possible trends in physical chemical variables.

3 EWR 2 GOEDEHOOP (CROCODILE RIVER)

3.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 3.1.

Table 3.1 EWR 2: Availability of data

Component	Data availability	Conf
Hydrology	Gauge records for 1985 to 2008 are available. The nearest reliable gauge is at Kwena Dam at the outlet of X21C.	4
Physico-chemical	Little DWA monitoring data exists for this site (PES; n = 9). Limited phytoplankton, periphyton and diatom data (n = 1). A very poor data set exists for this site, so expert judgment and knowledge of the area was relied on.	2
Geomorphology	Historical aerial photography (1956, 1964, 1975, 1985). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site with surveyed key vegetation points. Geomorphological, Index of Habitat Integrity (IHI), EcoRegion and associated information. Data collected from field assessment during October 2007. Aerial photos of site - 1956, 1964, 1975, 1985. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	3.5
Fish	Single site visit and fish sampling during October 2007. Kleynhans *et al.* (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. J. Engelbrecht).	4
Macroinvertebrates	Data and analysis from a single sampling trip to the site on 5 October 2007 (two sets of samples). Historical macroinvertebrate data from the Rivers Database for site X2CROC-GOEDE (the EWR site). Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	4

3.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 3.2) was rated as **HIGH**, as there are rare and endangered fish (*Chiloglanis bifurcus* (critically endangered) and *Kneria auriculata*). Fish species that are intolerant to flow and flow related water quality, are present and there is high fish species diversity at this site. The Verlorenkloof conservancy falls within this reach.

Table 3.2 EWR 2: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*C. bifurcus, K. Auriculata* and *Cliffortia* spp.
Unique (endemic, isolated, etc.)	2	4	*B. neefi, Amphilius natalensis.*
Intolerant (flow & flow related water quality)	4	4	*C. bifurcus, Chiloglanis pretoriae, Amphilius uranoscopus, A. natalensis and Barbus argenteus.*
Species/taxon richness	3	4	Ten fish species present.
RIPARIAN & INSTREAM HABITATS			
Diversity of types	2	4	Rapids, riffles and pools.
Refugia	2	3	
Sensitivity to flow changes	3	3	
Sensitivity to flow related water quality changes	3	3	Temperature
Migration route/corridor (instream & riparian)	1	3	Birds and eels.
Importance of conservation & natural areas	2	4	Verlorenkloof conservancy.
MEDIAN	2.5		
EIS EVALUATION	**HIGH**		

3.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 3.3. Additional information on fish and macroinvertebrate reference conditions are also provided.

Table 3.3 EWR 2: Reference conditions

Component	Reference conditions	Conf
Hydrology	This record is calculated from stage measurements in the Kwena Dam and low flows are probably not accurate. Virgin MAR: 55.82 MCM	4
Physico-chemical	Benchmark tables were used according to Kleynhans *et al.,* 2005. Refer to Table 2.4 as reference conditions are the same as for EWR 1.	1
Geomorphology	The reference state is similar to the current condition, although the river may have been slightly wider and perhaps less deeply incised.	2.5
Riparian vegetation	The site occurs in Lydenburg Thornveld in the Grassland biome. The marginal zone will be incised into the grassland floodplain with meandering channels and floodplain. Non-woody vegetation dominate both the marginal and non-marginal zones mostly, as well as the floodplains (*Miscanthus* spp. is dominant), with a minor woody presence (*Cliffortia*, *Combretum* and *Leucosidea* spp. mainly).	3.5
Fish	Ten species present. Refer to Table 3.4.	5
Macroinvertebrates	The reference total SASS 5 score is 260 and an ASPT of 7 and 59 taxa expected. Additional information is provided below.	3

Information on the expected fish reference conditions at the NRHP site X2CROC-UKWEN, as cited in Kleynhans *et al*. (2007b) was used to determine the expected fish reference conditions. This fish reference condition should be valid for the Crocodile River stretch within NRU Croc A that falls within EcoRegion 9.04. Ten indigenous fish species are expected under reference conditions. Most species are expected to have frequent occurrence within their optimal habitats at the site under reference conditions. Reference species detail is listed in Table 3.5.

Table 3.4 EWR 2: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 2 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Amphilius natalensis	Natal mountain catfish	ANAT	4	3
Amphilius uranoscopus	Mountain catfish	AURA	5	2
Barbus anoplus	Chubbyhead barb	BANO	5	4
Barbus argenteus	Rosefin barb	BARG	5	1
Barbus neefi	Sidespot barb	BNEE	5	5
Chiloglanis bifurcus	Incomati suckermouth	CBIF	3	0
Chiloglanis pretoriae	Shortspine suckermouth	CPRE	5	3
Kneria auriculata	Southern kneria	KAUR	5	3
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	5	5
Tilapia sparrmanii	Banded tilapia	TSPA	4	4

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Macroinvertebrate taxa expected under reference conditions are:
Culicidae, Notonectidae, Corixidae, Muscidae, Belostomatidae, Nepidae, Lymnaeidae, Planorbinae, Physidae, Turbellaria, Hirudinea, Potamonautidae, Chironomidae, Sphaeriidae, Oligochaeta, Veliidae, Gerridae, Dixidae, Hydrometridae, Hydraenidae, Hydracarina, Ecnomidae, Leptophlebiidae, Aeshnidae, Chlorocyphidae, Tricorythidae, Psephenidae, Elmidae, Lestidae, Protoneuridae, Athericidae, Philopotamidae, Corduliidae, Polymitarcyidae, Gyrinidae, Naucoridae, Dytiscidae, Hydrophilidae, Pleidae, Baetidae 2spp, Simuliidae, Hydropsychidae 2spp, Porifera, Ancylidae, Coenagrionidae, Hydroptilidae, Libellulidae, Ceratopogonidae, Leptoceridae, Caenidae, Tipulidae, Tabanidae, Corbiculidae, Gomphidae, Oligoneuridae, Baetidae >2spp, Helodidae, Perlidae, Prosopistomatidae, Heptageniidae, and Hydropsychidae >2spp.

3.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

3.4.1 Hydrology

The present MAR is 53.87 MCM (97% of natural). There have not been significant changes in this catchment over the period of recorded flow. The only change has been the construction of many trout dams which would reduce low flow periods and delay the first freshettes of spring. Dullstroom's abstraction has increased somewhat over the past 5 to 10 years. Some abstraction for agriculture also takes place.

3.4.2 Geomorphology (B EC, 85.1%)

The EWR site is within a meandering alluvial river section. Within the channel there are small riffles and long runs/pools. There is erosion on both banks (i.e. both banks are cut) suggesting a possible incision problem, but this is likely to be a localised impact associated with flow

confinements under the bridge crossing. Riparian vegetation plays an important role in stabilizing the banks.

3.4.3 Physico chemical variables (B EC, 87.4%)

The SPI indicates good water quality (15.3) at this site and the diatom based ecological classification indicates well oxygenated circumneutral water. Overall the diatom water quality is in a B category but the site is more impacted on than EWR 1.

Records (1992 – 1994 (n = 9) from water quality station X2H074Q01 were used for the PES assessment. The frequency of monitoring was monthly although intermittent. Farming and urban activities may be resulting in elevated nutrient levels. Abstraction is causing fluctuations in oxygen and temperature. PES values for the physico-chemical variables are the same as for EWR 1 (Table 2.6) and provided in Appendix C.

3.4.4 Instream and Riparian Habitat Integrity (IIHI: B EC, 84%; RIHI: B EC, 82.4%)

EWR 2 falls within the same MRU (MRU A) as EWR 1. As the IHI was done for MRU A, the results for EWR 2 are the same as for EWR 1.

3.4.5 Fish (B EC, 82.4%)

The PES reflects slightly deteriorated ecological integrity, primarily attributed to altered low flows and increased sedimentation and slightly altered water quality. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution.

3.4.6 Macroinvertebrates (B EC, 84.4%)

SASS5 score: 228 No of Taxa: 36 ASPT: 6.4

This slight decrease in the PES is due to water quality modification as a result of numerous instream trout dams in the upper catchment. Problems associated with this include nutrient enrichment of the water, which results in algal growth on instream habitat, effectively decreasing the availability of habitat for macroinvertebrate colonization. Flow modification and sedimentation are also having a negative impact on the instream habitat and resultant macroinvertebrate colonization. Flow sensitive taxa that were sampled included Perlidae, Prosopistomatidae, Heptageniidae, Tricorythidae. High scoring taxa included Prosopistomatidae, Heptageniidae and Perlidae. The burrowing mayfly, Polymitarcyidae, was also sampled at the site.

3.4.7 Riparian vegetation (A/B EC, 89.9%)

Marginal zone: This zone is most important for year-round refuge habitat, and overhanging vegetation is important for habitat creation/variability.

Lower zone: Has high seasonal importance for breeding habitat, and shading of aquatic habitats.

Upper zone: Is not directly important for instream habitat, but bank stability is indirectly important as it provides possible shading. The site is very close to reference condition, with minor impact of exotics on the marginal and non-marginal zones, and some bank slumping caused by livestock trampling.

3.4.8 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 3.5.

Table 3.5 EWR 2: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	A/B	4	Reduced base flows.	Forestry and agriculture.	NF	4
Physico-chemical	B	2	Elevated nutrients.	Farming activities.	NF	2
			Lower flows result in fluctuations in oxygen and temperature. Turbidity from farming activities. Slight elevation in toxics is expected.	Land use activities - site is below Dullstroom town.		
Geom	B	2.5	Channel incision/confinement and straightening.	Land use impacts from agriculture and roads.	NF	3
			Some slight changes to sediment supply.	Land use activities (agriculture).		
Rip veg	A/B	3.7	Some reduction in non-woody cover and abundance in marginal and non-marginal zones.	Small amount of exotics and some trampling which has caused bank destabilization (slumping has occurred) on marginal and marginal zones.	NF	4
Fish	B	4	Sedimentation of substrates.	Increased erosion, grazing and bank instability.	NF	3
			Loss of overhanging vegetation as cover.	Bank erosion and instability.		
			Pressure on fish assemblage / predation.	Aliens (rainbow trout).		
			Slightly reduced habitat diversity and availability.	Decreased flows related to abstraction.	F	
Inverts	B	4	Alteration of low flows.	Many small instream trout dams, abstraction.	F	3
			Increased sedimentation of instream habitat.	Land use.	NF	

3.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 3.6.

Table 3.6 EWR 2: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-chem	Upper B	Slow, but downward	Lower B	5 yrs	The presence of highly pollution tolerant diatom species (*S. seminulum*, *N. palea*, *N. tenelloides*, *N. gregaria*, *N. capitatoradiata*), although in small numbers, indicate that the pollution levels are higher than at EWR 1 and this could indicate a negative trend.	2
Geom	B	Stable	B		The current impacts are relatively small and the present state of the system is stable under these conditions.	2.5
Rip veg	A/B	Negative	B	10 years	There is a low impact of exotics, but if left unchecked will increase at the expense of indigenous species (some aggressive aliens present such as *Moris*, *Sesbania* and *Gleiditsia* spp.). Existing trampling pressure is also likely to cause additional bank slumping.	3

	PES	Trend	Trend PES	Time	Reasons	Conf
Fish	B	Stable	B		The fish assemblage has adapted to the slightly altered water quality and flows, as well as the presence of alien rainbow trout for many years, and should remain fairly stable over the long term.	3
Inverts	B	Negative	B/C	5 year	Land use and resulting erosion and sedimentation, abstraction, and water quality maintained at same levels. There have been a number of recent developments in the upper Crocodile catchment, including the Highland Gate development in the Kareekraal Spruit. The macroinvertebrates have not yet adapted to these changes.	2

3.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 3.7. The Instream EC is a B (83.4%).

Table 3.7 EWR 2: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	90		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2.5	70		
FISH ECOLOGICAL CATEGORY	12	350	**82.4**	**B**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	3	90		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	4	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	4	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	11	290	**84.4**	**B**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		640	**83.6**	**B**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.50	41.20	
Confidence rating for **macroinvertebrate** information	4	0.50	42.20	
	8	1.00	83.40	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B**	

To determine the EcoStatus, the VEGRAI EC and confidence are added to the equation (Table 3.8). The EcoStatus EC is a B (86.5%).

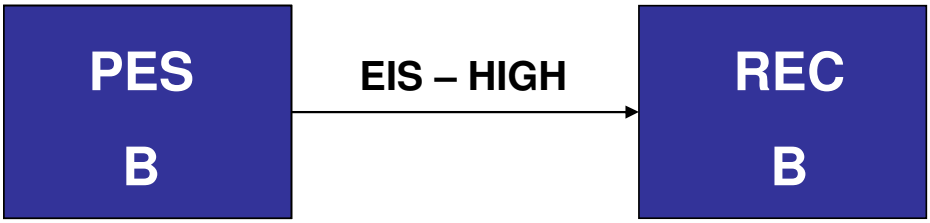
Table 3.8 EWR 2: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	89.9	A/B	
ECOSTATUS	Confidence rating	Proportions	Modified weights
Confidence rating for instream biological information	4	0.52	43.32
Confidence rating for riparian vegetation zone information	3.7	0.48	43.20
	7.7	1.00	86.52
ECOSTATUS	EC		B

3.7 REC: B

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 2 is **HIGH**. As the PES is also relatively high, the attainable and realistic objective is to maintain the PES even though a high EIS would normally warrant improvement. Furthermore, all the problems are mostly non-flow related and increased flows will not improve the EC.



3.8 AEC: C

A hypothetical scenario is designed which is the same as for EWR 1 and also includes the following:

- Some seasonality changes due to longer periods of low flow duration and some impact on moderate events.

Each component is adjusted to indicate the metrics that will react to the scenario. The changes in the rule based models are available electronically and summarised in Table 3.9.

Table 3.9 EWR 2: Alternative B/C EC

	PES	AEC	Comments	Conf
Physico-chem	A	B	A drop in flows will result in an increase in nutrient levels, salinity and toxics. More frequent and lower low flows will also affect oxygen and temperature levels.	2
Geom	B	C	It would be expected that there would be a reduction in the moderate floods. This would result in less frequent and shorter duration overtopping floods, which would result in partial desiccation of the floodplains and associated wetlands.	2

	PES	AEC	Comments	Conf
Rip veg	A	B	Reduced low and moderate flows will likely reduce the success of woody recruitment on marginal and non-marginal zones. Non-woody cover will increase as the as marginal zone follows the narrowing channel.	2.8
Fish	A	B/C	Altered flow regime (increase low flows) will negatively impact on the FROC of species that are intolerant to no flow conditions and prefer fast habitats (*A. natalensis, A. uranoscopus, B. argenteus, C. bifurcus* and *C. pretoriae*). Altered flows (decreases) may even result in the loss of the **critically endangered** *C. bifurcus* from this reach.	4
Inverts	B	C	A decrease in the quality of the instream habitat, with resultant algal growth and accumulation of fines in the stones in current habitat will occur. Less marginal vegetation will be available for colonization by macroinvertebrates. Increased alien vegetation may result in bank destabilization which will increase sedimentation affecting instream habitat. These changes to the system will reduce the abundance and/or frequency of occurrence of rheophilic taxa as well as taxa utilizing the marginal vegetation. Those taxa requiring good quality cobble habitat, will be negatively impacted by the increased sedimentation and algal growth on the cobbles. Certain tolerant taxa may increase in abundance with increased nutrients in the system.	2.5

3.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results for setting EWR scenarios are summarised in Table 3.10.

Table 3.10 EWR 2: Summary of EcoClassification results

IHI				Driver Components	PES & REC Category	Trend	AEC↓
INSTREAM	B	RIPARIAN	B	HYDROLOGY	B		C
				WATER QUALITY	B		C
				GEOMORPHOLOGY	B	Stable	B/C
				Response Components	**PES & REC Category**	**Trend**	**AEC↓**
				FISH	B	Stable	C
				MACRO INVERTEBRATES	B	Negative	C
				INSTREAM	B		C
				RIPARIAN VEGETATION	A/B	Negative	B
				ECOSTATUS	B		C

IHI Hydrology PES	A/B
Diatoms	B

4 EWR 3 POPLAR CREEK (CROCODILE RIVER)

4.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 4.1.

Table 4.1 EWR 3: Availability of data

Component	Data availability	Conf
Hydrology	The Montrose gauge (X2H013) is located just downstream of EWR 3 but this gauge is not considered to be particularly reliable.	4
Physico-chemical	DWA monitoring data was available for reference condition and PES. Limited phytoplankton, periphyton and diatoms was available (n = 1). No temperature, DO or turbidity data was available. Little metal data was available. Electrical conductivity (EC) and aggregated salts data available.	3
Geomorphology	Historical aerial photography (1956, 1964, 1975, 1985). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site with surveyed key vegetation points. Previous VEGRAI training site. Aerial photos of site - 1956, 1964, 1970, 1997. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Data collected from field assessment in 2007.	4
Fish	Single site visit and fish sampling during October 2007. Kleynhans et al. (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. J. Engelbrecht).	4
Macroinvertebrates	Data and analysis from a single sampling trip to the site on 5th October 2007 (two sets of samples). Data from the Rivers Database for site X2CROC-INDEM. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	4

4.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 4.2) was rated as **HIGH**, as there are rare and endangered fish (*C. bifurcus* (critically endangered) and vegetation species present. Fish and macroinvertebrate taxa which are intolerant to flow and flow related water quality changes are also present in this river reach.

Table 4.2 EWR 3: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*C. bifurcus*, birds, *Cliffortia* and *B. salicina.*
Unique (endemic, isolated, etc.)	1	4	*Barbus argenteus.*
Intolerant (flow & flow related water quality)	4	4	*C. bifurcus, C. pretoriae, A. uranoscopus*, *B. argenteus* and macroinvertebrates.
Species/taxon richness	2	4	Seven fish species, 30 macroinvertebrate taxa.
RIPARIAN & INSTREAM HABITATS			
Diversity of types	2.5	4	Pools, riffles, rapids, riparian vegetation.
Refugia	2	3	Riffles for rheophilics.
Sensitivity to flow changes	2	3	
Sensitivity to flow related water quality changes	2.5	3	
Migration route/corridor (instream & riparian)	2.5	3	*Anguilla mossambica*, birds.
Importance of conservation & natural areas	2	3	Schoemanskloof conservancy. Legogote sour bushveld - poorly protected and is an endangered vegetation type.
MEDIAN	2.25		
EIS EVALUATION	**HIGH**		

4.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 4.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 4.3 EWR 3: Reference conditions

Component	Reference conditions	Conf
Hydrology	Although low flows may not be accurate, the gauge record is long and 95% complete. Virgin MAR: 194.9 MCM.	4
Physico-chemical	DWA monitoring data: X3H006Q01; n = 149, 1976 – 1979. Refer to Table 4.4.	3
Geomorphology	The reference state would have been a pool-riffle channel type with (relative to current conditions) a wider channel experiencing more frequent floods; finer bed and gentler sloping banks with well-vegetated marginal zones. This would have been a lower energy channel with more fines and gravels. Possibly a bit of a sinuous channel; with some in-channel vegetated bars and more marginal vegetation.	3.5
Riparian vegetation	This site occurs in the Lowveld bioregion of the Savanna biome in the Legogote Sour Bushveld. The site occurs on a stretch of river which cuts through high ground. As a result a mixed vegetation is expected, but one predominated by woody vegetation. Marginal zone species would typically be *Syzigium* species, *Cliffortia sp* and *Breonadia salicina*, with *Combretum erythrophyllum* and *Acacia robusta* and *A. gerardii* on the lower and upper zones. Marginal zone would typically be a narrow band with some sedge and hydrophilic grasses.	3.5
Fish	Seven species present. Refer to Table 4.5.	4
Macroinvertebrates	The reference total SASS 5 score is 240 with >35 taxa and an ASPT of 7.5. Additional information is provided below.	3.5

Detailed physico-chemical reference conditions are provided in Table 4.4.

Table 4.4 EWR 3: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	5.314
	Na_2SO_4	1.191
	$MgCl_2$	1.104
	$CaCl_2$	2.315
	NaCl	6.238
	$CaSO_4$	0.460
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.007
	Total Inorganic Nitrogen (TIN)	0.090
Physical variables	pH (5^{th}+95^{th} percentiles)	6.5 + 7.7
	Electrical conductivity (mS/m)	17.00

Information on the expected fish reference conditions at the NRHP site X2CROC-DKWEN, as cited in Kleynhans *et al*. (2007b) was used to determine the expected reference conditions. This fish reference condition should be valid for the Crocodile River stretch within NRU Croc D and E (EcoRegions 10.01 and 10.02). Seven indigenous fish species are expected under reference conditions. Most species are expected to have frequent occurrence within their optimal habitats at the site under reference conditions. Reference species detail is listed in Table 4.5.

Table 4.5 EWR 3: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 3 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	4	3
Amphilius uranoscopus	Mountain catfish	AURA	5	5
Barbus argenteus	Rosefin barb	BARG	5	4
Chiloglanis bifurcus	Incomati suckermouth	CBIF	3	3
Chiloglanis pretoriae	Shortspine suckermouth	CPRE	5	5
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	3	3
Tilapia sparrmanii	Banded tilapia	TSPA	3	1

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Expected macroinvertebrate taxa include:

Baetidae >2spp, Helodidae, Pyralidae, Heptageniidae, Prosopistomatidae, Perlidae, Hydropsychidae >2spp, Polycentropodidae, Gyrinidae, Naucoridae, Hydrophilidae, Dytiscidae, Pleidae, Gomphidae, Corbiculidae, Unionidae, Caenidae, Tabanidae, , Tipulidae, Ceratopogonidae, Leptoceridae ,Coenagrionidae, Hydroptilidae, Empididae, Libellulidae, Simuliidae, Hydropsychidae 1sp ,Hydropsychidae 2spp, Porifera, Ancylidae, Veliidae, Gerridae, Dixidae, Hydrometridae, Hydraenidae, Hydracarina, Corduliidae, Polymitarcyidae, Pisuliidae, Lestidae, Atyidae, Athericidae, Philopotamidae, Aeshnidae, Leptophlebiidae, Chlorocyphidae, Elmidae, Dryopidae, Psephenidae, Tricorythidae, Psychomyiidae ,Culicidae, Corixidae, Notonectidae, Ephydridae, Belostomatidae, Sphaeriidae, Oligochaeta, Chironomidae, Hirudinea, Potamonautidae, Nepidae, Physidae, Thiaridae, Bulinae, Lymnaeidae, Planorbinae, and Turbellaria.

4.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

4.4.1 Hydrology

Present MAR is 169.9 MCM (87% of natural). Present flows include increased (from natural) low flows during the dry season and decreased low flows during the wet season. This has significant effect on the seasonal distribution of flows. As there are increased flows from natural during certain months, the total % flows of natural still present in the system is nonsensical in this case. The presence of the Kwena Dam upstream of EWR 3 will have had a major influence on the hydrology of the catchment. Large releases are made from the Kwena Dam to irrigators downstream of the dam. The Kwena Dam was completed in 1984 and after this date the natural and actual flow would have deviated significantly.

4.4.2 Geomorphology (C EC, 62.4%)

Cut banks are present on both banks (water is very turbid), and channel narrowing is evident from the aerial photographs. The channel in this pool riffle site is incising in response to the clean water releases, as well as the prolonged elevated base flows which are being released from Kwena Dam. The active channel is composed of loose cobbles with some gravels and occasional fixed boulders. There are no fines anywhere along the reach in the channel and very few gravels (extremely coarse) are present.

4.4.3 Physico chemical variables (C EC, 73.7%)

From the diatom assessment the SPI indicates good water quality (score: 14.6), although this falls within the lower ranges of the classification and the diatom based ecological classification indicates low oxygen saturation and alkaline conditions. Overall the diatom water quality is in a B category but the high flows (1 m^3/s on day of sampling) may have had a dilution effect (agricultural runoff) as there are species present that are very pollution tolerant and indicators of eutrophic conditions.

Records (1991 – 1999 (n = 39)) from the water quality station X3H013Q01 were used for the PES assessment. The frequency of monitoring was monthly although intermittent. Periphyton and diatoms indicate some nutrient pollution at this site. Elevated turbidity levels are present due to catchment activities. Most metal data indicates good quality (except for Zn), but pesticide use is practiced in area and is expected to impact on the site. As the site is downstream of Kwena Dam temperature and oxygen may be variables of concern particularly at low flows. PES values for the physico-chemical variables are provided in Table 4.6 and in Appendix C.

Table 4.6 EWR 3: Physico-chemical PES values

Water Quality Constituents		Value: PES
Inorganic salts (mg/L)	$MgSO_4$	8
	Na_2SO_4	0
	$MgCl_2$	3
	$CaCl_2$	3
	NaCl	9
Nutrients (mg/L)	SRP	0
	TIN	0.018
Physical variables	pH (5^{th}+95^{th} percentiles)	0.125
	Electrical conductivity (mS/m)	7.3 + 8.04

4.4.4 Instream and Riparian Habitat Integrity (IIHI: B EC, 72.6%; RIHI: B EC, 69.3%)

The IIHI is mostly due to changes in base flows and channel bed modification due to abstractions and land use. Erosion and channel incision has also impacted the marginal zone and there has been a change in the lateral connectivity due to the incision. The RIHI is due to erosion caused by land use activities in the area. The confidence in this assessment is medium - high.

4.4.5 Fish (B EC, 84.7%)

The PES reflects slightly deteriorated ecological integrity, based on the fish assemblage, primarily attributed to an altered low flow regime (Kwena Dam), increased sedimentation and slightly altered water quality. Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution. Species preferring fast habitats have been favoured and species with requirement for slower habitats have been impacted by the flow modification.

4.4.6 Macroinvertebrates (C EC, 74.5%)

SASS5 score: 218 No of Taxa: 32 ASPT: 6.8

The PES assemblage reflects moderately deteriorated ecological integrity, attributed primarily to the upstream Kwena Dam and land use activities. The unseasonal high releases from the Kwena Dam. The Macro Invertebrate Response Assessment Index (MIRAI) indicates that the main reasons for the deterioration in the macroinvertebrate assemblage are related to the change in habitat (scouring due to high velocities) and connectivity and seasonality. The main reason can be regarded as the unseasonal high flows during the winter months. The macroinvertebrate community collected included a suite of taxa in the sensitivity range of 10 - 15, including Heptageniidae, Baetidae (>2sp), Psephenidae, Prosopistomatidae and Athericidae.

4.4.7 Riparian vegetation (B EC, 77.3%)

This site has all the necessary elements of the reference condition, but is highly disturbed and has a high proportion of exotic species.

Marginal zone: Is a mix of woody (*Cliffortia, Breonadia, Syzigium)* and grass (*Setaria sphacelata*).

Lower and upper zones: Dominated by woody species with terrestrial grass understorey. Terrestrial species also indicate high levels of disturbance.

4.4.8 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 4.7.

Table 4.7 EWR 3: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	C	3	Altered low flow and flooding regime.	Kwena Dam.	F	4

	PES	Conf	Causes	Sources	F/NF	Conf
Physico-chemical	C	3	Slightly elevated nutrients.	Agricultural activities.	NF	3
			Temperature changes (releases and very low flows in wet season). Elevated turbidity levels. Slight elevation in toxics expected.	Operation of Kwena Dam.		
Geom	C	4	Channel incision – cut banks on both banks.	Kwena Dam upstream is the source of reduced floods, elevated low and base flows.	F	3.5
Rip veg	B	3.7	Loss of species composition and indigenous riparian species cover.	High level of invasion by exotic species	NF	4.5
			Reduced woody cover and abundance.	Extensive disturbance at the site, agricultural activities, roads within the riparian zone and targeted woody species removal.		
Fish	B	4	Sedimentation of substrates.	Increased erosion related to agriculture, forestry, grazing and bank instability.	NF	3
			Loss of overhanging vegetation as cover.	Bank erosion and instability.		
			Pressure on fish assemblage / Predation.	Introduced/translocated indigenous species (*Clarias gariepinus*).		
			Loss in habitat diversity.	Altered hydrological regime (Kwena Dam releases).	F	
			Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (especially Kwena dam, but also smaller weirs) impede natural migration. Altered hydrological events delay/prevent natural migratory cues (controlled releases from Kwena Dam).		
Inverts	C	4	Reduced low flows.	Operation of Kwena Dam.	F	2.5
			Alteration in moderate floods.	Operation of Kwena dam.		
			Increased sediment loading (high turbidity).	Kwena dam, altered flow regime.	NF	
			Bed and bank modified (sedimentation).	Land use in catchment.		

4.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 4.8.

Table 4.8 EWR 3: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-chem	Upper C	Negative	(Possibly move to a Lower C)	5 yrs	The present state is dependent on the operation of the dam, e.g. temperature and oxygen state is dependent on flow releases. So, although the water quality will move within the category, it may be better or worse depending on how and when water is released from Kwena Dam.	3
Geom	C	Slow negative	D	5 years	Continued altered flow releases will erode banks, and reduced flooding is desiccating the upper terraces/floodplain.	2.5
Rip veg	C	Negative	D	5-10 years	Exotic invasion is high (up to 40% in places) and if left unchecked will increase in proportion at the expense of indigenous riparian vegetation.	3.5

	PES	Trend	Trend PES	Time	Reasons	Conf
Fish	B	Stable	B	N/A	The fish assemblage has adapted to the slightly altered water quality and flows, as well as the presence of alien rainbow trout for many years, and should remain fairly stable over the long term.	3
Inverts	C	Downward	C/D	5 years	The operation of Kwena Dam has resulted in a severe change of seasonal flows, with high constant releases made during the dry season. Due to these constant releases sampling at this site is very difficult. Due to the development in the catchment the macroinvertebrates have not yet adapted to the reduced low flows, altered flood regime and higher turbidity.	2.5

4.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 4.9. The Instream EC is a B/C (77.9%).

Table 4.9 EWR 3: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	90		
2.What is the natural diversity of **fish** species with a preference for different cover types	3.5	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	90		
FISH ECOLOGICAL CATEGORY	13	380	**84.7**	**B**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	5	100		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	5	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	5	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**15**	300	**74.5**	**C**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		680	**77.9**	**B/C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.50	42.35	
Confidence rating for **macroinvertebrate** information	4	0.50	37.25	
	8	1.00	79.60	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B/C**	

To determine the EcoStatus, the VEGRAI EC and confidence are added to the equation (Table 4.10). The EcoStatus EC is a B/C (78.5%).

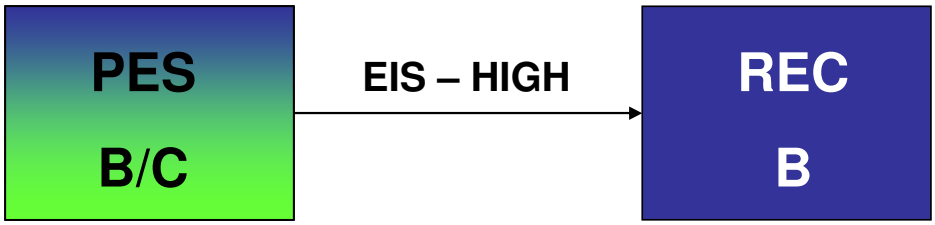
Table 4.10 EWR 3: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	77.3	C	
ECOSTATUS	Confidence rating	Proportions	Modified weights
Confidence rating for instream biological information	4	0.52	41.35
Confidence rating for riparian vegetation zone information	3.7	0.48	37.14
	7.7	1.00	78.49
ECOSTATUS	EC		B/C

4.7 REC: B

The REC is determined based on ecological criteria only and considers the EIS and the restoration potential and attainability there-of.

The EIS at EWR 3 is **HIGH** and the REC is therefore an improvement of the PES.



To achieve this improvement, the following is required:

- Lower flows in the dry season (than the unnatural high base flow releases and higher flows in summer.
- No improvement of the flooding regime as this will prevent the recolinisation of the marginal zone.
- An improvement of the marginal zone by the removal of exotic vegetation.

Each component is adjusted to indicate the metrics that will react to the REC scenario. The changes in the rule based models are available electronically and summarised in Table 4.11.

Table 4.11 EWR 3: REC B

	PES	REC	Comments	Conf
Physico -chem	C	B/C	Maintain the current EC. There will however be a slight improvement in oxygen and temperature.	3
Geom	C	C	It is not possible to improve the condition of the geomorphology. Although the loss of the moderate floods is a problem, due to the clean water being released from Kwena Dam the reinstatement of these large flows (from the dam) would actually increase the rate of erosion and channel incision in this reach.	3
Rip veg	C	B	More natural flows will facilitate non-woody establishment in the marginal zone, and will also facilitate *Cliffortia* spp. recruitment (presently absent). Flow manipulation will not improve the vegetation component on its own. In addition some woody exotics removal on the lower and upper zones will increase indigenous species cover and abundance, and improve species proportions which will improve species composition.	2.8

	PES	REC	Comments	Conf
Fish	B	B	Maintain the current EC.	4
Inverts	C	B	A number of taxa preferring slower water speeds are expected to occur more frequently and some of the molluscs and dipterans are expected to recolonise.	2.5

4.8 AEC: C/D

A hypothetical scenario is designed and includes the following:

- Lower flows than natural in both the dry season and the wet season which will lead to an associated increase in temperature and oxygen.
- Geomorphology: No change.
- Riparian vegetation: Marginal vegetation will not establish

Each component is adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models are available electronically and summarised in and summarised in Table 4.12.

Table 4.12 EWR 3: Alternative C/D EC

	PES	AEC	Comments	Conf
Physico-chem	C	C/D	Lower flows in both the dry and wet seasons, with associated temperature and oxygen changes. Lower flows therefore less dilution of toxics in the system.	3
Geom	C	C	There is unlikely to be any adjustment to the EC of the geomorphology.	N/A
Rip veg	C	D	**Marginal zone** Existing *Cliffortia* and *Salix* adults are likely to survive, but most recruitment will be reduced. Some recruitment will still take place, but the marginal zone will migrate towards a narrowing channel. For non-woody species, initially a reduction in cover and abundance will occur, followed by marginal zone migration. Lower zone species are likely to colonize "old marginal" zone areas, also potentially changing species composition. **Lower zone** Lower flows will facilitate improved conditions for aliens and terrestrial species in the lower zone. Indigenous cover and abundance will reduce accordingly, species composition will be negatively impacted and exotics will prevent indigenous riparian recruitment. Reduced recruitment will also alter population structures to deviate more from expected.	3
Fish	B	C	Increased duration of low flows, with lower water level will reduce the availability of riffle/rapid/run habitats (Fast Deep (FD)/Fast shallow (FS)), which will decrease the FROC of rheophilic and semi-rheophilic species (*A. uranoscopus, C. bifurcus* and *C. pretoriae*). Decreased low flows will further reduce the availability of overhanging vegetation as cover, which will also affect the FROC of species such as *P. philander* and *also T. sparrmanii*. Decreased flows will also increase the availability of the preferred habitats (slow) of the introduced *C. gariepinus* with resultant increased abundance of this species that may increase the predation pressure on the indigenous fish species.	4
Inverts	C	C/D	Deteriorating catchment condition will result in an increase in sedimentation and resultant loss of habitat. The deteriorating catchment condition is also likely to result in worsening water quality, thus resulting in the more sensitive macroinvertebrate taxa occurring less frequently and even disappearing.	3

4.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results for setting EWR scenarios are summarised in Table 4.13.

Table 4.13 EWR 3: Summary of EcoClassification results

IHI				Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	C	RIPARIAN	C	HYDROLOGY	C		B	D
				WATER QUALITY	C		B/C	C/D
				GEOMORPHOLOGY	C	Negative	C	C
				Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
				FISH	B	Stable	B	C
				MACRO INVERTEBRATES	C	Negative	B	C/D
				INSTREAM	B/C		B	C
				RIPARIAN VEGETATION	C	Negative	B	D
				ECOSTATUS	B/C		B	C/D

IHI Hydrology PES	B
Diatoms	B

5 EWR 4 KANYAMAZANE (CROCODILE RIVER)

5.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 5.1.

Table 5.1 EWR 4: Availability of data

Component	Data availability	Conf
Hydrology	The gauge X2H006 is located approximately 12km upstream of EWR 4. This gauge is considered to be reliable although probably underestimates high flows.	4
Physico-chemical	DWA monitoring data was available for reference condition and PES. Limited phytoplankton, periphyton and diatoms was available (n = 1). No temperature, DO or turbidity data was available. Little metal data was available. Electrical conductivity (EC) and aggregated salts data available.	3
Geomorphology	Historical aerial photography (1936, 1959, 1970, 1985, 1997). Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Hydrology records. Site survey information.	3
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site with surveyed key vegetation points. Data collected from field assessment in 2007. Previous VEGRAI training site Aerial photos of site - 1936, 1959, 1970, 1985, 1997. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4
Fish	Single site visit and fish sampling during October 2007. Kleynhans *et al*. (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. J. Engelbrecht)	4
Macroinvertebrates	Data and analysis from a single sampling trip to the site on 5th October 2007 (two sets of samples); Macroinvertebrate data from the Rivers Database for site X2NELS-R40RO sampled on 14/9/1999 and X2CROC-MONTR sampled on 13/9/1999. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	4

5.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 5.2) was rated as **HIGH**, as there are rare and endangered fish, vegetation and herpetofauna species present. There is a high occurrence of intolerant fish species present with regard to flow and water quality changes.

Table 5.2 EWR 4: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*Opsaridium peringueyi*, crocodiles, *B. salicina*.
Unique (endemic, isolated, etc.)	0	4	
Intolerant (flow & flow related water quality)	4	4	*O. peringueyi, C. pretoriae, B. eutaenia, A. uranoscopus.*
Species/taxon richness	3	4	Twenty fish species and 35 macroinvertebrate taxa.

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
RIPARIAN & INSTREAM HABITATS			
Diversity of types	3	4	Riffles, rapids, pools, bedrock.
Refugia	2.5	3	Riffle rapid sequence before Lowveld.
Sensitivity to flow changes	2	3	
Sensitivity to flow related water quality changes	2.5	3	The river is wide and sensitive to temperature changes.
Migration route/corridor (instream & riparian)	2	3	Birds, macroinvertebrates, *A. mossambica* and other fish.
Importance of conservation & natural areas	2	2	Krokodilpoort conservancy.
MEDIAN	2.25		
EIS EVALUATION	**HIGH**		

5.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 5.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 5.3 EWR 4: Reference conditions

Component	Reference conditions	Conf
Hydrology	There is uncertainty as to timing and quantity of releases from the Kwena dam for irrigators which affect the flow at this site. Virgin MAR: 754.1 MCM.	4
Physico-chemical	DWA monitoring data: X2H032Q01; n = 882, 1977 – 1980. Refer to Table 5.4.	3
Geomorphology	The site is close to the reference state (mixed pool-riffle).	3.5
Riparian vegetation	This site occurs in the Lowveld bioregion of the Savanna biome in the Pretoriuskop Sour Bushveld. The site occurs on a stretch of river which cuts through a gorge, but is still quite wide. As a result, a mixed vegetation is expected, but one predominated by woody vegetation. The site is also predominantly exposed bedrock and cobble/boulder. Marginal zone species would typically be *Syzigium* species, *Cliffortia sp* and *Breonadia salicina*, with *C. erythrophyllum, Ficus sycomorus* and *A. robusta* and *A. gerardii* on the lower and upper zones. Less *Phragmites mauritianus* expected than what is currently at the site. The marginal zone would typically be a narrow band with some sedge and hydrophilic grasses in between *Breonadia.*	3.5
Fish	Seven species present. Refer to Table 5.5.	3.5
Macroinvertebrates	The reference total SASS 5 is 270, with over 35 taxa and an ASPT of >7. Additional information is provided below.	3.5

Detailed physico-chemical reference conditions are provided in Table 5.4.

Table 5.4 EWR 4: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	11.450
	Na_2SO_4	2.160
	$MgCl_2$	1.057
	$CaCl_2$	1.283
	NaCl	11.070
	$CaSO_4$	0.501
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.014
	Total Inorganic Nitrogen (TIN)	0.270
Physical variables	pH (5^{th}+95^{th} percentiles)	6.33 + 7.22
	Electrical conductivity (mS/m)	18.53

Information on the expected fish reference conditions at the NHRP site X2CROC-DNELS, as cited in Kleynhans *et al*. (2007b) was used to determine the expected reference conditions. Two species, namely *Barbus paludinosus* (BPAU) and *Micralestes acutidens* (MACU) was sampled during the current study and was therefore added to the expected fish species list. The fish reference condition set should be valid for the Crocodile River stretch within NRU Croc F lying downstream of Nelspruit. Twenty indigenous fish species are expected under reference conditions. Reference species are listed in Table 5.4.

Table 5.5 EWR 4: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 4 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	3	2
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	2	1
Barbus eutaenia	Orangefin barb	BEUT	4	3
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	5
Barbus paludinosus	Goldie barb	BPAL	3	3
Barbus trimaculatus	Threespot barb	BTRI	4	3
Barbus unitaeniatus	Longbeard barb	BUNI	4	3
Barbus viviparous	Bowstripe barb	BVIV	4	3
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis pretoriae	Shortspine suckermouth (Rock catlet)	CPRE	5	5
Labeo cylindricus	Redeye labeo	LCYL	5	5
Labeo molybdinus	Leaden labeo	LMOL	5	5
Micralestis acutidens	Silver robber	MACU	3	3
Marcusenius macrolepidotus	Bulldog	MMAC	4	3
Oreochromus mossambicus	Mozambique tilapia	OMOS	4	4
Opsaridium peringueyi	Southern barred minnow	OPER	5	4
Petrocephalus wesselsi	Southern churchill	PCAT	3	2
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Tilapia rendalli	Redbreast tilapia	TREN	3	3
Tilapia sparrmanii	Banded tilapia	TSPA	3	3

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Expected macroinvertebrate taxa include:

Baetidae >2spp, Helodidae, Pyralidae, Heptageniidae, Prosopistomatidae, Perlidae, Hydropsychidae >2spp, Polycentropodidae, Gyrinidae, Naucoridae, Hydrophilidae, Dytiscidae, Pleidae, Gomphidae, Corbiculidae, Unionidae, Caenidae, Tabanidae, Tipulidae, Ceratopogonidae, Leptoceridae ,Coenagrionidae, Hydroptilidae, Empididae, Libellulidae, Simuliidae, Hydropsychidae 1sp, Hydropsychidae 2spp, Porifera, Ancylidae, Veliidae, Gerridae, Dixidae, Hydrometridae, Hydraenidae, Hydracarina, Corduliidae, Polymitarcyidae, Pisuliidae, Lestidae, Atyidae, Athericidae, Philopotamidae, Aeshnidae, Leptophlebiidae, Chlorocyphidae, Elmidae, Dryopidae, Psephenidae, Tricorythidae, Psychomyiidae ,Culicidae, Corixidae, Notonectidae, Ephydridae, Belostomatidae, Sphaeriidae, Oligochaeta, Chironomidae, Hirudinea, Potamonautidae, Nepidae, Physidae, Thiaridae, Bulinae, Lymnaeidae, Planorbinae, and Turbellaria.

5.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

5.4.1 Hydrology

Present MAR is 523.21 MCM (69% of natural). There is a slight change in the natural seasonal distribution due to water use and releases from the Kwena Dam. Overall there are reduced base flows from natural conditions except for late winter and early spring where base flows are supplemented by releases from Kwena Dam.

5.4.2 Geomorphology (B/C EC, 81.6%)

EWR 4 is classified as a mixed pool-rapid channel type and is representative of the macro-reach. The channel consists of an active channel inset into a wider macro-channel. There is strong bedrock influence, extensive lateral bars and well-developed terraces at the site. Riparian trees have been removed, probably through a combination of fire, grazing and direct curio/firewood harvesting. This will have an impact on back stabilisation and sedimentation. There has been some slight channel narrowing, possibly as a result of increased sediment loads (due to land degradation in the Lowveld) and associated vegetation encroachment. These factors have resulted in some degradation of the riparian, marginal and instream habitat conditions.

5.4.3 Physico chemical variables (C EC, 76.7%)

The SPI index indicates moderate water quality (9.7), although this falls within the lower ranges of the classification and the diatom based ecological classification indicates low oxygen saturation and circumneutral water. The biological water quality is a C category and there are indications that the electrolyte content could increase due to the presence of saline tolerant species (*N. perspicua*, and *N. etoshensis*). It is envisaged that bicarbonates and sulphides will increase during lower flows due to the presence of *N. valdecostata* while the presence of *N. veneta* indicates the presence of industrial effluent.

Records (2004 - 2007 (n = 108)) from water quality station X2H032Q01 were used for the PES assessment. Nutrients levels indicate some pollution and some turbidity are expected due to catchment activities. Although available metal data does not indicate high pollution, pesticide use is expected. Input from the Elands River upstream of the site and highly urbanised surroundings may cause elevated toxics levels at times. PES values for the physico-chemical variables are provided in Table 5.6 and in Appendix C.

Table 5.6 EWR 4: Physico-chemical PES values

Water Quality Constituents		Value: PES
Inorganic salts (mg/L)	$MgSO_4$	36
	Na_2SO_4	5
	$MgCl_2$	5
	$CaCl_2$	16
	NaCl	68
Nutrients (mg/L)	SRP	0
	TIN	0.072
Physical variables	pH (5^{th}+95^{th} percentiles)	0.881
	Electrical conductivity (mS/m)	7.0 + 7.9

5.4.4 Instream and Riparian Habitat Integrity (IIHI: C EC, 73.1%; RIHI: C EC, 65.5%)

The IIHI EC is mostly due to bed and bank modification, changes in hydrology and deteriorating water quality. The main causes of these impacts are base flow and flood regime changes due to

Kwena Dam, abstraction and land use activities. The RIHI EC is due to a decrease in lateral connectivity due to the roads in the area and invasive and alien vegetation in the non-marginal zone due to increase flow and land use activities.

5.4.5 Fish (B EC, 84.2%)

The PES reflects slightly deteriorated ecological integrity, based on the fish assemblage, primarily attributed to an altered low flow regime (Kwena Dam and small farm dams), increased sedimentation and altered water quality (including impacts from town of Nelspruit). Most of the expected fish species are however still present in this reach, although their relative abundance and spatial distribution have been altered. Species with a preference for fast habitats have been favoured as a result of flow modification (constant releases) and species with requirement for slower habitats have been negatively impacted as a result of this.

5.4.6 Macroinvertebrates (C EC, 75.9%)

SASS5 score: 153 No of Taxa: 26 ASPT: 5.9

The macroinvertebrate assemblage reflects moderately deteriorated ecological integrity, attributed primarily to the upstream land use activities and modified flow conditions. No specific group of macroinvertebrates have been affected by the condition in this stretch of the Crocodile River. The MIRAI indicates that the macroinvertebrates are affected by all aspects of the river condition but that the physico-chemical deterioration had the greatest impact.

5.4.7 Riparian vegetation (C EC, 64.7%)

The site is heavily impacted with a high (20 - 40%) proportion of exotic species present. Flow reduction has resulted in channel narrowing and expansion of *Phragmites mauritianus* and disturbance includes wood removal, cobble harvesting, road and rail disturbance, grazing and trampling and soil erosion.

Marginal zone: Dominated by *Phragmites mauritianus (*with some *Breonadia salicina*).

Lower and upper zones: Dominated by a mix of woody species (*Combretum erythrophyllum* and *Ficus sycomorus* mainly) and grasses, but the woody canopy is sparse due to removal and loss of recruitment from grazing.

5.4.8 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 5.7.

Table 5.7 EWR 4: Causes and sources

	PES	Conf[3]	Causes	Sources	F/NF	Conf
Hydro	C	3	Altered low flow and flooding regime.	Kwena Dam, irrigation and forestry.	F	4
Physico-chemical	C	3	Elevated nutrients and toxics. Temperature, turbidity and oxygen fluctuations	Extensive cultivation, urban/peri-urban areas. Poor land management – return flows.	NF	3

	PES	Conf[3]	Causes	Sources	F/NF	Conf
Geom	B/C	3	Reduced sediment transport capacity.	Reduced flood flows from the Kwena Dam and abstraction from Nelspruit.	F	3
			Increased sediment supply.	Agriculture and some informal settlement areas.	NF	
Rip veg	C	3.6	Increased reed cover.	Reduced flows with expansion of marginal zone.	F	4
			Change in species composition.	Exotic species invasion.	NF	
			Reduced woody cover and abundance and increased cover by grasses and open sand.	Vegetation removal, grazing & trampling and frequent fires.		
Fish	B	4	Altered fish assemblage (loss in abundance, breeding and feeding success).	Altered water quality (Nelspruit municipal area, White river municipal area, industrial runoff).	NF	3
			Altered fish assemblage (loss in abundance, breeding and feeding success).			
			Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (especially Kwena dam, but also smaller weirs) impede natural migration. Altered hydrological events delay/prevent natural migratory cues.	F	
Inverts	C	4	Significant alterations to low flows and floods.	Abstraction (irrigation) and Kwena Dam operation	F	3
			Increased salts, nutrients and toxics; decreased water clarity.	Irrigation return flows; other land-use practices.	NF	
			Increased sediment loading (related to erosion of banks as a result of clearing of crops e.g. sugarcane).	Land-use		

5.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 5.8.

Table 5.8 EWR 4: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-chem	C	Stable	C		Although water quality conditions are poor, it is stable due to the constant high flow, particularly high base flows.	3
Geom	B/C	Stable	B/C		In the medium term, current scenarios would be unlikely to cause a change in the Geomorphology EC.	2.5
Riparian vegetation	C	Negative	D	10 years	Targeted wood removal, trampling and grazing, cobble collecting and road and rail disturbance Exotic invasion high (up to 20 - 40%) and if left unchecked will increase in proportion at the expense of indigenous riparian vegetation. Reduced moderate flows have favoured an increase in woody vegetation on the lower zone.	3
Fish	B	Stable	B		The fish assemblage has adapted to the altered flow regime and modified water quality and should remain fairly stable over the long term.	3
Inverts	C	Stable	C		The macroinvertebrates have already reacted to the current conditions.	3

5.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 5.9. The Instream EC is a B/C (80.5%).

Table 5.9 EWR 4: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	4	90		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4.5	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	4	90		
FISH ECOLOGICAL CATEGORY	16.5	370	**84.2**	**B**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	3	60		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	5	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	5	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**13**	260	**75.9**	**C**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		630	**79.3**	**B/C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.50	42.10	
Confidence rating for **macroinvertebrate** information	4	0.50	37.95	
	8	1.00	80.05	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B/C**	

To determine the EcoStatus, the VEGRAI EC and confidence are added to the equation (Table 5.10). The EcoStatus EC is a C (72.8%).

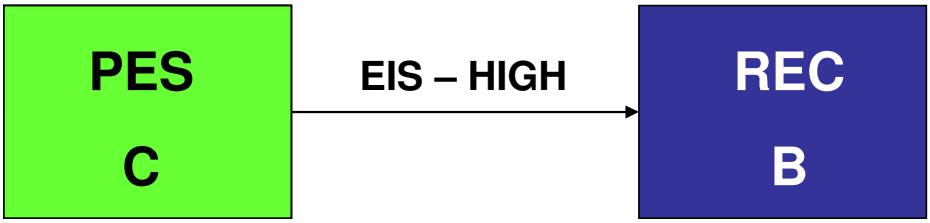
Table 5.10 EWR 4: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**64.7**	**C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	4	0.53	42.13
Confidence rating for riparian vegetation zone information	3.6	0.47	30.65
	7.6	1.00	72.78
ECOSTATUS	**EC**		**C**

5.7 REC: B

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 4 is **HIGH** and the REC is therefore an improvement of the PES.



To achieve the improvement from a C PES to a B REC, the following is required:

- An improvement in the geomorphology EC will be dependent on an improved flooding regime.
- An improvement in the riparian vegetation EC is based on non-flow related issues which include a decrease in grazing pressure and vegetation removal. Alien vegetation removal is included in this scenario.
- An overall improvement in the EcoStatus is dependent on water quality improvements, i.e. nutrients and toxics which would lead to an overall improvement in macroinvertebrates. Improvements in flow management will not improve the EcoStatus alone.

Each component is adjusted to indicate the metrics that will react to the above conditions to achieve a REC. The changes in the rule based models for the REC are provided electronically and summarised in Table 5.11.

Table 5.11 EWR 4: REC B

	PES	REC	Comments	Conf
Physico-chem	C	B	Nutrient levels and toxics would decrease due to flow improvement.	3
Geom	B/C	B	More effective scouring of sediment resulting in an improved EC.	3
Rip veg	C	B	Non-woody cover, abundance and species composition will improve on the marginal zone with reduced grazing/trampling pressure. Woody cover, abundance and species composition will improve on lower and upper zones with reduced wood removal and exotic removal; recruitment will improve with reduced grazing/trampling pressure and exotic removal (this will improve population structure).	2.7
Fish	B	B	A higher category is unlikely to be attainable.	3
Inverts	C	B	Improved catchment management will reduce the sediment loading and improve water quality. The improved conditions will lead to more sensitive taxa occurring more frequently and some moderately sensitive taxa such as Polymitarcyidae, Athericidae and Chlorocyphidae recolonising the river.	3

5.8 AEC: C/D

The scenario is based on the erection of Montrose Dam below the confluence of the Elands River. The impacts include:

- Pools will fill in, bars will appear, and riffles will be clogged and covered with sediment.
- Reed growth will increase, the marginal zone will expand and vegetation will encroach.
- The water quality will not change under this scenario as it is not expected that low flows will decrease.

Each component is adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models are available electronically and summarised in Table 5.12.

Table 5.12 EWR 4: Alternative C/D EC

	PES	AEC	Comments	Conf
Physico-chem	C	C	Increased sedimentation, with a resulting change within the C EC.	N/A
Geom	B/C	C	More rapid sedimentation of the pools and active channels.	2.5
Rip veg	C	D	Increased sedimentation will result in loss of exposed bedrock habitat which *B. salicina* requires for recruitment and establishment. Cover, abundance and recruitment of *B. salicina* will therefore reduce, and population structure will change over time. Reduced flooding and increased sedimentation will also cause reeds to increase, marginal zone migration will occur as sediment is colonised, and a change in species composition will occur i.e. initial loss of other non-woody marginal zone species.	2.8
Fish	B	C	Sedimentation of riffle/rapid areas will deteriorate conditions for species which have preference for substrate of good quality (AURA, CPRE, BEUT, LCYL, LMOL, OPER and BMAR). This scenario will also result in decreased availability of pools (slow habitats) and overhanging vegetation (albeit temporary) and may lead to decreased FROC for fish with preference for slower habitats and this cover type (especially BPAU, BVIV, MACU, MMAC, PWES, PPHI and TSPA).	4
Inverts	C	D	Increased return flow and worsening water quality. Increased industrial activities in Nelspruit could also result in higher levels of toxics occurring more frequently. The scenario will lead a more sensitive macroinvertebrates occurring less frequently and even disappearing from this section of the river. It is expected that the Stonefly Perlidae will disappear as well as the more sensitive species of the Baetidae and Hydropsychidae.	3

5.9 SUMMARY OF ECOCLASSIFICATION RESULTS

Results for setting EWR scenarios are summarised in Table 5.13.

Table 5.13 EWR 4: Summary of EcoClassification results

IHI			Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	C	RIPARIAN C	HYDROLOGY	C			
			WATER QUALITY	C		B	C
			GEOMORPHOLOGY	B/C	Stable	B	C
			Response Components	PES Category	Trend	REC	AEC↓
			FISH	B	Stable	B	C
			MACRO INVERTEBRATES	C	Stable	B	D
			INSTREAM	B/C		B	C
			RIPARIAN VEGETATION	C	Negative	B	D
			ECOSTATUS	C		B	C/D

IHI Hydrology PES	B
Diatoms	C

6 EWR 5 MALALANE (CROCODILE RIVER)

6.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 6.1.

Table 6.1 EWR 5: Availability of data

Component	Data availability	Conf
Hydrology	A reasonably reliable gauge X2H047 is located about 15 km downstream of EWR 5.	4
Physico-chemical	DWA monitoring data was available for reference condition and PES. Limited phytoplankton, periphyton and diatoms was available (n = 1). No temperature, DO or turbidity data was available. Little metal data was available. Electrical conductivity (EC) and aggregated salts data available.	3
Geomorphology	Historical aerial photography (1936, 1959, 1970, 1984, 1997). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Previous VEGRAI training site Aerial photos of site - 1936, 1959, 1970, 1984, 1997. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4.5
Fish	Single site visit and fish sampling during October 2007. Kleynhans *et al*. (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. A Deacon).	4
Macroinvertebrates	Data and analysis from a single sampling trip to the site on 5th October 2007 (two sets of samples); Data from the Rivers Database for site X2CROC-INDEM; Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS). Kleynhans *et al*. (2007a): *A Level II River EcoRegion classification System for South Africa, Lesotho and Swaziland.*	4

6.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 6.2) was rated as **VERY HIGH**, as there are rare and endangered fish, vegetation, birds and herpetofauna species present. The species/ taxon richness is high and there are fish and macroinvertebrate taxa present that are intolerant to flow and flow related water quality changes. This site falls within the Kruger National Park (KNP) and other reserves and the Granite Lowveld vegetation unit (which has a vulnerable status) occurs here.

Table 6.2 EWR 5: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*O. peringueyi*, *C. swierstrai*, Crocodiles, Birds, *B. salicina*.
Unique (endemic, isolated, etc.)	2	4	*Macrobrachium*.
Intolerant (flow & flow related water quality)	4	4	*O. peringueyi, C. pretoriae, B. eutaenia*, *C. swierstrai*, some macroinvertebrate taxa.
Species/taxon richness	4	4	Thirty five fish species.
RIPARIAN & INSTREAM HABITATS			
Diversity of types	3	4	Rapids, riffles, pools, braided sections, riparian vegetation, backwaters.
Refugia	3	3	In the KNP.
Sensitivity to flow changes	1.5	3	
Sensitivity to flow related water quality changes	2.5	3	
Migration route/corridor (instream & riparian)	3.5	4	*A. mossambica, Macrobrachium, A. marmorata*, birds, other fish species. In KNP, important migration route
Importance of conservation & natural areas	4	4	KNP and reserves. Vulnerable veg type (Granite Lowveld)
MEDIAN	3.25		
EIS EVALUATION	**VERY HIGH**		

6.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 6.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 6.3 EWR 5: Reference conditions

Component	Reference conditions	Conf
Hydrology	The gauge measures flow accurately, but unrecorded abstractions are made immediately upstream of the weir. Record available is from 1985 to present. Virgin MAR: 1006.23 MCM.	4
Physico-chemical	DWA monitoring data: X2H017Q01; n = 125, 1977 – 1980. Refer to Table 6.4.	3.5
Geomorphology	A very wide, sandy bed river system. Vegetation was restricted to the macro-channel banks (and encroachment prevented by bank to bank seasonal flows and large flood flows which scoured sediment from the channel). This combination of factors maintained a mobile sand bed which further inhibited vegetation establishment and stabilisation of sediment.	3
Riparian vegetation	This site occurs in the Lowveld bioregion of the Savanna biome in the Granite Lowveld vegetation unit. Mixed vegetation is expected, but one predominated by woody vegetation on the lower and upper zones (although historically more open than closed canopy). The site is predominantly alluvial and *Phragmites mauritianus* is expected to line the active channel with a mostly narrow (under natural flows) band. Marginal zone species would typically be *Phragmites mauritianus*, with *Combretum erythrophyllum, Ficus sycomorus* and *Diospyros mespiliformis* on the lower and upper zones. Less *Phragmites mauritianus* expected than what is currently at the site.	3.5
Fish	Thirty five species present. Refer to Table 6.5.	4
Macroinvertebrates	The reference total SASS 5 score is 180, with over 30 taxa and an ASPT of >6. Additional information is provided below.	3

Detailed physico-chemical reference conditions are provided in Table 6.4.

Table 6.4 EWR 5: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	16.63
	Na_2SO_4	11.07
	$MgCl_2$	0
	$CaCl_2$	0
	NaCl	32.72
	$CaSO_4$	0.55
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.014
	Total Inorganic Nitrogen (TIN)	0.37
Physical variables	pH (5^{th}+95^{th} percentiles)	6.7+ 7.9
	Electrical conductivity (mS/m)	58.86

Information on the expected reference conditions at the NRHP site X2CROC-MALEL (EWR 5), as cited in Kleynhans *et al*. (2007b) was used. The fish reference condition set should be valid for the Crocodile River stretch within NRU Croc G. Thirty-five indigenous fish species are expected under reference conditions. Reference species are listed in Table 6.5.

Table 6.5 EWR 5: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 5 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla marmorata	Giant mottled eel	AMAR	1	1
Anguilla mossambica	Longfin eel	AMOS	1	1
Barbus annectens	Broadstriped barb	BANN	3	1
Barbus eutaenia	Orangefin barb	BEUT	3	2
Barbus afrohamiltoni	Hamilton's barb	BAFR	1	1
Brycinus imberi	Imberi	BIMB	4	3
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	5
Barbus paludinosus	Goldie barb	BPAL	3	2
Barbus radiatus	Beira barb	BRAD	4	3
Barbus toppini		BTOP	3	2
Barbus trimaculatus	Threespot barb	BTRI	5	4
Barbus unitaeniatus	Longbeard barb	BUNI	4	4
Barbus viviparous	Bowstripe barb	BVIV	5	5
Clarias gariepinus	Sharptooth catfish	CGAR	5	5
Chiloglanis paratus	Sawfin suckermouth (Rock catlet)	CPAR	5	3
Chiloglanis pretoriae	Shortspine suckermouth (Rock catlet)	CPRE	4	2
Chiloglanis swierstrai	Lowveld suckermouth (Rock catlet)	CSWI	3	2
Glossogobius giurus	Tank goby	GGIU	3	2
Hydrocynus vittatus	Tigerfish	HVIT	2	2
Labeo congoro	Purple labeo	LCON	4	2
Labeo cylindricus	Redeye labeo	LCYL	5	3
Labeo molybdinus	Leaden labeo	LMOL	5	4
Labeo rosae	Rednose labeo	LROS	3	2
Labeo ruddi	Silver labeo	LRUD	1	1
Micralestis acutidens	Silver robber	MACU	4	3
Mesobola brevianalis	River sardine	MBRE	4	3
Marcusenius macrolepidotus	Bulldog	MMAC	3	2
Oreochromus mossambicus	Mozambique tilapia	OMOS	5	5

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 5 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Opsaridium peringueyi	Southern barred minnow	OPER	4	2
Petrocephalus wesselsi	Southern churchill	PWES	3	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	3	3
Schilbe intermedius	Silver catfish	SINT	3	2
Synodontis zambezensis	Brown squeaker	SZAM	2	1
Tilapia rendalli	Redbreast tilapia	TREN	4	4
Tilapia sparrmanii	Banded tilapia	TSPA	1	1

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Expected macroinvertebrate taxa include:

Oligoneuridae, Pyralidae, Perlidae, Heptageniidae, Hydropsychidae >2spp, Baetidae >2spp, Empididae, Pleidae, Leptoceridae, Hydropsychidae 2spp, Gyrinidae, Naucoridae, Hydrophilidae, Dytiscidae, Baetidae 2spp, Gomphidae, Caenidae, Ceratopogonidae, Coenagrionidae, Libellulidae, Simuliidae, Ancylidae, Corbiculidae, Unionidae, Tabanidae, Hydroptilidae, Haliplidae, Tipulidae, Elmidae, Veliidae, Gerridae, Hydrometridae, Calamoceratidae, Lestidae, Athericidae, Philopotamidae, Tricorythidae, Dixidae, Hydraenidae, Hydracarina, Polymitarcyidae, Atyidae, Leptophlebiidae, Aeshnidae, Paleomonidae, Corduliidae, Lepidostomatidae, Calopterygidae, Chlorocyphidae, Culicidae, Notonectidae, Psychodidae, Ephydridae, Belostomatidae, Syrphidae, Potamonautidae, Nepidae, Muscidae, Oligochaeta, Hirudinea, Bulinae, Lymnaeidae, Planorbinae, Hydrobiidae, Physidae, Thiaridae, Turbellaria, Corixidae, Sphaeriidae and Chironomidae.

6.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

6.4.1 Hydrology

Present MAR is 636.90 MCM (63% of natural). There is a significant reduction in flow due to extensive irrigation and afforestation upstream of the site. The volume of the base flows has reduced, but distribution remains approximately the same as natural.

6.4.2 Geomorphology (C/D EC, 60.1%)

The current state of the river is markedly different from the reference state – reduced flows and increased sediment loads from the upstream catchment has caused a smaller active channel to develop - the morphology is now represented by an active channel inset into a wider macro-channel. Subsequent encroachment of vegetation has allowed for the development of vegetated mid-channel bars, lateral bars and in-channel benches inside the former larger channel. The now smaller inset channel meanders between these increasingly vegetated, stabilised sedimentary bars on the macro-channel floor. The macro channel floor is dominated by sand, with limited bedrock exposure/influence.

6.4.3 Physico-chemical variables (C EC, 67.2%)

The SPI index indicates moderate water quality (Score: 13.2), although this falls within the lower ranges of the classification and the diatom based ecological classification indicates moderate oxygen saturation and alkalibontic water. The diatom water quality is in a B/C category but due to the presence of pollution tolerant species and species favouring elevated electrolyte levels, the water quality may be deteriorating at this site.

Records (2004 - 2007 (n = 114)) from water quality station X2H017Q01 were used for the PES assessment. Nutrients levels indicate some pollution and some turbidity is expected due to catchment activities including suspended solid loads from TSB sugar mill effluents. Temperature and oxygen may be problematic as the river is slow moving and wider in this reach and below many abstraction points. High temperature effluents from TSB sugar mill enter the river here and have resulted in localized fish kills. Toxicant use is expected due to citrus and sugarcane farming in the area. PES values for the physico-chemical variables are provided in Table 6.6 and in Appendix C.

Table 6.6 EWR 5: Physico-chemical PES values

Water Quality Constituents		Value: PES
Inorganic salts (mg/L)	$MgSO_4$	52
	Na_2SO_4	5
	$MgCl_2$	6
	$CaCl_2$	12
	NaCl	1
Nutrients (mg/L)	SRP	0
	TIN	0.041
Physical variables	pH (5^{th}+95^{th} percentiles)	0.684
	Electrical conductivity (mS/m)	7.51 + 8.40

6.4.4 Instream and Riparian Habitat Integrity (IIHI: C EC, 64%; RIHI: C EC, 63.9%)

The IIHI EC is mostly due to bed and bank modification (increased scouring and erosion) due to constant releases from the dam, changes in hydrology, especially the flooding regime due to abstractions for irrigation and deteriorating water quality due to land use. The RIHI EC is mostly due to a decrease in lateral connectivity due to the roads and crop fields in the area and substrate exposure and erosion due to increase flow and land use activities.

6.4.5 Fish (C EC, 66.1%)

The PES reflects moderately deteriorated ecological integrity, primarily attributed to an altered low flow regime, increased sedimentation, increased benthic algal growth and altered water quality. Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution. The presence of large part of this stretch and most of the left bank and local catchment falling within conservation area (KNP) contribute somewhat to preservation of the overall ecological integrity of this section.

6.4.6 Macroinvertebrates (C EC, 76.9%)

SASS5 score: 161 No of Taxa: 32 ASPT: 5

The assemblage reflects moderately deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and coinciding water quality problems. The MIRAI

indicates that the main reasons for the impaired state of the macroinvertebrate assemblage are due to connectivity and Sensitivity (69.7) and Water quality (73.6) problems.

6.4.7 Riparian vegetation (C EC, 76.3%)

The landuse differs for the left and right banks. The left bank (LB) is within KNP and right bank (RB) is impacted by recreational facilities/fencing.

Marginal zone: Has migrated and expanded towards the active channel as flows have been reduced and sediments have accumulated, and consists mainly of reedbeds (*Phragmites mauritianus*) and open sand with some *Cyperus sp*.

Lower zone: Mainly a mix of reeds and shrubs (*Gymnosporia senegalensis* and *Grewia* spp.) mainly, while the upper zone is a mix of sparse shrub/tree and open/grassed areas.

6.4.8 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 6.7.

Table 6.7 EWR 5: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	C	3	Altered base flows.	Abstractions, irrigation and forestry.	F	4
Physico-chemical	C	3	All variables are elevated including oxygen and temperature. Alkaline conditions.	Agricultural and urban activities, including extensive sugar cane and citrus plantations and land management on right bank, causing abnormal low flows. Return flows from sugar mill. Abstraction.	F	3
Geom	C/D	3.5	Reduced sediment transport capacity (leading to increased deposition and vegetation encroachment).	Reduced flood flows from upstream dams and very reduced/regulated low flows, abstraction from Nelspruit and large irrigation abstractions.	F	3
			Increased stabilization and vegetation of banks and bars.	Altered hydrological regime.		
			Increased sediment supply.	Erosion from agricultural and informal settlement areas.	NF	
Rip veg	C	3.4	Change to species composition.	Exotic vegetation high in the marginal zone (mainly non-woody aquatics).	NF	4
			Reduced vegetation cover in upper zone.	Clearing for recreation on RHB.		
			Expansion of marginal zone reeds.	As channel narrows due to reduced flows.	F	
Fish	C	4	Sedimentation of substrates.	Increased erosion related to agriculture, grazing and bank instability.	NF	3.5
			Altered fish assemblage (loss in abundance, breeding and feeding success).	Altered water quality especially increased nutrients related to seepage from sugarcane/agriculture).		
			Loss in natural habitat diversity (loss of deep pools due to sedimentation, loss of overhanging vegetation and undercut banks due to reduced flows).	Altered hydrological regime (especially as a result of abstraction for irrigation – primarily sugarcane).	F	
			Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (small weirs) impede on natural migration. Altered hydrological events delay/prevent natural migratory cues.		
Inverts	C	4	Significant alteration to low flows and floods.	Abstractions for irrigation.	F	3

	PES	Conf	Causes	Sources	F/NF	Conf
			Water quality issues including increased salts, nutrients, toxics, decreased water clarity.	Land use (return flows, etc.).	NF	
			Bed modified as a result of sedimentation.	Releases from the dam, land use.		

6.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 6.8.

Table 6.8 EWR 5: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-chem	C	Negative	C/D	5 yrs	Poor water quality state exacerbated by extensive abstractions in this stretch of river.	3
Geom	C/D	Negative	D	5 years	The aerial photographic record demonstrates a strong directional change from a wide, dynamic channel to a much smaller, narrower active channel. The bars and banks have become more vegetated and stabilised.	3
Rip veg	C	Negative	C/D	10 -15 years	Exotic invasion is high (up to 20 - 40%) on the marginal zone, and if left unchecked will increase in proportion at the expense of indigenous riparian vegetation.	3
Fish	C	Stable	C		The fish assemblage in this section of the Crocodile River have adapted to the altered flow regime and modified water quality and should remain fairly stable over the long term should current conditions prevail.	3
Inverts	C	Stable	C		The macroinvertebrates have already reacted to the changes in the river.	2.5

6.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 6.9. The Instream EC is a C (71.5%).

Table 6.9 EWR 5: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	4	90		
2.What is the natural diversity of **fish** species with a preference for different cover types	4.5	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	90		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	4	90		
FISH ECOLOGICAL CATEGORY	16.5	370	**66.1**	**C**

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	3.5	90		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	4	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	4	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**11.5**	290	**76.9**	**C**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		660	**72.1**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.50	33.05	
Confidence rating for **macroinvertebrate** information	4	0.50	38.45	
	8	1.00	71.50	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the VEGRAI EC and confidence are added to the equation (Table 6.10). The EcoStatus EC is a C (73.7%).

Table 6.10 EWR 5: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**76.3**	**C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	4	0.54	38.65
Confidence rating for riparian vegetation zone information	3.4	0.46	35.06
	7.4	1.00	73.71
ECOSTATUS	**EC**		**C**

6.7 REC: B

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 5 is **VERY HIGH** and the REC is therefore an improvement of the PES.

The REC can be achieved by the following:

- Low flows presently vary daily due to abstractions upstream and at times become very low to the point where almost no flow occurs. In order to achieve the REC of a B EC, the system must be operated in a manner that ensures that the low flow regime improves. This will include increased low flows than present during certain months.

Each component is adjusted to indicate the metrics that will react to the above conditions to achieve a REC. The changes in the rule based models are available electronically and summarised in Table 6.11.

Table 6.11 EWR 5: REC B

	PES	REC	Comments	Conf
Physico -chem	C	B	Increased flows, particularly low flows, will improve the water quality state by dilution. It is assumed that enough water will be provided at the right time to reduce the toxics by a category.	3
Geom	C/D	C	Improved low flow conditions would slightly improve the stabilisation and deepening of the channel, and result in a small increase in the active channel and a small reduction in the extent of bars.	3
Rip veg	C	B	Improved low flows and more natural flow variability: Reduce reedbed encroachment due to inundation and sediment accumulation. Creates additional recruitment opportunities for woody vegetation and prevents terrestrial species colonization.	2.9
Fish	C	B	Improved flows (higher low flows, less regulated flows) will improve quality and abundance of FS and FD habitats, with a positive impact on the FROC of some species with high preference for these habitats (especially CPAR, CPRE, LCON, LCYL, LMOL and OPER). Improved flows will inundate more reeds and more overhanging vegetation will become available, which will benefit species with a preference for this habitat type, with a possible improvement in the FROC of these species (BPAU, BRAD and BTRI).	4
Inverts	C	B	Improved flow regime and catchment management can lead to reduced return flows and less sedimentation in the river. The gastropod snails will occur less frequently and a number of moderately sensitive taxa such as Polymitarcyidae and Corduliidae will recolonise the river.	3

6.8 AEC: D

A hypothetical scenario is designed and includes the following:

- Decreased low flows and periods of zero flows in some stretches of the river.
- This will result in increased algal growth.
- Some deep channel sections will be lost (similar to Letaba River) and result in a sandy shallower channel. Reeds and vegetation will follow.
- Nutrients will increase, as well as temperature and oxygen as the dilution factor will be lost.

Each component is adjusted to indicate the metrics that will react to the described scenarios. The changes in the rule based models are available electronically and summarised in Table 6.12.

Table 6.12 EWR 5: Alternative D EC

	PES	AEC	Comments	Conf
Physico-chem	C	D	Lower flows will result in a poorer water quality state, with elevations in nutrients, salts and toxics. Increases in temperatures and drops in oxygen level will also be seen.	4
Geom	C/D	D	Further reduced flows (and possible very low/no flow periods) would result in further degradation of the EC. The channel would continue to become shallower and sandier.	3.5
Rip veg	C	D	Reduction in base flows and small floods: Expansion of reedbeds and increased terrestrialisation with reduced flood disturbance.	2.7
Fish	B	D	Decreased low flows and periods of zero flow in some stretches will have a radical impact on flow dependant species (BEUT, CPRE, CSWI, OPER) and most probably also on species moderately intolerant to no flow conditions (BMAR, CPAR, LCON, LCYL, LMOL and MACU- and probably also HVIT). Loss of deep channels, becoming sandier shallow channel will affect especially species like HVIT and LCON negatively. Increased nutrients will further degrade the available substrate through excessive algal growth, affecting species with a preference for substrate of good quality. A further decrease in the FROC of BEUT, BMAR, CPAR, CPRE, MACI and OPER can therefore be expected. Increased algal growth may benefit some a species like LCON. Further deterioration in water quality will result in decreased FROC and even absence of species intolerant to water quality alterations (MMAC, and possible loss of OPER).	4
Inverts	C	D	Decreased low flows: increased return flows: Lead to worse water quality and increased sedimentation due to further bank erosion. This will result in less available habitat and the disappearance of a number of the more sensitive macroinvertebrates (e.g. Perlidae and the more sensitive species of the Baetidae) while others will occur less frequently.	3

6.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results for setting EWR scenarios are summarised in Table 6.13.

Table 6.13 EWR 5: Summary of EcoClassification results

IHI				Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	C	RIPARIAN	C	HYDROLOGY	C		B	D
				WATER QUALITY	C		B	D
				GEOMORPHOLOGY	C/D	Negative	C	D
				Response Components	PES Category	Trend	REC	AEC↓
				FISH	C	Stable	B	D
				MACRO INVERTEBRATES	C	Stable	B	D
				INSTREAM	C		B	D
				RIPARIAN VEGETATION	C	Negative	B	D
				ECOSTATUS	C		B	D

IHI Hydrology PES	B
Diatoms	B/C

7 EWR 6 NKONGOMA (CROCODILE RIVER)

7.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 7.1.

Table 7.1 EWR 6: Availability of data

Component	Data availability	Conf
Hydrology	A reasonable gauge X2H016 is located about 6 km upstream of EWR 6.	4
Physico-chemical	DWA monitoring data was available for reference condition and PES. Limited phytoplankton, periphyton and diatoms was available (n = 1). No temperature, DO or turbidity data was available. Little metal data was available. Electrical conductivity (EC) and aggregated salts data available.	3
Geomorphology	Historical aerial photography (1939, 1963, 1977, 1997). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Aerial photos of site - 1939, 1963, 1977, 1997 Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4.5
Fish	Single site visit and fish sampling during October 2007. Kleynhans *et al*. (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. A Deacon).	4
Macroinvertebrates	Data and analysis from a single sampling trip to the site on 5th October 2007 (two sets of samples); Data from the River Health Program 'Rivers Client' for sites X2CROC_NGONG. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	4

7.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 7.2) was rated as **VERY HIGH**, as there are rare and endangered fish, vegetation, birds and herpetofauna species present. The species/ taxon richness is very high, and there are fish and macroinvertebrate taxa present that are intolerant to flow and flow related water quality changes. The site has a very high diversity of riparian and instream habitats that include pools, riffles, rapids and anastomosing braided riparian vegetation. This site falls within the Kruger National Park, and is an important refuge for aquatic biota as well as a migration corridor for fish.

Table 7.2 EWR 6: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*C. swierstrai*, birds, *B. salicina,* crocodiles.
Unique (endemic, isolated, etc.)	2	4	*Acanthopagrus berda, Macrobrachium*.
Intolerant (flow & flow related water quality)	4	4	*C. swierstrai, C. pretoriae*, Oligoneuridae.
Species/taxon richness	4	4	Thirty four fish species, 25 macroinvertebrate taxa.
RIPARIAN & INSTREAM HABITATS			
Diversity of types	4	4	Riffles, rapids, pools, gorge, anastomosing braided riparian vegetation.
Refugia	4	4	In the KNP.
Sensitivity to flow changes	2	3	
Sensitivity to flow related water quality changes	2.5	3	Bedrock.
Migration route/corridor (instream & riparian)	4	3	*Hydrocynus vittatus*, eels, *Macrobrachium, A. berda.*
Importance of conservation & natural areas	4	4	KNP.
MEDIAN	4		
EIS EVALUATION	**VERY HIGH**		

7.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 7.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 7.3 EWR 6: Reference conditions

Component	Reference conditions	Conf
Hydrology	The gauge probably does not measure flow accurately, due to the accumulation of debris. Record available is from 1960 to present. Virgin MAR: 1063.13 MCM.	4
Physico-chemical	DWA monitoring data: X2H016Q01; n = 163, 1977 – 1980. Refer to Table 7.4.	3
Geomorphology	The reference state is a more open wider active channel, larger (wider) rapids and smaller bar areas.	3
Riparian vegetation	This site occurs in the Lowveld bioregion of the Savanna biome in the Tshokwane-Hlane Basalt Lowveld vegetation unit. Mixed vegetation is expected, but one predominated by woody vegetation on the lower and upper zones (although historically more open than closed canopy existed). The site is predominantly exposed bedrock, but is entering the gorge so alluvial deposits occur where *Phragmites mauritianus* is expected. Marginal zone species would typically be *Phragmites mauritianus*, with *Cyperus spp.* where open sand occurs. C. *erythrophyllum, Nuxia oppositifolia, F. sycomorus* and *Diospyros mespiliformis* on the lower and upper zones, interspersed with shrubs (*Gymnosporia senegalensis* and *Grewia spp.*).	3.5
Fish	Thirty four species present. Refer to Table 7.5.	4
Macroinvertebrates	The reference total SASS 5 score is 230, with over 32 taxa and an ASPT of >6. Additional information is provided below.	3.5

Detailed physico-chemical reference conditions are provided in Table 7.4.

Table 7.4 EWR 6: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	17
	Na_2SO_4	10.54
	$MgCl_2$	4.48
	$CaCl_2$	8.26
	NaCl	50.4
	$CaSO_4$	0.63
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.007
	Total Inorganic Nitrogen (TIN)	0.33
Physical variables	pH (5^{th}+95^{th} percentiles)	6.71 + 8.02
	Electrical conductivity (mS/m)	69.36

Information on the expected reference conditions at the NRHP site X2CROC-NKONG (EWR6), as cited in Kleynhans *et al.* (2007b) was used. The fish reference condition set should be valid for the Crocodile River stretch within NRU Croc I. Thirty four indigenous fish species are expected under reference conditions. Reference species detail is listed in Table 7.5.

Table 7.5 EWR 6: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 6 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Acanthopagrus berda	Riverbream	ABER	2	1
Anguilla bengalensis labiata	African mottled eel	ALAB	1	1
Anguilla marmorata	Giant mottled eel	AMAR	2	1
Anguilla mossambica	Longfin eel	AMOS	2	1
Barbus annectens	Broadstriped barb	BANN	1	1
Barbus afrohamiltoni	Hamilton's barb	BFRI	3	2
Brycinus imberi	Imberi	BIMB	5	3
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	4
Barbus paludinosus	Goldie barb	BPAL	3	2
Barbus radiatus	Beira barb	BRAD	3	2
Barbus trimaculatus	Threespot barb	BTRI	4	3
Barbus unitaeniatus	Longbeard barb	BUNI	3	2
Barbus viviparous	Bowstripe barb	BVIV	5	4
Clarias gariepinus	Sharptooth catfish	CGAR	4	3
Chiloglanis paratus	Sawfin suckermouth (Rock catlet)	CPAR	5	3
Chiloglanis pretoriae	Shortspine suckermouth (Rock catlet)	CPRE	1	1
Chiloglanis swierstrai	Lowveld suckermouth (Rock catlet)	CSWI	4	3
Glossogobius callidus	River goby	GCAL	2	1
Glossogobius giurus	Tank goby	GGIU	5	4
Hydrocynus vittatus	Tigerfish	HVIT	5	3
Labeo congoro	Purple labeo	LCON	5	3
Labeo cylindricus	Redeye labeo	LCYL	5	4
Labeo molybdinus	Leaden labeo	LMOL	5	4
Labeo rosae	Rednose labeo	LROS	4	3
Labeo ruddi	Silver labeo	LRUD	1	1
Micralestis acutidens	Silver robber	MACU	5	3
Mesobola brevianalis	River sardine	MBRE	4	3

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 6 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Marcusenius macrolepidotus	Bulldog	MMAC	4	2
Oreochromus mossambicus	Mosambique tilapia	OMOS	5	5
Petrocephalus wesselsi	Southern churchill	PWES	2	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	3	3
Schilbe intermedius	Silver catfish	SINT	4	2
Synodontis zambezensis	Brown squeaker	SZAM	3	1
Tilapia rendalli	Redbreast tilapia	TREN	5	5

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Expected macroinvertebrate taxa include:

Oligoneuridae, Pyralidae, Perlidae, Heptageniidae, Hydropsychidae >2spp, Baetidae >2spp, Empididae, Pleidae, Leptoceridae, Hydropsychidae 2spp, Gyrinidae, Naucoridae, Hydrophilidae, Dytiscidae, Baetidae 2spp, Gomphidae, Caenidae, Ceratopogonidae, Coenagrionidae, Libellulidae, Simuliidae, Ancylidae, Corbiculidae, Unionidae, Tabanidae, Hydroptilidae, Haliplidae, Tipulidae, Elmidae, Veliidae, Gerridae, Hydrometridae, Calamoceratidae, Lestidae, Athericidae, Philopotamidae, Tricorythidae, Dixidae, Hydraenidae, Hydracarina, Polymitarcyidae, Atyidae, Leptophlebiidae, Aeshnidae, Paleomonidae, Corduliidae, Lepidostomatidae, Calopterygidae, Chlorocyphidae, Culicidae, Notonectidae, Psychodidae, Ephydridae, Belostomatidae, Syrphidae, Potamonautidae, Nepidae, Muscidae, Oligochaeta, Hirudinea, Bulinae, Lymnaeidae, Planorbinae, Hydrobiidae, Physidae, Thiaridae, Turbellaria, Corixidae, Sphaeriidae and Chironomidae.

7.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

7.4.1 Hydrology

Present MAR is 593.82 MCM (46% of natural). Change from reference condition is largely due to large scale irrigation and afforestation in the area. The river stops flowing at certain places in the MRU depending on abstractions and return flows.

7.4.2 Geomorphology (C EC, 66.6%)

EWR 6 is a mixed anastomosing channel type and is representative of the macro-reach. The site runs across a bedrock rapid area. Downstream there is a deep pool. The channel consists of a number of active channels inset into a wider macro-channel. There is strong bedrock influence. A relatively thin, mostly sandy veneer of alluvium overlies the dominant bedrock. The bed is mobile, even under the lowest flow conditions. The aerial photographic record demonstrates a strong directional change from a wide channel to a few much smaller, narrower active channel, probably due to reduced floods and flows generally. The bars and banks have become more vegetated and stabilised.

7.4.3 Physico chemical variables (C EC, 67.5%)

The SPI index indicates moderate water quality (score: 13.1), although this falls within the lower ranges of the classification and the diatom based ecological classification indicates low oxygen saturation and alkaline water. The diatom water quality is in a B/C category but the trend for this site is negative as an increase in nutrient loading is expected during low flows and an increase in pollution levels and electrolyte levels.

Records (2004 - 2007 (n = 119)) from water quality station X2H016Q01 were used for the PES assessment. Nutrient levels are elevated and filamentous algal sheets are evident at low flows. The river is wide and shallow, so increased abstractions exacerbate oxygen fluctuations and temperature rises. Turbidity is problematic at this site due to suspended solids present in the TSB sugar mill effluent. Due to the sugar cane farming and citrus plantations in the area, Cadmium levels are elevated and these activities are impacting the water quality at this site downstream. PES values for the physico-chemical variables are provided in Table 7.6 and in Appendix C.

Table 7.6 EWR 6: Physico-chemical PES values

Water Quality Constituents		Value: PES
Inorganic salts (mg/L)	$MgSO_4$	50
	Na_2SO_4	8
	$MgCl_2$	17
	$CaCl_2$	33
	NaCl	2.1
Nutrients (mg/L)	SRP	0
	TIN	0.031
Physical variables	pH (5^{th}+95^{th} percentiles)	0.341
	Electrical conductivity (mS/m)	7.78 + 8.50
Toxics (mg/L)	Fluoride	86.08
	Ammonia	50

7.4.4 Instream and Riparian Habitat Integrity (IIHI: C/D EC, 60.9%; C/D, 59.1%)

The IIHI EC is due to abstraction and irrigation for citrus and sugar cane farming which has led to bed and bank modification (increased scouring and erosion), a change in base flows and the flooding regime and an overall deterioration in water quality (increased salinity, nutrients and toxics). The RIHI is due to a decrease in lateral connectivity (roads and crop fields in the area), substrate exposure and erosion due to flow alteration and land use activities.

7.4.5 Fish (C EC 65.6%)

The PES indicates moderately deteriorated ecological integrity, reflective of all the impacts in the catchment upstream of this reach. Primary local impacts include increased sedimentation, increased benthic algal growth and altered water quality related to agricultural activities (mostly sugarcane). Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution. The presence the left bank and local catchment falling within the conservation area (KNP) contribute to preservation of the overall ecological integrity of this section.

7.4.6 Macroinvertebrates (C EC, 74.9%)

SASS5 score: 121 No of Taxa: 25 ASPT: 4.8

The PES of the macroinvertebrate assemblage reflects moderately deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and sedimentation of instream habitats with coinciding water quality problems. This can be seen most clearly in the disappearance of the taxa preferring cobbles as well as surface dwelling macroinvertebrates. MIRAI indicates that the main reasons for the deterioration in the macroinvertebrates are due to water quality (62.2) and connectivity and seasonality (58.9) problems.

7.4.7 Riparian vegetation (C EC, 76.6%)

The site is fairly close to reference condition in structure and composition with the exception of low (<10%) impact of exotic vegetation. Reduced flows have however made significant changes to the marginal zone especially. Marginal zone reeds have expanded with reduced flows and *B. salicina* population shows a marked reduction to what is expected due to water stress.

7.4.8 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 7.7.

Table 7.7 EWR 6: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	D	3	Reduced base flows, altered flooding regime, zero flows	Abstractions and international water use.	F	4
				Afforestation.		
Physico-chemical	C	3	Elevated nutrients, salinity, toxics and temperatures.	Agricultural activities. Downstream of sugar mill and citrus processing.	NF	3
			Reduced oxygen levels.	Low flows exacerbate temperature and oxygen levels.		
Geom	C	3	Reduced sediment transport capacity.	Reduced flows from the Kwena Dam; abstraction from towns; extensive irrigation abstractions.	F	3
			Increased sediment supply.	Primarily agriculture, but also sediment introduction due to erosion in informal settlement areas.	NF	
Rip veg	C	3.6	Increased reed cover.	Reduced flows.	F	3.5
			Changes to species composition.	Exotic vegetation (<10%).	N	
Fish	C	4	Sedimentation of substrates.	Increased erosion related to agriculture, grazing and bank instability.	NF	4
			Altered fish assemblage (loss in abundance, breeding and feeding success).	Altered water quality especially increased nutrients related to seepage from sugarcane/agriculture).		
			Loss in natural habitat diversity (loss of deep pools due to sedimentation, loss of overhanging vegetation and undercut banks due to reduced flows).	Altered hydrological regime (especially as a result of abstraction for irrigation – primarily sugarcane).	F	
			Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (small weirs) impede on natural migration. Altered hydrological events delay/prevent natural migratory cues.		
Inverts	C	4	Significant variation in low flows and floods.	Abstraction for irrigation.	F	3
			Zero flows.			

	PES	Conf	Causes	Sources	F/NF	Conf
			Water quality deterioration (particularly salts, toxics and nutrients).	Land use.	NF	
			Instream and bank modification through sedimentation (resulting from erosion).	Clearing of sugarcane and orchards, overall land use.		

7.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 7.8.

Table 7.8 EWR 6: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico -chem	C	Negative	C/D	5 yrs	Poor water quality state is exacerbated by low flows.	3
Geom	C	Negative	C/D	10 years	The aerial photographic record demonstrates a strong directional change from a wide channel to a few much smaller, narrower active channel probably due to reduced floods and flows generally. The bars and banks have become more vegetated and stabilised.	3
Rip veg	C	Negative	C/D	10 -15 years	Exotic invasion low (up to 10%) on marginal zone mainly, and if left unchecked will increase in proportion at the expense of indigenous riparian vegetation.	3
Fish	C	Stable	C		The fish assemblage have adapted to the altered flow regime and modified water quality and should remain fairly stable over the long term should current conditions prevail.	3
Inverts	C	Stable	C		Invertebrates already adapted to changes	2.5

7.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 7.9. The Instream EC is a C (69.6%).

Table 7.9 EWR 6: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	4	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	4.5	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	100		

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	4	100		
FISH ECOLOGICAL CATEGORY	16.5	400	**65.6**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	3.5	100		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	3	95		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	3	95		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**9.5**	290	**74.9**	**C**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		690	**70.3**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.57	37.49	
Confidence rating for **macroinvertebrate** information	3	0.43	32.10	
	7	1.00	69.59	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the VEGRAI EC and confidence are added to the equation (Table 7.10). The EcoStatus EC is a C (73.1%).

Table 7.10 EWR 6: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**76.6**	**C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	3.57143	0.50	34.65
Confidence rating for riparian vegetation zone information	3.6	0.50	38.45
	7.17143	1.00	73.11
ECOSTATUS	**EC**		**C**

7.7 REC B

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 6 is **VERY HIGH** and the REC is therefore an improvement of the PES.

The REC can be achieved by the following:

- Low flows presently vary daily due to abstractions and sometimes get very low and to zero flows in places. The system must be better operated to ensure that the low flow regime improves and no zero flow periods occur.
- Improved flows will prevent reed encroachment due to the inundation.
- Geomorphology component will improve.

Each component is adjusted to indicate the metrics that will react to the above conditions to achieve a REC. The changes in the rule based models are available electronically and summarised in Table 7.11.

Table 7.11 EWR 6: REC B

	PES	REC	Comments	Conf
Physico-chem	C	B	Improved operation of low flows will result in an improvement of the water quality state due to increased dilution.	3
Geom	C	C	The pools have filled in extensively due to a combination of reduced flows and increased erosion in the catchment and it will therefore not be possible to improve the geomorphology beyond the C EC.	3
Rip veg	C	B	Improve low flows and naturalise variability in flow. Improved recruitment opportunities for *Breonadia salicina* will increase woody cover and abundance. Increased inundation stress will also cause reeds to recede, but maintain vigour and density along the narrowed (but more natural) marginal zone.	3
Fish	C	B	Improved flows (higher low flows, less regulated flows) will improve quality and abundance of FS and FD habitats, with a positive impact on the FROC of some species with high preference for these habitats (especially AMOS, BMAR, CPAR, CSWIE, HVIT and LCON). Improved flows will inundate more reeds and more overhanging vegetation will become available, which will benefit species with a preference for this habitat type as cover, with a possible improvement in the FROC of these species (BPAU, BRAD, BVIV, MMAC and MACU).	4
Inverts	C	B	Improved land management related to irrigation practices will lead to improved flow conditions, less erosion and therefore less sedimentation. Reduced return flows from agriculture will improve the water quality. These improvements will lead to a more natural macroinvertebrate assemblage with the return of some moderately sensitive taxa such as Heptageniidae, Aeshnidae and Athericidae.	3

7.8 AEC: D

A hypothetical scenario is designed and includes the following:

- Decreased low flows and periods of zero flows in some stretches of the river.
- This will result in increased algal growth.
- Geomorphology will react to erosion in the catchment so only changing flow will not necessarily decrease the geomorphology.
- Fewer floods (moderate) will have some impact on sedimentation.
- Reed beds will become less dense and B. *salicina* will disappear.

Each component is adjusted to indicate the metrics that will react to the above scenario. The changes in the rule based models are available electronically and summarised in Table 7.12.

Table 7.12 EWR 6: Alternative D EC

	PES	AEC	Comments	Conf
Physico chem	C	D	Decreased low flows and periods of zero flows in some stretches of the river will result in associated water quality changes, e.g. increases in nutrient levels, toxics, salinity levels and temperature. Oxygen levels will drop under these conditions.	4
Geom	C	C/D	Reduced floods and reduced low/base flows will exacerbate the sedimentation of the pools in this area.	2.5
Rip veg	C	D	Decrease low flows and increased zero flow periods will result in expansion of reedbeds (migration of marginal zone). Terrestrialisation of the riparian zone also likely to increase.	2.7
Fish	B	D	Decreased low flows and longer periods of zero flow in some stretches will have a radical impact on flow dependant species and result in decreased FROC of species as BMAR, CPAR, HVIT, LCON, LCYL, LMOL and MACU and a possible loss of CPRE, CSWI from this stretch under extreme conditions. Loss of deep channels, becoming sandier shallow channel will affect especially species like HVIT and LCON negatively. Increased nutrients will further degrade the available substrate through excessive algal growth, affecting species with a preference for substrate of good quality. A further decrease in the FROC of BMAR, CPAR, and GGIU can therefore be expected. Increased algal growth may benefit some a species like LCON. Impact on species with preference for substrate as cover will be aggravated by increased sedimentation as a result of fewer floods. Loss of overhanging, undercut banks and aquatic vegetation as a result of the decreased water levels will also negatively impact on the FROC of species with a high preference for these cover features (BPAU, BVIV, BTRI, BUNI, BVIV and MMAC).	4
Inverts	C	C/D	A larger area of irrigated sugarcane will result in increased periods of low flow and poorer water quality due to increased return flow. The poor land use practices will also result in greater erosion and sedimentation in the river. Because these activities are restricted to one bank only, the macroinvertebrates will only go down to a C/D category. As a result of the changed conditions a number of the more sensitive macroinvertebrates (Tricorythidae and the more sensitive species of Baetidae) will disappear from the system, while others will occur less frequently and in lower abundances.	3

7.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results for setting EWR scenarios are summarised in Table 7.13.

Table 7.13 EWR 6: Summary of EcoClassification results

IHI				Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	C/D	RIPARIAN	C/D	HYDROLOGY	D		B	D
				WATER QUALITY	C		B	D
				GEOMORPHOLOGY	C	Negative	C	C/D
				Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
				FISH	C	Stable	B	D
				MACRO INVERTEBRATES	C	Stable	B	C/D
				INSTREAM	C		B	D
				RIPARIAN VEGETATION	C	Negative	B	D
				ECOSTATUS	C		B	D

IHI Hydrology PES	C
Diatoms	B/C

8 EWR 7: HONEYBIRD (KAAP RIVER)

8.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 8.1.

Table 8.1 EWR 7: Availability of data

Component	Data availability	Conf
Hydrology	The gauge X2H022 is located approximately 20km downstream of EWR 7. It appears as if this is a reasonable gauge.	4
Physico-chemical	DWA monitoring data was available for reference condition and PES. Limited phytoplankton, periphyton and diatoms was available (n = 1). No temperature, DO or turbidity data was available. Little metal data was available. EC was used instead of aggregated salts as TEACHA could not be applied.	3
Geomorphology	Historical aerial photography (1936, 1959, 1970, 1984, 1997). Hydrology records. Sediment transport analysis (adapted from Dollar and Biker, Geomorphology Specialist report for the Ecological Reserve of the Crocodile River catchment; 2002). Site survey information.	3
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1936, 1959, 1970, 1984, 1997. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	3.5
Fish	Single site visit and fish sampling during October 2007. Kleynhans *et al.* (2002): *Ecological importance and sensitivity, fish integrity and indicators of fish ecological reserve requirements.* Rivers Database (2007): *Database on fish distribution in South African Rivers.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Dr. J. Engelbrecht)	4
Macroinvertebrates	Data and analysis from a single sampling trip during October 2007 (two sets of samples available). Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	4

8.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 8.2) was rated as **HIGH**, as there are rare and endangered fish, vegetation, and bird species present. Fish and macroinvertebrate taxa that are intolerant to flow and flow related water quality changes are also present in this river reach.

Table 8.2 EWR 7: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	3	*O. peringueyi, C. swierstrai,* undescribed macroinvertebrate species of Polycentropodidae, *B. salicina.*
Unique (endemic, isolated, etc.)	2	1	Macrobrachium.
Intolerant (flow & flow related water quality)	4	4	*O. peringueyi, C. swierstrai, C. pretoriae*, *B. eutaenia.* Various macroinvertebrate taxa.
Species/taxon richness	3	3	Seventeen fish species, 34 macroinvertebrate taxa.
RIPARIAN & INSTREAM HABITATS			
Diversity of types	2	3	Riffles, rapids, cascades, pools, bedrock.
Refugia	2	3	
Sensitivity to flow changes	3	3	Small stream with riffles.
Sensitivity to flow related water quality changes	3	3	Bedrock.
Migration route/corridor (instream & riparian)	2	2	*A. mossambica,* Macrobrachium.
Importance of conservation & natural areas	1	2	Gorge. Vulnerable vegetation type (Granite Lowveld).
MEDIAN	2.5		
EIS EVALUATION	**HIGH**		

8.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 8.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 8.3 EWR 7: Reference conditions

Component	Reference conditions	Conf
Hydrology	The gauge measures low and zero flow accurately. Record available is from 1960 to present. Virgin MAR: 169.02 MCM.	4
Physico-chemical	DWA monitoring data: X2H022Q01, 1977 - 1981, n = 96. Refer to Table 8.4.	3
Geomorphology	The current state is close to the reference condition.	2.5
Riparian vegetation	This site occurs in the Lowveld bioregion of the Savanna biome in the Granite Lowveld vegetation unit. Mixed vegetation is expected with the marginal zone dominated by *B. salicina* where exposed bedrock occurs and *P. mauritianus* where alluvial deposits occur. Lower and upper zones are expected to be dominated by woody vegetation which includes *C. erythrophyllum, S. cordatum,* and *F. sycomorus* with mixed grass.	3.5
Fish	Seventeen species present. Refer to Table 8.5.	4
Macroinvertebrates	The reference total SASS 5 score is 250, with over 5 taxa and an ASPT of >7. Additional information is provided below.	3.5

Detailed physico-chemical reference conditions are provided in Table 8.4.

Table 8.4 EWR 7: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No available data.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.027
	Total Inorganic Nitrogen (TIN)	0.44
Physical variables	pH (5^{th}+95^{th} percentiles)	6.96 + 8.18
	Electrical conductivity (mS/m)	70.15

Information on the expected fish reference conditions at site X2KAAP-HONEY, as cited in Kleynhans *et al.* (2007b) was used to determine the expected reference conditions. The fish reference condition set should be valid for the Kaap River stretch within NRU Kaap A. Seventeen indigenous fish species are expected under reference condition. Reference species detail is listed in Table 8.5.

Table 8.5 EWR 7: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 7 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	3	2
Barbus eutaenia	Orangefin barb	BEUT	5	4
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	5
Barbus trimaculatus	Threespot barb	BTRI	5	5
Barbus unitaeniatus	Longbeard barb	BUNI	5	5
Barbus viviparous	Bowstripe barb	BVIV	5	5
Clarias gariepinus	Sharptooth catfish	CGAR	3	3
Chiloglanis paratus	Sawfin suckermouth (Rock catlet)	CPAR	4	4
Chiloglanis pretoriae	Shortspine suckermouth (Rock catlet)	CPRE	5	4
Chiloglanis swierstrai	Lowveld suckermouth (Rock catlet)	CSWI	3	2
Labeo cylindricus	Redeye labeo	LCYL	4	4
Labeo molybdinus	Leaden labeo	LMOL	4	4
Labeo rosae	Rednose labeo	LROS	2	1
Micralestis acutidens	Silver robber	MACU	3	3
Opsaridium peringueyi	Southern barred minnow	OPER	3	2
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Tilapia rendalli	Redbreast tilapia	TREN	3	2

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Expected macroinvertebrate taxa include:

Baetidae >2spp, Oligoneuridae, Helodidae, Pyralidae, Prosopistomatidae, Perlidae, Heptageniidae, Hydropsychidae >2spp, Polycentropodidae, Gyrinidae, Naucoridae, Hydrophilidae, Dytiscidae, Baetidae 2spp, Pleidae, Gomphidae, Corbiculidae, Caenidae, Tabanidae, Tipulidae, Ceratopogonidae, Leptoceridae, Coenagrionidae, Hydroptilidae, Libellulidae, Simuliidae, Hydropsychidae 2spp, Porifera, Ancylidae, Veliidae, Gerridae, Dixidae, Hydrometridae, Hydraenidae, Hydracarina, Dipseudopsidae, Calamoceratidae, Corduliidae, Limnichidae, Polymitarcyidae, Pisuliidae, Lepidostomatidae, Lestidae, Protoneuridae, Philopotamidae, Athericidae, Aeshnidae, Leptophlebiidae, Ecnomidae, Chlorocyphidae, Elmidae, Tricorythidae, Psephenidae, Psychomyiidae, Culicidae, Muscidae, Corixidae, Notonectidae, Psychodidae, Belostomatidae, Sphaeriidae, Oligochaeta, Chironomidae, Hirudinea, Potamonautidae, Nepidae, Thiaridae, Physidae, Planorbinae, Lymnaeidae, and Turbellaria.

8.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

8.4.1 Hydrology

Present MAR is 81.72 MCM (48% of natural). Change from reference condition is largely due to large scale irrigation and afforestation in the area. There are periods of no flow.

8.4.2 Geomorphology (B EC, 86.1%)

EWR 7 is classified as a bedrock gorge channel type and is representative of the Kaap River. The cross-section traverses a riffle. The strong bedrock influence means that the site is highly resistant to change so that little morphological adjustment is likely to occur in response to flow regulation. The bed material is predominantly cobble and boulder with very little sand and gravel. It is possible that upstream of the bridge there has been some enhanced sediment deposition at high flows due to flow constrictions through the narrow bridge crossing, and also associated with disturbance on the banks.

8.4.3 Physico chemical variables (B EC, 85.36%)

Overall the water quality is in a B category with a SPI score of 15.8. There are pollutant tolerant species present although in lower levels, but pollution may be on the increase due to species present that are tolerant to high levels of pollution (e.g. *E. subminuscula*, *G. parvulum, G parvulum f. saprophilum*).

Bi-monthly biomonitoring data records (2004 - 2007 (n = 174)) from water quality station X2H022Q01 were used for the PES assessment. Nutrient levels at this site indicate some pollution. Some turbidity is expected due to catchment activities and due to the bedrock dominance of the system temperature fluctuations are expected. There are extensive upstream mining activities (primarily along the Noord and Suid-Kaap and around Barberton; and irrigation return flows from irrigation in the middle of the catchment. Although elevated Arsenic has been reported in the area, no Arsenic was seen in the recent (2006 - 2007) DWA regional office monitoring data; although peaks of elevated Iron were evident in the 1990s. PES values for the physico-chemical variables are provided in Table 8.6 and in Appendix C.

Table 8.6 EWR 7: Physico-chemical PES values

Water Quality Constituents		Value: PES
Nutrients (mg/L)	SRP	0.032
	TIN	0.72
Physical variables	pH (5^{th}+95^{th} percentiles)	7.96 + 8.53
	Electrical conductivity (mS/m)	90.8

8.4.4 Instream and Riparian Habitat Integrity (IIHI: C EC, 69.7%, RIHI: C EC, 62.6%)

The IIHI EC is due to abstraction and periods of zero flow which have caused changes in hydrology (decreased flows) and a decrease in longitudinal connectivity. The RIHI is due a decreased base flows and zero flows due to abstraction and an increase in alien vegetation due to land use activities.

8.4.5 Fish (C EC, 76.8%)

The PES reflects moderately deteriorated ecological integrity, related to impacts such altered flow regimes, forestry and agriculture. Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution.

8.4.6 Macroinvertebrates (B EC, 83.6%)

SASS5 score: 194 No of Taxa: 34 ASPT: 5.7
A number of sensitive taxa were found at this site including: Heptageniidae, Perlidae, >2 spp Baetidae and >2 spp Hydropsychidae. The macroinvertebrate composition at this site indicates the relatively good water quality for the Kaap River at this point.

8.4.7 Riparian vegetation (C/D EC, 59.7%)

In the marginal zone it appears that *Breonadia* is "stranded" in bedrock areas due to reduced flow and water stress is high. Recruitment is absent. There is an extensive seep zone, especially the right hand bank (RHB) with typical wetland plants. The lower zone is predominantly a reed and grass mix with scattered woody individuals. Selective wood removal is apparent. The Upper zone is dominated by woody vegetation but agricultural and civil disturbance is high. The Lower and upper zone has high degree of exotic infestation, especially *Arunda spp.*

8.4.8 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 8.7.

Table 8.7 EWR 7: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	D	3	Reduced base flows and zero flow.	Abstraction.	F	4
				Afforestation.	NF	
Physico-chem	B	3	Elevated nutrients and salts. Slightly alkaline waters. Slightly elevated turbidity and toxics.	Mining activities in the upper catchment. Agricultural and other activities (e.g. pole treating) in the catchment immediately above the site.	NF	3
Geom	B	2.5	Reduced sediment transport capacity.	Reduced flows from abstraction, forestry etc.	F	3
			Increased sediment supply.	Primarily agriculture, but also sediment introduction due to erosion in informal settlement areas.	NF	
Rip veg	C/D	3.1	Reduced woody cover in marginal zone.	Reduced low flows.	F	4
			Changes to species composition.	High (60 - 80%) impact by exotic vegetation.	NF	
			Reduced woody cover.	Selected wood removal, agricultural and civil disturbance.		
Fish	C	3.5	Loss in natural habitat diversity.	Altered hydrological regime.	F	3.5
			Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (small weirs) impede on natural migration. Altered hydrological events delay/prevent natural migratory cues.	NF	
Inverts	B	3	Reduced base flows and zero flow.	Abstraction for irrigation.	F	3
			Water quality deterioration.	Land use.	NF	

8.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 8.8.

Table 8.8 EWR 7: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-chem	B	Stable	B		Water quality conditions stable, although there is evidence of pollutant tolerant diatom species at low levels.	2
Geom	B	Negative	B/C	10 years	The aerial photos demonstrate a directional change towards a narrower, less dynamic river channel.	3
Rip veg	C/D	Negative	D	5 years	Wood removal, earth works and roads have had high disturbance in upper and lower zone. The previous photographs of this site has shown a significant increase in exotics which will keep on increasing.	3
Fish	C	Stable	C		The fish assemblage in this section of the Crocodile River have adapted to the altered flow regime and modified water quality and should remain fairly stable over the long term should current conditions prevail.	3
Inverts	B	Stable	B		The macroinvertebrates have already adapted to the changes in the system.	2.5

8.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 8.9. The Instream EC is a B/C (81%).

Table 8.9 EWR 7: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	90		
2.What is the natural diversity of **fish** species with a preference for different cover types	3.5	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	90		
FISH ECOLOGICAL CATEGORY	13	380	**76.8**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	4	100		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	4	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	4	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**12**	300	**83.6**	**B**

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
INSTREAM ECOLOGICAL CATEGORY (No confidence)		680	**81.0**	**B/C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3.5	0.54	41.35	
Confidence rating for **macroinvertebrate** information	3	0.46	38.58	
	6.5	1.00	79.94	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B/C**	

To determine the EcoStatus, the VEGRAI EC and confidence are added to the equation (Table 8.10). The EcoStatus EC is a B/C (70.1%).

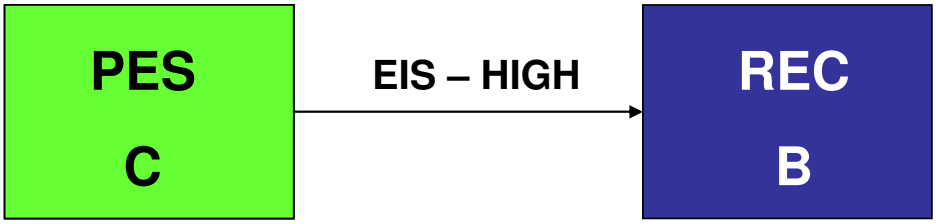
Table 8.10 EWR 7: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**59.7**	**C/D**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	3.26923	0.51	41.03
Confidence rating for riparian vegetation zone information	3.1	0.49	29.06
	6.36923	1.00	70.09
ECOSTATUS	**EC**		**C**

8.7 REC: B

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 7 is **HIGH** and the REC is therefore an improvement of the PES.



To achieve the REC, the following improvements are required:

- The improvement of low flow regimes through improved system operation as there are periods of zero flows and the moderate floods are impacted.
- Improved management will improve the water quality and vegetation components although alien vegetation removal is necessary to bring about a significant improvement.

Each component is adjusted to indicate the metrics that will react to the above conditions to achieve a REC. The changes in the rule based models are available electronically and summarised in Table 8.11.

Table 8.11 EWR 7: REC B

	PES	REC	Comments	Conf
Physico-chem	B	B	Improved flows would only improve turbidity levels. Other water quality issues would have to be improved at the source.	N/A
Geom	B	B	Maintain the current EC, but address the negative trend. This will require the provision of adequate moderate floods to scour the channel and prevent narrowing and encroachment. An improvement in EC is not possible.	N/A
Rip veg	C/D	B/C	An improvement in the flow regime will lead to a C EC with increased *Breonadia salicina* cover and reduced *Phragmites mauritianus* cover. The removal of exotics will improve the EC to a B/C.	3
Fish	C	B	This scenario may result in improved FROC on a variety of species, including species with requirement for FS and FD habitats and those that are intolerant to no flow conditions (OPER, CPAR and BMAR). This may also lead to the more tolerant species utilising this section optimally, with their FROC returning close to natural state (BTRI, BUNI, and BVIV).	3
Inverts	B	B	Maintain the current EC.	N/A

8.8 AEC: D

A hypothetical scenario is designed and includes the following:

- The presence of Mountain View Dam which will result in much lower flows than present and decreased floods.
- The channel will be narrower; some riffles will be sandier and smaller in general. This will result in more reeds, and a narrower marginal zone.
- Marginal zone woody species such as *B. salicina* (Mingerhout/Matumi) would be more stressed.

Each component is adjusted to indicate the metrics that will react to the scenario. The changes in the rule based models are available electronically and summarised in Table 8.12.

Table 8.12 EWR 7: Alternative D EC

	PES	AEC	Comments	Conf
Physico chem	B	C	Mining effluents will probably be caught in the dam. Flushing below the dam will be reduced, resulting in some elevation of nutrient levels due to agricultural activities upstream of the site and below the dam. Note that turbidity levels will drop, having a negative effect on a river that seems naturally slightly turbid due to possible build-up of periphyton.	3
Geom	B	C	The proposed Mountain View Dam in this upper catchment would reduce the flooding frequency and size of floods.	2

	PES	AEC	Comments	Conf
Rip veg	C/D	D	Extensive loss of woody riparian species will occur in the marginal and lower zones. Reeds are likely to reduce, depending on the severity of the scenario.	2.5
Fish	C	D	Altered hydrological regime, with much less flows (lower base flows) will lead to reduced riffle/rapid/run habitats, with reduced FROC of species with preference for FD and FS habitats (BEUT, BMAR, CPAR, CPRE, CSWIE, LCYL, LMOL, MACU and OPER). This may even lead to the total loss of OPER from this section. With fewer floods the riffles will become sandier and negatively impact some species with a high preference for substrate of good quality (especially BEUT, CPRE). Degradation of overhanging vegetation will also result in decreased FROC of species with a preference for this cover type, i.e. BTRI, BUNI, BVIV and PPHI.	3
Inverts	B	C	Increased abstraction from the Kaap River will result in a decrease in available habitat for the macroinvertebrates. Decreased water quality will result from increased irrigation return flow. The decreased flow and water quality will cause higher temperatures and more algal growth reducing the available cobble habitat. As a result some of the more sensitive species of the Baetidae and Hydropsychidae will disappear while others (e.g. Perlidae, Heptageniidae and Chlorocyphidae) will occur less frequently.	3

8.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results for setting EWR scenarios are summarised in Table 8.13.

Table 8.13 EWR 7: Summary of EcoClassification results

IHI				Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	C	RIPARIAN	C	HYDROLOGY	D		C	D
				WATER QUALITY	B		B	C
				GEOMORPHOLOGY	B	Negative	B	C
				Response Components	PES Category	Trend	REC	AEC↓
				FISH	C	Stable	B	D
				MACRO INVERTEBRATES	B	Stable	B	C
				INSTREAM	B/C		B	C
				RIPARIAN VEGETATION	C/D	Negative	B/C	D
				ECOSTATUS	C		B	D

IHI Hydrology PES	E
Diatoms	B

9 SUMMARY OF RESULTS AND CONCLUSIONS: CROCODILE SYSTEM

9.1 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results for EWR 1 to 7 in the Crocodile River System are summarised in Table 9.1.

Table 9.1 EcoClassification Results summary – Crocodile system

EWR 1 Valeyspruit (Crocodile River)

EIS: Moderate
Highest scoring metric were diversity of sensitive habitat types present e.g. wetlands (including floodplains containing various oxbows).

PES: A/B
Minor impacts, mainly due to farming, exotic vegetation species and trout. Impacts are mostly non-flow related

REC: A/B
Maintain the PES as only moderate EIS.

AEC down: B/C
Scenario includes decreased low flows due to e.g. increased golf estates, trout farms and increased abstractions for Dullstroom. Growth of Dullstroom will also result in increased sewage. Increased grazing causing trampling and destabilisation of banks.

Driver Components	PES & REC Category	Trend	AEC↓
HYDROLOGY	A/B		B
WATER QUALITY	A		B
GEOMORPHOLOGY	B	Stable	C
Response Components	**PES & REC Category**	**Trend**	**AEC↓**
FISH	A	Stable	B/C
MACRO INVERTEBRATES	B	Stable	B/C
INSTREAM	A/B		B/C
RIPARIAN VEGETATION	A	Stable	B
ECOSTATUS	A/B		B/C

EWR 2 Goedehoop (Crocodile River)

EIS: High
Rare and endangered fish spp. which are sensitive to flow and quality changes. High species diversity.

PES: B
Impacts as for EWR 1 with increased agricultural activities and decreased flows. However, impacts mostly still non-flow related.

REC: B
Although the EIS is high, the PES is already a B and as the impacts are mostly non-flow related, it would not be realistic to improve the PES through flow related interventions.

AEC down: C
See EWR 1. Possible zero flow situations and additional impacts on moderate events.

Driver Components	PES & REC Category	Trend	AEC↓
HYDROLOGY	B		C
WATER QUALITY	B		C
GEOMORPHOLOGY	B	Stable	B/C
Response Components	**PES & REC Category**	**Trend**	**AEC↓**
FISH	B	Stable	C
MACRO INVERTEBRATES	B	Negative	C
INSTREAM	B		C
RIPARIAN VEGETATION	A/B	Negative	B
ECOSTATUS	B		C

EWR 3 Poplar Creek (Crocodile River)

EIS: High
Rare and endangered fish, vegetation and bird spp, some of which are sensitive to flow and quality changes.

PES: B/C
Major problems related to upstream Kwena Dam and its operation, e.g. migration, sedimentation, changed flow regime. The changed flow regime consists of higher than natural flows in the dry season and much lower low flows in the wet season.

REC: B
The EIS is high; therefore the REC is an improvement of the PES. This can be achieved by improving the flow regime (low flows) and removal of exotic vegetation species.

AEC down: C/D
Lower flows than natural in both the dry and wet season. Associated increase in temperature and oxygen.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C		B	D
WATER QUALITY	C		B/C	C/D
GEOMORPHOLOGY	C	Negative	C	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B	Stable	B	C
MACRO INVERTEBRATES	C	Negative	B	C/D
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	B/C		B	C/D

EWR 4 KaNyamazane (Crocodile River)

EIS: High
Rare and endangered species that are sensitive to flow and quality changes are present. There is also a high species taxon richness and a diversity of habitat types

PES: C
Combination of flow and non-flow related impacts. Changes mostly related to changes in flow regime due to upstream Kwena Dam and the operation of upstream system. Abstractions, return flows, landuse mismanagement, water quality issues, and sedimentation.

REC: B
The EIS is HIGH, therefore the REC is an improvement of the PES. Improvements to flow regime will be required. Only successful if combined with removal of exotic vegetation and if there are some improvement in grazing and browsing.

AEC down: C/D
Montrose Dam with decreased floods. Pools will fill in, bars will appear, riffles will be clogged and covered with sediment, reed growth will increase, the marginal zone will expand and vegetation will encroach.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C			
WATER QUALITY	C		B	C
GEOMORPHOLOGY	B/C	Stable	B	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B	Stable	B	C
MACRO INVERTEBRATES	C	Stable	B	D
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	C/D

EWR 5 Malelane (Crocodile River)

EIS: Very High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on LB.

PES: C
Change in low flows, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.

REC: B
The EIS is VERY HIGH, therefore the REC is an improvement of the PES. Changes mostly focussing on improving the low flow regime and some land use management.

AEC down: D
Decreased low flows and periods of zero flows in some stretches of the river which will result in increased algal growth, temperature and nutrient problems, loss of deeper channel sections, increased reed and vegetation growth.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C		B	D
WATER QUALITY	C		B	D
GEOMORPHOLOGY	C/D	Negative	C	D
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	C	Stable	B	D
INSTREAM	C		B	D
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	D

EWR 6 Nkongoma (Crocodile River)

EIS: Very High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on left bank.

PES: C
Change in low flows, even zero flows present, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.

REC: B
The EIS is VERY HIGH, therefore the REC is an improvement of the PES. Changes mostly focussing on improving the low flow regime and some land use management.

AEC down: D
Decreased low flows and periods of zero flows in some stretches of the river which will result in increased algal growth, temperature and nutrient problems, loss of deeper channel sections, increased reed and vegetation growth.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	D		B	D
WATER QUALITY	C		B	D
GEOMORPHOLOGY	C	Negative	C	C/D
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	C	Stable	B	C/D
INSTREAM	C		B	D
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	D

EWR 7 Kaap (Kaap River)

EIS: High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and habitat types sensitive to flow and quality changes.

PES: C
Changes are flow and non-flow related. Low to zero flows present due to upstream abstractions. Land-use activities related to agriculture and mining. Extensive exotic vegetation present.

REC B:
The EIS is high, therefore the REC is an improvement of the PES.
No zero flows, increased low flows, more moderate floods. This must happen in conjunction with exotic vegetation removal.

AEC D:
Mountain View Dam will be present which will result in much lower flows than present and decreased floods. The channel will be narrower, some riffles will be sandier and smaller in general which will result in more reeds and a narrower marginal zone.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	D		C	D
WATER QUALITY	B		B	C
GEOMORPHOLOGY	B	Negative	B	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	B	Stable	B	C
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	C/D	Negative	B/C	D
ECOSTATUS	C		B	D

9.1.1 Confidence in results

The confidence in EcoClassification is provided in Table 9.2. The confidence provided is for data availability and EcoClassification:

- Data availability: The evaluation is based on the adequacy of any available data for interpretation of the Ecological Category and AEC.
- EcoClassification: The evaluation is based on the confidence in the accuracy of the Ecological Category.

Table 9.2 Confidence in the EcoClassification process

1 (very low confidence) 2 (low confidence) 3 (medium confidence)
4 (high confidence) 5 (very high confidence)

Data Availability									EcoClassification								
Hydrology	Geomorphology	Physico-chemical	IHI (instream & riparian	Fish	Macroinvertebrates	Vegetation	Average	Median	Hydrology	Geomorphology	Physico-chemical	IHI (instream & riparian	Fish	Macroinvertebrates	Vegetation	Average	Median
EWR 1																	
4	3	2	4	4	4	4	3.57	4	4	3	2	3.75	5	4	4.1	3.69	4
The data availability and EcoClassification is **HIGH** due to the recent and previous Reserve, RHP and VEGRAI surveys and testing at the sites as well as availability of historical information. The physico-chemical variables confidence is low due to the lack of a nearby measuring station.																	
EWR 2																	
4	3	2	4	4	4	3.5	3.5	4	4	2.5	2	3.75	4	4	3.7	3.42	3.75
The data availability and EcoClassification is **HIGH** and **MEDIUM - HIGH** due to the recent and previous Reserve and RHP surveys at the sites as well as availability of historical information. The physico-chemical variables confidence is low due to the lack of a nearby measuring station.																	
EWR 3																	
4	3	3	4	4	4	4	3.71	4	4	4	3	3.75	4	4	3.7	3.78	4
The data availability and EcoClassification is **HIGH** due to the recent and previous Reserve (1998, 2006), RHP and VEGRAI surveys and testing at the sites as well as availability of historical information.																	
EWR 4																	
4	3	3	4	4	4	4	3.71	4	4	3	3	3.3	4	3	3.6	3.41	3.3
The data availability and EcoClassification is **HIGH** and **MEDIUM - HIGH** due to the recent and previous Reserve, RHP and VEGRAI surveys and testing at the sites as well as availability of historical information. The reason the confidence in the EcoClassification is not high is due to the unsuitability of the previous selected cross-section which makes it difficult to interpret.																	
EWR 5																	
4	3	3	4	4	4	3	3.57	4	4	3.5	3	3.25	4	4	3.4	3.59	3.5
The data availability and EcoClassification is **HIGH** for the instream components and hydrology (recent Reserve studies, previous RHP studies and recent VEGRAI testing), but **MEDIUM - HIGH** overall basically due to the medium vegetation confidence (lack of presence of suitable species).																	
EWR 6																	
4	3	3	4	4	4	4.5	3.79	4	4	3	3	3.3	4	3	3.6	3.41	3.3
The data availability and EcoClassification is **HIGH** and **MEDIUM** due to the recent and previous Reserve, and RHP surveys at the sites as well as availability of historical information. The reason the confidence in the EcoClassification is not high is due to difficulties of surveying the site and lack of critical habitats (e.g. riffles and rapids).																	
EWR 7																	
4	3	3	4	4	4	3.5	3.64	4	4	2.5	3	2.9	3.5	3	3.1	3.14	3
The data availability and EcoClassification is **HIGH** and **MEDIUM.** Although also a previous Reserve study site, the site has few critical habitats and has significant alien vegetation problems.																	

A summary of the confidences are given below in Table 9.3. The colour coding is as follows:
Green: High to Very High
Yellow: Medium to high
Red: Very low to Medium

Table 9.3 Summary of the confidence in the available data and EcoClassification results for each of the EWR Sites in the Crocodile River catchment

EWR site	EWR 1		EWR 2		EWR 3		EWR 4		EWR 5		EWR 6		EWR 7	
Confidence	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification
Hydrology	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Geomorphology	3	3	3	2.5	3	4	3	3	3	3.5	3	3	3	2.5
Physico-chemical	2	2	2	2	3	3	3	3	3	3	3	3	3	3
IHI (instream & riparian	4	3.75	4	3.75	4	3.75	4	3.3	4	3.25	4	3.3	4	2.9
Fish	4	5	4	4	4	4	4	4	4	4	4	4	4	3.5
Macroinvertebrates	4	4	4	4	4	4	4	3	4	4	4	3	4	3
Vegetation	4	4.1	3.5	3.7	4	3.7	4	3.6	3	3.4	4.5	3.6	3.5	3.1
Median	4	4	4	3.75	4	4	4	3.3	4	3.5	4	3.3	4	3

9.2 CONCLUSIONS

The results in Table 9.3 indicated that there was a lot of data available and therefore the confidence in data availability was rated as HIGH. This is due to the recent and historical information collected during national and provincial River Health Programme (RHP) surveys, research in the Kruger national Park (KNP), previous EWR studies and the detailed updated hydrological study recently undertaken. Historical information from surveys undertaken by the Transvaal Provincial Administration's Nature Conservation Department (Mpumalanga Department of Nature Conservation) also contributed to the data that used to undertake the EcoClassification assessments at each site.

Whereas a HIGH level of confidence in the EcoClassification results was obtained for EWR 1 and 3, a MEDIUM to HIGH level of confidence was obtained for EWR 2, 4, 5 and 6 and a MEDIUM level of confidence was obtained for EWR 7.

Medium levels of confidence in the EcoClassification results were attributed to the following:

- EWR 2: Lack of measured water quality data.
- EWR 4: Unsuitability of previously selected cross-section which makes interpretation difficult.
- EWR 5: Interpretation of vegetation is problematic and not necessarily representative of the rest of the reach.
- EWR 6: Problems with biological surveys (difficult habitats) and lack of critical habitats (e.g. riffles).
- EWR 7: Same problem as at EWR 6 as well as the presence of extensive alien vegetation which is increasing continuously, thus resulting in the lack of indigenous vegetation that can be used as indicators for flow requirements along the cross sections.

9.3 RECOMMENDATIONS

The amount and accuracy of the data available at each site was high and therefore no more detailed work is needed to improve data availability.

To improve the confidence in the EcoClassification results at EWR 2, 4, 6 and 7 the following is recommended as part of monitoring:

- Due to the lack of a nearby water quality monitoring station at EWR 2 diatom assessments as part of future monitoring is recommended. This will provide a good indication of the trend of the physico-chemical variables and if problems are indicated, a more detailed physico-chemical analysis can be undertaken. This is also relevant for EWR 1 as data availability is low for the physico-chemical component.
- A new cross section has been selected in the riffle immediately downstream of EWR 4 and future monitoring must focus on this area.
- An alien eradication programme is required at EWR 7.

More work has been undertaken at these sites than for most, if not any, river in South Africa and it is unlikely that further work will increase confidences. A Water Resources Monitoring Programme is recommended where some of the issues listed above can possibly be addressed. Some of the uncertainties are due to the natural nature of the site (which results in difficulties in surveying and interpretation) as well as a lack of measured water quality. This will be confirmed once the assessment of the adequacy of the baseline information is undertaken as part of the Ecological Specifications assessment (the results of which will be provided in what report 26/8/3/10/12/012).

10 EWR 1 UPPER SABIE (SABIE RIVER)

10.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 10.1.

Table 10.1 EWR 1: Availability of data

Component	Data availability	Conf
Hydrology	The nearest reliable gauge is the Sabie River gauge located about 9 km upstream of EWR 1. The gauge seems reasonable but has suspicious zero flows prior to 1969.	3
Physico-chemical	DWA monitoring data was available for setting reference condition and PES. Limited phytoplankton, periphyton and diatoms was available (n = 1). No temperature, DO or turbidity data was available. Little metal data was available. EC was used instead of aggregated salts as TEACHA could not be used.	3
Geomorphology	Historical aerial photography (1944, 1956, 1965, 1997). Sediment transport modelling and analysis undertaken for this study. Hydrology records. Site survey information at time of study.	3
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Previous VEGRAI training site. Aerial photos of site - 1944, 1956, 1965, 1997. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4
Fish	Single site visit and fish sampling during September 2007. Rivers Database (2007): *Database on fish distribution in South African Rivers.* Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	3
Macroinvertebrates	Data and analysis from a single sampling trip during September, 2007. Data from the River Health Program for sites X3KSAB-TWEEF. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	3

10.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 10.2) was rated as **HIGH** (present), as there are rare and endangered species at this site which include *B. brevipinnis, B. salicina* and tree ferns. Fish species intolerant to flow and flow related water quality occur here.

Table 10.2 EWR 1: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*B. brevipinnis* (endangered on IUCN[1]), *B. salicina* and tree ferns (protected). Vegetation type as a whole is poorly protected.
Unique (endemic, isolated, etc.)	3	3	*Varicorhinus nelspruitensis, C. anoterus.*
Intolerant (flow & flow related water quality)	4	4	*V. nelspruitensis, C. anoterus, A. uranoscopus.*
Species/taxon richness	3	3	Macroinvertebrates.
RIPARIAN & INSTREAM HABITATS			
Diversity of types	2	3	Pools, rapids, riffles, cascades, overhanging vegetation.
Refugia	2.5	3	
Sensitivity to flow changes	2	3	
Sensitivity to flow related water quality changes	2.5	3	Although some impact on temperature and dissolved oxygen may take place, the river is large enough that this impact will not be too severe.
Migration route/corridor (instream & riparian)	2	3	Birds and macroinvertebrates.
Importance of conservation & natural areas	1	3	
MEDIAN	2.5		
EIS EVALUATION	**HIGH**		

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10.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 10.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 10.3 EWR 1: Reference conditions

Component	Reference conditions	Conf
Hydrology	Gauging record from 1948 to present is available. It seems that low flows were not measured accurately by the gauge. Virgin MAR: 140.18 MCM.	3
Physico-chemical	DWA monitoring data was available. Water quality station X3H001Q01 was used to set reference conditions with n = 82, and data available from 1977 – 1979. Refer to Table 10.4.	3
Geomorphology	The reference condition is a pool-riffle system, with a boulder/cobble bed with gravels. The valley is confined, and thus whilst there is a large flood terrace on one bank, the opposite bank is a steep cut bank. Woody cover under natural condition probably less than present.	3
Riparian vegetation	**Marginal zone:** Dominated by a mixture of reeds (*P. mauritianus*) and herbaceous vegetation (*Setaria megaphylla*, ferns, *Cyperus* and *Berulla* spp.; with the reed component in smaller proportions than herbs), but with fairly high influence from overhanging lower zone trees (*Syzigium* spp. and *B. salicina*). Stable vegetated geomorphic features with minimal open areas exist. **Lower zone:** Tree and shrub dominated riparian vegetation is present, which is fairly dense with a high proportion of riparian obligates (*S. cordatum*, *C. erythrophyllum*, *Cliffortia* and *Euclea* spp.). High proportion of shading for both lower and marginal zones (overhang) exists. **Upper zone:** Tree and shrub dominated as with the lower zone, but with greater variability of species (no additional riparian obligates present though), and fairly dense (*Syzigium* sp., *C.*	3.5

Component	Reference conditions	Conf
	erythrophyllum, *Tremma orieltalis*, *Halleria lucida*, *Diospyros mespiliformis*, *Celtis africana*, *Euclea* spp.)	
Fish	Three species. Refer to Table 10.5.	3
Macroinvertebrates	The reference total SASS 5 score is 220, with >30 taxa and an ASPT of 7.5. More detail regarding reference taxa is provided below.	3

Detailed physico-chemical reference conditions are provided in Table 10.4.

Table 10.4 EWR 1: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.018
	Total Inorganic Nitrogen (TIN)	0.20
Physical variables	pH (5^{th}+95^{th} percentiles)	6.46+7.30
	Electrical conductivity (mS/m)	12.21

No specific fish reference condition information is available for the reach of the Sabie River where EWR 1 is situated. The closest site available with a defined reference condition is X3-Sabi-Brand (downstream of Mac-Mac River confluence), which was primarily used to derive the expected reference conditions and is valid for the Sabie River stretching from below the Sabie falls (downstream of Sabie town) to the confluence with the Mac-Mac River. Seven fish species are expected in this section of the Sabie River with all species expected to be naturally present at more than 50% of sites sampled in a reach. These species are listed in Table 10.5.

Table 10.5 EWR 1: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 1 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	4	2
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	4	3
Barbus anoplus	Chubbyhead barb	BANO	4	3
Barbus brevipinnis	Shortfin barb	BBRE	4	3
Chiloglanis anoterus	Rock catlet	CANO	5	5
Tilapia sparrmanii	Banded tilapia	TSPA	4	3
Varicorhinus nelspruitensis	Incomati chiselmouth	VNEL	5	5

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Macroinvertebrate taxa expected under reference conditions are:

Turbellaria, Oligochaeta, Potamonautidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Tricorythidae, Coenagrionidae, Gomphidae, Corixidae, Gerridae, Naucoridae, Veliidae, Hydropsychidae 2spp, Philopotamidae, Psychomyiidae, Hydroptilidae, Leptoceridae, Elmidae, Gyrinidae, Helodidae, Psephenidae, Athericidae, Chironomidae, Dixidae, Simuliidae, and Tipulidae.

10.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

10.4.1 Hydrology

The present MAR is 109.58 MCM (78% of natural). There have been significant reductions in natural base flow due to afforestation and domestic use by the town of Sabie. The volume of the base flows has reduced and the seasonal distribution has only been slightly changed. There have been no changes in frequency and seasonality of moderate and large floods except for slight decreases in peak floods.

10.4.2 Geomorphology (B EC, 83.3%)

The site is a pool-riffle system with a boulder/cobble bed and gravel and large sand component. It is possible that the sand component has increased due to upstream forestry activities and has led to a reduction in channel size. Aerial photos indicate an increase in woody vegetation cover. The riparian zone is heavily infested with exotic vegetation and has recently burnt prior to the site visit. The flood terraces are composed of fine sands and not paired, as one bank is a steep cut bank.

10.4.3 Physico-chemical variables (A/B EC, 92.3%)

Some diatom data was also collected. The Specific Pollution Index (SPI[5]) indicates good water quality although this falls within the lower ranges of the classification. The presence of species tolerant to moderate to heavy pollution indicates that upstream anthropogenic activities may be impacting on this EWR site and may be the source of slightly elevated concentrations of organically bound nitrogen. This is supported by the physico-chemical variables analysis which indicates some pollution present due to elevated nutrient levels.

Records (2004 – 2007 (n = 42)) from water quality station X3H001Q01 were used for the PES assessment. The frequency of monitoring was monthly. Elevated turbidity levels are expected due to catchment activities and return flows from old mines (toxics) are impacting this site. PES values for the physico-chemical variables are provided in Table 10.6 and in Appendix C.

Table 10.6 EWR 1: Physico-chemical PES values

Water Quality Constituents		Value: PES
Nutrients (mg/L)	SRP	0.02
	TIN	0.45
Physical variables	pH (5^{th}+95^{th} percentiles)	7.37+7.87
	Electrical conductivity (mS/m)	15.58

[5] A diatom based water quality index. The index evaluates organic and inorganic pollution based on the sensitivity of each taxon, while taking into account the response of the whole diatom community (Almeida, 2001). The index is used to indicate general water quality.

10.4.4 Instream and Riparian Habitat Integrity (IIHI: B/C EC, 81.5%; RIHI: B/C EC, 80.1%)

There has been a reduction in flow due to forestry and small abstractions in the Sabie town vicinity as well as elevated nutrient levels due to forestry and input from Sabie. Erosion is also visible due to forestry. The main impact on the riparian integrity is flow reduction and erosion caused by forestry. Exotic vegetation has also contributed to erosion.

10.4.5 Fish (B/C EC, 78.3%)

The main changes to the reference fish assemblage can primarily be attributed to the reduced flows and increased sedimentation. Most of the expected fish species are however still present in this reach, although at reduced abundance and spatial distribution.

10.4.6 Macroinvertebrates (B EC, 82.1%)

SASS5 score: 170 No of Taxa: 27 ASPT: 6.3
Habitat diversity was high and a number of sensitive flow dependent taxa were collected including Baetidae (>2spp); Perlidae, Heptageniidae, and Athericidae. The PES of the macroinvertebrate assemblage reflects slightly deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and sedimentation of instream habitats with coinciding water quality problems. This can be seen most clearly in the disappearance of the stoneflies (Perlidae) and the cobble dwelling Chlorocyphid mayflies.

10.4.7 Riparian vegetation (B/C EC, 80.1%)

Marginal zone: This zone is generally close to reference condition, although exotic species (>10% of the species composition) are present (*Ageratum* species mainly). *B. salicina* is present, but should be slightly better represented. The marginal zone is dominated by non-woody vegetation with high levels of overhanging and submerged vegetation. There is a low abundance of woody vegetation, which plays an important role in flood attenuation and overhang (shade and falling leaves) which is important for instream habitat.

Lower zone: The vegetation type is generally as expected on the lower zone, but disturbance (non-flow related) is high (picnic areas, roads) with moderately high levels of vegetation removal. Exotic species also compose about 20% of vegetation (*Lantana camara*, and *Acacia mearnsii*). The lower zone is dominated by woody vegetation (shading) but non-woody vegetation is important for fish breeding sites during floods/higher flows.

Upper zone: Similar to the lower zone, but fewer exotics are present. The upper zone is dominated by woody vegetation, but the non-woody understorey is important for bank stabilization.

10.4.8 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 10.7.

Table 10.7 EWR 1: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	A/B	3	Reduced base flows.	Forestry and abstraction.	F	3
			Small change in seasonal distribution.	Return flows from Sabie town and old mines.	NF	
Physico-chemical	A/B	3	Elevated nutrients from urban activities in Sabie and surrounding areas.	Urban and per-urban fringe, with related impacts such as uncompliant releases from Sewage Treatment Works (STW).	NF	3
			Elevated turbidity levels.	Forestry.		
			Return flows.	Old mines.		
Geomorph	B	3.5	Small changes to the sediment supply.	Forestry activities.	NF	3.5
			Decreased flows due to a reduction in size of the active channel.		F	
			Forestry and abstraction.	Flow reduction.	F	
Rip veg	B/C	3.4	Reduced riparian vegetation cover and abundance.	Exotic species (up to 20% on lower zone), particularly *L. camara* and forest escapees utilize resources (light and space) that would otherwise be used by indigenous riparian species. Physical disturbance such as roads and vegetation removal for past picnic areas.	NF	3.3
			Reduced recruitment which also skews population structure to "older" individuals.			
Fish	B/C	4	Abstraction	Forestry and Sabie town and small scale irrigation.	F	3
			Loss of habitat (decreased fast habitats and overhanging vegetation) diversity as a result of decreased base flows.	Alien vegetation encroachment.	NF	
			Increased sedimentation resulting in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Hillslope erosion related to afforestation.	NF	
Inverts	B	4	Nutrient enrichment and increased turbidity.	Minor return flows from Sabie town and forestry in catchment. Large sawmill and Plywood factory upstream of Sabie town.	NF	3
			Flow reduction.	Abstraction (forestry and Sabie town), small scale irrigation.	F	

10.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 10.8.

Table 10.8 EWR 1: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-Chem	A/B	Stable	A/B	N/A		2
Geom	B	Stable	B	N/A		3

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	B/C	Negative	C	5 - 10 years	Non-flow related impacts (combination of loss of recruitment and exotic invasion) likely to alter woody vegetation component for all vegetation metrics, non-woody vegetation response expected to be more stable.	2.5
Fish	B/C	Stable	B/C	N/A	The fish assemblage in this section have adapted to the altered water quality and flows and should remain fairly stable over the long term should current conditions prevail.	4
Inverts	B	Stable	B	N/A	Macroinvertebrates have adapted to current altered flow and water quality conditions.	2

10.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 10.9. The Instream EC is a B/C (80.2%)

Table 10.9 EWR 1: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3.5	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	70		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	80		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	60		
FISH ECOLOGICAL CATEGORY	13	310	**78.3**	**B/C**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	4	100		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	4	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	3	90		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**11**	290	**82.1**	**B**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		600	**80.6**	**B/C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.50	39.15	
Confidence rating for **macroinvertebrate** information	4	0.50	41.05	
	8	1	80.20	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B/C**	

To determine the EcoStatus, the Vegetation Response Assessment Index (VEGRAI) EC and confidence is included in the EcoStatus assessment index (Table 10.10). The EcoStatus is a B/C (80.15%).

Table 10.10 EWR 1: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**80.1**	**B/C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	4	0.54	43.35
Confidence rating for riparian vegetation zone information	3.4	0.46	36.80
	7.4	1	80.15
ECOSTATUS	**EC**		**B/C**

10.7 B REC

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 1 is **HIGH** and the REC is an improvement of half a category to a B. A full category was not deemed attainable.

In order to achieve the REC the following is required:

- Improving cover linked to riparian vegetation (exotics and forestry activities) which in turn will improve cover for fish.
- Periodic removal of aliens.
- Inactivity of picnic sites.

Each component is adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models for the REC are provided electronically and summarised in Table 10.11.

Table 10.11 EWR 1: B REC

	PES	REC	Comments	Conf
Physico-chem	A/B	A/B	The current scenario will not result in an improvement of the EC.	N/A
Geom	B	B	The current scenario will not result in an improvement of the EC.	N/A

	PES	REC	Comments	Conf
Rip veg	B/C	B	An improved EC due to periodic removal of alien species and a cessation of picnic activities at the site.	3.3
Fish	B/C	B	Improvement of cover in the form of overhanging vegetation and undercut banks (overall riparian condition, decreased alien vegetation) and improved habitat for species preferring slow habitats will result in an improvement of the EC.	4
Inverts	B	A/B	Improving the condition of the marginal zone of the riparian vegetation will provide more habitat for vegetation dwelling macroinvertebrates.	3

10.8 C/D AEC

The scenario includes the following:

- Decreased low flows due to more abstraction.
- Increased sediment.
- Increased nutrient input, turbidity and temperature as a result of decreased low flows.
- Additional toxics.
- Increased presence of alien vegetation, and potentially increased reeds on bars.

Each component is adjusted to indicate the metrics that will react to the scenarios. The rule based models are available electronically and summarised in Table 10.12.

Table 10.12 EWR 1: C/D AEC

	PES	AEC	Comments	Conf
Physico-chem	A/B	B/C	This scenario will cause an overall deterioration in the current EC.	4
Geom	B	C	Increased sediment load due to poor land management in forestry and other upstream landuse activities will result in a C EC due to serious changes in channel morphology and increased bars. Vertical and horizontal channel connectivity will be impacted due to more weirs.	2.5
Rip veg	B/C	C/D	Alien vegetation will increase substantially and the reduced flows and associated sedimentation on the channel floor will result in alluvial bars colonised by reedbeds.	2.5
Fish	B/C	C/D	Decreased low flows will result in reduced fast habitats (riffles, rapids, runs) with a resultant loss or decreased FROC of rheophilic and semi-rheophilic species (VNEL, AURA, CANO, BBRI). Increased sediments and nutrients will reduce quality of habitat in especially riffles and rapids (interstitial spaces) with negative impact on above-mentioned species. Increased temperatures may also affect FROC of species such as TSPA, VNEL, BBRI and BANO. Increased toxins will also have a significant impact as a large proportion of species is intolerant to modified water quality.	4
Inverts	B	C	Increased nutrient enrichment will result in a decrease in the quality of the instream habitat, with potential resultant algal growth and accumulation of fines in the stones in current habitat impacting taxa requiring good quality cobble habitat. Less marginal vegetation will be available for colonization by macroinvertebrates due to lower flows. These changes to the system will reduce the abundance and/or FROC of rheophilic taxa as well as taxa utilizing the marginal vegetation. Certain tolerant taxa may increase in abundance with increased nutrients in the system.	3

10.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results for setting EWR scenarios are summarised in Table 10.13.

Table 10.13 EWR 1: Summary of EcoClassification results

IHI				Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	B/C	RIPARIAN	B/C	HYDROLOGY	A/B		A/B	B/C
				WATER QUALITY	A/B		A/B	B/C
				GEOMORPHOLOGY	B	Stable	B	C
				Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
				FISH	B/C	Stable	B	C/D
				MACRO INVERTEBRATES	B	Stable	A/B	C
				INSTREAM	B/C		B	C
				RIPARIAN VEGETATION	B/C	Negative	B	C/D
				ECOSTATUS	B/C		B	C/D

IHI Hydrology PES	B
Diatoms	B/C

11 EWR 2: AAN DE VLIET (SABIE RIVER)

11.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 11.1.

Table 11.1 EWR 2: Availability of data

Component	Data availability	Conf
Hydrology	The new gauge at Emmet is located just upstream of EWR 2. This is a reliable gauge as it measures low flows and zero flows accurately. A gauging record from 2002 to present is available.	4
Physico-chemical	DWA monitoring data was available for setting reference condition and PES. Limited phytoplankton, periphyton and diatoms was available (n = 1). No DO data was available. Little metal data was available. EC was used instead of aggregated salts as TEACHA could not be used. Limited temperature and turbidity data was available from Weeks *et al.,* 1996.	3
Geomorphology	Historical aerial photography (1944, 1954, 1965, 1974, 1984, 1997). Sediment transport modelling and analysis undertaken for this study. Hydrology records. Site survey information at time of study.	3
Riparian vegetation	Historical aerial photography (1944, 1954, 1965, 1974, 1984, 1997). Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Previous VEGRAI training site. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4
Fish	Single site visit and fish sampling during September 2007. This site is a provincial RHP site with adequate historic and present data available. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park*. Rivers Database (2007): *Database on fish distribution in South African Rivers*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4
Macroinvertebrates	Data and analysis from a single sampling trip to the site on 5 September 2007. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS). Macroinvertebrate data from the Rivers Database.	4

11.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 11.2) was rated as **HIGH** (present), as there are endangered fish and vegetation species present. Species and taxon richness is high, and fish and macroinvertebrate species that are intolerant to flow and flow related water quality changes are present. Diversity of habitats is also very high.

Table 11.2 EWR 2: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*O. peringueyi*, *B. brevipinnis*, *C. swierstrai*, *B. salicina* and tree ferns (protected).
Unique (endemic, isolated, etc.)	3	4	*V. nelspruitensis, C. anoterus, L. polylepis*.
Intolerant (flow & flow related water quality)	4	4	*V. nelspruitensis*, *C. anoterus*, *A. uranoscopus*, *O. peringueyi*, *B. argenteus, C. swierstrai*, Perlidae
Species/taxon richness	4	3	Twenty two fish species, macroinvertebrates.
RIPARIAN & INSTREAM HABITATS			
Diversity of types	3	3	Rapids, riffles, riparian vegetation, anastomosing sections, waterfall, floodplains and backwaters.
Refugia	3	3	Pools.
Sensitivity to flow changes	3	3	Wide shallow riffles.
Sensitivity to flow related water quality changes	3	3	River is a bedrock-boulder system, so sensitive to temperature changes.
Migration route/corridor (instream & riparian)	3	3	Birds.
Importance of conservation & natural areas	2	3	Principle region of plant diversity - Maputoland Pondoland region.
MEDIAN	3		
EIS EVALUATION	**HIGH**		

11.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 11.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 11.3 EWR 2: Reference conditions

Component	Reference conditions	Conf
Hydrology	A good calibration was obtained against a reliable gauge and the water use upstream of the gauge is fairly well understood. There is some uncertainty about the contribution of the A42E catchment. Virgin MAR: 262.11 MCM	4
Physico-chemical	DWA monitoring data was available. Water quality station X3H006Q01 was used to set reference conditions with n = 149, and data available from 1976 – 1979. Refer to Table 11.4.	3
Geomorphology	The 1940's condition of the river (prior to any intensive catchment development) is assumed to represent a component of the natural (reference state) dynamics of the site. At this site, the reference condition would thus range from the current well-wooded banks and bars with associated narrow channel across a range of morphologies which would also include a slightly wider active channel and more open (i.e. less well wooded) channel banks and bars. The larger bedrock exposures downstream would not be covered with sediment. Thus the current condition of the river currently is close to natural. The only anticipated changes from reference state are probably a higher component of fines in the bed material and slightly infilled pools (both due to higher sediment loads from forestry and other disturbed areas in the catchment).	3
Riparian vegetation	**Marginal zone** Dominated by a mixture of reeds *(P. mauritianus*), herbaceous aquatics (ferns, *Cyperus, Persecaria* and *Ludwigia* sp.) and grasses (*Setaria megaphylla,* and *Cynodon dactylon*) (reeds in smaller proportions than herbs and grasses), with fairly high influence from overhanging lower zone trees (*Syzigium* sp and *B. salicina*). Small proportion of the marginal zone will be woody and shady (*B. salicina* and *Syzigium* spp.) mainly. **Lower zone** Tree and shrub dominated vegetation type, fairly dense and shady (*S. cordatum* and *guineense, C. erythrophyllum, F. sycomorus* mainly). **Upper zone** Also tree and shrub dominated, also fairly dense and shady (*Syzigium sp., C. erythrophyllum, T. orieltalis, D. mespiliformis, C. africana, Euclea* and *Anthocleista*	3.5

	species mainly).	
Fish	Twenty two species present. Refer to Table 11.5.	3
Macroinvertebrates	The reference SASS 5 score is 220, with over 30 taxa present and an ASPT of > 7.5. More detail regarding reference taxa is provided below.	3

Detailed physico-chemical reference conditions are provided in Table 11.4.

Table 11.4 EWR 2: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	9.37
	Na_2SO_4	1.19
	$MgCl_2$	0.82
	$CaCl_2$	2.04
	NaCl	6.72
	$CaSO_4$	0.45
Nutrients (mg/L)	SRP	0.007
	TIN	0.12
Physical variables	pH (5^{th}+95^{th} percentiles)	6.46+7.54
	Electrical conductivity (mS/m)	13.16

No specific fish reference information is available for the EWR site or other site in this section of the Sabie River (Kleynhans *et al.,* 2007b). The closest site with reference condition is the NHRP site, X3-Sabi-Brand, which was primarily used to derive the expected reference conditions for fish of EWR 1, higher up in the Sabie River. *Barbus argenteus* was added as this species was previously sampled in this reach (Kleynhans, 1997). The reference condition set for EWR 2 is valid for the Sabie River stretching from below the confluence with the Mac-Mac River to the confluence with the Marite River. This equates to secondary natural resource unit (S NRU) Sabie B.2 downstream of the of Sabie falls. Twenty-two fish species are expected in this section of the Sabie River and are listed in Table 11.5.

Table 11.5 EWR 2: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 2 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	4	2
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	4	4
Barbus argenteus	Rosefin barb	BARG	3	2
Barbus brevipinnis	Shortfin barb	BBRE	4	1
Barbus eutaenia	Orangefin barb	BEUT	5	5
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	4
Labeobarbus polylepis	Smallscale yellowfish	BPOL	5	4
Barbus trimaculatus	Threespot barb	BTRI	5	3
Barbus unitaeniatus	Longbeard barb	BUNI	4	2
Chiloglanis anoterus	Rock catlet	CANO	5	5
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	3	2
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	4	4
Labeo cylindricus	Redeye labeo	LCYL	4	2
Labeo molybdinus	Leaden labeo	LMOL	4	2

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 2 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Micralestis acutidens	Silver robber	MACU	4	3
Marcusenius macrolepidotus	Bulldog	MMAC	4	3
Opsaridium peringueyi	Southern barred minnow	OPER	5	5
Petrocephalus wesselsi	Southern churchill	PWES	4	2
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Tilapia sparrmanii	Banded tilapia	TSPA	4	3
Varicorhinus nelspruitensis	Incomati chiselmouth	VNEL	5	5

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Macroinvertebrate taxa expected under reference conditions are:
Baetidae >2spp, Perlidae, Heptageniidae, Hydropsychidae >2spp, Gyrinidae, Naucoridae, Pleidae, Gomphidae, Caenidae, Tabanidae, Tipulidae, Leptoceridae, Coenagrionidae, Hydroptilidae, Libellulidae, Simuliidae, Hydropsychidae 1sp, Ancylidae, Veliidae, Gerridae, Hydracarina, Athericidae, Philopotamidae, Leptophlebiidae, Chlorocyphidae, Elmidae, Tricorythidae, Muscidae, Belostomatidae, Oligochaeta, Chironomidae, and Turbellaria.

11.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

11.4.1 Hydrology

The present MAR is 193.74 MCM (74% of natural). There has been significant reduction in natural base flows due to afforestation. Significant abstractions and therefore damming in tributaries such as the Sabane and abstractions for domestic use by the town of Sabie upstream of the site contribute to changes in the flow regime whereas the volume of the base flows have been reduced and the seasonal distribution has only undergone a slight change. There have been small changes in frequency and seasonality of moderate and large floods and slight decreases in peak floods.

11.4.2 Geomorphology (B EC, 85.3%)

Although the site where the cross-section is located consists of pools and riffles, the reach also has numerous bedrock anastomosing sections. The site has riffles, vegetated banks and islands, pools and runs, and an extensive floodplain area. A wide floodplain pocket occurs on the southern bank, and thus the site may not be typical of the reach MRU Sabie A as this very wide floodplain section is somewhat atypical. Landscaping/disturbance of the banks have occurred for garden/park creation, and placement of chalets along the river banks. The northern bank is eroding, and the southern bank has likely been engineered, and small scale sand mining has occurred here. The active channel at the site has shrunk, and the riparian zone has become well-wooded. It is likely that the bed material has similarly fined.

11.4.3 Physico-chemical variables (B EC, 87.5%)

The SPI score for this site is 15.3 (good water quality) and current conditions are alkaline eutrophic waters with low oxygen saturation. Biological water quality is therefore a B category. It is expected that the water quality might deteriorate as the effect of upstream land use on this site includes industrial effluent (presence of *Navicula veneta*) and very high levels of pollution (*N. gregaria*, *N. capitatoradiata*, *N. reichardtiana*, and *E. minima*). The community composition indicates increased eutrophication and a general increase in electrolyte content if conditions persist.

Records (2004 – 2007 (n = 77)) from the water quality station X3H006Q01 were used for the PES assessment. The frequency of monitoring was bi-monthly. There are elevated nutrient levels at this site indicating pollution. The site is bedrock dominated so temperature increases are expected at low flows. Due to farming activities in the area pesticide use is expected. PES values for the physico-chemical variables are provided in Table 11.6 and in Appendix C.

Table 11.6 EWR 2: Physico-chemical PES values

Water Quality Constituents		Value: PES
Inorganic salts (mg/L)	$MgSO_4$	11
	Na_2SO_4	0
	$MgCl_2$	10
	$CaCl_2$	9
	NaCl	56
	$CaSO_4$	0
Nutrients (mg/L)	SRP	0.02
	TIN	0.214
Physical variables	pH (5^{th}+95^{th} percentiles)	7.23+7.99
	Electrical conductivity (mS/m)	15.7

11.4.4 Instream and Riparian Habitat Integrity (IIHI: C EC, 76.9%; RIHI: C EC, 77.2%)

EWR 2 falls within the same MRU as EWR 1 (MRU CROC A). The IHI was done for the MRU and the results are therefore the same as for EWR 1 (Section 8.4.4).

11.4.5 Fish (B/C EC, 78.6%)

The PES reflects slightly reduced conditions in terms of habitat and substrate. This is primarily attributed to the reduced flows and increased sedimentation. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution.

11.4.6 Macroinvertebrates (B/C EC, 79.7%)

SASS5 score: 167 No of Taxa: 24 ASPT: 7

This slight decrease in the PES is due to water quality modification as a result of numerous instream trout dams in the upper catchment. Problems associated with this include nutrient enrichment of the water, which results in algal growth on instream habitat, effectively decreasing the availability of habitat for macroinvertebrate colonization. Flow modification and sedimentation are also having a negative impact on the instream habitat and resultant macroinvertebrate colonization. Sensitive flow-dependent taxa collected include >2 spp Baetidae, Perlidae, and Athericidae. The majority of taxa were collected in the stones-in-current (SIC) habitat, followed by

the marginal vegetation habitat. Stones-out-of-current (SOOC) and gravel, sand, mud (GSM) biotopes were sampled in the pool areas.

11.4.7 Riparian vegetation (C EC, 74.3%)

Marginal zone: Is generally close to reference condition, with exotic species abundance 10 - 20% (*Ageratum* and *Nasturtium* mainly i.e. non-woody). *B. salicina* and *S. cordatum* is present and recruiting well in uncleared areas. The zone is dominated by non-woody vegetation with high levels of overhang and submerged vegetation. There is a low abundance of woody vegetation, which plays an important role in flood attenuation and overhang (shade and falling leaves) which is important for instream habitat.

Lower zone: The vegetation type on the lower zone is generally as expected, but disturbance (non-flow related) is high (picnic areas, roads, resort activities) with high levels of vegetation removal including regular mowing. Exotic species also compose about 20% of the vegetation *(L. camara, A. mearnsii, Psidium guava, Ageratum, Canna,* and *Tichonia* spp.). The lower zone is dominated by woody vegetation (shading) but non-woody vegetation dominates a high proportion of the zone due to clearing of woody species.

Upper zone: Similar to the lower zone, but with fewer exotics present. The upper zone is dominated by woody vegetation, but the non-woody understorey is important for bank stabilization. Non-woody vegetation dominates in areas that are regularly cleared/mowed.

11.4.8 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 11.7.

Table 11.7 EWR 2: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	C	4	Reduced flows.	Forestry and abstraction.	F	3
Physico-chem	B	3	Elevated nutrient levels and toxicants.	Forestry and Sabie town and small scale irrigation.	NF	3
Geom	B	3.5	Channel incision/confinement and straightening.	Landscaping/disturbance of the RB have occurred for garden/park creation, and placement of chalets along the river banks and impacts on the floodplain to some extent.	NF	3
			Some slight changes to sediment supply.	Landuse activities (agriculture).		
Rip veg	C	3.2	Reduced riparian vegetation cover and abundance.	Presents of exotic species in the marginal and lower zone (agricultural and forestry escapees mainly). Resort activities especially on RB, and mowing.	NF	3.3
			Reduced recruitment which also skews population structure to "older" individuals.			
Fish	B/C	4	Abstraction.	Forestry and Sabie town and small scale irrigation.	F	3
			Loss of habitat (decreased fast habitats and overhanging vegetation) diversity as a result of decreased base flows.	Alien vegetation encroachment.	NF	

	PES	Conf	Causes	Sources	F/NF	Conf
			Reduced migration success as a result of alteration of natural cues for migration and migration barriers.	Migration barriers (especially Corumanu dam, but also smaller weirs).		
			Potential water quality deterioration at times (diatoms indicate possible pollution events)	Agriculture and lodges.	NF	
			Increased sedimentation result in deterioration of substrate as habitat.	Hillslope erosion related to afforestation.		
Inverts	C	4	Reduction in base flows.	Forestry and irrigation.	F	3
			Change in bed morphology.	Roads, forestry and irrigation.		
			Clearing of right bank and associated erosion.	Roads, forestry and irrigation. Resort activities.	NF	

11.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 11.9.

Table 11.8 EWR 2: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Geom	B	Negative	B/C	10 years	Geomorphology will degrade slowly due to the cumulative effects of forestry and agriculture (likely sedimentation of pools in less steep areas of the reach, etc.).	3
Physico-chem	A/B	Negative	B	5 years	Water quality will deteriorate due to the impact of upstream land use on this site. Diatoms indicate the presence of industrial effluents (*N. veneta*) and high levels of pollution (*N. gregaria*, *N. capitatoradiata*, *N. reichardtiana*, and *E. minima*).	3
Rip veg	C	Negative	C/D	5-10 years	Response due to clearing/mowing is stable since activities will not increase nor decrease, but exotics, if left unchecked will increase in proportion at the expense of indigenous riparian vegetation. Confidence is low since alien clearing activities are unknown.	2
Fish	B/C	Stable	B/C	N/A	The fish assemblage in this section have adapted to the altered water quality and flows and should remain fairly stable over the long term should current conditions prevail.	4
Inverts	B/C	Stable	B/C	N/A	The community is not highly sensitive (despite the presence of a number of high scoring taxa) and appears to have adjusted to existing conditions.	2

11.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrate and fish results must first be combined to determine an instream category (Table 11.10). The Instream EC is a B/C (79.05%)

Table 11.9 EWR 2: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	4.5	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	70		

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	90		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3.5	80		
FISH ECOLOGICAL CATEGORY	15	340	**78.6**	**B/C**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	3	80		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	4	90		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	5	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**12**	270	**79.5**	**B/C**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		610	**79.1**	**B/C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.50	39.30	
Confidence rating for **macroinvertebrate** information	4	0.50	39.75	
	8	1.00	79.05	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B/C**	

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 11.11). The EcoStatus EC is a C (76.94%).

Table 11.10 EWR 2: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**74.3**	**C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	4	0.56	43.92
Confidence rating for riparian vegetation zone information	3.2	0.44	33.02
	7.2	1.00	76.94
ECOSTATUS	**EC**		**C**

11.7 B REC

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 2 is **HIGH** and the REC is an improvement of a full category to a B.

Although an improvement in flows is not required, a number of non-flow related interventions should be undertaken in order to improve the current state, this scenario includes:

- Improving cover linked to riparian vegetation (exotics and forestry activities) which in turn will improve cover for fish.
- Periodic removal of alien riparian vegetation. Mowing in the riparian zone at Aan de Vliet Resort must cease and a reduction of recreational disturbances is needed.
- An improvement in the nutrient status of the river.

Each component is adjusted to indicate the metrics that will react to the REC scenario. The changes in the rule based models for the REC are provided electronically and summarised in Table 11.12.

Table 11.11 EWR 2: REC B

	PES	REC	Comments	Conf
Physico-chem	B	A/B	An improvement in land use, will improve the nutrient status which will result in an overall improvement to an A/B EC.	3
Geom	B	B	Maintain the current EC.	N/A
Rip veg	C	B	To improve the EC, exotic vegetation must be selectively removed on the lower and upper zones. Current exotics on the marginal site are non-woody and therefore difficult to control. Vegetation removal and mowing within the riparian zone and recreational activities should be reduced in intensity but importantly also in extent i.e. areas within the riparian zone, especially on the floodplain.	2.8
Fish	B/C	B	Improved riparian zone (marginal) conditions with adequate natural overhanging vegetation will improve conditions for species with high requirement for this habitat (slow shallow and deep with overhanging vegetation) such as BBRI, BTRI and BUNI.	4
Inverts	B/C	B	Improving the condition of the marginal zone of the riparian vegetation will provide more habitat for vegetation dwelling macroinvertebrates resulting in the return of a number of molluscs as well as Aeshnidae and Atyidae.	3

11.8 C/D AEC

The scenario includes the following:

- Decreased low flows due to more abstraction. This will lead to more return flows and impact water quality.
- Increased sediment, nutrient input, turbidity and temperature as a result of decreased low flows and additional toxics.

- Increased alien vegetation and bush clearing due to mismanagement in terms of forestry and agriculture.

Each component is adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models for the AEC are provided electronically and summarised in Table 11.13.

Table 11.12 EWR 2: Alternative C/D EC

	PES	AEC	Comments	Conf
Physico chem	B	C	Increased pesticide use due to farming activities will lead to elevated nutrient levels and toxics. Due to reduced flows and increased sediment load, an increase in temperature and decrease in oxygen is expected.	4
Geom	B	C	Sedimentation would increase and flood frequency will be reduced due to increased abstraction.	2
Rip veg	C	D	Alien vegetation will increase substantially, with associated reductions in indigenous riparian species cover, abundance and recruitment. With less recruitment, over time populations will become skewed toward older individuals and proportions of species in the assemblage will change and expected species will be less well represented.	3.1
Fish	B/C	C/D	Deteriorated water quality will result in decreased FROC of species with requirement for high water quality, such as AURA, BARG, BEUT, CANO, and OPER. Decreased low flows (lower water levels) will lead to a loss in habitat diversity during these periods (reduction in riffle/rapid areas, decreased overhanging vegetation as cover as a result of decreased water level not reaching the edge of stream) with a resultant decrease in FROC for species preferring riffle/rapid/run (fast) habitats (AURA, BARG, BEUT, BMAR, BPOL, CANO, CPAR, OPER, and VNEL) and with high requirement for overhanging vegetation (BEUT, MMAC, PPHI, and TSPA).	4
Inverts	B/C	C	Increased sedimentation will result in a decrease in the quality and quantity of the cobble habitat. Decreased flows will result in less available vegetation habitat. As a result of these changes the more sensitive taxa inhabiting these biotopes will occur less frequently.	3

11.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results for setting EWR scenarios are summarised in Table 11.14.

Table 11.13 EWR 2: Summary of EcoClassification results

IHI				Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	C	RIPARIAN	C	HYDROLOGY	C		B/C	D
				WATER QUALITY	B	Negative	A/B	C
				GEOMORPHOLOGY	B	Negative	B	C
				Response Components	PES Category	Trend	REC	AEC↓
				FISH	B/C	Stable	B	C/D
				MACRO INVERTEBRATES	B/C	Stable	B	C
				INSTREAM	B/C		B	C
				RIPARIAN VEGETATION	C	Negative	B	D
				ECOSTATUS	C		B	C/D

IHI Hydrology PES	B
Diatoms	B

12 EWR 3 KIDNEY (SABIE RIVER)

12.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 12.1.

Table 12.1 EWR 3: Availability of data

Component	Data availability	Conf
Hydrology	There is no reliable gauge for this site. Gauge X3H021 is located approximately 25 km downstream of the site but this gauge is missing data (> 12%) and is reportedly not calibrated correctly due to the addition of a fish ladder. The gauge record from 1990 to present is available.	3
Physico-chemical	DWA monitoring data was available for reference condition and PES, although data for present state was only available up to 1999. Limited phytoplankton, periphyton and diatoms was available (n = 1). No temperature, DO or turbidity data was available. Little metal data was available. EC was used instead of aggregated salts as TEACHA could not be used.	2.5
Geomorphology	Historical aerial photography (1956, 1964, 1970, 1997). Sediment transport modelling and analysis undertaken for this study. Hydrology records. Site survey information at time of study, and previous cross-sectional surveys over the last 15 years (from unpublished PhD research and KNP River Research Programme).	5
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1956, 1964, 1970, 1997. 1996 IFR site information (Godfrey, 2002). Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Numerous postgraduate studies on the Sabie especially inside KNP (Appendix H).	5
Fish	Single site visit and fish sampling during September 2007. Rivers Database (2007): *Database on fish distribution in South African Rivers*. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* 1996 IFR site information (Godfrey, 2002).	4
Macroinvertebrates	Data and analysis from a single sampling trip during September, 2007. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS). 1996 IFR site information (Godfrey, 2002).	4

12.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 12.2) was rated as **VERY HIGH** (present), as there are a high occurrence of endangered fish, vegetation tree species and herpetofauna. Species and taxon richness is very high and there is a high occurrence of species that are intolerant to flow and flow related water quality changes. The site serves as refuge area for biota and is an important migration corridor for birds and fish. This site falls within the Kruger National Park and is an Ecotone between the Lowveld and Highlands. This site also falls within the Maputoland Pondoland vegetation region which is a principle region of plant diversity.

Table 12.2 EWR 3: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*O. peringueyi*, *Serranochromus meridianus*, *C. swierstrai*, crocodiles, *B. salicina*, Birds, *Balanites maughamii* (Green thorn tree).
Unique (endemic, isolated, etc.)	1	4	*C. anoterus*.
Intolerant (flow & flow related water quality)	4	4	*C. swier*strai, *O. peringueyi*, *B. eutaenia*, *A. uranoscopus*, Perlidae.
Species/taxon richness	4	4	Thirty four fish spp. and macroinvertebrates. Principal region of plant diversity - Maputoland/Pondoland.
RIPARIAN & INSTREAM HABITATS			
Diversity of types	3	3	Pools, riffles, rapids, braided bedrock, anastomosing sections, and riparian vegetation.
Refugia	4	4	Kruger National Park.
Sensitivity to flow changes	2	3	
Sensitivity to flow related water quality changes	2.5	3	Temperature due to bedrock.
Migration route/corridor (instream & riparian)	4	4	Ecotone - Lowveld and Highlands, cold finger, *Hydrocinus vittatus*, eels.
Importance of conservation & natural areas	4	4	Kruger National Park.
MEDIAN	4		
EIS EVALUATION	**VERY HIGH**		

12.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 12.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 12.3 EWR 3: Reference conditions

Component	Reference conditions	Conf
Hydrology	The gauge does not measure low and zero flows accurately and the completion of the Inyaka Dam in 2000 should have changed the hydrology at this site. Virgin MAR: 495.86 MCM.	3
Physico-chemical	DWA station X3H006Q01 was used; n = 149, 1976 – 1979. Refer to Table 12.4.	3
Geomorphology	This is a very well-studied site within the Kruger National Park. The site has representative sections of the bedrock anastomosing channel type. Although from 1944 until 1984, there was a very strong trend of increasing extent of woody vegetation, this trend was reversed following an extreme flood in February 2000. Thus the post – 2000 imagery appears very similar to the earliest 1944 imagery – the system has been "reset" by the 2000 flood, as has the 1944 image following the similarly large 1921 flood. The degrees of changes recorded by this sequence of aerial photography record a commonly identified pattern of sediment storage within Southern African eastern seaboard river (Rountree *et al*., 2000; Rountree *et al*., 2001; Rountree and Rogers, 2004). Sediment (and vegetation) accumulates in river systems over a period of decades and then this is removed when large infrequent flood events occur.	4
Riparian vegetation	**Marginal zone** Sections that are characterised by unconsolidated alluvia will tend to be dominated by reedbeds (*P. mauritianus*); while sections characterised by cobble/boulder or exposed bedrock will tend to be dominated by grasses (*C. dactylon*) and herbaceous aquatics (*Cyperus* sp, *Persecaria* sp, *and Ludwigia* sp). A small proportion of the marginal zone will be woody (*Breonadia* and *Syzigium* spp. mainly). **Lower zone** Mix of tree and shrub dominated vegetation (*B. salicina, S. cordatum* and *guineense, and Nuxia oppositifolia* mainly) where substrates tend to be more rocky or consolidated. Reeds/open sand (*P. mauritianus*) occurs where substrates tend to be unconsolidated. **Upper zone**	4

Component	Reference conditions	Conf
	Tree and shrub dominated mainly (*C. erythrophyllum, F. sycomorus,* and *D. mespiliformis* with some *Spirostachys africana* expected in localised pockets*).*	
Fish	Thirty five species present. Refer to Table 12.5.	4
Macroinvertebrates	The reference total SASS 5 score is 220, with over 32 taxa and an ASPT of >7. More detail regarding reference taxa is provided below.	3

Detailed physico-chemical reference conditions are provided in Table 12.4.

Table 12.4 EWR 3: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	$MgSO_4$	9.37
	Na_2SO_4	1.19
	$MgCl_2$	0.82
	$CaCl_2$	2.04
	NaCl	6.72
	$CaSO_4$	0.45
Nutrients (mg/L)	SRP	0.007
	TIN	0.12
Physical variables	pH (5^{th}+95^{th} percentiles)	6.46+7.54
	Turbidity (NTU)	-
	Electrical conductivity (mS/m)	13.16

The fish reference condition information, as set for the NRHP site X3-SABI-SEKUR (Kleynhans *et al*., 2007c) is directly applicable to EWR 3. The reference condition set, in the context of this study, is valid for the Sabie River within secondary NRU Sabie C.1. Thirty five fish species can be expected in this section of the Sabie River under natural conditions. Expected species are listed in Table 12.5.

Table 12.5 EWR 3: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 3 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	2	1
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	1	1
Barbus annectens	Broadstriped barb	BANN	3	3
Barbus argenteus	Rosefin barb	BARG	1	0
Barbus eutaenia	Orangefin barb	BEUT	4	4
Barbus afrohamiltoni	Hamilton's barb	BFRI	1	1
Brycinus imberi	Imberi	BIMB	1	1
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	5
Barbus paludinosus	Goldie barb	BPAU	2	2
Barbus radiatus	Beira barb	BRAD	3	3
Barbus toppini		BTOP	1	1
Barbus trimaculatus	Threespot barb	BTRI	4	4
Barbus unitaeniatus	Longbeard barb	BUNI	4	4
Barbus viviparous	Bowstripe barb	BVIV	5	5
Chiloglanis anoterus	Rock catlet	CANO	4	4
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	4	3

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 3 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	4	4
Hydrocynus vittatus	Tigerfish	HVIT	1	1
Labeo congoro	Purple labeo	LCON	2	2
Labeo cylindricus	Redeye labeo	LCYL	5	5
Labeo molybdinus	Leaden labeo	LMOL	5	5
Labeo rosae	Rednose labeo	LROS	4	4
Micralestis acutidens	Silver robber	MACU	5	5
Mesobola brevianalis	River sardine	MBRE	5	5
Marcusenius macrolepidotus	Bulldog	MMAC	4	3
Oreochromus mossambicus	Mozambique tilapia	OMOS	5	5
Opsaridium peringueyi	Southern barred minnow	OPER	5	4
Petrocephalus wesselsi	Southern churchill	PCAT	2	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Schilbe intermedius	Silver catfish	SINT	4	3
Serranochromus meridianus	Lowveld largemouth	SMER	5	4
Synodontis zambezensis	Brown squeaker	SZAM	1	1
Tilapia rendalli	Redbreast tilapia	TREN	5	5
Tilapia sparrmanii	Banded tilapia	TSPA	2	2

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Macroinvertebrate taxa expected under reference condition include:
Baetidae >2spp, Helodidae, Pyralidae, Perlidae, Heptageniidae, Naucoridae, Pleidae, Gomphidae, Caenidae, Tabanidae, Tipulidae, Ceratopogonidae, Leptoceridae, Coenagrionidae, Hydroptilidae, Libellulidae, Simuliidae, Hydropsychidae 2spp, Veliidae, Hydracarina, Philopotamidae, Athericidae, Aeshnidae, Leptophlebiidae, Chlorocyphidae, Elmidae, Tricorythidae, Muscidae, Corixidae, Notonectidae, Belostomatidae, Oligochaeta, Chironomidae, Hirudinea, Potamonautidae, Thiaridae, and Planorbinae.

12.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

12.4.1 Hydrology

The present MAR is 333.06 MCM (67% of natural). There has been a significant reduction in natural base flow due to afforestation and irrigation. The volume of the base flows has reduced and the seasonal distribution has changed slightly. Moderate flood frequencies have decreased due to the Inyaka Dam and there has been a slight decrease in large flood frequency (flood peaks) due to afforestation and Inyaka Dam.

12.4.2 Geomorphology (B EC, 84.6%)

The site is a bedrock anastomosing channel form type with steep slopes; multiple channels with high bedrock influence and large mixed alluvial and bedrock core bars in between the several active channels. The channels are diverse, having bedrock, boulder, cobbles, gravels and sandy

sections. The bedrock core bars (usually dominated by *B. salicina*) separate the channels. At the downstream end of this section there are large sandy lateral bars. These are high elevation, stable macro-channel features.

The site is located downstream of Hazyview, and this section of the river forms on border of the Kruger National Park. There is one dam upstream, but floods are only moderately affected.

Although the site is in a B category, the reach is likely to be in a lower (lower B or B/C) category. This is because the bedrock anastomosing channel type (in which this EWR site is located) is the least sensitive of all channel types to sedimentation. Sedimentation is the primary problem in this section of the river, due to the increased erosion and decreased flows arising from upstream.

It is in the narrow sections of the river, characterised by braided and pool-rapid channel types, where sediment is preferentially deposited and stored. This increase in sediment storage results in the loss of exposed bedrock areas and riffles, as well as deep pools, causing a decrease in the instream habitat diversity as the sites all tend towards sandy shallow systems. Therefore the confidence in the PES assessment is a 4.

12.4.3 Physico-chemical variables (B EC, 84.91%)

The SPI indicates good water quality (Score: 14.5), although this falls within the lower ranges of the classification and the diatom based ecological classification indicates low oxygen saturation and alkaline conditions. Overall the biological water quality is in a B category but the high flows (1.3 m^3/s on day of sampling) may have had a dilution effect as there are species present that are very pollution tolerant and indicators of eutrophic conditions.

Records (1991 – 1999 (n = 39)) from the water quality station X3H006Q01 were used for the PES assessment. There are indications of some enrichment and pollution upstream of the KNP. Elevated turbidity levels can be expected due to catchment activities and although the site falls within the Kruger National Park some toxics are expected due to extensive citrus cultivation and urban activities upstream. Low flows will result in changes to temperature and oxygen. PES values for the physico-chemical variables are provided in Table 12.6 and in Appendix C.

Table 12.6 EWR 3: Physico-chemical PES values

Water Quality Constituents		Value: PES
Inorganic salts (mg/L)	$MgSO_4$	-
	Na_2SO_4	-
	$MgCl_2$	-
	$CaCl_2$	-
	NaCl	-
	$CaSO_4$	-
Nutrients (mg/L)	SRP	0.01
	TIN	0.175
Physical variables	pH (5^{th}+95^{th} percentiles)	7.11+8.44
	Turbidity (NTU)	Mean: 12.5 NTU 95^{th} percentile: 53 NTU
	Electrical conductivity (mS/m)	14.71

12.4.4 Instream and Riparian Habitat Integrity (IIHI: B/C EC, 81.5%; RIHI: B/C EC, 80.1%)

The IIHI EC is due to a reduction in flows caused by upstream abstraction and land use activities impacting on sedimentation and water clarity. A change in the moderate floods due to abstraction, forestation and Inyaka Dam are the driving factors for the RIHI assessment. Erosion and substrate exposure in the non-marginal zone due to land use activities are evident at this site.

12.4.5 Fish species (B EC, 85.6%)

The PES reflects slightly reduced conditions, primarily attributed to the reduced flows, increased sedimentation and increased algal growth. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution. The presence of a conservation area (KNP) improves the ecological integrity of this section and limits local catchment impacts.

12.4.6 Macroinvertebrates (B EC, 86.9%)

SASS5 score: 203 No of Taxa: 32 ASPT: 6.3

The PES of the macroinvertebrate assemblage reflects a slightly deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and sedimentation of instream habitats with coinciding water quality problems. This can be seen most clearly in the disappearance of cobble dwelling taxa preferring faster velocities such as the Tricorythid mayflies. The MIRAI metrics indicates that the main reason for the altered macroinvertebrate conditions are seasonality and connectivity (74.1%) and to a lesser degree a deterioration in water quality (88.4%). Habitat diversity was high and a suite of sensitive flow dependent taxa were collected in SIC, MV and SOOC habitat which included Athericidae, Helodidae, Pyralidae, Chlorocyphidae, Heptageniidae, Perlidae and Hydracarina.

12.4.7 Riparian vegetation (A/B EC, 89.3%)

Marginal zone: The condition of this zone is close to reference condition, with exotic species present at <10% (*Ageratum* mainly i.e. non-woody). Some vegetation has been removed as a result of the small unnatural component of flooding during 2000. This zone is dominated by a non-woody component that includes a mix of reedbeds and grass/herb areas.

Lower zone: Vegetation is close to expected, with < 10% exotic invasion that consists of woody (*Lantana* and *Sesbania* spp. mainly) and non-woody (*Ageratum* spp. and mexican sunflower mainly) components. The lower zone is dominated by both woody (trees) and non-woody (reeds) vegetation patches.

Upper zone: The upper zone is similar to the lower zone, also with < 10% exotic invasion that consists of woody (*Lantana* and *Sesbania* spp. mainly, and some *Melia* spp.) and non-woody (*Ageratum* spp. and mexican sunflower mainly) components. The upper zone is dominated by woody vegetation, which is on the increase. This is a natural trajectory for this site following the large flooding disturbance during 2000.

12.4.8 PES causes and sources

The PES for the components at EWR 3 as well as the reasons for the PES are summarised in Table 12.7.

Table 12.7 EWR 3: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	C	3	Reduced base flows, moderate floods and frequency of large floods.	Forestation, abstraction and Inyaka Dam.	F	3
Physico-chem	B	2.5	Elevated nutrient levels, turbidity and temperatures. Drop in oxygen levels.	Poor land management outside the KNP. Urban and rural activities outside the KNP. Changes in flow.	NF	4
Geom	B	4	Increased sediment supply – increased fines and deposition, loss of pools.	Intensive settlement (extensive peri-urban areas with large bare areas) and heavy grazing pressures. Extensive forestry and poor landuse in lower catchment as well as erosion.	NF	3
			Decreased flows – reduced sediment transport potential.	Forestry; irrigation, and abstraction.	F	
Rip veg	A/B	4	Reduced riparian vegetation cover and abundance.	Exotic vegetation.	NF	3.5
				Small unnatural component of 2000 floods due to increased velocity volume from cleared upstream areas.	F	
Fish	B	4	Abstraction.	Forestry and Sabie town and small scale irrigation.	F	3
			Reduced migration success as a result of alteration of natural cues for migration and presence of migration barriers.	Migration barriers (especially Corumanu Dam, but also smaller weirs, up- and downstream and within the reach).		
			Loss of habitat (decreased fast habitats and overhanging vegetation) diversity as a result of decreased base flows.	Alien vegetation encroachment.	NF	
			Increased sedimentation and excessive algal growth result in deterioration of substrate as habitat and loss of deep habitats.	Hillslope erosion related, especially attributed to small-scale farming on one bank and increased nutrients.		
Inverts	B	4	Increased turbidity.	Land-use.	NF	3
			Sedimentation.			
			Reduction in flow.	Upstream abstractions, Inyaka Dam.	F	
			Altered high flows (moderate floods).	Forestry, abstraction, Inyaka Dam.		

12.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 12.8.

Table 12.8 EWR 3: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico- chemical	High B	Negative	Low B	5 yrs	The presence of pollutant tolerant species e.g. *E. minima*, *N. frustulum*, *N. capitatoradiata* and *S. seminulum* indicate pollution problems and the Mkuhlu township upstream from this site may be the main source of these pollutants. This is supported by the presence of *A. minutissima var. saprophila* which indicates enrichment and favours eutrophic water. However, the overall water quality seems stable, depending on the periods of low flows not increasing in frequency.	3

	PES	Trend	Trend PES	Time	Reasons	Conf
Geom	B	Negative	B/C	10 years	Increased sediment and decreased transport capacity will continue to cause aggradation and loss of bedrock influence. Although this particular site is not very sensitive to sedimentation, other sections of the river (immediately up- and downstream) would show the effects of sedimentation, and loss of habitat diversity, more quickly.	3.5
Rip veg	A/B	Stable	A/B	N/A	Exotics, if left unchecked would increase in proportion at the expense of indigenous riparian vegetation, but the actions of Working for Water inside KNP appear to be ongoing and frequent enough to stabilise the site. Stability does however depend on the continued action of Working for Water.	2.5
Fish	B	Stable	B	N/A	The fish assemblage in this section have adapted to the altered water quality and flows and should remain fairly stable over the long term should current conditions prevail.	4
Inverts	B	Stable	B	N/A	Invertebrate community composition and abundance suggests that the taxa present have adjusted to current conditions in the catchment and the reduction in flows.	3

12.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrate and fish results must first be combined to determine an instream category (Table 12.9). The Instream EC is a B (86.16%).

Table 12.9 EWR 3: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3.5	80		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4.5	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	70		
FISH ECOLOGICAL CATEGORY	15	340	**85.6**	**B**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	4	100		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	4	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	4	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**12**	300	**86.9**	**B**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		640	**86.4**	**B**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.57	48.91	
Confidence rating for **macroinvertebrate** information	3	0.43	37.24	
	7	1.00	86.16	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B**	

To determine the EcoStatus, the VEGRAI EC and confidences are added to the equation (Table 12.10). The EcoStatus EC is an A/B (87.76%).

Table 12.10 EWR 3: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**89.3**	**A/B**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	3.57143	0.49	42.32
Confidence rating for riparian vegetation zone information	3.7	0.51	45.44
	7.27143	1.00	87.76
ECOSTATUS	**EC**		**A/B**

12.7 A/B REC

The REC is determined based on ecological criteria only and considers the EIS and the restoration potential and attainability there-of.

The EIS at EWR 3 is **VERY HIGH.** As the PES is also relatively high, the attainable and realistic objective is to maintain the PES even though a high EIS would normally warrant improvement.

12.8 B/C AEC

The scenario includes the following:

- Increased abstractions and no Reserve implementation.
- Less floods due to more use from Inyaka Dam.
- Change in flows will cause increased nutrients and turbidity (also from land use), changes in temperature, oxygen etc. The riffles will be lost due to sedimentation (not at the cross-section, but upstream and downstream) and the instream channel will become shallower.

Each component is adjusted to indicate the metrics that will react to the scenarios to achieve an AEC. The changes in the rule based models are available electronically and summarised in Table 12.11.

Table 12.11 EWR 3: B/C AEC

	PES	AEC	Comments	Conf
Physico-chem	B	C	Decreased flows will cause an increase in oxygen and temperature. Poor land management outside the KNP will lead to higher nutrient and turbidity levels.	4
Geom	B	C	Increased sedimentation, particularly in the braided and pool-rapid channel type sections of this reach. Habitat changes will include more extensive reeds, shallower channels and a loss of deep pools and bedrock rapids and riffles.	3
Rip veg	A/B	B/C	Alien vegetation will increase unabated. This will result in slightly reduced woody cover and abundance and a subsequent change in species composition. Increased sedimentation and the loss of bedrock habitat which will result in a loss of *Breonadia* recruitment and a subsequent change in population structure. Sedimentation will also facilitate reed colonisation and expansion (especially of the marginal zone), and an increase in cover and abundance on the lower zone.	3
Fish	B	C	Rheophilic and semi rheophilic species, with a preference for FS and FD habitats and species that are intolerant to no flow conditions (BEUT, BMAR, CANO, CSWIE, LCYL and OPER) will be affected. Decreased water quality will further affect species intolerant to water quality change (e.g. BEUT, CANO, OPER, MACU and MMAC). Deterioration of substrates (increased sediment) will further decrease FROC of species with high preference for this habitat (BMAR, CANO, and CPAR). Loss of SD habitats will decrease FROC of LCON and SINT.	3
Inverts	B	C	Increased sedimentation will lead to cobbles becoming more embedded, resulting in decreased habitat availability. The lower flows and increased return flows are likely to lead to higher nutrient levels and increased temperatures which will result in increased algal growth reducing available habitat even further. A number of the more sensitive taxa such as Helodidae, Pyralidae and the more sensitive species of Baetidae and Hydropsychidae will disappear and other less sensitive cobble dwelling taxa will occur less frequently.	3

12.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results to be used for setting of EWR scenarios are summarised in Table 12.12.

Table 12.12 EWR 3: Summary of EcoClassification results

IHI				Driver Components	PES & REC Category	Trend	AEC?
INSTREAM	B	RIPARIAN	B	HYDROLOGY	C		C/D
				WATER QUALITY	B		C
				GEOMORPHOLOGY	B	Negative	C
				Response Components	PES & REC Category	Trend	AEC?
				FISH	B	Stable	C
				MACRO INVERTEBRATES	B	Stable	C
				INSTREAM	B		C
				RIPARIAN VEGETATION	A/B	Stable	B/C
				ECOSTATUS	A/B		B/C

IHI Hydrology PES	B
Diatoms	B

13 EWR 4 MAC MAC (MAC MAC RIVER)

13.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 13.1.

Table 13.1 EWR 4: Availability of data

Component	Data availability	Conf
Hydrology	Gauge X3H003 is located approximately 25 km upstream of the site, but this is too far upstream relative to the catchment size to reliably represent the flow at the site. The gauge does however appear to be relatively reliable with few data gaps and measures low and zero flows accurately. The gauge record from 1948 to 2006 is available.	3
Physico-chemical	DWA monitoring data was available for reference condition and PES. Limited phytoplankton, periphyton and diatoms was available (n = 1). No temperature, DO or turbidity data was available. Little metal data was available. Electrical conductivity (EC) was used instead of aggregated salts as TEACHA could not be used.	3
Geomorphology	Historical aerial photography (1944, 1954, 1965, 1974, 1984, 1996). Site survey information at time of study. Daily flow data is required to undertake sediment (potential bed material) transport modelling so that effective discharge classes can be determined. At this site, no daily hydrological data were available – the nearest flow gauge is too far away to be used with any confidence to represent the flows at this site.	3
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1944, 1954, 1965, 1974, 1984, 1996. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4
Fish	Single site visit and fish sampling during September 2007. Rivers Database (2007): *Database on fish distribution in South African Rivers*. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	3
Macroinvertebrates	Data and analysis from a single sampling trip during September, 2007. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	3

13.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 13.2) was rated as **HIGH** (present), as there are a high occurrence of rare and endangered fish, and tree species. Fish and macroinvertebrate species that are intolerant to flow and flow related water quality are also present.

Table 13.2 EWR 4: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*O. peringueyi, B. brevipinnis, B. salicina*, tree ferns, and a poorly protected vegetation type (Maputoland-Pondoland).
Unique (endemic, isolated, etc.)	3	4	*V. nelspruitensis*, *C. anoterus*.
Intolerant (flow & flow related water quality)	4	4	*V. nelspruitensis*, *C. anoterus*, *A. uranoscopus*, *O. peringueyi*, *B. brevipinnis*, *B. eutaenia* and Perlidae.
Species/taxon richness	3	4	Twelve fish species, macroinvertebrates, and principal region of plant diversity (Maputoland-Pondoland).
RIPARIAN & INSTREAM HABITATS			
Diversity of types	3	3	Rapids, riffles, riparian vegetation, waterfall.
Refugia	3	3	
Sensitivity to flow changes	3	3	Depth related.
Sensitivity to flow related water quality changes	3	3	Bedrock section, temperature sensitive.
Migration route/corridor (instream & riparian)	3	3	Birds, macroinvertebrates.
Importance of conservation & natural areas	2	3	Protected area within forestry.
MEDIAN	3		
EIS EVALUATION	**HIGH**		

13.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 13.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 13.3 EWR 4: Reference conditions

Component	Reference conditions	Conf
Hydrology	There were no major differences between observed and modelled hydrology. Virgin MAR: 65.78 MCM	3
Physico-chemical	DWA monitoring data: X3H003Q01; n = 48, 1977 – 1979. Refer to Table 13.4.	2.5
Geomorphology	From the aerial photographs, there appears to have been an increase in woody vegetation. The channel and areas of exposed bedrock which were evident in 1944 are again evident in the 2006/7 Google Earth imagery (which represents the site post the large floods in 2000). Overall, however, the site is very close to the natural condition.	3.5
Riparian vegetation	**Marginal zone** This section of the river occurs in hilly, steep sided area. The marginal zone will therefore tend to be dominated by a mix of open rocky/cobble/boulder areas and non-woody vegetation (grasses such as *Setaria sphacelata*, and herbaceous aquatics such as *Cyperus*, *Schoenoplectus*, and *Juncus* spp.). A small proportion of the marginal zone will be woody (*Breonadia* and *Syzigium* spp. mainly), but the marginal zone will be largely shady due to extensive overhang from lower zone woody vegetation. Water will therefore have lower temperatures and high amounts of leaf litter. **Lower zone** Mix of tree and shrub dominated vegetation (*B. salicina, S. cordatum, C. africana, Anthocleista* spp. mainly) typical of kloof areas, and open exposed bedrock areas. **Upper zone** Typical kloof vegetation, tree and shrub dominated mainly *C. africana, Anthocleista, Ficus sp., Erythrina,* and *Bequaertiodendron* spp.	3.5
Fish	Twelve species present. Refer to Table 13.5.	3
Macroinvertebrates	The reference range for the site is SASS 5 scores of 270, with >35 taxa and an ASPT of > 7.3. More detail regarding reference taxa is provided below.	3

Detailed physico-chemical reference conditions are provided in Table 13.4.

Table 13.4 EWR 4: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.011
	Total Inorganic Nitrogen (TIN)	0.25
Physical variables	pH (5^{th}+95^{th} percentiles)	6.5+7.5
	Electrical conductivity (mS/m)	14.5

No specific fish reference condition information is available for the EWR 4 (Kleynhans *et al*., 2007b). The closest site with reference condition information is site X3MACM-BRAND closer to the confluence of the Mac Mac and Sabie River. This reference condition was primarily used to derive the expected reference conditions for fish with emphasis being placed on the fish species that can be expected in habitat compositions in the vicinity of site EWR 4. The reference NRHP site X3MACM-BRAN is very close to the confluence of the Sabie River and may be influenced by some fish species from the Sabie River that frequent the lower reaches of the Mac Mac river from time to time, but does not necessarily utilise the entire reach (within EcoRegion 4.04) of the Mac-Mac River. The reference condition set, is valid for the Mac-Mac River falling within EcoRegion 4.04. Twelve fish species are expected to have inhabited this section of the river under natural condition and are listed in Table 13.5.

Table 13.5 EWR 4: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 4 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	4	2
Amphilius natalensis	Natal mountain catfish	ANAT	1	1
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	4	4
Barbus brevipinnis	Shortfin barb	BBRI	4	2
Barbus eutaenia	Orangefin barb	BEUT	5	4
Labeobarbus polylepis	Smallscale yellowfish	BPOL	1	1
Chiloglanis anoterus	Rock catlet	CANO	5	5
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Opsaridium peringueyi	Southern barred minnow	OPER	5	3
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Tilapia sparrmanii	Banded tilapia	TSPA	4	3
Varicorhinus nelspruitensis	Incomati chiselmouth	VNEL	5	5

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Taxa expected under reference condition include:

Porifera, Turbellaria, Oligochaeta, Potamonautidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Tricorythidae, Chlorocyphidae, Coenagrionidae, Aeshnidae, Gomphidae, Libellulidae, Gerridae, Nepidae, Notonectidae, Hydropsychidae 2spp, Hydropsychidae >2spp, Philopotamidae, Leptoceridae, Elmidae, Gyrinidae, Helodidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, and Planorbinae.

13.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

13.4.1 Hydrology

The present MAR is 51.54 MCM (78% of natural). There has been a significant reduction in natural base flows due to afforestation. The volume of the base flows has been reduced and the seasonal distribution has been slightly altered. These changes are continual throughout the year. Moderate flood frequency has decreased and there has been a slight decrease in large flood frequency (flood peaks) due to afforestation.

13.4.2 Geomorphology (A EC, 93.01%)

The site is a pool-rapid section with boulder, cobble covered bed, with extensive bedrock exposure. Very large *B. salicina* trees are located in the upper terrace of this site (which appears to follow an old seasonal or backwater channel at the edge of the macro-channel). No paired terraces are present and the terrace upon which the *B. salicina* are currently growing may be an old bedrock core bar which has become bank-attached. The site is close to natural.

13.4.3 Physico-chemical variables (A/B EC, 89.32%)

The SPI index indicates moderate water quality (Score: 14), with well oxygenated slightly to moderate polluted eutrophic water. The diatom water quality is in a B category, but the diatom community shows traces of the onset of severe water quality impacts with the presence of *E. minima*, *N. veneta*, *N. tenelloides*, *N. frustulum* and *N. palea*. The presence of pollution tolerant species indicates increased eutrophication and pollution due to Graskop WWTW and deteriorating water quality conditions.

Records (2004 - 2007 (n = 56)) from water quality station X3H003Q01 was used to determine the PES. Elevated nutrient levels are present, probably due to the output from Graskop WWTW. As the system is boulder-bedrock dominated elevated temperatures are expected, although most of the channel is well-shaded. Toxicants are not presently a problem at this site and Venus sawmill is not expected to contribute much to toxicity although the physical impacts of wood-chips layering the streambed should be guarded against. PES values for the physico-chemical variables are provided in Table 11.6 and in Appendix C.

Table 13.6 EWR 4: Physico-chemical PES values

Water Quality Constituents		Value: PES
Nutrients (mg/L)	SRP	0.013
	TIN	0.28
Physical variables	pH (5^{th}+95^{th} percentiles)	7.2+7.9
	Electrical conductivity (mS/m)	15.43

13.4.4 Instream and Riparian Habitat Integrity (IIHI: B EC, 83.2%; RIHI: A/B EC, 89.3%)

Decreased base flows, deteriorating water quality (nutrients) and non-marginal bank modification is caused by forestry and Graskop WWTW impacting on the IIHI. A change in the moderate floods and erosion, due to forestry are the main riparian impacts.

13.4.5 Fish (B/C EC, 80.4)

The PES reflects slightly deteriorated ecological integrity, primarily attributed to the reduced flows and increased sedimentation, the primary source of deterioration being forestry. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution.

13.4.6 Macroinvertebrates (A/B EC, 88.2%)

SASS5 score: 225 No of Taxa: 35 ASPT: 6.4
The PES reflects slightly deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and sedimentation of instream habitats. This can be seen most clearly in the disappearance of cobble dwelling taxa preferring faster velocities such as the Tricorythid mayflies. The MIRAI metrics indicates that the main reason for the altered macroinvertebrate conditions is changes in seasonality and connectivity (80.0%) and to a far lesser degree a slight deterioration in water quality (89.7%). Diverse communities of macroinvertebrates were collected in all habitats, with the sensitive (mostly flow dependent) element comprised of Dixidae, Philopotamidae, Hydropsychidae, Chlorocyphidae, Heptageniidae, and Baetidae >2spp.

13.4.7 Riparian vegetation (A/B EC, 89.9%)

Marginal zone: This zone is close to reference condition, with exotic species invasion at < 10% (small impact). Some vegetation has been removed as a result of picnic and road activities in area, but this is a small impact. Some root exposure and undercutting is evident and may be from extended lower low flows. The marginal zone is dominated by non-woody vegetation.

Lower zone: This zone is close to expected, with < 10% exotic infestation (*Senna* spp. mainly). Some vegetation removal due to picnic and road activities downstream at site has occurred, as well as some targeted removal of large woodies - presumably Working For Water activity (WFW). The Lower zone is dominated by both woody (trees) and open area (exposed bedrock) patches.

Upper zone: Is similar to the Lower zone, also with < 10% exotic woody species invasion (*Lantana*, *Senna* and *Ceasalpinea* spp. mainly). Some vegetation removal due to picnic and road activities downstream of site has occurred, as well as some targeted removal of large woodies - presumably WFW activity. The Upper zone is dominated by woody vegetation. Interestingly several extremely large *B. salicina* specimens occur on the upper zone and may indicate much wetter and wider active channel in the last 100 years.

13.4.8 PES causes and sources

The PES for the components at EWR 4 as well as the reasons for the PES are summarised in Table 13.7.

Table 13.7 EWR 4: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	C	3	Reduced base flows and moderate floods.	Forestry.	F	3
Physico-chem	A/B	3	Elevated nutrients.	Wastewater input to the river, e.g. Graskop WWTW which disposes to the Mac Mac River.	NF	3
Geom	A	3	Small changes to the sediment supply due to forestry, but steep river precludes any morphological adjustment.	Extensive Forestry.	NF	3.5
			Decreased low flows and lower fines transport.		F	
Rip veg	A/B	3.9	Reduced riparian vegetation cover and abundance (minimal impact).	< 10% exotics on all zones.	NF	3.5
				Some root exposure and undercutting may be from extended lower low flows.	F	
Fish	B/C	4	Loss of fish habitat diversity (decreases fast habitats, overhanging vegetation and undercut banks) as a result of decreased base flows.	Primarily afforestation.	F	3
			Reduced migration success as a result of migration barriers (primarily downstream).	Migration barriers (especially Corumanu dam, but also smaller weirs).	N	
			Increased sedimentation result in deterioration of substrate as habitat and loss of deep habitats.	Hillslope erosion related to afforestation.		
Inverts	A/B	3	Slight eutrophication.	Input from upstream wastewater treatment works, forestry.	NF	2.5
			Altered flooding regime (moderate and high floods).	Forestry.		
			Reduced low flows.	Forestry.	F	

13.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 13.8.

Table 13.8 EWR 4: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-.chem	A/B	Negative	B	5 yrs	The diatom community shows traces of the onset of severe water quality impacts with the presence of *E. minima*, *N. veneta*, *N. tenelloides*, *N. frustulum* and *N. palea*. Graskop WWTW may be exacerbating conditions at the site.	3
Geom	A	Stable	A	N/A	Extensive forestry and associated increased sediment runoff may increase the sediment load, but this steep bedrock river section is not sensitive to such small changes.	2.5
Rip veg	A/B	Negative	B	10 -15 years	Exotics, if left unchecked will increase in proportion at the expense of indigenous riparian vegetation.	3
Fish	B/C	Stable	B/C	N/A	The fish assemblage in this section have adapted to the altered water quality and flows and should remain fairly stable over the long term should current conditions prevail.	4

	PES	Trend	Trend PES	Time	Reasons	Conf
Inverts	A/B	Stable	A/B	N/A	Scores approximate reference, with the forestry already established in the catchment. It is likely that the community will remain stable.	2.5

13.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrate and fish results must first be combined to determine an instream category (Table 13.9). The Instream EC is a B (84.3%).

Table 13.9 EWR 4: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3.5	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	90		
FISH ECOLOGICAL CATEGORY	13	380	**80.4**	**B/C**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	5	100		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	5	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	4	95		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**14**	295	**88.2**	**A/B**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		675	**85.5**	**B**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.50	40.20	
Confidence rating for **macroinvertebrate** information	4	0.50	44.10	
	8	1.00	84.30	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B**	

To determine the EcoStatus, the VEGRAI EC and confidences are added to the equation (Table 13.10). The EcoStatus EC is a B (87.06%).

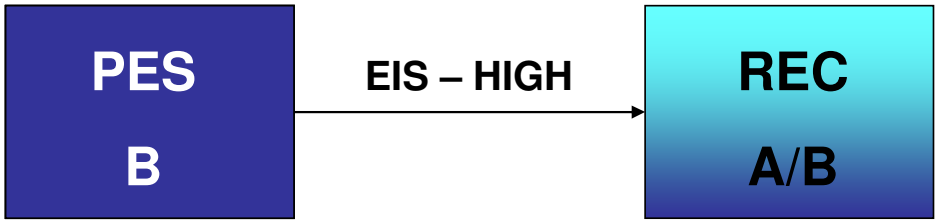
Table 13.10 EWR 4: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	89.9	A/B	
ECOSTATUS	Confidence rating	Proportions	Modified weights
Confidence rating for instream biological information	4	0.51	42.68
Confidence rating for riparian vegetation zone information	3.9	0.49	44.38
	7.9	1.00	87.06
ECOSTATUS	EC		B

13.7 A/B REC

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 4 is **HIGH** and the REC is therefore to improve the PES. For an overall improvement in the PES the fish component however needs to improve. This may be achieved by improving water quality. Improving water quality and the fish EC will result in an improved EcoStatus of an A/B.



The scenario includes the following:

- Improved nutrient levels and reduced temperature increases.

The components are adjusted to indicate the metrics that will react to the scenario to achieve the REC. The changes in the rule based models are available electronically and summarised in Table 13.11.

Table 13.11 EWR 4: A/B REC

	PES	REC	Comments	Conf
Physico-chem	A/B	A	Improve nutrient levels and reduce temperature increases with more flow.	3
Fish	B/C	B	Improved water quality should result in improved frequency of occurrence of species with requirement for high water quality, namely BBRI and OPER, species currently present in reduced frequency of occurrence.	4

13.8 C AEC

The scenario includes the following:

- Decreased low flows due to possibly a weir or small dam in the upper catchment. This will result in embedded cobbles.
- Nutrients and temperature will increase.
- Increased alien vegetation in the riparian zone.

Each component is adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models are available electronically and summarised in Table 13.12.

Table 13.12 EWR 4: C AEC

	PES	AEC	Comments	Conf
Physico-chem	A/B	B/C	Increased nutrient loads from Graskop WWTW at lower flows will exacerbate problems relating to Temp, DO and nutrient input and lead to a drop in EC.	4
Geom	A	B	Channel connectivity will decrease due to more weirs in the system. Increased sediment loads will occur due to increased hillslope erosion and more weirs.	2
Rip veg	A/B	B/C	Aliens will increase to around 30 - 40% on all zones, especially forestry escapees and *Lantana*. Additional aliens will mean less available resource (water, light, space and nutrients) for the recruitment and survival of indigenous riparian species (both woody and non-woody). Subsequently cover and abundance will reduce, and populations will become biased toward older individuals. Species composition will also change more from reference condition since proportions of indigenous species will reduce or vanish.	2.9
Fish	B/C	C/D	Decreased low flows will result in reduced fast habitats (riffles, rapids, runs) with a resultant loss or decreased FROC of rheophilic and semi-rheophilic species (VNEL, BEUT, AURA, CANO, and OPER). Embeddedness of cobbles and nutrient increases will reduce quality of habitat especially in riffles and rapids (interstitial spaces) with negative impact on above-mentioned species. Increased temperatures and resultant decreased oxygen will also affect FROC of above mentioned species. Increased alien vegetation will reduce bank stability and decrease overhanging vegetation, impacting on species with high requirement for this cover type, i.e. BBRI, BEUT, TSPA and PPHI.	4
inverts	A/B	B/C	Higher temperatures and lower oxygen concentrations will occur. An increase in the road networks and poorly maintained stream crossings will lead to increased sedimentation and corresponding decrease in available habitat quality. This decreased habitat will lead to cobble dwelling taxa occurring less frequently.	3

13.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results to be used for setting of EWR scenarios are summarised in Table 13.13.

Table 13.13 EWR 4: Summary of EcoClassification results

IHI				Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	B	RIPARIAN	A/B	HYDROLOGY	C		C	C
				WATER QUALITY	A/B		A	B/C
				GEOMORPHOLOGY	A	Stable	A	B
				Response Components	PES Category	Trend	REC	AEC↓
				FISH	B/C	Stable	B	C/D
				MACRO INVERTEBRATES	A/B	Stable	A/B	B/C
				INSTREAM	B		B	C
				RIPARIAN VEGETATION	A/B	Negative	A/B	B/C
				ECOSTATUS	B		A/B	C

IHI Hydrology PES	B
Diatoms	B

14 EWR 5 MARITE (MARITE RIVER)

14.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 14.1.

Table 14.1 EWR 5: Availability of data

Component	Data availability	Conf
Hydrology	X3H011 appears to be reliable but is missing data (> 11%) and is located a bit too far upstream of the EWR site relative to the catchment size. Inyaka Dam now provides a reliable gauge for calibration purposes. The gauge measures low flows, and records zero flows accurately. The gauge record from 1948 to present is available.	4
Physico-chemical	DWA monitoring data was available for reference condition and PES. No DO data was available. Limited temperature and turbidity data from Week *et al*., 1995. Use of Water Quality on CD to provide information for some variables Electrical conductivity (EC) was used instead of aggregated salts as TEACHA could not be used.	3
Geomorphology	Historical aerial photography (1944, 1954, 1965, 1974, 1984, 1997). Sediment transport modelling and analysis undertaken for this study. Hydrology records. Site survey information at time of study. Previous 1996 IFR study.	3.5
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Previous VEGRAI training site Aerial photos of site - 1944, 1954, 1965, 1974, 1984, 1997. Previous IFR studies. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4
Fish	Single site visit and fish sampling during September 2007. Rivers Database (2007): *Database on fish distribution in South African Rivers*. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park*. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4
Macroinvertebrates	Data and analysis from a single sampling trip to the site on 3 September 2007. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	3

14.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 14.2) was rated as **HIGH** (present), as there is a high occurrence of rare and endangered fish, and tree species. Species and taxon richness and uniqueness is very high and there are fish and macroinvertebrate species present that are intolerant to flow and flow related water quality changes.

Table 14.2 EWR 5: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*O. peringueyi*, *B. brevipinnis*, *C. swierstrai*, and *B. salicina*.
Unique (endemic, isolated, etc.)	4	4	V *nelspruitensis*, *C. anoterus*, Oligoneuridae, and Pyralidae.
Intolerant (flow & flow related water quality)	4	4	V *nelspruitensis*, *C. anoterus*, *A. uranoscopus*, *O. peringueyi*, and *B. argenteus*.
Species/taxon richness	4	4	Twenty three fish species, 41 macroinvertebrate taxa and principal region of plant diversity (Maputoland/Pondoland).
RIPARIAN & INSTREAM HABITATS			
Diversity of types	3	4	Rapids, riffles, riparian vegetation, small anastomosing sections, pools and sandy runs.
Refugia	3	3	Pools and backwaters.
Sensitivity to flow changes	3	3	Main channel not sensitive, but side channels with wide cobble riffles only activated during high flows.
Sensitivity to flow related water quality changes	2	3	
Migration route/corridor (instream & riparian)	3	3	Birds, *A. mossambica* and *A. marmorata*.
Importance of conservation & natural areas	2	4	Small isolated natural area.
MEDIAN	3		
EIS EVALUATION	**HIGH**		

14.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 14.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 14.3 Reference conditions

Component	Reference conditions	Conf
Hydrology	There were major differences between observed and modelled hydrology. The completion of the Inyaka Dam in 2000 will definitely have changed the flow regime at EWR 5. Virgin MAR: 157.09 MCM	4
Physico-chemical	DWA monitoring data: X3H011Q01; n=84, 1979 - 1981. Refer to Table 12.4.	3
Geomorphology	Reference condition is a more open, dynamic channel. The scale of photography and size of channel makes it difficult to confidently assess the (likely) sedimentation issues. It is suspected that this is a sensitive reach for sedimentation and instream habitat changes, but there is not enough data available for a higher confidence rating.	3
Riparian vegetation	**Marginal zone** Sections that are characterised by unconsolidated alluvia will tend to be dominated by reedbeds (*P. mauritianus*), while sections characterised by cobble/boulder or exposed bedrock will tend to be dominated by woody vegetation (*Breonadia* and *Syzigium* mainly), although open sandy and rocky areas are frequent within these vegetation types. **Lower zone** A mix of tree and shrub dominated vegetation (*B. salicina*, *S. cordatum* and *guineense*, *Nuxia oppositifolia* and *C. erythrophyllum* mainly) is present where substrates tend to be more rocky or consolidated and reeds/open sand is present (*P. mauritianus*) where substrates tend to be unconsolidated. **Upper zone** Tree and shrub dominate mainly (*C. erythrophyllum*, *F. sycomorus*, *and D. mespiliformis*) with some *Spirostachys africana* expected in localised pockets. Some *B. salicina* expected where fragmented exposed bedrock occurs.	3.7
Fish	Twenty three species present. Refer to Table 12.5.	4
Macroinvertebrates	The range of scores for the reference is set at 240, with >34 taxa and an ASPT of > 7. Additional information is provided below.	3

Detailed physico-chemical reference conditions are provided in Table 14.4.

Table 14.4 EWR 5: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.005
	Total Inorganic Nitrogen (TIN)	0.08
Physical variables	pH (5^{th}+95^{th} percentiles)	6.2+7.4
	Turbidity (NTU)	-
	Electrical conductivity (mS/m)	25.6

The reference condition as set for the NRHP site X3-MARI-SANDF (Kleynhans *et al.*, 2007b) is directly applicable to site EWR 5. One fish species, namely *Barbus brevipinnis* (BBRI) was added to the list of fish species expected under natural conditions, as this species was sampled at this site during 1997 (Kleynhans Fish Database). The reference condition is, in the context of this study, valid for the section of the Marite River within EcoRegion 4.04. Twenty three fish species can be expected in this section and are listed in Table 14.5.

Table 14.5 EWR 5: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 5 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla marmorata	Giant mottled eel	AMAR	2	1
Anguilla mossambica	Longfin eel	AMOS	3	2
Amphilius natalensis	Natal mountain catfish	ANAT	3	1
Amphilius uranoscopus	Stargazer, mountain catfish	AURA	4	4
Barbus brevipinnis	Shortfin barb	BBRI	1	1
Barbus eutaenia	Orangefin barb	BEUT	4	4
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	4
Barbus trimaculatus	Threespot barb	BTRI	4	3
Barbus unitaeniatus	Longbeard barb	BUNI	4	2
Chiloglanis anoterus	Rock catlet	CANO	5	5
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	3	2
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	2	2
Labeo cylindricus	Redeye labeo	LCYL	1	1
Labeo molybdinus	Leaden labeo	LMOL	3	3
Micralestis acutidens	Silver robber	MACU	3	2
Marcusenius macrolepidotus	Bulldog	MMAC	4	4
Oreochromus mossambicus	Mozambique tilapia	OMOS	3	2
Opsaridium peringueyi	Southern barred minnow	OPER	4	3
Petrocephalus wesselsi	Southern churchill	PCAT	3	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Tilapia sparrmanii	Banded tilapia	TSPA	4	4
Varicorhinus nelspruitensis	Incomati chiselmouth	VNEL	4	2

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Macroinvertebrate taxa expected under reference condition include:
Culicidae, Muscidae, Notonectidae, Belostomatidae, Chironomidae, Potamonautidae, Lymnaeidae, Corixidae, Psychodidae, Sphaeriidae, Oligochaeta, Hirudinea, Nepidae, Bulinae, Planorbinae, Physidae, Turbellaria, Leptophlebiidae, Tricorythidae, Veliidae, Hydracarina, Atyidae, Athericidae, Aeshnidae, Elmidae, Lestidae, Gerridae, Dixidae, Hydrometridae, Hydraenidae, Corduliidae, Lepidostomatidae, Calopterygidae, Philopotamidae, Chlorolestidae, Ecnomidae, Chlorocyphidae, Psephenidae, Petrothrincidae, Leptoceridae, Simuliidae, Baetidae 2spp, Corbiculidae, Gyrinidae, Naucoridae, Dytiscidae, Pleidae, Gomphidae, Caenidae, Tipulidae, Tabanidae, Ceratopogonidae, Coenagrionidae, Libellulidae, Porifera, Ancylidae, Hydrophilidae, Haliplidae, Hydroptilidae, Empididae, Hydropsychidae 2spp ,Baetidae >2spp, Hydropsychidae >2spp, Heptageniidae, Perlidae, Helodidae, Pyralidae, Oligoneuridae, and Prosopistomatidae.

14.4 PRESENT ECOLOGICAL STATE

The component assessment models for the Present Ecological State (PES) are part of the electronic information provided with the final report.

14.4.1 Hydrology

The present MAR is 112.17 MCM (71% of natural). There have been significant reductions in the natural base flow due to afforestation and Inyaka Dam. The volume of the base flows has reduced and the seasonal distribution has only been slightly changed. These changes are continual throughout the year. Moderate and large flood frequency and seasonality have changed - decrease in flood peaks and frequency due to Inyaka Dam and to a lesser extent due to afforestation.

14.4.2 Geomorphology (C EC, 65.23%)

The river is sand and boulder dominated. Riffles and deep pools are present with sandy runs upstream. The site has shown progressively more stabilisation and vegetation encroachment of the bars since the 1980's, and there has been little removal of this vegetation from the extreme 2000 floods. The scale of photography and size of the channel makes it difficult to confidently assess the (likely) sedimentation issues at the site and hence ascribe the "natural" flux of the system to determine PES with high accuracy.

14.4.3 Physico-chemical variables (B EC, 84.44%)

The biological water quality is an A category as determined by the diatom assessment. The SPI indicates high quality (Score: 19.4), well oxygenated circumneutral water. Due to the elevated flows (0.5 m^3/s) present on the day of sampling the diatom community may not be a true reflection of biological water quality. Although *A. minutissima* indicates anthropogenic disturbances and the presence of diffuse pollutants (upstream citrus farming), the community does not show serious impacts at the moment.

Weekly monitoring data (2004 – 2007 (n = 129)) from water quality station X3H011Q01 was used to determine the PES. Nutrient pollution is evident from the diatom and periphyton samples (n = 1 for both indicators). The catchment downstream of Inyaka Dam is disturbed, with extensive clearing for subsistence use, but due to constant releases from Inyaka Dam, turbidity levels stay low. Due to the extensive citrus cultivation in the area, so some toxics expected. Temperature

and oxygen are not affected as the site is downstream of Inyaka Dam, and there are constant releases from the Dam. PES values for the physico-chemical variables are provided in Table 14.6 and in Appendix C.

Table 14.6 EWR 5: Physico-chemical PES values

Water Quality Constituents		Value: PES
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.013
	Total Inorganic Nitrogen (TIN)	0.28
Physical variables	pH (5^{th}+95^{th} percentiles)	7.0+7.9
	Turbidity (NTU)	Mean: 12 NTU Maximum value: 30 NTU (Weeks et al., 1995)
	Electrical conductivity (mS/m)	8.9

14.4.4 Instream and Riparian Habitat Integrity (IIHI: C EC, 64.1%; RIHI: B/C EC, 80.8%)

The IIHI EC is due to the presence of Inyaka Dam that has impacted on flows and resulted in increased base flows and decreased flooding. Water temperature and sedimentation has increased, and water clarity has deteriorated. Due to changes in the flooding regime marginal and non-marginal bank modification has occurred. The RIHI EC is due to decreased flooding and land use activities i.e. subsistence farming, housing and vegetation removal have impacted the riparian integrity.

14.4.5 Fish (B/C EC, 77.9%)

The PES reflects deteriorated ecological integrity primarily attributed to the altered hydrological regime, (operation of Inyaka Dam), increased sedimentation (overgrazing, rural areas) and slight deterioration in water quality. Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution.

14.4.6 Macroinvertebrates (B/C EC, 80.5%)

SASS5 score: 231 No of Taxa: 36 ASPT: 6.4

The PES reflects moderately deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows and the altered flow regime resulting from the operation of Inyaka Dam. This can be seen most clearly in the disappearance of cobble dwelling taxa preferring faster velocities such as the Tricorythid mayflies and Philopotamid caddisflies. The MIRAI metrics indicate that the main reason for the altered macroinvertebrate conditions is changes in seasonality and connectivity (66.1%) and to a far lesser degree a slight deterioration in water quality (80.7%).

14.4.7 Riparian vegetation (B/C EC, 80.4%)

Marginal zone: The marginal zone is close to reference condition, with exotic species present at less than 10%. Some vegetation has been removed as a result of livestock accessing the river and footpaths have been cut. Root exposure and undercutting may be from extended lower low flows. The marginal zone is dominated by patches of reedbeds, grassed areas and tree clumps (*Breonadia* and *Syzigium* spp.).

Lower zone: Vegetation in this zone is close to expected, although there is a presence of 10 - 20% woody exotics (*Lantana, Caesalpinea, Sesbania, Psidium,* and *Senna* spp. mainly). Vegetation removal is mainly due to grazing and trampling from livestock, selected wood removal, cutting of footpaths, and recent fires. The lower zone is dominated by both woody (trees) and open area (exposed bedrock) patches.

Upper Zone: Similar to the lower zone, with less than 10% woody exotic species present (*Lantana, Caesalpinea, Sesbania, Psidium,* and *Senna* spp. mainly). Vegetation removal is mainly due to grazing and trampling from livestock, selected wood removal, cutting of footpaths, and recent fires. The upper zone is dominated by woody vegetation.

14.4.8 PES Causes and Sources

The PES for the components at EWR 5 as well as the reasons for the PES are summarised in Table 14.7.

Table 14.7 EWR 5: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	C	4	Reduced base flows and moderate floods.	Inyaka Dam.	F	4
Physico-chem	B	3.5	Increased suspended solids loads. Elevated nutrients and toxics. Temperature and oxygen fluctuations at low flows.	Extensive citrus cultivation in the area. Clearing for subsistence farming. The diatom *A. minutissima* indicates anthropogenic disturbances and the presence of diffuse pollutants (upstream citrus farming).	NF	3
Geom	C	3.5	Changes to the sediment supply - the size of the active channel is reduced; larger component of fines on the bed.	Reduced flows from Inyaka Dam.	F	3.5
			Decreased flows - the size of the active channel is reduced; woody vegetation encroachment and stabilisation of the bed.	Inyaka Dam is upstream – reduced flows and floods.		
Rip veg	B/C	4	Reduced riparian vegetation cover and abundance (minimal impact)	10 - 20% presence of exotic species in all vegetation zones Some vegetation removal due to grazing and trampling from livestock, selected wood removal, cutting of footpaths, and recent fires.	NF	3.7
			Expansion of marginal zone by reed colonization of sand bars over time	Increased low flows (reduced variability) due to releases from Inyaka Dam.	F	
Fish	B/C	4	Increased sedimentation result in deterioration of substrate as habitat and loss of deep habitats.	Increased sedimentation from hillslope erosion related to rural areas (over grazing, small-scare agriculture, and informal settlements) as well as changed flow regime	NF/F	3
			Loss of fish habitat diversity	Flow modification related to Inyaka Dam.	F	
			Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (especially Corumanu and Inyaka Dam, but also smaller weirs) impede natural migration. Altered moderate and large hydrological events as result of Inyaka dam can delay/prevent natural migratory cues).		
Inverts	B/C	2.5	Increase in low flows.	Releases from Inyaka Dam.	F	3
			Reduction in floods.			

	PES	Conf	Causes	Sources	F/NF	Conf
			Altered water temperature and clarity.			
			Change in sedimentation.			
			Change in bank structure.			

14.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 14.8.

Table 14.8 EWR 5: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-chem	B	Stable	B	N/A	Although extensive activities in the area, the water quality status seem stable.	3
Geom	C	Negative	D	10 years	The dam is relatively new and the channel will continue to adjust to the new flows.	3
Rip veg	B/C	Negative	C/D	10 -15 years	Exotics, if left unchecked will increase in proportion at the expense of indigenous riparian vegetation.	3
Fish	B/C	Negative	C	Long term	It can be expected that the fish assemblage is still adapting to the major alteration in hydrological regimes brought about by the construction of the Inyaka Dam.	3
Inverts	B/C	Stable	B/C	N/A	The macroinvertebrate community has a reasonably high sensitivity and appears to have adjusted to current flow conditions, despite their difference from natural state.	2

14.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrate and fish results must first be combined to determine an Instream category. Results are given in Table 14.9. The Instream EC is a B/C (79.2%).

Table 14.9 EWR 5: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3.5	90		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	70		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3.5	90		
FISH ECOLOGICAL CATEGORY	14	350	**77.9**	**B/C**

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	3	80		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	4	90		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	5	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**12**	270	**80.5**	**B/C**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		620	**79.5**	**B/C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.50	38.95	
Confidence rating for **macroinvertebrate** information	4	0.50	40.25	
	8	1.00	79.20	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B/C**	

To determine the EcoStatus, the VEGRAI EC and confidences are added to the equation (Table 14.10). The EcoStatus EC is a B/C (79.78%).

Table 14.10 EWR 5: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**80.4**	**B/C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	4	0.50	39.60
Confidence rating for riparian vegetation zone information	4	0.50	40.20
	8	1.00	79.80
ECOSTATUS	**EC**		**B/C**

14.7 REC B

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 5 is **HIGH** and the REC is therefore an improvement of the PES.

The scenario includes the following:

- No more constant releases, i.e. a more natural distribution of flows.
- Grazing and trampling should be reduced.
- Alien vegetation should be reduced.
- The improved flooding regime will improve the marginal zone.

Each component is adjusted to indicate the metrics that will react to the scenarios to achieve a REC. The changes in the rule based models are available electronically and summarised in Table 14.11.

Table 14.11 EWR 5: B REC

	PES	REC	Comments	Conf
Physico-chem	B	B	No changes are expected under this scenario.	N/A
Geom	C	C	Given the relatively recent completion of the large dam upstream of the site, it would be difficult to improve the condition of the Geomorphology of the areas downstream of the dam (such as at our site) One option would be to release at least some of the high flows, as this may halt the negative trajectory and maintain the current EC. However restoration of some flows is insufficient to counteract the catchment-wide degradation, and thus this action would only result in an improvement within the EC.	3
Rip veg	B/C	B	Selective removal of exotic vegetation in the lower and upper zones will improve the EC. Current exotics present in the marginal zone are low or non-woody and therefore difficult to control. A reduction in vegetation removal, grazing and trampling will result in increased natural cover and abundance of woody and non-woody riparian vegetation.	3.3
Fish	B/C	B	An improved flow regime (close to natural regime) will improve habitat diversity and abundance, with a resultant improved FROC of species such as ANAT, BUNI and VNEL.	4
Inverts	B/C	B	An improved flow regime (close to natural regime) will improve habitat and slower water velocities should result in slightly more sediments in the system. This will result in a number of the taxa preferring slower water (e.g. gastropods) returning.	2.5

14.7.1 C/D AEC

The scenario includes the following:

- More nutrients and toxics will be present.
- No flow releases will be made for the EWR.
- There will be less dilution and fewer floods due to e.g. direct abstraction from the dam.
- The geomorphological response will be a sandier river with more vegetated instream bars.
- Decrease in the vegetation EC will further be accompanied by increased aliens, removal, grazing, and trampling.

Each component is adjusted to indicate the metrics that will react to the scenario. The changes in the rule based models are available electronically and summarised in Table 14.12.

Table 14.12 EWR 5: C/D AEC

	PES	AEC	Comments	Conf
Physico-chem	B	C	No EWR release and fewer floods would result in less dilution of toxics, higher build-up of nutrients and an expected small increase in turbidity levels.	4
Geom	C	D	Continuing erosion in the lower catchment would cause an increase in sediment storage in the channel (sediment production remains high, but the ability of the river to remove/transport it is reduced as a result of reduced flows). This will result in a sandier river, some riffles and bedrock areas in the reach will be lost, vegetation encroachment on bars and banks will take place and cobbles will be embedded.	2
Rip veg	B/C	C/D	The scenario will result in the reduction of indigenous riparian species cover, abundance and recruitment. With less recruitment, over time populations will become skewed toward older individuals and proportions of species in the assemblage will change and expected species will be less well represented.	2.7
Fish	B/C	C/D	Water quality deterioration (more nutrients, toxics, less dilution) will lead to decreased FROC of water quality intolerant and moderately intolerant species (AURA, BEUT, CANO, CSWIE, LMOL, MMAC, and OPER). No releases for the EWR will result in loss of habitat diversity, reflected by reduced FROC of most expected species. It will also affect the migratory cues, impacting negatively on species migrating between reaches (especially BMAR, CGAR, TSPAR, and VNEL). Increased sediment will reduce the quality of substrate as habitat through embeddedness, impacting on species with high preference for substrates (BEUT, CPAR and LMOL). Reduced marginal vegetation related to riparian zone degradation will result in decreased FROC of species with high requirements for overhanging vegetation (BEUT, BTRI, BUNI, MMAC, and PPHI).	4
inverts	B/C	C	The lower flows, smaller floods, more sandy habitat and increased nutrient concentrations will result in a decrease in cobble dwelling habitat as a result of less and poorer habitat as well as an increase in the more tolerant taxa depending on the water column and GSM. The decrease in vegetation will also result in a depauperate vegetation-dwelling assemblage.	3

14.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The results to be used for setting of EWR scenarios are summarised in Table 14.13.

Table 14.13 EWR 5: Summary of EcoClassification results

IHI				Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	C	RIPARIAN	B / C	HYDROLOGY	C			D
				WATER QUALITY	B		B	C
				GEOMORPHOLOGY	C	Negative	C	D
				Response Components	PES Category	Trend	REC	AEC↓
				FISH	B/C	Negative	B	C/D
				MACRO INVERTEBRATES	B/C	Stable	B	C
				INSTREAM	B/C		B	C/D
				RIPARIAN VEGETATION	B/C	Negative	B	C/D
				ECOSTATUS	B/C		B	C/D

IHI Hydrology PES	B/C
Diatoms	A

15 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER)

15.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 15.1.

Table 15.1 EWR 6: Availability of data

Component	Data availability	Conf
Hydrology	No reliable gauge was available for this site. The only gauge is the Sand River gauge X3H008 which is remote from the. The gauge measures low flows, and records zero flows accurately. The gauge record from 1967 to present is available.	2
Physico-chemical	DWA monitoring data for RC and PES at X3H008Q01 used, and present state extrapolated from EWR 8. Limited periphyton and diatom data available (n = 1). No DO temperature and turbidity data was available. Limited metal data available. Electrical conductivity (EC) was used instead of aggregated salts as TEACHA could not be used.	2
Geomorphology	Historical aerial photography (1954, 1965, 1974, 1984, 2001). Site survey information at time of study. 1996 IFR site information (Godfrey, 2002). Daily flow data is required to undertake sediment (potential bed material) transport modelling so that effective discharge classes can be determined. At this site, no daily hydrological data were available – the nearest flow gauge is too far away to be used with any confidence to represent the flows at our site.	3
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1954, 1965, 1974, 1984. 1996 IFR site information (Godfrey, 2002). Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4
Fish	Single site visit and fish sampling during September 2007. Angliss and Rodgers, 2002: *Sand River Catchment Biomonitoring Report.* Rivers Database (2007): *Database on fish distribution in South African Rivers.* Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Mr. M. Angliss)	3
Macroinvertebrates	Data and analysis from a single sampling trip during September, 2007. Information from RHP site X3MUTL-NEWFO. Maps of study area and catchment information. 1996 IFR site information (Godfrey, 2002). Rivers database. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	3

15.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 15.2) was rated as **HIGH** (present), as there are a high occurrence of rare and endangered fish, and tree species. Species and taxon richness and uniqueness is very high and there are fish and macroinvertebrate species present that are intolerant to flow and flow related water quality changes.

Table 15.2 EWR 6: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	OPER, BBRI, CSWI, and *B. salicina*.
Unique (endemic, isolated, etc.)	4	4	VNEL, CANO, Oligoneuridae, and Pyralidae.
Intolerant (flow & flow related water quality)	4	4	VNEL, CANO, AURA, OPER, and BARG.
Species/taxon richness	4	4	Twenty three fish species, 41 macroinvertebrate taxa.
RIPARIAN & INSTREAM HABITATS			
Diversity of types	3	4	Rapids, riffles, riparian vegetation, small anastomosing sections, pools, and sandy runs.
Refugia	3	3	Pools, backwaters.
Sensitivity to flow changes	3	3	Main channel not sensitive, but side channels with wide cobble riffles only activated during high flows.
Sensitivity to flow related water quality changes	2	3	
Migration route/corridor (instream & riparian)	3	3	Birds, AMOS, and AMAR.
Importance of conservation & natural areas	2	4	Small isolated natural area. Principal region of plant diversity (Maputoland/Pondoland).
MEDIAN	3		
EIS EVALUATION	**HIGH**		

15.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 15.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 15.3 EWR 6: Reference conditions

Component	Reference conditions	Conf
Hydrology	There were major differences between field observations and modelled hydrology. For a few years water from the Inyaka Dam was discharged into a tributary of the Mutlumuvi River. Also, abstraction that used to take place upstream of the EWR site for domestic purposes have probably now ceased since these users are now supplied from Inyaka Dam. Return flows from these domestic users should be on the increase. Virgin MAR: 44.99 MCM	2
Physico-chemical	DWA monitoring data: X3H011Q01; n = 84, 1979 – 1981. Refer to Table 15.4.	3
Geomorphology	Reference state is a sandy, wide channel with bedrock outcrops and large boulders in the channel. The macro-channel floor is moderately vegetated.	3
Riparian vegetation	**Marginal zone** Sections are characterised by unconsolidated alluvia will tend to be dominated by reedbeds (*P. mauritianus*), while sections characterised by cobble/boulder or exposed bedrock will tend to be dominated by woody vegetation (*Breonadia* and *Syzigium* spp. mainly). **Lower zone** Mix of tree and shrub dominated vegetation (*B. salicina*, *S. cordatum* and *S. guineense*, and *N. oppositifolia* mainly) where substrates tend to be more rocky or consolidated and reeds/open sand (*P. mauritianus*) where substrates tend to be unconsolidated. **Upper zone** Tree and shrub dominated with terrestrial grasses. High diversity of woody vegetation expected *(Lonchcarpus capassa*, *Ficus sycomorus* and *F. sur*, *Diospyros mespiliformis*, *Schotia brachypetala*) with some *Spirostachys africana* expected in localised pockets).	3.5
Fish	Twenty nine species present. Refer to Table 15.5.	4
Macroinvertebrates	The reference total SASS 5 score is 270, with over 35 taxa and an ASPT of > 7.5. Additional information is provided bellow.	3

Detailed physico-chemical reference conditions are provided in Table 15.4.

Table 15.4 EWR 6: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.025
	Total Inorganic Nitrogen (TIN)	0.081
Physical variables	pH (5^{th}+95^{th} percentiles)	6.83+7.70
	Electrical conductivity (mS/m)	12.48

The reference condition as set for the NHRP site X3MUTL-THULA (Kleynhans *et al*., 2007) was applied for the determination of the reference condition. *Anguilla mossambica* (AMOS) was added to the list of fish species expected under natural conditions, as this species was sampled at this site during 1997 (Kleynhans Fish Database). The reference condition set is, in the context of this study, valid for the section of the Mutlumuvi River within EcoRegion 3.07, which equates secondary natural resource unit MUT A.3. Twenty nine fish species can be expected in this section and are listed in Table 15.5.

Table 15.5 EWR 6: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 6 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	1	1
Barbus annectens	Broadstriped barb	BANN	4	3
Barbus eutaenia	Orangefin barb	BEUT	4	3
Barbus afrohamiltoni	Hamilton's barb	BFRI	3	1
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	4
Barbus paludinosus	Goldie barb	BPAU	4	2
Barbus radiatus	Beira barb	BRAD	4	2
Barbus toppini		BTOP	4	2
Barbus trimaculatus	Threespot barb	BTRI	5	4
Barbus unitaeniatus	Longbeard barb	BUNI	5	3
Barbus viviparous	Bowstripe barb	BVIV	5	4
Chiloglanis anoterus	Rock catlet	CANO	5	4
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	5	4
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	5	3
Glossogobius callidus	River goby	GCAL	3	2
Glossogobius giurus	Tank goby	GGIU	5	3
Labeo cylindricus	Redeye labeo	LCYL	5	3
Labeo molybdinus	Leaden labeo	LMOL	5	4
Micralestis acutidens	Silver robber	MACU	5	4
Mesobola brevianalis	River sardine	MBRE	5	4
Marcusenius macrolepidotus	Bulldog	MMAC	4	3
Oreochromus mossambicus	Mozambique tilapia	OMOS	5	5
Opsaridium peringueyi	Southern barred minnow	OPER	4	1
Petrocephalus wesselsi	Southern churchill	PCAT	4	2
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Schilbe intermedius	Silver catfish	SINT	3	2

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 6 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Serranochromus meridianus	Lowveld largemouth	SMER	3	2
Tilapia rendalli	Redbreast tilapia	TREN	4	4
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%)		3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)		

Expected macroinvertebrate taxa include:

Baetidae >2spp, Oligoneuridae, Heptageniidae, Perlidae, Hydropsychidae >2spp, Gyrinidae, Naucoridae, Hydrophilidae, Dytiscidae, Haliplidae, Gomphidae, Caenidae, Tabanidae, Tipulidae, Ceratopogonidae, Leptoceridae, Coenagrionidae, Hydroptilidae, Libellulidae, Simuliidae, Ancylidae, Veliidae, Gerridae, Hydracarina, Corduliidae, Lepidostomatidae, Atyidae, Athericidae, Leptophlebiidae, Chlorocyphidae, Elmidae, Tricorythidae, Culicidae, Corixidae, Notonectidae, Belostomatidae, Oligochaeta, Chironomidae, Lymnaeidae, Planorbinae, and Turbellaria

15.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

15.4.1 Hydrology

The present MAR is 37.92 MCM (84.3% of natural). Before domestic users were supplied from Inyaka Dam it is likely that base flows were reduced to zero during dry months. The decreased base flows are continuous but more noticeable during late winter and early spring. There are small changes from reference condition with regard to moderate and high floods.

15.4.2 Geomorphology (C EC, 71%)

The site is a multi-channelled, bedrock to mixed anastomosing channel type; strongly bedrock controlled. The macro-channel floor has become more stabilised through larger, increasingly vegetated bars and sediment loads from the upstream catchment areas have increased significantly due to poor land management. Some (small-scale) sand mining within the macro-channel is occurring along the MRU. There are no morphological cues, so Potential Bed Material Transport (PBMT, or bedload sediment) modelling is essential at this site. Possibly a terrace occurs, but is not paired. The general absence of fine sediment in the channels indicates a typically high energy environment.

15.4.3 Physico-chemical variables (B/C EC, 80.92%)

The SPI index indicates moderate water quality (Score: 15.6), with well oxygenated circumneutral waters. The biological water quality is in a B category. The dominance of *G. parvulum* and *G. parvulum f. saprophilum* indicates pollution input from upstream anthropogenic activities as these species are extremely pollution tolerant. As the river had very little to no flow on the day of sampling elevated temperatures could have occurred and is substantiated by the presence of *E. adnata* as this species occurs in waters with elevated temperatures and nutrient load and *R. gibba* which occurs in standing water (Taylor *et al.*, 2007).

Data was extrapolated from EWR 8 and therefore confidence is extremely low as actually, this site will not be applicable at all. Nutrients (n = 1) indicate some pollution is present. Elevated turbidity levels are expected due to catchment activities. The river stops flowing at times and therefore temperature and oxygen fluctuations will take place. PES values for the physico-chemical variables are provided in Table 15.6 and in Appendix C.

Table 15.6 EWR 6: Physico-chemical PES values

Water Quality Constituents		Value: PES
Nutrients (mg/L)	SRP	0.032 (<0.02: on-site, Nov 07)
	TIN	0.45 (1.933: on-site, Nov 07)
Physical variables	pH (5^{th}+95^{th} percentiles)	7.46+8.12
	Electrical conductivity (mS/m)	35.1 (18.7: on-site, Nov 07)

15.4.4 Instream and Riparian Habitat Integrity (IIHI: C EC, 67.4%; C, 65.3%)

The IIHII can mainly be attributed to a reduction in the low flows (due to abstraction) and bank and bed modification (caused by land use activities, including vegetation removal and cattle grazing). The RIHI EC is due to land use activities have caused substrate exposure and erosion in the non-marginal zone.

15.4.5 Fish (C EC, 69.2%)

The PES reflects deteriorated ecological integrity, primarily attributed to the altered hydrological regime (i.e. a serious increase in zero flow duration, large change in low flows and a small alteration in moderate events), extensive sedimentation (overgrazing, rural areas) and deterioration in water quality. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution. Rheophilic and semi-rheophilic species have been affected negatively.

15.4.6 Macroinvertebrates (B/C EC, 77.7%)

SASS5 score: 189 No of Taxa: 32 ASPT: 5.9

The PES reflects moderately deteriorated ecological integrity, attributed primarily to land use activities resulting in decreased low flows, increased periods of zero flow and altered beds and banks. This can be seen most clearly in the disappearance of cobble dwelling taxa preferring faster velocities such as the Tricorythid mayflies and Philopotamid caddisflies. The MIRAI metrics indicate that the main reason for the altered macroinvertebrate conditions is changes in seasonality and connectivity (68.6%) and to a far lesser degree a moderate deterioration in water quality (77.4%). Despite the lack of substantial flow habitat and depth at the site at the time of sampling, a number of more sensitive macroinvertebrates were collected in SIC, GSM and MV. These include Heptageniidae, Baetidae (>2spp), Perlidae, Chlorocyphidae, Atyidae, and Athericidae.

15.4.7 Riparian vegetation (C EC, 75.6%)

Marginal zone: Close to reference, but selected wood removal has reduced some of the tree species and therefore cover, abundance and recruitment have been reduced. Reeds have also expanded due to colonization of additional sediment.

Lower zone: The zone has been invaded by 10 - 20%, woody exotics (*Lantana*, *Caesalpinea*, *Sesbania*, *Psidium*, and *Senna* spp. mainly). As with the marginal zone, selected wood removal has reduced some of the tree species and therefore cover, abundance and recruitment has been reduced. Reeds have also expanded due to colonization of additional sediment.

Upper zone: Close to reference, but grazing and trampling has removed large proportions of the understorey.

15.4.8 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 15.7.

Table 15.7 EWR 6: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	C	2	Reduced base flows and moderate floods.	Forestry and abstraction	F	1.5
Physico-chem	B/C	2	Elevated nutrient levels. Elevated turbidity and temperature. Reduced oxygen levels.	Subsistence farming and extensive urban/rural settlements. Some forestry activities.	NF	2
Geom	C	3	The channel banks and bed have become more stable.	Reduced flows.	F	3
			Reduced size of the active channel.	Sediment as a result of poor land use management in lower areas.	NF	
Rip veg	C	3.8	Reduced cover and abundance of indigenous riparian species.	High levels of alien species invasion (especially in lower and upper zones).	NF	5
			Changes to species composition and population structure of indigenous riparian species.	High levels of vegetation removal (grazing and trampling mainly) especially in lower and upper zones.		
Fish	C	4	Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (especially Corumanu Dam, but also smaller weirs) impede natural migration. Altered hydrological events delay/prevent natural migratory cues.	NF	
			Loss of fish habitat diversity (especially FS and FD habitat).	Flow modification and abstraction.	F	
			Increased sedimentation and benthic growth result in deterioration of substrate as habitat.	Hillslope erosion related to rural areas (over grazing, small-scare agriculture, and informal settlements). Increased nutrients result in aggregated benthic growth.	NF	
			Increased pressure on fish assemblage.	Large scale harvesting take place with use of nets.		
			Local fish habitats are altered and deteriorated.	Solid waste disposal.		
Inverts	B/C	3.5	Substantially reduced low flows.	Abstraction.	F	2.5
			Increase in zero flow duration.			
			Alteration of flood regime.			
			Bed and bank modification.	Land use.		

15.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 15.8.

Table 15.8 EWR 6: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-chem	B/C	Stable	B/C	Short term	The presence of pollution tolerant diatom species, although in very small numbers, indicates that upstream anthropogenic activities may be impacting slightly on this EWR site.	2
Geom	C	Stable	C	N/A	No large scale impacts and the higher sediment yields from the catchment should be consistent in future.	2.5
Rip veg	C	Negative	D	10 years	Exotics, if left unchecked will increase in proportion at the expense of indigenous riparian vegetation. Grazing and trampling from livestock, wood removal (selected *Breonadia* spp., *Ficus sur, Erythrina,* and *Spirostachys* spp.) and cutting of footpaths has high impact.	3
Fish	C	Stable	C	N/A	The fish assemblage in this section have adapted to the altered water quality and flows and should remain fairly stable over the long term should current conditions prevail.	3
Inverts	B/C	Negative	C	Short term	The macroinvertebrate community will undergo further changes over a five year period. This relates to loss of connectivity and increase in sedimentation.	3

15.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrate and fish results must first be combined to determine an Instream category. Results are given in Table 15.9. The Instream EC is a C (73.45%).

Table 15.9 EWR 6: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	2.5	70		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	90		
FISH ECOLOGICAL CATEGORY	12	350	**69.2**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	3	100		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	2	60		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	2	60		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**7**	220	**77.7**	**B/C**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		570	**73.6**	**C**

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.50	34.60	
Confidence rating for **macroinvertebrate** information	4	0.50	38.85	
	8	1.00	73.45	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the VEGRAI EC and confidence are added to the equation (Table 15.10). The EcoStatus EC is a C (74.5%).

Table 15.10 EWR 6: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**75.6**	**C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	4	0.51	37.67
Confidence rating for riparian vegetation zone information	3.8	0.49	36.83
	7.8	1.00	74.50
ECOSTATUS	**EC**		**C**

15.7 B REC

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 6 is **HIGH** and the REC is therefore an improvement of the PES.

The improved B scenario includes the following:

- Low flows presently vary daily due to abstractions and sometimes get very low. The system should be operated better to ensure that the low flow regime improves. This will improve the geomorphology and inundate some reeds which will prevent encroachment.

- Removal of exotic vegetation.

Each component is adjusted to indicate the metrics that will react to the REC scenario. The changes in the rule based models are available electronically and summarised in Table 15.11.

Table 15.11 EWR 6: B REC

	PES	REC	Comments	Conf
Physico-chem	B/C	B/C	This scenario will maintain the current EC.	N/A
Geom	C	C	Flows alone will not lead to an improvement. Primarily the river is responding to poor landuse activities and associated increased erosion and sedimentation in the river.	N/A
Rip veg	C	B	No change to the marginal zone. On the lower and upper zones a reduction in exotic vegetation together with marked reduction in selected wood removal was used to improve EC.	3.2
Fish	C	B	Improved flow management (release of EWR, increased low flows, decreased zero flows) will improve the FROC of at least some species with preference of FS and FD, as well as species intolerant to no flow (e.g. BEUT, BMAR, CSWIE, LCYL, and OPER). Improved substrate condition (reduced sedimentation) will further improve the habitat quality of the above mentioned species.	3
Inverts	B/C	B	Flow sensitive taxa will increase and sensitive taxa e.g. Oligoneuridae and the more sensitive species of Baetidae and Hydropsychidae will return. The increased low flows and shorter periods of no flow will also result in more frequent inundation of marginal vegetation. The improved habitat in the marginal vegetation will result in a return of some of the vegetation dwelling taxa such as Pleidae and Aeshnidae.	3

15.8 C/D AEC

A hypothetical scenario was designed and included the following:

- Decreased low flows and longer periods of zero flows in some stretches of the river. Increased algal growth.
- As the geomorphology is reacting to erosion in the catchment, only changing flow will not necessarily decrease the category although less moderate floods will cause some impact on sedimentation.
- The reed beds will become less dense and *B. salicina* will disappear.
- Increased use of the riparian zone.

Each component is adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models are available electronically and summarised in Table 15.12.

Table 15.12 EWR 6: C/D AEC

	PES	AEC	Comments	Conf
Physico-chem	B/C	C/D	Deterioration in land management will result in higher nutrient and turbidity levels. Use of fertilizers and pesticides will lead to the presence of toxics in the system. Interruptions in flow will result in oxygen and temperature fluctuations.	3
Geom	C	D	This scenario assumes that a large dam in the upper catchment is removing many of the flood flows, as well as deteriorated landuse management practices.	2

	PES	AEC	Comments	Conf
Rip veg	C	D	Increase selected wood removal of large trees (Breonadia mainly) from the marginal zone, as well as trampling in marginal zone. Increase grazing of lower and upper zone non-woody species as well as proportion of exotics in these zones.	2.5
Fish	C	D	Deteriorated flow management will decrease the FROC of at least some species with preference of FS and FD, as well as species intolerant to no flow (e.g. BEUT, BMAR, CSWIE, and LCYL). Flow intolerant species such as OPER may even be lost under such conditions, although they may recolonise from downstream section during favourable conditions. Deteriorated substrate condition (increased sedimentation and excessive algal growth) will further contribute to the loss or decreased FROC of the above mentioned species.	3
inverts	B/C	C	This scenario will lead to a decrease of the available vegetation and consequently in a decrease in the frequency of occurrence of a number of taxa.	3

15.9 SUMMARY OF ECOCLASSIFICATION RESULTS

The results to be used for setting of EWR scenarios are summarised in Table 15.13.

Table 15.13 EWR 6: Summary of EcoClassification results

IHI				Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	C	RIPARIAN	C	HYDROLOGY	C			
				WATER QUALITY	B/C		B	C/D
				GEOMORPHOLOGY	C	Stable	C	D
				Response Components	**PES Category**	**Trend**	**AEC ↑**	**AEC↓**
				FISH	C	Stable	B	D
				MACRO INVERTEBRATES	B/C	Negative	B	C
				INSTREAM	C		B	C/D
				RIPARIAN VEGETATION	C	Negative	B	D
				ECOSTATUS	C		B	C/D

IHI Hydrology PES	B/C
Diatoms	B

16 EWR 7 TLULANDZITEKA (TLULANDZITEKA RIVER)

16.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 16.1.

Table 16.1 EWR 7: Availability of data

Component	Data availability	Conf
Hydrology	No reliable gauge was available for this site. The only gauge is the Sand River gauge X3H008 which is remote from the site. The gauge record from 1967 To present is available.	2.5
Physico-chemical	DWA monitoring data for RC and PES at X3H008Q01 used, and present state extrapolated from EWR 8. Limited periphyton and diatom data available (n = 1). No DO temperature and turbidity data was available. Limited metal data available. Electrical conductivity (EC) was used instead of aggregated salts as TEACHA could not be used.	2
Geomorphology	Historical aerial photography (1944, 1965, 1974, 1997). Site survey information.	2
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1944, 1965, 1974, 1997. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	2
Fish	Single site visit and fish sampling during September 2007. Angliss and Rodgers, 2002: *Sand River Catchment Biomonitoring Report.* Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Regional specialist input (Mr. M. Angliss)	3
Macroinvertebrates	Data and analysis from a single sampling trip during September, 2007. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS). Rivers Database.	3

16.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 16.2) was rated as MODERATE (present). There is a high occurrence of rare and endangered fish, macroinvertebrate and tree species. Species and taxon richness is high. There are fish and macroinvertebrate species that are intolerant to flow and flow related water quality changes present.

Table 16.2 EWR 7: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*Opsaridium peringueyi*, *Serranochromus meridianus*, *Barbus brevipinnis*, *Chiloglanis swierstrai*, *B. salicina*, Pyralidae, Helodidae, and Philopotamidae.
Unique (endemic, isolated, etc.)	3	4	*Chiloglanis anoterus*
Intolerant (flow & flow related water quality)	4	4	*Chiloglanis anoterus*, *Barbus eutaenia*, *Barbus trimaculatus*, *Chiloglanis swierstrai*, *Opsaridium peringueyi*, Perlidae
Species/taxon richness	4	4	Twenty eight fish species, 41 invert taxa, and principal region of plant diversity (Maputoland/Pondoland).
RIPARIAN & INSTREAM HABITATS			
Diversity of types	2	4	Riffle, pools, and sandy runs.
Refugia	2	4	
Sensitivity to flow changes	2	4	
Sensitivity to flow related water quality changes	2	4	
Migration route/corridor (instream & riparian)	2	4	Birds, macroinvertebrates, and eels.
Importance of conservation & natural areas	0	4	
MEDIAN	2		
EIS EVALUATION	**MODERATE**		

16.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 16.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 16.3 EWR 7: Reference conditions

Component	Reference conditions	Conf
Hydrology	There were major differences between field observations and modelled hydrology. The gauge measures low flows and zero flows accurately. Afforestation has been implemented in the catchment which should result in increased runoff. Virgin MAR: 28.88. MCM	2.5
Physico-chemical	DWA monitoring data: X3H008Q01; n = 82, 1977 – 1979. Refer to Table 14.4.	2
Geomorphology	Historically had a much wider active channel and more open macro-channel (i.e. less woody vegetation).	3
Riparian vegetation	**Marginal zone** Sections that are characterised by unconsolidated alluvia will tend to be dominated by reedbeds (*P. mauritianus*), while sections characterised by cobble/boulder or exposed bedrock will tend to be dominated by woody vegetation (*Breonadia* and *Syzigium* spp. mainly). **Lower zone** Mix of tree and shrub dominated vegetation (*B. salicina*, *S. cordatum* and *S. guineense*, and *N. oppositifolia* mainly) where substrates tend to be more rocky or consolidated and reeds/open sand (*P. mauritianus*) where substrates tend to be unconsolidated. **Upper zone** Tree and shrub dominated with terrestrial grasses. High diversity of woody vegetation expected. *(Lonchcarpus capassa, F. sycomorus* and *F. sur, Diospyros mespiliformis, Schotia brachypetala* with some *Spirostachys africana* expected in localised pockets*).*	3.5
Fish	Twenty eight species present. Refer to Table 14.5.	3
Macroinvertebrates	The reference SASS 5 score range is >250, with >35 taxa and ASPT of >7. Additional information is provided below.	2.5

Detailed physico-chemical reference conditions are provided in Table 16.4.

Table 16.4 EWR 7: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.025
	Total Inorganic Nitrogen (TIN)	0.081
Physical variables	pH (5^{th}+95^{th} percentiles)	6.83+7.70
	Electrical conductivity (mS/m)	12.48

The fish reference condition information as set for NHRP site X3Mutl-Thula (Kleynhans & Louw, 2007) was applied for the determination of the reference condition. One fish species, namely AMOS was added to the list of fish species expected under natural conditions, as this species was sampled at this site during 1997 (Kleynhans Fish Database). The reference condition set, is in the context of this study, valid for the section of the Tlulandziteka River within EcoRegion 3.07, which equates secondary NRU Thul A.3. Twenty-eight fish species can be expected in this section of the Tlulandziteka River under natural conditions and is listed in Table 16.5.

Table 16.5 EWR 7: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 7 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla mossambica	Longfin eel	AMOS	2	1
Barbus annectens	Broadstriped barb	BANN	4	2
Barbus anoplus	Chubbyhead barb	BANO	3	2
Barbus brevipinnis	Shortfin barb	BBRI	3	1
Barbus eutaenia	Orangefin barb	BEUT	4	3
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	4
Barbus neefi	Sidespot barb	BNEE	3	2
Barbus paludinosus	Goldie barb	BPAU	4	3
Barbus radiatus	Beira barb	BRAD	4	3
Barbus trimaculatus	Threespot barb	BTRI	5	4
Barbus unitaeniatus	Longbeard barb	BUNI	5	4
Barbus viviparous	Bowstripe barb	BVIV	5	4
Chiloglanis anoterus	Rock catlet	CANO	5	4
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	5	3
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	5	2
Labeo cylindricus	Redeye labeo	LCYL	5	2
Labeo molybdinus	Leaden labeo	LMOL	5	3
Micralestis acutidens	Silver robber	MACU	5	3
Mesobola brevianalis	River sardine	MBRE	5	3
Marcusenius macrolepidotus	Bulldog	MMAC	4	2
Oreochromus mossambicus	Mozambique tilapia	OMOS	5	5
Opsaridium peringueyi	Southern barred minnow	OPER	4	2
Petrocephalus wesselsi	Southern churchill	PCAT	4	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Schilbe intermedius	Silver catfish	SINT	3	1
Serranochromus meridianus	Lowveld largemouth	SMER	3	2

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 7 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Tilapia rendalli	Redbreast tilapia	TREN	4	3

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Expected macroinvertebrate taxa include:

Baetidae >2spp, Helodidae, Heptageniidae, Perlidae, Hydropsychidae >2spp, Gyrinidae, Naucoridae, Dytiscidae, Gomphidae, Caenidae, Tipulidae, Tabanidae, Ceratopogonidae, Leptoceridae, Coenagrionidae, Hydroptilidae, Libellulidae, Simuliidae, Hydropsychidae 1sp, Ancylidae, Veliidae, Gerridae, Hydracarina, Corduliidae, Atyidae, Philopotamidae, Athericidae, Leptophlebiidae, Chlorocyphidae, Elmidae, Culicidae, Corixidae, Notonectidae, Belostomatidae, Sphaeriidae, Oligochaeta, Chironomidae, Hirudinea, Potamonautidae, Nepidae, Planorbinae, and Turbellaria

16.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

16.4.1 Hydrology

The present MAR is 26.83 MCM (92.9% of natural). There are two small upstream dams and a diversion works 5 km upstream of site which diverts all the low flows. This results that the river almost stops flowing in the dry season. There are no major changes from natural conditions except for a decrease in base flows as there is some irrigation upstream of the EWR site. The changes are continuous during the year but more noticeable during late winter and early spring. There are small changes from reference condition with regard to moderate and high floods.

16.4.2 Geomorphology (C/D EC, 61.44%)

The active channel width has reduced significantly and there has been a net increase of vegetation on the active channel floor, suggesting a reduction in flood flows and stabilization of the sediment. A combination of reduced floods and possible increased nutrients and sediment derived from the catchment activities may have promoted the expansion of the reeds in the channel. The banks and bars are highly stabilised by the dense reedbeds, and these reedbeds are likely to persist through most management scenarios since reeds are very robust and difficult to reduce.

16.4.3 Physico-chemical variables (C EC, 76.62%)

Data was extrapolated from EWR 8. Nutrients: Periphyton and diatoms (based on one sample for both indicators) indicate the presence of some pollution. Elevated turbidity occurs due to poor land management and agricultural and forestry activities will probably result in an increase in toxics. Impacts on temperature and oxygen are due to fluctuating flows. PES values for the physico-chemical variables are provided in Table 16.6 and in Appendix C.

Overall the biological water quality is a B/C category with a SPI score of 12.8 although this falls within the lower ranges of the classification and the diatom based ecological classification indicates low oxygen saturation and alkaline conditions. There are pollutant tolerant species present

although in lower levels, but pollution may be on the increase due to species present that are tolerant to high levels of pollution.

Table 16.6 EWR 7: Physico-chemical PES values

Water Quality Constituents		Value: PES
Nutrients (mg/L)	SRP	0.032
	TIN	0.45 (0.57: on-site, Nov 07)
Physical variables	pH (5^{th}+95^{th} percentiles)	7.46+8.12
	Electrical conductivity (mS/m)	35.1 (8.9: on-site, Nov 07)

16.4.4 Instream and Riparian Habitat Integrity (IIHI: C/D EC, 60.5%; RIHI: C EC, 67.3%)

Major impacts on the IIHI EC are diversion of low flows due to diversion banks, upstream dams and bank and bed modification due to land use activities which include vegetation removal and cattle grazing. The RIHI evaluation is due to land use activities which have caused substrate exposure and erosion in the non-marginal zone.

16.4.5 Fish (C EC, 65.4%)

The PES reflects deteriorated ecological integrity, based on the fish assemblage, primarily attributed to the altered hydrological regime (serious increase in zero flow duration, large change in low flows and small alteration in moderate events), extensive sedimentation (overgrazing, rural areas) and deterioration in water quality. Most of the expected fish species are however still present in this reach, although be it in reduced abundance and spatial distribution. Rheophilic and semi-rheophilic species have been affected negatively.

16.4.6 Macroinvertebrates (B/C EC, 78.1%)

SASS5 score: 197 No of Taxa: 32 ASPT: 6.2

Instream habitat at this site has been altered by sediment loading, flow alteration and deterioration in water quality. There is also encroachment of *Phragmites sp*. into the channel. There is plentiful coarse substrate, creating a 'flow over coarse substrate' hydraulic habitat. This is currently largely mobile, but is becoming armoured by the additional sediment loading. Despite the alteration to instream habitat and banks at this site, a number of more sensitive macroinvertebrates were collected in SIC, GSM and MV. These include Heptageniidae, Baetidae (>2spp), Perlidae, Chlorocyphidae, Hydropsychidae (>2sp), Helodidae, and Athericidae.

16.4.7 Riparian vegetation (C EC, 66.6%)

Marginal zone: This zone is reed dominated, with a reduced woody component.

Lower zone: Dominated by reedbeds and exotic vegetation, and largely cultivated and woody vegetation has been extensively removed.

Upper zone: Close to reference, but grazing and trampling has removed large proportions of understorey and selected wood removal has reduced the woody component.

16.4.8 PES causes and sources

The PES for the components at EWR 7 as well as the reasons for the PES are summarised in Table 16.7.

Table 16.7 EWR 7: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	C	2.5	Reduced low flows.	Upstream diversion works	F	1.5
			Reduced base flows and moderate floods.	Forestry and abstraction. Acornhoek and Kasteel Dam (although small dams).		
Physico-chem	C	2	Elevated nutrients and turbidity levels. Low flows impact on oxygen and temperature levels.	Poor land management in the catchment. No releases from upstream dam.	NF	2
Geom	C	2	Small changes to the sediment supply.	Few dams, roads, extensive grazing.	NF	3.5
			Decreased flows - the size of the active channel is reduced.	Abstraction, forestry, dam upstream.	F	
Riparian vegetation	C	3.7	Reduced cover and abundance of indigenous riparian species.	High levels of alien species invasion (especially in lower and upper zones).	NF	4.5
			Changes to species composition and population structure of indigenous riparian species.	High levels of vegetation removal (grazing and trampling mainly) especially in lower and upper zones.		
			Expansion of reedbeds.	Narrowing of channel due to reduced flows.	F	
Fish	C	3	Loss of fish habitat diversity (especially FS and FD).	Flow modification and abstraction.	F	3
			Reduced migration success as a result of migration barriers and altered migratory cues.	Migration barriers (especially Corumanu dam, but also smaller weirs) impede natural migration. Altered hydrological events delay/prevent natural migratory cues.		
			Increased sedimentation and benthic growth result in deterioration of substrate as habitat.	Hillslope erosion related to rural areas (over grazing, small-scare agriculture, and informal settlements). Increased nutrients result in aggregated benthic growth.	NF	
			Increased pressure on fish assemblage, especially if large scale harvesting takes place.	Fishing (with nets).		
			Local fish habitats are altered and deteriorate.	Solid waste disposal.		
Inverts	B/C	2	Low flow reductions.	Abstraction.	F	2
			Bed and bank modification.	Landuse in catchment (cattle, roads etc.).	NF	
			Nutrient enrichment.			
			Erosion in the riparian zone.			

16.5 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 16.8.

Table 16.8 EWR 7: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-chem	Upper C	Negative	Lower C	5 yrs	Diatom indicators suggest natural/anthropogenic disturbances and indicate the presence of diffuse pollutants at the site.	2
Geom	C/D	Stable	C/D	N/A	No further changes expected as reeds have dominated the channel bed and therefore it is unlikely that they would be removed. Additional vertical increases in the reedbeds (due to flood deposition) may occur, but this is not likely to result in a channel morphology change.	**2.5**
Rip veg	C	Negative	D	5 - 10 years	Presence of exotics species are high, with an occurrence of up to 40 - 60% on the Upper zone. If left unchecked will increase in proportion at the expense of indigenous riparian vegetation. Grazing and trampling from livestock, wood removal (selected *Breonadia, F. sur, Erythrina,* and *Spirostachys* spp.) and cutting of footpaths is high. Expansion of reedbeds could continue to areas where open sand still exists.	**3**
Fish	C	Stable	C	N/A	The fish assemblage in this section has adapted to the altered water quality and flows and should remain fairly stable over the long term.	**3**
Inverts	B/C	Negative	C/D	5 years	It is likely that the macroinvertebrate community has already 'reset' itself following disturbance to the bed through vegetation encroachment and subsequent sedimentation (road building etc.). However the likely continuation of the increasing sediment loading will gradually decrease all flow habitats and further deterioration in the macroinvertebrate community is inevitable.	**2.5**

16.6 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 16.9. The Instream EC is a C (72.66%).

Table 16.9 EWR 7: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	90		
2.What is the natural diversity of **fish** species with a preference for different cover types	3.5	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3.5	100		
FISH ECOLOGICAL CATEGORY	13.5	390	**65.4**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	3	90		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	4	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	4	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**11**	290	**78.1**	**B/C**

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
INSTREAM ECOLOGICAL CATEGORY (No confidence)		680	**72.9**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3	0.43	28.03	
Confidence rating for **macroinvertebrate** information	4	0.57	44.63	
	7	1.00	72.66	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the VEGRAI EC and confidence are added to the equation (Table 16.10). The EcoStatus EC is a C (59.58%).

Table 16.10 EWR 7: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**66.6**	**C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	3.57143	0.49	35.69
Confidence rating for riparian vegetation zone information	3.7	0.51	33.89
	7.27143	1.00	69.58
ECOSTATUS	**EC**		**C**

16.7 C REC

The REC is determined based on ecological criteria only and considers the EIS and the restoration potential and attainability there-of.

The EIS at EWR 7 is **MODERATE** and the REC is therefore to maintain the PES. This site was assessed at Rapid level and therefore confidence is too low in the EcoClassification results to provide management options to maintain the PES.

16.8 B AEC

The improved scenario includes the following:

- Improved flows through reparation of canals, rehabilitation of forestry areas and better management of canal system and forestry.
- Better land use will result in reduced turbidity levels. Nutrients will improve related to improved flows, as will temperature and oxygen.
- Geomorphology will improve if the upstream dam is maintained near capacity to ensure floods which occur overtop the dam and sufficient high flows are provided downstream and improving landuse management (and thus reducing erosion and sediment delivery to the channel).
- Vegetation will be improved if the aliens are removed, agricultural disturbance minimised and unused orchards are removed.
- Fish will improve with improved flows and water quality.

Each component is adjusted to indicate the metrics that will react to the above scenario. The changes in the rule based models are available electronically and summarised in Table 16.11.

Table 16.11 EWR 7: B AEC

	PES	AEC	Comments	Conf
Physico-chem	C	B	Improved flows will assist in reducing nutrient levels, and reduce fluctuations in temperature and oxygen. Improved land management will drop turbidity levels.	2
Geom	C/D	C	Reduction in sediment delivery to channel and reduced erosion. Sufficient high flows are provided by overtopping of the dam.	3
Rip veg	C	B	Reduced removal of vegetation on all zones and significantly reduced proportion of exotic species on the Lower and Upper zones. This results in more natural cover and abundance of woody vegetation especially, although non-woody (reed) encroachment is likely to continue.	2.9
Fish	C	B	Improved flows will result in more FD and FS habitats, improving the current FROC of species with preference for fast habitats (CPAR, CSWIE, LCYL, LMOL, and OPER). This will also improve conditions for species sensitive to no flows, such as BBRI and CSWI. Improved water quality will be reflected by improved FROC of BEUT, CANO, MACU, MMAC and PCAT. General improvement in the riparian zone condition should result in improved overhanging vegetation as cover with a resultant increase in the FROC of species such as BBIV.	3
Inverts	B/C	B	Improved land use such as less grazing and trampling in the riparian zone will reduce the erosion and thus also the sedimentation. This will improve the cobble and vegetation habitat for the macroinvertebrates increasing the frequency at which a number of the taxa occur as well as the return of the sensitive mayfly family Tricorythidae.	2

16.9 D AEC

The deteriorated scenario includes the following:

- Increased abstraction which will result in less spills, i.e. less floods.
- Increased forestry and declining land use practices resulting in more erosion and sediment delivery to the channel
- Nutrients, temperature, oxygen, and turbidity levels will change linked to decreased flows.
- More reeds, alien vegetation and increased vegetation removal will decrease the vegetation EC.

Each component is adjusted to indicate the metrics that will react to the above scenario. The changes in the rule based models are available electronically and summarised in Table 16.12.

Table 16.12 EWR 7: D AEC

	PES	AEC	Comments	Conf
Physico -chem	C	D	These changes would result in elevated nutrients, toxics and turbidity levels; and greater fluctuations in temperature and oxygen levels. Under these conditions of less dilution, salt levels are also expected to increase.	2
Geom	C/D	D	The geomorphological consequences will be an increase in bed height, more subsurface flows and sediment with resulting decrease in riffles and shallower pools.	3
Rip veg	C	D	Increased presence of exotic species will lead to a decrease in woody vegetation (especially cover and abundance). Reedbeds will increase on marginal and lower zones.	3
Fish	C	D	Reduced flows and increased zero flows will reduce FS and FD habitat and also lead to loss of flow intolerant and moderately flow intolerant species (BEUT, BMAR, CANO, CPAR, CSWI, LCYL, and LMOL) and probably the complete eradication of OPER. Reduced water quality will lead to further pressure on the water quality intolerant species. Deterioration in substrates as a result of sedimentation and benthic algae will lead to decreased FROC of BNEE, BEUT, BMAR, *Chiloglanis* and *Labeo* spp. Deterioration in riparian zone with decreased overhanging vegetation will be reflected by decreased FROC of species such as BANO, BNEE, BPAU, BRAD, BTRI, BUNI and BVIV.	3
inverts	B/C	C/D	This scenario will result in sedimentation of the river bed, decreasing the interstitial spaces and therefore the available habitat for cobble dwelling taxa. The decreased flows and resulting increased temperatures and decreased oxygen concentrations will also affect the more sensitive taxa. A number of the less sensitive taxa will occur less frequently, while some of the more sensitive taxa (Athericidae, Leptophlebiidae, Chlorocyphidae, and Perlidae etc.) will disappear from the river reach.	2

16.10 SUMMARY OF ECOCLASSIFICATION RESULTS

The results to be used for setting of EWR scenarios are summarised in Table 16.13.

Table 16.13 EWR 7: Summary of EcoClassification results

IHI				Driver Components	PES & REC Category	Trend	AEC ↑	AEC↓
INSTREAM	C/D	RIPARIAN	C	HYDROLOGY	A?			D
				WATER QUALITY	C		B	D
				GEOMORPHOLOGY	C/D	Stable	C	D
				Response Components	**PES &REC Category**	**Trend**	**AEC ↑**	**AEC↓**
				FISH	C	Stable	B	D
				MACRO INVERTEBRATES	B/C	Negative	B	C/D
				INSTREAM	C		B	D
				RIPARIAN VEGETATION	C	Negative	B	D
				ECOSTATUS	C		B	D

IHI Hydrology PES	B/C
Diatoms	B/C

17 EWR 8 LOWER SAND (SAND RIVER)

17.1 DATA AVAILABILITY

Detailed information regarding available data is provided in the specialist appendices. Summarised data is given in Table 17.1.

Table 17.1 EWR 8: Availability of data

Component	Data availability	Conf
Hydrology	Although the only gauge in the Sand River X3H008 is located near the site, this gauge is not reliable. The gauge measures low flows. A gauge record from 1967 to present is available.	4
Physico-chemical	DWA monitoring data for RC and PES, but present state data only until 2006. Limited diatom data (n = 1); no peri- or phytoplankton data. No DO and metal data. Limited temperature and turbidity data from Weeks *et al*. (1995). Electrical conductivity (EC) was used instead of aggregated salts as TEACHA could not be used.	3
Geomorphology	Historical aerial photography (1944, 1965, 1974, 1984, 1997). Sediment transport modelling and analysis undertaken for this study. Hydrology records. Site survey information at time of study.	3.5
Riparian vegetation	Satellite images (Google earth) of the respective reach. Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows. Data collected from field assessment in 2007. Aerial photos of site - 1944, 1965, 1974, 1984, 1997. Numerous postgraduate studies on the Sabie especially inside KNP. Previous IFR studies. Available floristic data – biomes, bioregions and vegetation type etc. WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.*	4.5
Fish	Single site visit and fish sampling during September 2007. Angliss and Rodgers, 2002: *Sand River Catchment Biomonitoring Report.* Rivers Database (2007): *Database on fish distribution in South African Rivers*. Weeks *et al*. (1996): *A Pre-impoundment Study of the Sabie-Sand River System, Mpumalanga with special reference to predicted impacts on the Kruger National Park.* WRC (2001): *State of Rivers Report on the Crocodile, Sabie-Sand & Olifants River Systems.* Deacon (2007): *Fish Database of Kruger National Park Rivers (1960 to present).*	4
Macroinvertebrates	Data and analysis from a single sampling trip during September, 2007. Maps of study area and catchment information. Personal communications and assistance with data from Christa Thirion and Colleen Todd (DWA: RQS).	3

17.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS (Table 17.2) was rated as **HIGH** (present), as there are high occurrences of endangered fish, herpetofauna and vegetation tree species. Species and taxon richness is very high and there are fish and macroinvertebrate species intolerant to flow and flow related water quality that occurs here. This site is in the KNP and falls within the Maputoland-Pondoland principle region of plant diversity.

Table 17.2 EWR 8: EIS results

DETERMINANTS / METRICS	PRESENT		COMMENTS
	RATING	CONF[1]	
	(0 - 4)		
BIOTA (RIPARIAN & INSTREAM)			
Rare & endangered	4	4	*Opsaridium peringueyi*, *Serranochromus meridianus*, *Chiloglanis swierstrai*, *B. salicina*, birds, and crocodiles.
Unique (endemic, isolated, etc.)	2	4	*Chiloglanis anoterus*, *Machadorythus*.
Intolerant (flow & flow related water quality)	4	3	*Opsaridium peringueyi*, *Chiloglanis swierstrai*, *Chiloglanis anoterus*, and Heptageniidae.
Species/taxon richness	4	4	Thirty one fish species, 20 macroinvertebrate taxa, principal region of plant diversity (Maputoland/Pondoland).
RIPARIAN & INSTREAM HABITATS			
Diversity of types	2	4	Pools, rapids, and riparian vegetation.
Refugia	2.5	4	Pools, river stops flowing at times and therefore not so good for refuge.
Sensitivity to flow changes	2	3	Riffles.
Sensitivity to flow related water quality changes	2	3	
Migration route/corridor (instream & riparian)	2.5	4	Eels, birds, macroinvertebrates, migration problematic due to no flow periods.
Importance of conservation & natural areas	4	4	Kruger National Park.
MEDIAN	2.5		
EIS EVALUATION	**HIGH**		

17.3 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 17.3. Additional information on physico-chemical variables, fish and macroinvertebrate reference conditions are also provided.

Table 17.3 EWR 8: Reference conditions

Component	Reference conditions	Conf
Hydrology	There are possibly major differences between observed and modelled hydrology. Afforestation has been implemented in the catchment which should result in increased runoff. Virgin MAR: 133.61 MCM	4
Physico-chemical	DWA monitoring data: X3H008Q01; n = 82, 1977 – 1979. See Table 15.4.	3
Geomorphology	Reference condition includes a wide active channel with a less stable macro channel floor.	3.5
Riparian vegetation	**Marginal zone** Sections that are characterised by unconsolidated alluvia will tend to be dominated by reedbeds (*P. mauritianus*); while sections characterised by cobble/boulder or exposed bedrock will tend to be dominated by grasses (*Cynodon dactylon*) and herbaceous aquatics (*Cyperus*, *Persecaria*, and *Ludwigia* species). Small proportion of the marginal zone will be woody (*Breonadia* and *Syzigium* species mainly). **Lower zone** Mix of tree and shrub dominated vegetation (*B. salicina*, *S. cordatum* and *S. guineense*, and *N. oppositifolia* mainly) where substrates tend to be more rocky or consolidated and reeds/open sand (*P. mauritianus*) where substrates tend to be unconsolidated. **Upper zone** Tree and shrub dominated mainly (*C. erythrophyllum, F. sycomorus*, *and D. mespiliformis* with some *S. africana* expected in localised pockets).	3.5
Fish	Thirty species present. Refer to Table 15.5.	4
Macroinvertebrates	The reference total SASS 5 score is >235, with over 30 taxa and an ASPT of >7. Additional information is provided below.	3

Reference condition values for physico-chemical variables are provided in Table 17.4.

Table 17.4 EWR 8: Physico-chemical reference condition values

Water Quality Constituents		Value: RC
Inorganic salts (mg/L)	No data available.	
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.025
	Total Inorganic Nitrogen (TIN)	0.081
Physical variables	pH (5^{th}+95^{th} percentiles)	6.83+7.70
	Turbidity (NTU)	-
	Electrical conductivity (mS/m)	12.48

The reference as set for NRHP site X3SAND-SKUKU (Kleynhans *et al*., 2007b) was directly applicable as reference condition for EWR 8. GCAL was added to the list of fish species expected under natural conditions, as this species was sampled at this site during 1997 (Kleynhans Fish Database). The reference condition set is, in the context of this study, valid for the section of the Sand River within RAU S and B.1. Thirty fish species can be expected in this section and are listed in Table 17.5.

Table 17.5 EWR 8: Reference fish species

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 8 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Anguilla marmorata	Giant mottled eel	AMAR	1	1
Anguilla mossambica	Longfin eel	AMOS	1	1
Barbus annectens	Broadstriped barb	BANN	4	3
Barbus afrohamiltoni	Hamilton's barb	BFRI	3	3
Brycinus imberi	Imberi	BIMB	4	3
Labeobarbus marequensis	Largescale yellowfish	BMAR	5	5
Barbus radiatus	Beira barb	BRAD	3	3
Barbus toppini		BTOP	3	3
Barbus trimaculatus	Threespot barb	BTRI	5	5
Barbus unitaeniatus	Longbeard barb	BUNI	3	3
Barbus viviparous	Bowstripe barb	BVIV	5	5
Chiloglanis anoterus	Rock catlet	CANO	2	1
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Chiloglanis paratus	Sawfin suckermouth	CPAR	4	2
Chiloglanis swierstrai	Lowveld suckermouth	CSWI	4	2
Glossogobius callidus	River goby	GCAL	2	2
Glossogobius giurus	Tank goby	GGIU	3	2
Labeo cylindricus	Redeye labeo	LCYL	5	4
Labeo molybdinus	Leaden labeo	LMOL	5	4
Labeo rosae	Rednose labeo	LROS	3	3
Micralestis acutidens	Silver robber	MACU	4	4
Mesobola brevianalis	River sardine	MBRE	3	3
Marcusenius macrolepidotus	Bulldog	MMAC	4	3
Oreochromus mossambicus	Mozambique tilapia	OMOS	5	5
Opsaridium peringueyi	Southern barred minnow	OPER	2	1
Petrocephalus wesselsi	Southern churchill	PCAT	2	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4

Expected Reference and Habitat derived Frequency of Occurrence (FROC) of fish at EWR 8 (Values used in FRAI) Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Schilbe intermedius	Silver catfish	SINT	3	3
Serranochromus meridianus	Lowveld largemouth	SMER	3	3
Tilapia rendalli	Redbreast tilapia	TREN	5	5

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

Expected macroinvertebrate taxa include:

Baetidae >2spp, Oligoneuridae, Heptageniidae, Gyrinidae, Naucoridae, Hydrophilidae, Dytiscidae, Baetidae 1sp, Gomphidae, Caenidae, Tabanidae, Coenagrionidae, Hydroptilidae, Libellulidae, Simuliidae, Hydropsychidae 1sp, Ancylidae, Veliidae, Gerridae, Hydraenidae, Hydracarina, Corduliidae, Atyidae, Leptophlebiidae, Aeshnidae, Chlorocyphidae, Tricorythidae, Elmidae, Culicidae, Corixidae, Notonectidae, Psychodidae, Chironomidae, Nepidae, and Thiaridae.

17.4 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information (RDM Report 26/8/3/10/12/016) provided with the final report (RDM Report 26/8/3/10/12/015).

17.4.1 Hydrology

The present MAR is 94.74 MCM (70.9% of natural). The base flows have decreased from natural due to irrigation upstream of the site. This change from natural is ccontinuous but more noticeable during late winter and early spring. There are slight changes from reference condition with regard to moderate and high flows.

17.4.2 Geomorphology (C EC, 71.82%)

This section is a mixed anastomosing channel type section and consists of multiple mixed (sandy with bedrock influence) channels across the macro-channel floor. There are sandy areas with large bedrock outcrops, extensive reed vegetation across the macro channel floor, and large sandy lateral bars in places. The increased sediment loads from the degrading catchment have likely caused an increase in sediment storage and likely reduction in instream habitat diversity, depth of channel and volume of instream habitat. This has been verified by independent unpublished rapid assessments of the condition of bedrock sections of the Sand River (Rountree, unpublished report for the Kruger National Park).

17.4.3 Physico chemical (B EC, 84.48%)

The SPI score for this site is 13.2 (B category) although this falls within the lower ranges of the categorization. It seems that pollution (organic enrichment) is increasing as the majority of species present at this site is tolerant to high and extreme levels of pollution.

Increased turbidity is expected due to catchment activities as the pools have filled up due to sedimentation (Kleynhans and Swart, *pers. comm.*). Temperature and oxygen fluctuations are expected due to low flows in winter. PES values for the physico-chemical variables are provided in Table 15.6 and in Appendix C.

Table 17.6 EWR 8: Physico-chemical PES values

Water Quality Constituents		Value: PES
Nutrients (mg/L)	Soluble Reactive Phosphate (SRP)	0.032
	Total Inorganic Nitrogen (TIN)	0.45
Physical variables	pH (5^{th}+95^{th} percentiles)	7.46+8.12
	Turbidity (NTU)	Mean: 27 NTU Maximum value: 70 NTU (Weeks et al., 1995)
	Electrical conductivity (mS/m)	35.1

17.5 Instream and Riparian Habitat Integrity (IIHI: C EC, 73%; RIHI: C EC, 79.1%)

Abstraction, weirs and small dams are the main impacts on the instream and riparian integrity of this site.

17.5.1 Fish (B EC, 86.8%)

The PES reflects slightly deteriorated ecological integrity, based on the fish assemblage, primarily attributed to the slightly altered hydrological regime (low flows), some increased sedimentation (overgrazing in rural areas of upper catchment) and slight deterioration in water quality. Most of the expected fish species are however still present in this reach, although in reduced abundance and spatial distribution. The majority of this reach lies within conservation areas, which contributed to general good ecological integrity.

17.5.2 Macroinvertebrates (C EC, 68.8%)

SASS5 score: 105 No of Taxa: 20 ASPT: 5.3

The habitat at this site is dominated by coarse mobile sands and *Phragmites sp.* reeds. Standing water habitats only were present during the field visit. Water temperatures in pools were high due to the lack of flow and shading. The macroinvertebrate fauna collected were, as expected under such conditions, predominantly resilient, low-scoring taxa, which occur in these types of habitats. The only higher scoring taxon collected were Heptageniid mayflies. The balance of the fauna is typical of a temporary sand-dominated system with a marginal vegetation component.

17.6 Riparian vegetation (B EC, 86.7%)

Marginal zone: The zone has expanded as sedimentation occurs, since reeds have colonised and stabilised additional sand deposits. Marginal species composition is as expected, but reeds occur in greater proportions and abundance.

Lower and Upper zone: These zones are close to reference condition, with low alien vegetation impact, but reedbeds are more extensive than expected i.e. a greater patchiness with reeds and open sediment was expected.

17.6.1 PES causes and sources

The PES for the components s well as the reasons for the PES are summarised in Table 17.7

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Table 17.7 EWR 8: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	C	4	Reduced base flows.	Irrigation	F	4
			Reduced moderate and high flows.	Abstraction weirs.		
Physico-Chem	B	2	Elevated nutrients, turbidity levels and temperatures at low flows. Oxygen levels drop at low flows.	Although this site is in a conservation area (the KNP), poor land management upstream is affecting the site.	NF	3
Geom	C	3	Increased sediment supply - the size of the active channel has probably reduced, macro-channel floor is stabilizing.	Landuse practices.	NF	3
			Decreased flows - the size of the active channel is reduced.	Extensive Forestry; irrigation, abstraction.	F	
Rip veg	B	3.7	Reduced indigenous vegetation cover and changes to species composition.	Exotic vegetation impact low (<10%).	F	4.5
			Expansion of reedbeds.	Narrowing of channel due to reduced flows.	NF	
Fish	B	4	Slightly altered low flows reduce FS habitats.	Abstraction, livestock watering.	F	
			Reduced migration success as a result of migration barriers. and	Migration barriers (especially Corumanu dam, but also smaller weirs) impede natural migration.	NF	
			Altered migratory cues.	Altered hydrological events delay/prevent natural migratory cue.	F	
			Increased sedimentation and benthic growth result in deterioration of substrate as habitat. Sedimentation transforms deep habitats to shallow habitats.	Hillslope erosion in catchment (over grazing, small-scare agriculture, informal settlements). Increased nutrients result in slightly aggregated benthic growth.	NF	
Inverts	C	3.5	Reduction in low flows.	Abstraction.	F	2
			Modified water quality.	Land-use upstream.	NF	

17.7 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 17.8.

Table 17.8 EWR 8: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Physico-chem	B	Stable	B	N/A	-	3
Geom	C	Negative	C/D	10 years	The sandy nature of the river means that this reach is relatively resilient to moderate flow reductions and sediment increases. However the high sediment loads derived from this catchment are reducing in-channel bedrock influence (Rountree, unpublished report) and filling in pools (Kleynhans, *pers comm.*).	2.5
Rip veg	B	Stable	B	N/A	Exotics, if left unchecked would increase in proportion at the expense of indigenous riparian vegetation, but the actions of WFW inside KNP appear to be ongoing and frequent enough to stabilize the site. Stability does however depend on the continued action of Working for Water.	2.5

	PES	Trend	Trend PES	Time	Reasons	Conf
Fish	B	Stable	B	N/A	The fish assemblage in this section has adapted to the altered water quality and flows and should remain fairly stable.	3
Inverts	C	Negative	C/D	5 years	Maintenance of current abstraction will have the effect of reducing the already low overall sensitivity of the macroinvertebrate community. There is little habitat to buffer this change.	2

17.8 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 17.9. The Instream EC is a B (73.45%).

Table 17.9 EWR 8: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	2.5	80		
2.What is the natural diversity of **fish** species with a preference for different cover types	3.5	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3	90		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	90		
FISH ECOLOGICAL CATEGORY	12	360	**86.8**	**B**
MACROINVERTEBRATES				
1. What is the natural diversity of **macroinvertebrate** biotopes	3	100		
2. What is the natural diversity of **macroinvertebrate** taxa with different velocity requirements	3	100		
3. What is the natural diversity of **macroinvertebrate** taxa with different tolerances to modified water quality	3	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**9**	300	**68.8**	**C**
INSTREAM ECOLOGICAL CATEGORY (No confidence)		660	**76.5**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.62	34.60	
Confidence rating for **macroinvertebrate** information	2.5	0.38	38.85	
	6.5	1.00	73.45	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B**	

To determine the EcoStatus, the VEGRAI EC and confidence are added to the equation (Table 7.10). The EcoStatus EC is a B (83.41%).

Table 17.10 EWR 8: EcoStatus

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**86.7**	**B**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	3.42308	0.48	38.38
Confidence rating for riparian vegetation zone information	3.7	0.52	45.04
	7.12308	1.00	83.41
ECOSTATUS	**EC**		**B**

17.9 B REC

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of.

The EIS at EWR 8 is HIGH. As the PES is also relatively high, the attainable and realistic objective is to maintain the PES. This would require stabilising the current negative trends i.e. improving the macroinvertebrate EC by improving low flows.

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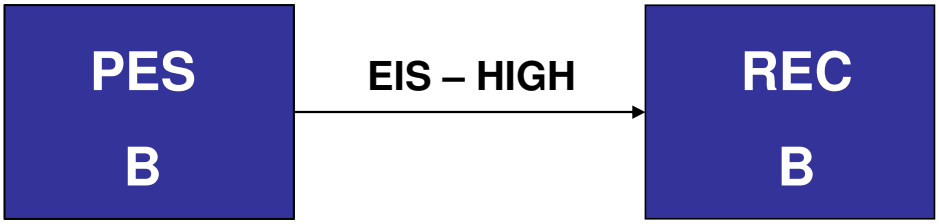

17.9.1 Macroinvertebrates: B REC

The macroinvertebrate component is adjusted to indicate the metrics that will react to the above conditions to achieve a REC. The changes in the rule based models for the REC are provided electronically and summarised in Table 17.11.

Table 17.11 EWR 8: B REC

	PES	REC	Comments	Conf
Inverts	C	B	With improved low flows and possibly small to moderate floods (due to improved catchment management) habitat quality will improve, with a subsequent increase in overall macroinvertebrate diversity and abundance. More sensitive taxa are likely to increase in abundance and the number of high scoring taxa could increase.	3

17.10 C AEC

The scenario includes the following:

- More decreased low flows.
- Longer periods of zero flow.

Each component is adjusted to indicate the metrics that will react to the scenario. The changes in the rule based models are available electronically and summarised in Table 17.12.

Table 17.12 EWR 8: C AEC

	PES	AEC	Comments	Conf
Physico-chem	B	C	Lower and longer low flow periods, resulting in more extreme temperature and oxygen fluctuations, and higher nutrient loadings.	3
Geom	C	C	This will cause a slight reduction in the EC but will not be enough to cause a change in category.	2
Rip veg	B	B/C	Reduced flows and increased sedimentation will facilitate channel narrowing and a shift in vegetation as the marginal zone migrates. Reeds will colonise new sand and further aid channel narrowing, while reeds on the lower zone will remain. Species composition is unlikely to change. It is assumed that alien vegetation is kept at bay and does not increase.	2.5
Fish	B	C	The scenario will result in decreased FROC of species with preference for FS and FD habitats (BMAR, CPAR, LCYL, LMOL, and MACU), and a complete loss in species intolerant to no flow conditions (CANO, CSWIE, OPER, and HVIT).	4
inverts	C	C/D	Further loss of low flows and alteration of flood regime will lead to further impairments in water quality, proliferation of algae, deposition of fines, and overall degradation of instream habitat. The hydraulic habitat; Fast over Coarse Sediment (FCS) and Marginal Vegetation In Current (MVIC), both of which harbour the more sensitive elements of the macroinvertebrate community, are likely to be most compromised both in terms of quality and quantity.	2.5

17.11 SUMMARY OF ECOCLASSIFICATION RESULTS

The results to be used for setting of EWR scenarios are summarised in Table 17.13.

Table 17.13 EWR 8: Summary of EcoClassification results

IHI				Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	C	RIPARIAN	B/C	HYDROLOGY	C?		C	D?
				WATER QUALITY	B		B	C
				GEOMORPHOLOGY	C	Negative	C	Lower C
				Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
				FISH	B	Stable	B	C
				MACRO INVERTEBRATES	C	Negative	B	C/D
				INSTREAM	B/C		B	C
				RIPARIAN VEGETATION	B	Stable	B	B/C
				ECOSTATUS	B	Negative	B	C

IHI Hydrology PES	C
Diatoms	B/C

18 SUMMARY OF RESULTS AND CONCLUSIONS: SABIE - SAND SYSTEM

18.1 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results for EWR 1 to 8 in the Sabie-Sand River system are summarised in Table 18.1.

Table 18.1 EcoClassification Results summary – Sabie-Sand system

The EcoClassification results for the Sabie-Sand River system are summarised below.

EWR 1: Upper Sabie (Sabie River)

EIS: High
Rare and endangered fish and vegetation species. Fish species present that are intolerant to flow and flow related water quality changes. .

PES: B/C
Impacts due to forestry, exotic vegetation species, and abstraction. Impacts largely non-flow related.

REC: B
The EIS is high; therefore the REC is an improvement of the PES. Inactivity of picnic site and removal of aliens is required. Improved fish EC dependent on improved vegetation cover.

AEC down: C/D
Decreased low flows resulting in increased sediment with increased nutrients, turbidity, temperature, additional toxics. Increased vegetation exotics and reeds on bars.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	A/B		A/B	B/C
WATER QUALITY	A/B		A/B	B/C
GEOMORPHOLOGY	B	Stable	B	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Stable	B	C/D
MACRO INVERTEBRATES	B	Stable	A/B	C
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	B/C	Negative	B	C/D
ECOSTATUS	B/C		B	C/D

EWR 2: Aan de Vliet (Sabie River)

EIS: High
Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.

PES: C
Forestry and landuse activities, mostly non-flow related.

REC: B
Changes in flow are not required to improve the state.
Remove exotic vegetation and cease mowing in the riparian zone. Reduce recreational disturbances. The nutrient status must also be improved.

AEC down: C/D
Increased abstraction could lead to increased return flows that will cause problems due to pesticides, nutrient loading etc. Mismanagement of land use in terms of forestry and agriculture

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C		B/C	D
WATER QUALITY	B		A/B	C
GEOMORPHOLOGY	B	Negative	B	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Stable	B	C/D
MACRO INVERTEBRATES	B/C	Stable	B	C
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	C/D

EWR 3 Kidney (Sabie River)

EIS: Very High
Rare and endangered species, taxon richness and species intolerant to flow and flow related water quality changes. Refuge area for biota and an important migration corridor for birds and fish. Within KNP.

PES: A/B
Forestry, abstraction, Inyaka Dam and landuse activities. (Flow and non-flow related)

REC: A/B
As the PES is already an A/B, the REC = the PES.

AEC Down: B/C
Increased abstractions, no Reserve implementation, less floods. Increased nutrients, changes in temperature, oxygen etc. Riffles lost due to sedimentation, channel shallower and sandier. Vegetation exotics will increase.
More reeds will be present in sandier areas.

Driver Components	PES & REC Category	Trend	AEC↓
HYDROLOGY	C		C/D
WATER QUALITY	B		C
GEOMORPHOLOGY	B	Negative	C
Response Components	**PES & REC Category**	**Trend**	**AEC↓**
FISH	B	Stable	C
MACRO INVERTEBRATES	B	Stable	C
INSTREAM	B		C
RIPARIAN VEGETATION	A/B	Stable	B/C
ECOSTATUS	A/B		B/C

EWR 4 Mac Mac (Mac Mac River)

EIS: High
Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.

PES: B
Forestry, exotic vegetation and wastewater input. Impacts are flow and non-flow related.

REC: A/B
The EIS at EWR 4 is high and the REC is therefore to improve the PES by improving the fish. Improved water quality required.

AEC down: C
Decreased low flows due to e.g. a weir or small dam in the upper catchment. This will result in embedded cobbles. Nutrients and temperature will increase. Increased exotic vegetation in the riparian zone.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C		C	C
WATER QUALITY	A/B		A	B/C
GEOMORPHOLOGY	A	Stable	A	B
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Stable	B	C/D
MACRO INVERTEBRATES	A/B	Stable	A/B	B/C
INSTREAM	B		B	C
RIPARIAN VEGETATION	A/B	Negative	A/B	B/C
ECOSTATUS	B		A/B	C

EWR 5 Marite (Marite River)

EIS: High.
Rare, endangered and unique biota. Species richness high and species intolerant to flow and flow related water quality changes present.

PES: B/C
Increased low flows and landuse activities. Impacts mostly flow related

REC: B
The EIS is high; therefore the REC is an improvement of the PES. More natural distribution of flows required. Reduce grazing and trampling, remove exotic vegetation.

AEC down: C/D
No flow releases for the EWR, less dilution and less floods due to e.g. direct abstraction from the dam. More nutrients and toxics present. Sandier river, some riffles and bedrock areas in the reach will be lost, vegetation encroachment on bars and banks and embedded cobbles. Increased aliens, removal, grazing, and trampling.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C			D
WATER QUALITY	B		B	C
GEOMORPHOLOGY	C	Negative	C	D
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Negative	B	C/D
MACRO INVERTEBRATES	B/C	Stable	B	C
INSTREAM	B/C		B	C/D
RIPARIAN VEGETATION	B/C	Negative	B	C/D
ECOSTATUS	B/C		B	C/D

EWR 6 Mutlumuvi (Mutlumuvi River)

EIS: High
Rare, endangered and unique biota. Taxon species richness high and species intolerant to flow and flow related water quality changes present.

PES: C
Abstraction, forestry, informal settlements and landuse activities. Impacts flow and non-flow related.

REC: B
The EIS is high and improvement requires improved system operation which improves the low flow regime.

AEC down: C/D
Decreased low flows and longer periods of zero flows. Increased algal growth. Less moderate floods will cause some impact on sedimentation. The reedbeds will become less dense and Matumi will disappear.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C			
WATER QUALITY	B/C		B	C/D
GEOMORPHOLOGY	C	Stable	C	D
Response Components	**PES Category**	**Trend**	**AEC ↑**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	B/C	Negative	B	C
INSTREAM	C		B	C/D
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	C/D

EWR 7 Tlulandziteka (Tlulandziteka River)

EIS: Moderate
Rare and endangered species, high taxon richness, species intolerant to flow and flow related water quality changes.

PES: C
Forestry, abstraction, flow modification and poor landuse management. Impacts flow and non-flow related.

REC: C
Due to the moderate EIS, the REC = the PES.

AEC Up: B
Improved flows through fixing of canals, rehabilitation of forestry areas and improved management of canal system and landuse. Remove exotic vegetation, minimise agricultural disturbance and remove unused orchards.

AEC Down: D
Increased use of the dam with less spills, i.e. less floods. More abstraction and forestry. Nutrients, temperature, oxygen, and turbidity levels will change. Increase in bed height, more subsurface flows and sediment with resulting decrease in riffles and shallower pools. More reeds, alien vegetation and more removal.

Driver Components	PES & REC Category	Trend	AEC ↑	AEC↓
HYDROLOGY	A?			D
WATER QUALITY	C		B	D
GEOMORPHOLOGY	C/D	Stable	C	D
Response Components	**PES &REC Category**	**Trend**	**AEC ↑**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	B/C	Negative	B	C/D
INSTREAM	C		B	D
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	D

EWR 8 Lower Sand (Sand River)

EIS: High
Rare and endangered species, high taxon richness and species intolerant to flow and flow related water quality changes. Situated in KNP

PES: B
Abstraction, dams, weirs, poor landuse management. Impacts are flow and non-flow related.

REC: B
Although the EIS is High, the PES is already in a B therefore the REC = PES. Improve the macroinvertebrate EC by increasing low flows.

AEC down: C
More decreased low flows and longer periods of no flow.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C?		C	D?
WATER QUALITY	B		B	C
GEOMORPHOLOGY	C	Negative	C	Lower C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B	Stable	B	C
MACRO INVERTEBRATES	C	Negative	B	C/D
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	B	Stable	B	B/C
ECOSTATUS	B	Negative	B	C

18.1.1 Confidence in results

The confidence in EcoClassification is provided in Table 18.2. The confidence provided is for data availability and EcoClassification:

- Data availability: The evaluation is based on the adequacy of any available data for interpretation of the Ecological Category and AEC.
- EcoClassification: The evaluation is based on the confidence in the accuracy of the Ecological Category.

Table 18.2 Confidence in EcoClassification

1 (very low confidence) 2 (low confidence) 3 (medium confidence)
4 (high confidence) 5 (very high confidence)

Data Availability									EcoClassification								
Hydrology	Geomorphology	Physico-chemical	IHI (instream & riparian	Fish	Macroinvertebrates	Vegetation	Average	Median	Hydrology	Geomorphology	Physico-chemical	IHI (instream & riparian	Fish	Macroinvertebrates	Vegetation	Average	Median
EWR 1																	
3	3	3	4	3	3	4	3.29	3.00	3	3.5	3	3.2	4	4	3.4	3.44	3.40
The confidence in the EcoClassification is **MEDIUM - HIGH**. The scores are similar for all components, so a median score is applicable.																	
EWR 2																	
4	3	3	4	4	4	4	3.71	4.00	4	3.5	3	3.1	4	4	3.2	3.54	3.50
The confidence in data availability is **HIGH** in all components apart from geomorphology physico-chemical data which has a **MEDIUM** confidence level. This is primarily due to the nature of the EWR site in terms of geomorphology (which is complicated and unrepresentative of the reach) and lack of measured data for water quality. The EcoClassification confidence **is MEDIUM - HIGH** (lower than data availability) which basically reflects the **MEDIUM** confidence in data availability of the physico-chemical variables.																	
EWR 3																	
3	5	2.5	4	4	4	5	3.93	4.00	3	4	2.5	3.1	4	4	4	3.51	4.00
The EcoClassification and data availability confidence is **HIGH**. This is due to the large amount of work previously done on this site, both pre- and post the 2000 flood.																	
EWR 4																	
3	3	3	4	3	3	4	3.29	3.00	3	3	3	3.4	4	3	3.9	3.33	3.00
The EcoClassification and data availability confidence is **MEDIUM**. The reason why this is not higher is because the Mac Mac River was not previous studied and there is no nearby gauging weir or water quality measuring point.																	
EWR 5																	
4	3.5	3	4	4	3	4	3.64	4.00	4	3.5	3	3.2	4	2.5	4	3.46	3.50
The confidence in data availability is **HIGH**. The EcoClassification confidence is **MEDIUM - HIGH**. The macroinvertebrates has a lower confidence than the other components due to the fact that data from only one recent survey for macroinvertebrates was available at this site.																	
EWR 6																	
2	3	2	4	3	3	4	3.00	3.00	2	3	2	2.9	4	3.5	3.8	3.03	3.00
The EcoClassification and data availability confidence is **MEDIUM**. Although a 1996 EWR site, little work has since been done at this site and therefore the confidence of medium only. The hydrology and physico-chemical evaluations are low due to a lack of measuring stations.																	
EWR 7																	
2.5	2	2	4	3	2.5	2	2.57	2.50	2.5	2	2	2.9	3	2	3.7	2.59	2.50
The confidence is **LOW - MEDIUM.** This is a new site with only one survey undertaken. This study therefore equates more to a Rapid Ecological Reserve study for which these confidence evaluations are appropriate. The hydrology and physico-chemical evaluations are low due to a lack of measuring stations.																	
EWR 8																	
4	3.5	3	4	3	3	4.5	3.57	3.50	4	3	2	2.9	4	3.5	3.7	3.30	3.50
The data availability is medium to **HIGH**. This is a 1996 IFR site and biomonitoring has also since taken place there. The confidence is not higher due to the complexity of the site and the often no-flow situations which are encountered.																	

A summary of data availability, the confidence of the available data as well as the confidence in the results of the EcoClassification assessment for each of the EWR sites in the Sabie-Sand River catchments is given in Table 18.3. The colour coding is as follows:

Green: High to Very High
Yellow: Medium to high
Red: Very low to Medium

Table 18.3 Summary of confidences for all the sites

EWR site	EWR 1		EWR 2		EWR 3		EWR 4		EWR 5		EWR 6		EWR 7		EWR 8	
Confidence	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification
Hydrology	3	3	4	4	3	3	3	3	4	4	2	2	2.5	2.5	4	4
Geomorphology	3	3.5	3	3.5	5	4	3	3	3.5	3.5	3	3	2	2	3.5	3
Physico-chemical	3	3	3	3	2.5	2.5	3	3	3	3	2	2	2	2	3	2
IHI (instream & riparian	4	3.2	4	3.1	4	3.1	4	3.4	4	3.2	4	2.9	4	2.9	4	2.9
Fish	3	4	4	4	4	4	3	4	4	4	3	4	3	3	3	4
Macroinvertebrates	3	4	4	4	4	4	3	3	3	2.5	3	3.5	2.5	2	3	3.5
Vegetation	4	3.4	4	3.2	5	4	4	3.9	4	4	4	3.8	2	3.7	4.5	3.7
Median	3	3.4	4	3.5	4	4	3	3	4	3.5	3	3	2.5	2.5	3.5	3.5

18.2 CONCLUSIONS

The results from Table 18.3 indicated MEDIUM to HIGH confidence for data availability at all the sites except for EWR 7. The confidence at EWR 7 is LOW to MEDIUM as this site was only surveyed at a Rapid Level. There is also no hydrological gauge or water quality measuring station nearby. Although good biological response information was available for EWR sites 1, 4 and 6, information on the ecological drivers was not sufficient and therefore the confidence is MEDIUM. The MEDIUM-HIGH (EWR 8) and HIGH (EWR 2, 3 and 5) confidence are due to data collated during national and provincial RHP surveys, research that was conducted in the KNP as well as the 1996 and 1997 Reserve studies (previously referred to as 'IFR studies'). An updated hydrology study was also undertaken for the Sabie and Sand Rivers. However, confidence in the hydrology data for the Sand River will always be low due to the fact that there is only one gauge that represents the whole catchment.

MEDIUM to LOW levels of confidence in the EcoClassification results in the Sabie-Sand River catchments were attributed to the following:

- EWR 1: Apart from the instream biological surveys and one geomorphology survey, no other work had been undertaken at this site.
- EWR 2: This site is a complex site from a vegetation point of view which resulted in the site not having a HIGH EcoClassification confidence.
- EWR 4 and 7: EWR 7 was an additional site, and as such the EcoClassification assessment was only conducted at a Rapid level III. There was also no nearby hydrological or water quality measuring gauge for both EWR sites.
- EWR 5: There was a lack of macroinvertebrate information (probably due to the bedrock nature of the system), as well as lack of hydrological and water quality measuring data.
- EWR 8: The lack of confidence was a result of a lack of physico-chemical information, especially as this site dries up which means that temperature and oxygen information becomes crucial.

18.3 RECOMMENDATIONS

EWR 1, 4 and 7 should be included as RHP sites. More work has been undertaken on the Sabie River within the KNP and it is unlikely that further work will increase confidences on these sites. A Water Resources Monitoring Programme is recommended where most of the problems listed above can be addressed. Some of the uncertainties are due to the natural nature of the site (bedrock and alluvial), which results in problems with the interpretation of the results, especially in terms of the macroinvertebrate assessments. The lack of measured water quality and hydrology data should be addressed as it is crucial for monitoring as well as for improving confidences in the long term. More specifically, the following is recommended in terms of future monitoring requirements:

- Due to the lack of a nearby water quality monitoring stations, diatom assessments as part of future monitoring is recommended especially at EWR 3 and 8. This will provide a good indication of the trend of the physico-chemical variables and if problems are indicated, more detailed physico-chemical analysis can be undertaken; however only based on available data.
- Instream and riparian vegetation monitoring should take place at EWR 1, 2, 4 and 7 as this will bring the level of confidences for these sites to the same level as the other sites.
- Macroinvertebrates should be monitored at EWR 5 and 7 as part of the RHP. This will provide additional information and add further detail to the Ecological Category, and therefore the EcoSpecs.

In general it is recommended that the EWR sites become the RHP sites where in close proximity to one another. The other EWR sites should be included as RHP sites. Most of the problems above can be addressed within a monitoring programme, and it is not recommended that any specific additional work is undertaken to address the confidences. This will be confirmed once the assessment of the adequacy of the baseline information is undertaken as part of the EcoSpec assessment.

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