

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

PROJECT NO: WP 9133

Ecological Water Resources Monitoring: EcoSpecs



MARCH 2010

REPORT NO.: 26/8/3/10/12/012



water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

CHIEF DIRECTORATE: RESOURCE DIRECTED MEASURES

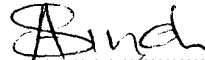
**COMPREHENSIVE RESERVE DETERMINATION STUDY FOR SELECTED
WATER RESOURCES (RIVERS, GROUNDWATER AND WETLANDS) IN
THE INKOMATI WATER MANAGEMENT AREA, MPUMALANGA.**

SABIE AND CROCODILE SYSTEMS: ECOSPECS REPORT: FINAL

Approved for Rivers for Africa by:

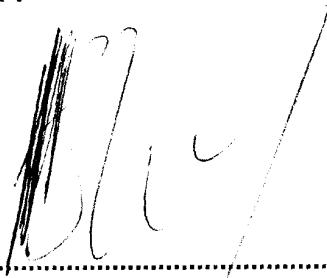


.....
Delana Louw
Technical Project Manager



.....
Adhishri Singh
Administrative Project Manager

Approved for the Chief Directorate: Resource Directed Measures by:



.....
Barbara Weston
Study Manager

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

Bold indicates this report

REFERENCES

This report is to be referred in bibliographies as:

Department of Water Affairs, South Africa. 2010. 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. Prepared by Water for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/011.

AKNOWLEDGEMENTS

Dr Neels Kleynhans, DWA: RQS, for providing methods and approaches, review, and guidance.

Contributors to the report and specialist meeting:

Dr Deacon, Andrew (Fish)

Ms Koekemoer, Shael (Diatoms and Editing)

Dr Kotze, Piet (Fish and report review)

Ms Louw, Delana (Process facilitator)

Mr Mackenzie, James (Riparian vegetation)

Mr Rountree, Mark (Fluvial Geomorphology)

Dr Scherman, Patsy (Physico-chemical variables)

Ms Thirion, Christa (Macroinvertebrates)

Dr Uys, Mandy (Macroinvertebrates)

EXECUTIVE SUMMARY

BACKGROUND

The National Water Act (NWA, Act No. 36 of 1998, Section 3) requires that the quantity, quality and reliability of water needed to sustain both human use and aquatic ecosystems (the Reserve) be determined so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems.

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.

STUDY AREA

The Inkomati Water management Area (WMA) is largely located within the Mpumalanga 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 Inkomati 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. Fifteen Ecological Water Requirement (EWR) sites were chosen to represent these catchments, the locality and characteristics of which are provided in the table below. 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, 2008a).

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	Goedenhoop	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 site no	EWR site name	River	Coordinates		EcoRegion (Level 2)	Geomorphic Zone	Quat
			Latitude	Longitude			
EWR 7	Tlulanziteka	Tlulanziteka 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

The purpose of this report is to present the Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) for each of the EWR sites on the Crocodile, Sabie-Sand River Systems. These EcoSpecs define the conditions that would occur under the Present Ecological State (PES). TPCs are provided to indicate worsening conditions. Where relevant, the conditions that describe the REC (when different than the PES) are also provided. This information forms the key inputs into an Ecological Water Resource Monitoring (EWRM) Program for these catchments. Further information on EcoSpecs and TPCs and their use in Ecological Water Resources Monitoring can be obtained from DWA (2009), and Kleynhans *et al.* (2009).

APPROACH

The NWA requires the establishment of a national monitoring system that must provide for the collection of appropriate data and information necessary to assess water resources. Such a system must collect relevant information that contributes to the management of the resource in a desirable ecological condition

Initially the aim was to develop an Ecological Reserve Monitoring programme. This would have run separately to the River Health Programme (RHP). However, the implications of simultaneously operating two separate ecological monitoring programmes have serious resource implications. To mitigate this and still maintain an operational ecological monitoring programme that provides useful management information, integration of the ERM and RHP within an adaptive management approach is proposed (Kleynhans *et al.*, 2009). **This forms the basis of the integrated Ecological Water Resource Monitoring (EWRM) approach.**

During Reserve determination studies, EcoSpecs are developed and specified in terms of the Resource Quality Objectives (RQOs) as per the Resource Directed Measures and EcoClassification process (Kleynhans and Louw 2007). This encompasses biological specifications or biocriteria (in the form of numerical values or narrative statements) that define a desired biological condition for a waterbody (Burton and Gerritsen, 2003). EcoSpecs then indicates the ecological detail that characterizes the EC.

TPCs indicate the values around the EcoSpecs that, if being approached would initiate more detailed investigation or even management action. TPCs are based on the acceptance that there is uncertainty as to accuracy or validity of EcoSpecs i.e. is deviation from EcoSpecs due to natural variation, sampling error, etc. In the context of EWRM, TPCs are regarded as early warning indicators of potential change from a particular Ecological Category (EC) to another (lower) EC.

EWRM operates within the following concepts (based on Elzinga *et al.*, 1998):

- The reference condition is the natural or unimpaired condition of the system.
- The monitoring baseline is a series of measurements taken before the initiation of the impact or management activity and is used for comparison with the series of measurements taken after the management activity. If the Present Ecological State (PES) of the resource is unimpaired (natural), the reference will also be the baseline.

- It is important to assess whether there is a trend in the baseline, i.e. is it stationary or changing in a particular direction at the time when it is determined.
- This is the standard (“benchmark”) against which future deviations can be compared.

Therefore the Present Ecological State (PES) of the system must be determined prior to management interventions. The PES will then serve as the baseline ecological state from which all changes can be measured and evaluated. i.e.:

PES = BASELINE = BASELINE ECOLOGICAL CATEGORY (BEC)

Management actions are designed to maintain, or attain (if different from the PES) the REC. These management actions relate to the management objectives which are described in terms of the flow and quality (physico-chemical) EcoSpecs. Additional land use objectives may also be described if there are non-flow related impacts that are contributing to the PES of the system and which will need to be improved in order to achieve the REC.

Therefore one must clearly distinguish between setting management objectives to achieve/maintain certain Ecological Categories in terms of the drivers (flow and water quality), and defining EcoSpecs for the biophysical response, that describes, in a different level of detail, the Ecological Categories.

In essence, during an EWR study, flow requirements (main driver) are defined that could result in a certain ecological state defined through an Ecological Category. These flow **requirements (main driver) inform the management objectives supported by the other driver components**. Note that the word ‘could’ is used as the biological responses to driver conditions are all predicted and must be tested through monitoring. Monitoring the ecological responses will test the predictions made during an EWR study. It furthermore will test whether adjustments to the EcoSpecs and TPCs are required and whether the overall management objective in terms of the REC (or class) is being achieved. It is therefore crucial that monitoring be driven by objectives as it forms the foundation of a monitoring project (cf. Elzinga *et al.*, 1998).

The condition and response of the resource is therefore monitored to determine if the REC has been attained or maintained.

What is required at this stage is to provide detailed EcoSpecs and TPCs for the baseline, i.e. the BEC for the biological responses, physico-chemical variables and geomorphology.

The focus on this study is thus to provide the detailed EcoSpecs and to define the TPCs for (the BEC, i.e. the current or initial PES) at each EWR site on the Crocodile, Sabie and Sand River Systems. Note that TPCs are set within the PES to indicate the probability or relative risk of the BEC changing to a lower EC. The purpose of this is to implement management actions to prevent this degradation, unless the Classification system has resulted in a state worse than the PES (BASELINE EC) being selected as the CLASS.

Note that the same level (qualitative/narrative to quantitative) of detail for the EcoSpecs is thus not set for the REC or any other EC as the focus is on the BEC. The level of EcoSpecs defined during the EcoClassification process will be sufficient during the initiation of monitoring. The EcoSpecs for ECs other than the PES are predictions and dependant on many driver variables. It, represents only one combination of driver conditions out of many that could result in this EC.

RESULTS

EcoSpecs and TPCs are listed in detail in the main text for each EWR site for:

- Physico-chemical variables
- Geomorphology
- Riparian vegetation
- Fish
- Macroinvertebrates

These are highly detailed and quantified data that must be refined during an Adaptive Management process within EWRM. A summary of the EcoSpecs and TPCs in tabular form per site will be provided in the main report as the EcoSpecs chapter.

CONCLUSIONS AND RECOMMENDATIONS

To date formal implementation of the monitoring step of the Reserve has not taken place (CJ Kleynhans, C Thirion, *pers. comm*). Furthermore, there has been minimal (only informally on the Palmiet River and on a private dam in the Western Cape) implementation (with reference to the supply of the flows and management of other drivers to achieve the required EC) of the Ecological Reserve. This is of major concern as all EWRs, EcoSpecs; TPCs etc. are hypotheses until tested. With increased development and pressure on the water resources in this country there are no structures in place to monitor the further deterioration of our rivers. All methods related to monitoring and the identification of EcoSpecs and TPCs therefore require testing and refinement.

The Crocodile River system has high demands imposed on it by the irrigation sector, international requirements (IncoMaputo Water Use Agreement) as well as industrial and domestic sectors. The Sabie-Sand River system supplies the bulk of the irrigation requirements in this sub-catchment as well as international water requirements. These river systems are also of national importance with respect to the Kruger National Park (KNP) and monitoring is of vital importance.

No specific Ecological Reserve Monitoring has been initiated in the Crocodile and Sabie Sand River systems. Limited monitoring has taken place outside the KNP as part of provincial initiatives to report on the 'State of the Rivers'. More detailed biomonitoring has taken place in the KNP; however the focus was not on Ecological Reserve Monitoring.

Immediate monitoring is necessary as the surveys undertaken during the Reserve study represent the baseline against which change is measured. These surveys were undertaken during 2007 and it can already (pending changes in the catchments), not be applicable. The longer monitoring is delayed, the bigger the chance is that the baseline surveys will have to be repeated because of outdated data.

The Rapid Habitat Assessment Method (RHAM) was developed during 2007 – 2009. A RHAM survey was undertaken during 2009 and this data is available as part of the electronic information and data of this study (RDM Report 26/8/3/10/14/016) (DWA, 2010) and from D:RQS (Dr CJ Kleynhans). The D:RQS is currently analysing the data to further streamline the monitoring techniques and process to determine EcoSpecs and TPCs. As a low intensity method aimed to minimise the dependence on specialist resources, it is important that the methods are included in the monitoring.

TABLE OF CONTENTS

REFERENCES	i
ACKNOWLEDGEMENTS	ii
EXECUTIVE SUMMARY	iii
ABBREVIATIONS AND ACRONYMS	xvi
1 BACKGROUND AND INTRODUCTION	1-1
1.1 BACKGROUND	1-1
1.2 STUDY AREA	1-1
1.1 PURPOSE OF THE REPORT.....	1-5
1.2 OUTLINE OF THE REPORT	1-5
2 APPROACH	2-1
2.1 BACKGROUND TO ECOLOGICAL WATER RESOURCES MONITORING (SUMMARISED FROM DWAF, 2009a)	2-1
2.1.1 Ecological monitoring	2-1
2.1.2 EcoSpecs and Thresholds of Potential Concern.....	2-2
2.1.3 Different levels of monitoring	2-2
2.2 ECOSPECS AND TPCs (SUMMARISED FROM DWA, 2009a)	2-4
2.3 APPROACH FOR APPLYING THE PRINCIPLES OF EWRM, ECOSPECS AND TPCs WITHIN THIS STUDY	2-4
2.4 ECOLOGICAL CATEGORIES: TERMINOLOGY RELEVANT TO EWRM (provided by CJ Kleynhans)	2-6
2.5 ECOLOGICAL CATEGORIES: MONITORING DATA INTERPRETATION (provided by CJ Kleynhans)	2-6
2.5.1 Steps to follow when the REC is the same as the BEC (BEC (PES) = REC)	2-6
2.5.2 Steps to follow when the REC is higher than the BEC (BEC (PES) <REC)	2-7
2.5.3 Implications of the Classification system and the Class on steps for setting EcoSpecs and TPCs	2-7
2.6 ECOSPEC DETERMINATION AS APPLIED IN THIS STUDY (written by D Louw)	2-8
2.7 CONSTRAINTS	2-9
3 METHODOLOGY	3-1
3.1 GEOMORPHOLOGY	3-1
3.2 PHYSICO-CHEMICAL VARIABLES	3-3
3.3 DIATOMS.....	3-4
3.3.1 Approach.....	3-5
3.3.2 EcoSpecs and TPCs derived for this study.....	3-5
3.4 RIPARIAN VEGETATION	3-6
3.4.1 Exotic invasion	3-6
3.4.2 Terrestrialisation.....	3-7
3.4.3 Indigenous Riparian woody cover.....	3-7
3.4.4 Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs)	3-8
3.4.5 <i>Phragmites</i> (reeds) cover	3-8
3.5 FISH.....	3-9
3.6 MACROINVERTEBRATES	3-12

3.7	DATA USED FOR DETERMINING ECOSPECS AND TPC	3-13
4	RESULTS: ECOSPECS AND TPCs FOR EWR 1: VALEYSRUIT (CROCODILE RIVER)..	4-1
4.1	ECOCLASSIFICATION SUMMARY OF EWR 1	4-1
4.2	GEOMORPHOLOGY	4-1
	4.2.1 EcoSpecs and TPCs relating to RHAM monitoring data	4-1
	4.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC	4-2
4.3	PHYSICO-CHEMICAL VARIABLES	4-3
	4.3.1 TPCs relating to RHAM water quality indicators	4-3
	4.3.2 EcoSpecs relating to physico-chemical data: PES and REC	4-3
	4.3.3 TPCs relating to physico-chemical data: PES.....	4-4
4.4	DIATOMS.....	4-4
	4.4.1 Diatom EcoSpecs and TPCs relating to RHAM water quality indicators: PES.....	4-4
4.5	RIPARIAN VEGETATION	4-5
	4.5.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	4-5
4.6	FISH.....	4-6
	4.6.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES.....	4-7
	4.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	4-8
4.7	MACROINVERTEBRATES	4-8
	4.7.1 Baseline description	4-8
	4.7.2 Indicator taxa.....	4-8
	4.7.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	4-8
5	RESULTS: ECOSPECS AND TPCs FOR EWR 2: GOEDEHOOP (CROCODILE RIVER)	5-1
5.1	ECOCLASSIFICATION SUMMARY OF EWR 2	5-1
5.2	GEOMORPHOLOGY	5-1
	5.2.1 EcoSpecs and TPCs relating to RHAM monitoring data	5-1
	5.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC	5-2
5.3	PHYSICO-CHEMICAL VARIABLES	5-3
	5.3.1 TPCs relating to RHAM water quality indicators	5-3
	5.3.2 EcoSpecs relating to physico-chemical data: PES and REC	5-3
	5.3.3 TPCs relating to physico-chemical data: PES.....	5-4
5.4	DIATOMS.....	5-4
5.5	RIPARIAN VEGETATION	5-4
	5.5.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	5-5
5.6	FISH.....	5-5
	5.6.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES.....	5-6
	5.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	5-8
5.7	MACROINVERTEBRATES	5-8
	5.7.1 Baseline description	5-8
	5.7.2 Indicator taxa.....	5-8
	5.7.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	5-8

	.....	5-8
6	RESULTS: ECOSPECS AND TPCs FOR EWR 3: POPLAR CREEK (CROCODILE RIVER)	6-1
6.1	ECOCLASSIFICATION SUMMARY OF EWR 3.....	6-1
6.2	GEOMORPHOLOGY	6-1
	6.2.1 EcoSpecs and TPCs relating to RHAM monitoring data	6-1
	6.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC	6-2
6.3	PHYSICO-CHEMICAL VARIABLES.....	6-2
	6.3.1 TPCs relating to RHAM water quality indicators	6-3
	6.3.2 EcoSpecs relating to physico-chemical data: PES.....	6-3
	6.3.3 EcoSpecs relating to physico-chemical data: REC	6-3
	6.3.4 TPCs relating to physico-chemical data: PES.....	6-4
6.4	DIATOMS.....	6-4
	6.4.1 Diatom EcoSpecs and TPCs relating to RHAM water quality indicators	6-4
6.5	RIPARIAN VEGETATION	6-5
	6.5.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	6-5
	.....	6-5
6.6	FISH.....	6-6
	6.6.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES and REC .	6-7
	6.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for	6-9
	baseline (PES) conditions	6-9
6.7	MACROINVERTEBRATES	6-9
	6.7.1 Baseline description	6-9
	6.7.2 Indicator taxa.....	6-9
	6.7.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	6-9
	.....	6-9
7	RESULTS: ECOSPECS AND TPCs FOR EWR 4: KANYAMAZANE (CROCODILE RIVER)	7-1
7.1	ECOCLASSIFICATION SUMMARY OF EWR 4.....	7-1
7.2	GEOMORPHOLOGY	7-1
	7.2.1 EcoSpecs and TPCs relating to GAI monitoring data: REC	7-1
7.3	PHYSICO-CHEMICAL VARIABLES.....	7-2
	7.3.1 EcoSpecs relating to physico-chemical data: PES.....	7-2
	7.3.2 EcoSpecs relating to physico-chemical data: REC	7-2
	7.3.3 TPCs relating to physico-chemical data: PES.....	7-3
7.4	RIPARIAN VEGETATION	7-3
	7.4.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	7-3
	.....	7-3
7.5	FISH.....	7-4
	7.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC.....	7-5
	7.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for	7-7
	baseline (PES) conditions	7-7
7.6	MACROINVERTEBRATES	7-7
	7.6.1 Baseline description	7-7
	7.6.2 Indicator taxa.....	7-7
	7.6.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	7-8
	.....	7-8
8	RESULTS: ECOSPECS AND TPCs FOR EWR 5: MALELANE (CROCODILE RIVER)..	8-1

8.1	ECOCLASSIFICATION SUMMARY OF EWR 5	8-1
8.2	GEOMORPHOLOGY	8-1
8.2.1	EcoSpecs and TPCs relating to GAI monitoring data: REC	8-1
8.3	PHYSICO-CHEMICAL VARIABLES	8-2
8.3.1	Physico-chemical data: EcoSpecs: PES.....	8-2
8.3.2	Physico-chemical data: EcoSpecs: REC	8-2
8.3.3	TPCs relating to physico-chemical data: PES.....	8-3
8.4	RIPARIAN VEGETATION	8-3
8.4.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	8-3
8.5	FISH.....	8-4
8.5.1	EcoSpecs and TPCs relating to FRAI data: PES.....	8-5
8.5.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	8-7
8.6	MACROINVERTEBRATES	8-8
8.6.1	Baseline description	8-8
8.6.2	Indicator taxa.....	8-8
8.6.3	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	8-8
9	RESULTS: ECOSPECS AND TPCs FOR EWR 6: NKONGOMA (CROCODILE RIVER) 9-1	
9.1	ECOCLASSIFICATION SUMMARY OF EWR 6	9-1
9.2	GEOMORPHOLOGY	9-1
9.2.1	EcoSpecs and TPCs relating to RHAM monitoring data	9-1
9.2.2	EcoSpecs and TPCs relating to GAI monitoring data: PES and REC	9-2
9.3	PHYSICO-CHEMICAL VARIABLES	9-2
9.3.1	TPCs relating to RHAM water quality indicators	9-2
9.3.2	EcoSpecs relating to physico-chemical data: PES.....	9-3
9.3.3	EcoSpecs relating to physico-chemical data: REC	9-3
9.3.4	TPCs relating to physico-chemical data: PES.....	9-4
9.4	DIATOMS.....	9-4
9.5	RIPARIAN VEGETATION	9-4
9.5.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	9-5
9.6	FISH.....	9-5
9.6.1	EcoSpecs and TPCs relating to RHAM and FRAI data: PES.....	9-6
9.6.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	9-8
9.7	MACROINVERTEBRATES	9-8
9.7.1	Baseline description	9-8
9.7.2	Indicator taxa.....	9-9
9.7.3	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	9-9
10	RESULTS: ECOSPECS AND TPCs FOR EWR 7: HONEYBIRD (CROCODILE RIVER)	10-1
10.1	ECOCLASSIFICATION SUMMARY OF EWR 7	10-1
10.2	GEOMORPHOLOGY	10-1
10.2.1	EcoSpecs and TPCs relating to RHAM monitoring data	10-1
10.2.2	EcoSpecs and TPCs relating to GAI monitoring data: PES and REC ..	10-2

10.3	PHYSICO-CHEMICAL VARIABLES	10-3
10.3.1	EcoSpecs relating to physico-chemical data: PES and REC	10-3
10.3.2	TPCs relating to physico-chemical data: PES.....	10-3
10.4	RIPARIAN VEGETATION	10-4
10.4.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	10-4
10.5	FISH.....	10-4
10.5.1	EcoSpecs and TPCs relating to RHAM and FRAI data: PES.....	10-5
10.5.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	10-7
10.6	MACROINVERTEBRATES	10-7
10.6.1	Baseline description	10-7
10.6.2	Indicator taxa.....	10-7
10.6.3	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC	10-8
11	EWR 1: UPPER SABIE (SABIE RIVER)	11-1
11.1	ECOCLASSIFICATION SUMMARY OF EWR 1	11-1
11.2	GEOMORPHOLOGY	11-1
11.2.1	EcoSpecs and TPCs relating to RHAM monitoring data	11-1
11.2.2	EcoSpecs and TPCs relating to GAI monitoring data: PES and REC ..	11-2
11.3	PHYSICO-CHEMICAL VARIABLES.....	11-3
11.3.1	TPCs relating to RHAM water quality indicators	11-3
11.3.2	EcoSpecs relating to physico-chemical data: PES and REC	11-3
11.3.3	TPCs relating to physico-chemical data: PES.....	11-3
11.4	DIATOMS.....	11-4
11.5	RIPARIAN VEGETATION	11-4
11.5.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES PES.....	11-4
11.6	FISH.....	11-5
11.6.1	EcoSpecs and TPCs relating to RHAM and FRAI data: PES.....	11-5
11.6.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	11-7
11.7	MACROINVERTEBRATES	11-7
11.7.1	Baseline description	11-7
11.7.2	Indicator taxa.....	11-7
11.7.3	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC	11-8
12	RESULTS: ECOSPECS AND TPCs FOR EWR 2: AAN DE VLIET (SABIE RIVER)	12-1
12.1	ECOCLASSIFICATION SUMMARY OF EWR 2	12-1
12.2	GEOMORPHOLOGY	12-1
12.2.1	EcoSpecs and TPCs relating to GAI monitoring data: PES and REC ..	12-1
12.3	PHYSICO-CHEMICAL VARIABLES.....	12-2
12.3.1	Physico-chemical data: EcoSpecs – PES.....	12-2
12.3.2	Physico-chemical data: EcoSpecs – REC	12-2
12.3.3	TPCs relating to physico-chemical data: PES.....	12-3
12.4	RIPARIAN VEGETATION	12-3
12.4.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	12-3

12.5	FISH.....	12-4
12.5.1	EcoSpecs and TPCs relating to FRAI data: PES.....	12-4
12.5.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	12-6
12.5.3	MACROINVERTEBRATES	12-6
12.5.4	Baseline description	12-6
12.5.5	Indicator taxa.....	12-6
12.5.6	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	12-7
13	RESULTS: ECOSPECS AND TPCs FOR EWR 3: KIDNEY (SABIE RIVER)	13-1
13.1	ECOCLASSIFICATION SUMMARY OF EWR 3	13-1
13.2	GEOMORPHOLOGY	13-1
13.2.1	EcoSpecs and TPCs relating to RHAM monitoring data	13-1
13.2.2	EcoSpecs and TPCs relating to GAI monitoring data: PES and REC ..	13-2
13.3	PHYSICO-CHEMICAL VARIABLES.....	13-2
13.3.1	TPCs relating to RHAM water quality indicators	13-3
13.3.2	EcoSpecs relating to physico-chemical data: PES and REC	13-3
13.3.3	TPCs relating to physico-chemical data: PES.....	13-3
13.4	DIATOMS.....	13-4
13.5	RIPARIAN VEGETATION	13-4
13.5.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	13-4
13.6	FISH.....	13-5
13.6.1	EcoSpecs and TPCs relating to RHAM and FRAI data: PES.....	13-6
13.6.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	13-9
13.6.3	MACROINVERTEBRATES	13-9
13.6.4	Baseline description	13-9
13.6.5	Indicator taxa.....	13-10
13.6.6	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	13-10
14	RESULTS: ECOSPECS AND TPCs FOR EWR 4: MAC MAC (MAC MAC RIVER)	14-1
14.1	ECOCLASSIFICATION SUMMARY OF EWR 4	14-1
14.2	GEOMORPHOLOGY	14-1
14.2.1	EcoSpecs and TPCs relating to RHAM monitoring data	14-1
14.2.2	EcoSpecs and TPCs relating to GAI monitoring data: PES and REC ..	14-2
14.3	PHYSICO-CHEMICAL VARIABLES.....	14-3
14.3.1	EcoSpecs relating to physico-chemical data: PES.....	14-3
14.3.2	EcoSpecs relating to physico-chemical data: REC	14-3
14.3.3	TPCs relating to physico-chemical data: PES.....	14-4
14.4	RIPARIAN VEGETATION	14-4
14.4.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	14-4
14.5	FISH.....	14-5
14.5.1	EcoSpecs and TPCs relating to RHAM and FRAI data: PES.....	14-6
14.5.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	14-8
14.6	MACROINVERTEBRATES.....	14-8

14.6.1	Baseline description	14-8
14.6.2	Indicator taxa.....	14-8
14.6.3	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	14-9
15	RESULTS: ECOSPECS AND TPCs FOR EWR 5: MARITE (MARITE RIVER)	15-1
15.1	ECOCLASSIFICATION SUMMARY OF EWR 5.....	15-1
15.2	GEOMORPHOLOGY	15-1
15.2.1	EcoSpecs and TPCs relating to RHAM monitoring data	15-1
15.2.2	EcoSpecs and TPCs relating to GAI monitoring data: PES and REC ..	15-2
15.3	PHYSICO-CHEMICAL VARIABLES.....	15-3
15.3.1	EcoSpecs relating to physico-chemical data: PES and REC	15-3
15.3.2	TPCs relating to RHAM water quality indicators: PES	15-3
15.4	RIPARIAN VEGETATION	15-4
15.4.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	15-4
15.5	FISH.....	15-4
15.5.1	EcoSpecs and TPCs relating to RHAM and FRAI data: PES.....	15-5
15.5.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	15-7
15.6	MACROINVERTEBRATES	15-7
15.6.1	Baseline description	15-7
15.6.2	Indicator taxa.....	15-7
15.6.1	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	15-8
16	RESULTS: ECOSPECS AND TPCs FOR EWR 6: MUTLUMUVI (MUTLUMUVI RIVER).....	16-1
16.1	ECOCLASSIFICATION SUMMARY OF EWR 6.....	16-1
16.2	GEOMORPHOLOGY	16-1
16.2.1	EcoSpecs and TPCs relating to GAI monitoring data: PES and REC ..	16-1
16.3	PHYSICO-CHEMICAL VARIABLES.....	16-2
16.3.1	EcoSpecs relating to physico-chemical data: PES.....	16-2
16.3.2	EcoSpecs relating to physico-chemical data: REC	16-2
16.3.3	TPCs relating to physico-chemical data: PES.....	16-3
16.4	RIPARIAN VEGETATION	16-3
16.4.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	16-3
16.5	FISH.....	16-4
16.5.1	EcoSpecs and TPCs relating to FRAI data: PES.....	16-5
16.5.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	16-7
16.6	MACROINVERTEBRATES	16-7
16.6.1	Baseline description	16-7
16.6.2	Indicator taxa.....	16-8
16.6.3	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	16-8
17	RESULTS: ECOSPECS AND TPCs FOR EWR 7: TLULANDZITEKA (TLULANDZITEKA RIVER).....	17-1
17.1	ECOCLASSIFICATION SUMMARY OF EWR 7	17-1
17.2	GEOMORPHOLOGY	17-1

	17.2.1	TPCs relating to GAI monitoring data: REC.....	17-1
17.3		PHYSICO-CHEMICAL VARIABLES.....	17-2
	17.3.1	EcoSpecs relating to physico-chemical data: PES.....	17-2
	17.3.2	EcoSpecs relating to physico-chemical data: REC	17-2
	17.3.3	TPCs relating to physico-chemical data: PES.....	17-3
17.4		RIPARIAN VEGETATION	17-3
	17.4.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	17-3
17.5		FISH.....	17-4
	17.5.1	EcoSpecs and TPCs relating to FRAI data: PES.....	17-5
	17.5.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	17-7
17.6		MACROINVERTEBRATES	17-7
	17.6.1	Baseline description	17-7
	17.6.2	Indicator taxa.....	17-8
	17.6.3	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC..	17-8
18		RESULTS: ECOSPECS AND TPCs FOR EWR 8: LOWER SAND (SAND RIVER)	18-1
18.1		ECOCCLASSIFICATION SUMMARY OF EWR 8.....	18-1
18.2		GEOMORPHOLOGY	18-1
	18.2.1	EcoSpecs and TPCs relating to RHAM monitoring data	18-1
	18.2.2	EcoSpecs and TPCs relating to GAI monitoring data: PES and REC ..	18-2
18.3		PHYSICO-CHEMICAL VARIABLES.....	18-2
	18.3.1	TPCs relating to RHAM water quality indicators	18-3
	18.3.2	EcoSpecs relating to physico-chemical data: PES and REC	18-3
	18.3.3	TPCs relating to physico-chemical data: PES.....	18-3
18.4		DIATOMS.....	18-4
18.5		RIPARIAN VEGETATION	18-4
	18.5.1	EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES	18-4
18.6		FISH.....	18-4
	18.6.1	EcoSpecs and TPCs relating to RHAM and FRAI data: PES.....	18-5
	18.6.2	Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions	18-7
18.7		MACROINVERTEBRATES	18-7
	18.7.1	Baseline description	18-7
	18.7.2	Indicator taxa.....	18-8
	18.7.3	EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data:	
		REC	18-8
19		RECOMMENDATIONS	19-1
20		REFERENCES	20-1

LIST OF TABLES

Table 1.1	Locality of EWR sites for the Inkomati River System	1-2
Table 2.1	Purposes and principles of EcoSpecs and TPCs (from DWA, 2009a)	2-4
Table 3.1	Diatom and physico-chemical results	3-5

Table 3.2	Hypothesis on which EcoSpecs for exotic species occurrence in the riparian zone is based	3-6
Table 3.3	Hypothesis for EcoSpecs concerning terrestrialisation of the riparian zone	3-7
Table 3.4	Hypotheses for EcoSpecs concerning indigenous riparian woody cover	3-8
Table 3.5	Hypotheses for EcoSpecs concerning indigenous non-woody cover	3-8
Table 3.6	Hypotheses for EcoSpecs concerning <i>Phragmites</i> (reed) cover	3-9

LIST OF FIGURES

Figure 1–1	The 8-step Ecological Reserve procedure (adapted from DWAF, 1999)	1-1
Figure 1–2	Crocodile River catchment and locality of EWR sites	1-3
Figure 1–3	Sabie-Sand River catchment and locality of EWR sites.....	1-4
Figure 2–1	Elements of a prototype DSS	2-3
Figure 2–2	Relationship between BEC and the REC in terms of defining and quantifying EcoSpecs and TPCs	2-7
Figure 2–3	Example showing how the relationship between the EcoSpecs, TPCs and ECs ...	2-9

ABBREVIATIONS AND ACRONYMS

AEC	Alternative Ecological Category
Alg	Algae/Algal
ASPT	Average Score Per Taxon
BEC	Baseline Ecological Category
CD: RDM	Chief Directorate: Resource Directed Measures
CEC	Classification Ecological Category
CEV	Chronic Effects Value
CPUE	Catch Per Unit Effort
D:RQS	Directorate: Resource Quality Services
DSS	Decision Support System
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EC	Electrical Conductivity
EIS	Ecological Importance and Sensitivity
Emb	Embedded
ERM	Ecological Resource Monitoring
EWR	Ecological Water Requirements
EWRM	Ecological Water Resource Monitoring
FD	Fast Deep
FDI	Flow Dependent macroinvertebrate
FRAI	Fish Response Assessment Index
FROC	Fish Frequency of Occurrence
FS	Fast Shallow
GAI	Geomorphology Assessment Index
ind/min	Individual/s per minute
LB	Left Bank
MIRAI	Macro Invertebrate Assessment Index
MRU	Management Resource Unit
MV	Marginal Vegetation
MVI	Marginal Vegetation Macroinvertebrate
NAEHMP	National Aquatic Ecosystem Health Monitoring Programme
NWA	National Water Act
PES	Present Ecological State
Quat	Quaternary catchment
RB	Right Bank
RDM	Resource Directed Measures
R-DRAM	Rapid Diatom Assessment Method
REC	Recommended Ecological Category
RHAM	Rapid Habitat Assessment Method
RHP	River Health Programme
RQO	Resource Quality Objective
SASS5	South African Scoring System version 5
SCS	Slow over Coarse Substrate
SD	Slow Deep
SPI	Specific Pollution sensitivity Index
SRP	Soluble Reactive Phosphate
SS	Slow Shallow
TEACHA	Tool for Ecological Aquatic Chemical Habitat Assessment
TIN	Total Inorganic Nitrogen

TPC	Threshold of Potential Concern
TWQR	Target Water Quality Range
Veg	Vegetation
VEGRAI	Riparian Vegetation Response Assessment Index
VFCS	Very Fast over Coarse Substrate
WMA	Water Management Area
WMS	Water Management System

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 systems. 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 7 of the Ecological Reserve process.

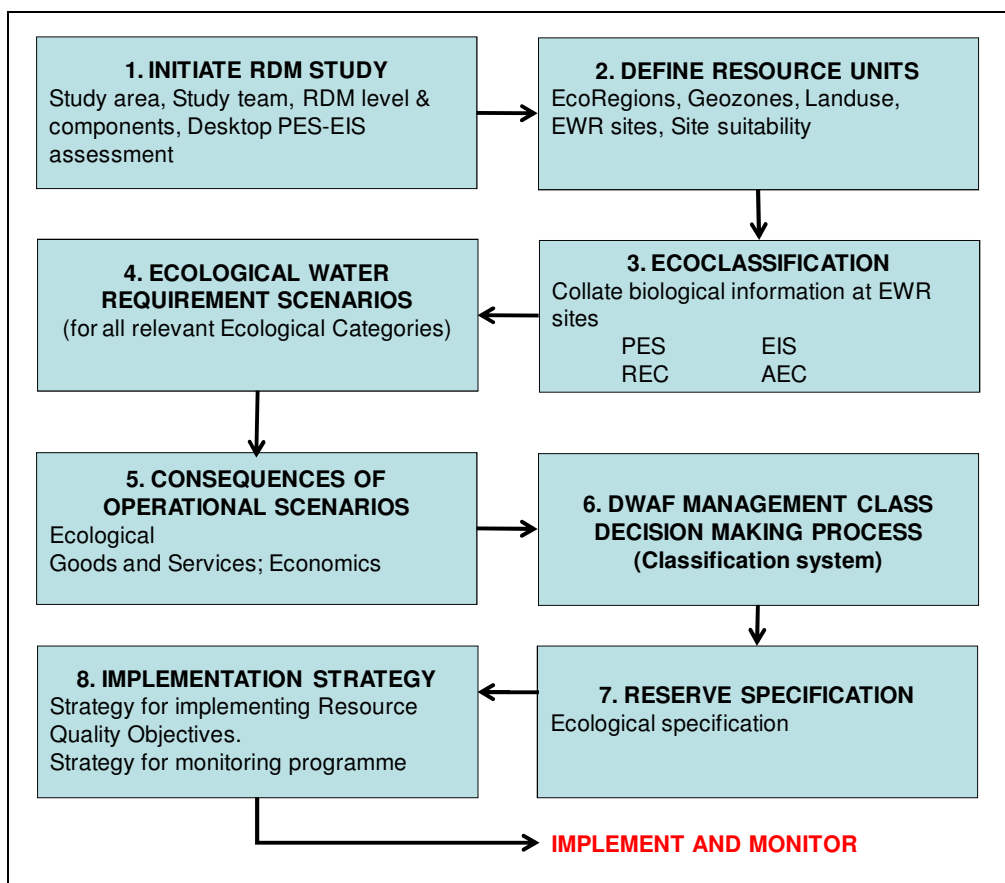


Figure 1–1 The 8-step Ecological Reserve procedure (adapted from DWAF, 1999)

1.2 STUDY AREA

The focus of this study is on the determination of the Crocodile (X2) and Sabie-Sand (X3) River systems. Fifteen Ecological Water Requirement (EWR) sites were chosen to represent these catchments, the locality and characteristics of which are provided in the table below. 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 systems 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, 2008a).

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 River	S25 29.647	E30 08.656	9.02	Upper Foothills	X21A
EWR 2	Goedenhoop	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

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

² Quaternary catchment

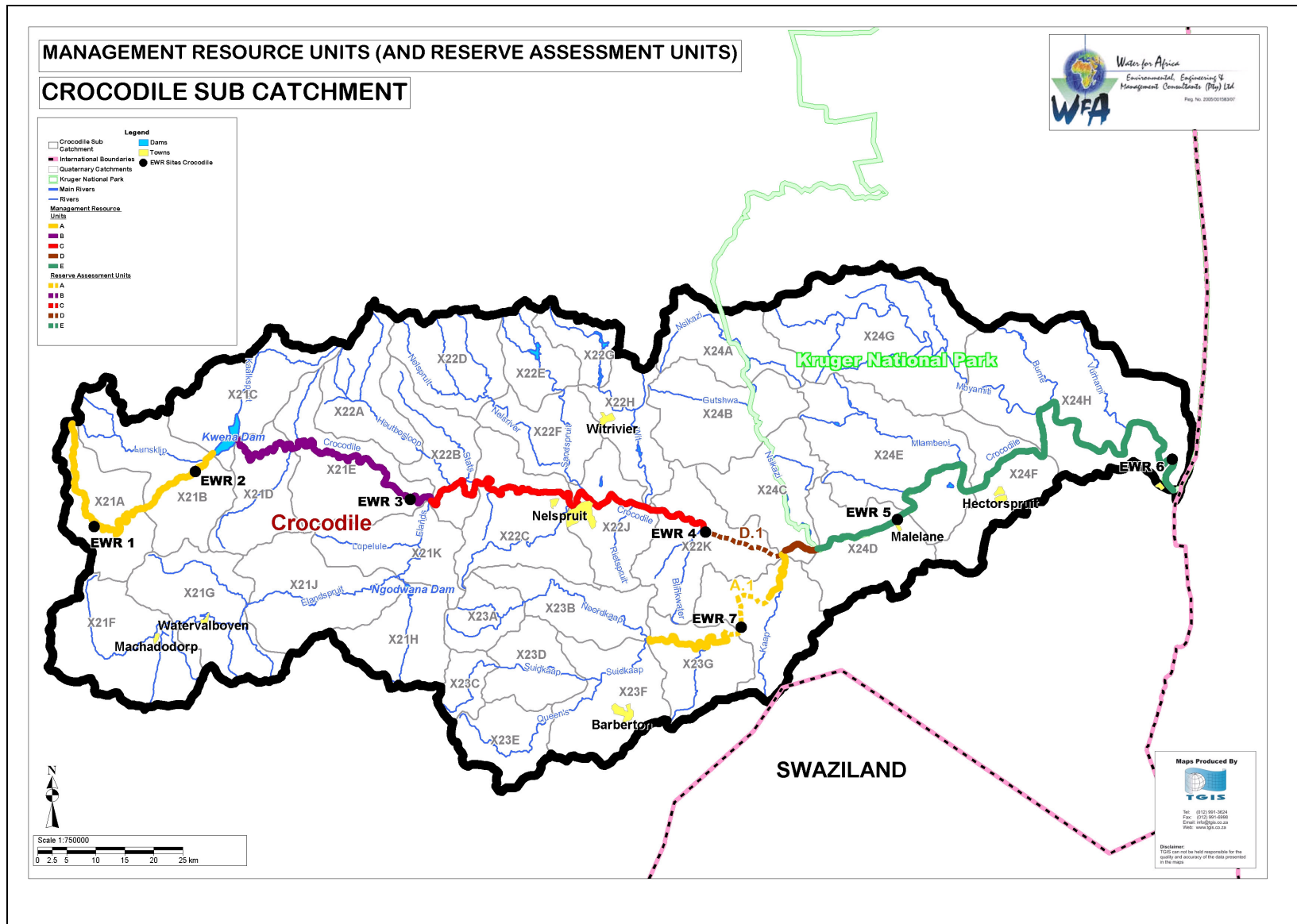


Figure 1–2 Crocodile River catchment and locality of EWR sites

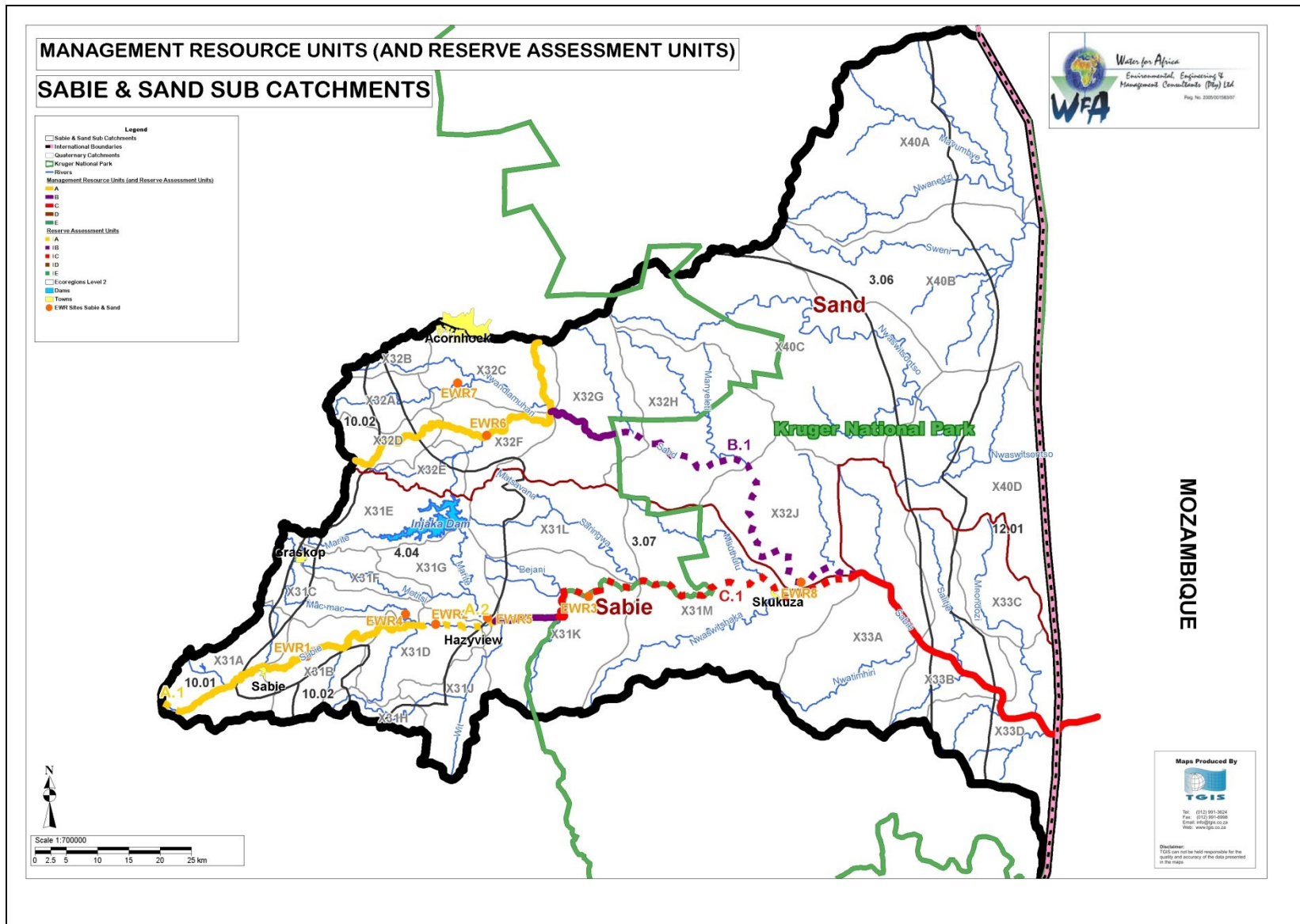


Figure 1–3 Sabie-Sand River catchment and locality of EWR sites

1.1 PURPOSE OF THE REPORT

The purpose of this report is to present the Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) for each of the EWR sites on the Crocodile, Sabie-Sand River Systems. These EcoSpecs define the conditions that would occur under the Present Ecological State (PES). TPCs are provided to indicate worsening conditions. Where relevant, the conditions that describe the REC (when different than the PES) are also provided. This information forms the key inputs into an Ecological Water Resource Monitoring (EWRM) Program for these catchments. Further information on EcoSpecs and TPCs and their use in Ecological Water Resources Monitoring can be obtained from DWA (2009), and Kleynhans *et al.* (2009).

1.2 OUTLINE OF THE REPORT

The contents and structure of this report is outlined below. All electronic information is available from RDM Report 26/8/3/10/12/016 - Electronic information and data (DWA, 2010).

Chapter 1: Introduction

This chapter.

Chapter 2: Approach

This chapter provides general background to the development and refinement of Ecological Water Resource Monitoring within the Ecological Reserve and RHP framework. Information is provided on ecological monitoring, EcoSpecs and TPCs, levels of monitoring, relevant terminology and interpretation of data. The approach and application of this monitoring to the Crocodile, Sabie and Sand catchment is also discussed.

Chapter 3: Methodology

This section describes the methods and data that were used to identify metrics and TPCs to determine the EcoSpecs and TPCs for the different Reserve components.

Chapter 4 – 8: Determination of EcoSpecs and TPCs

These chapters provide results of different EWR scenarios with respect to low and high flows for the respective EWR sites. Aspects covered in these chapters are component and integrated/stress curves, generating stress requirements, general approach to high flows, final results and confidence in the final results.

Chapter 9: Recommendations

Recommendations are made in terms of the current tools available for monitoring and the application thereof.

Chapter 16: References

2 APPROACH

The EWRM (referred to previously as the Ecological Reserve Monitoring Programme), was first developed as an initial protocol during the Kromme River Reserve study in 2006 (DWAF, 2006). Further development was undertaken during the Operationalisation of the Reserve study where the Rapid Habitat Assessment Method (RHAM) was developed and the initial concepts of the Monitoring Decision Support System deliberated. The intention with the development of RHAM was to address the capacity and funding shortages by simplifying monitoring techniques as much as possible. Specialist input in the setting of the baseline and identifying EcoSpecs and TPCs is however required.

2.1 BACKGROUND TO ECOLOGICAL WATER RESOURCES MONITORING (SUMMARISED FROM DWAF, 2009a)

The National Water Act (NWA, Act No. 36 of 1998) requires the establishment of a national monitoring system that must provide for the collection of appropriate data and information necessary to assess water resources. Such a system must collect relevant information that contributes to the management of the resource in a desirable ecological condition by providing information on:

- Compliance with Resource Quality Objectives (RQOs). This relates to Ecological Reserve Monitoring following on from the specification of Ecological Water Requirements (EWRs). The EWR process, results in an extensive amount of data at a relatively limited number of sites that can be used for ERM to determine if the Recommended Ecological Category (REC) following from the EWR is achieved.
- The health of aquatic ecosystems. This relates to the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP) and in this particular situation, to the River Health Programme (RHP) part of the NAEHMP. The RHP is primarily aimed at providing information on the health or integrity of rivers for national state of the rivers reporting and as input to resource management at a large number of sites based on biological responses.

Initially the aim was to develop an Ecological Reserve Monitoring programme. This would have run separately to the River Health Programme (RHP). However, the implications of simultaneously operating two separate ecological monitoring programmes have serious resource implications. To mitigate this and still maintain an operational ecological monitoring programme that provides useful management information, integration of the ERM and RHP within an adaptive management approach is proposed (Kleynhans *et al.*, 2009). **This forms the basis of the integrated Ecological Water Resource Monitoring (EWRM) approach.**

2.1.1 Ecological monitoring

Ecological monitoring is the collection and analysis of repeated observations or measurements **to evaluate changes in the condition of the resource and the progress towards meeting the management objective (Elzinga *et al.*, 1998)**. In terms of EWRM, it is the measurement of EcoSpecs (ecological specifications) to determine if the Ecological Category is attained (Kleynhans *et al.*, 2009). EWRM operates within the following concepts (based on Elzinga *et al.*, 1998):

- The reference condition which is the natural or unimpaired condition of the system.
- The monitoring baseline which is a series of measurements taken before the initiation of

the impact or management activity and used for comparison with the series of measurements taken afterward.

- Response monitoring occurs at a particular detail, frequency and intensity as guided by the Ecological Importance and Sensitivity (EIS) of the resource. In the case of Ecological Reserve implementation, the scale and potential impact of the development also plays a role in the frequency and detail included. Response monitoring results are evaluated by analysis within a management objective framework. This allows measurement of how the resource is changing over time, i.e. to measure the trend.
- Implementation monitoring assesses whether the activities are carried out as designed. Implementation monitoring can also identify which variables are most likely to be causing a change in the resource, and help eliminate from consideration some potential causes of change (Kershner, 1997; Elzinga *et al.*, 1998). In terms of the Ecological Reserve this would, inter alia, refer to whether flows are released as was specified for the attainment of a particular Ecological Category (EC).
- Effectiveness monitoring measures whether RQOs (the Ecological Category in terms of EcoSpecs) are attained by following the particular management scenario (Kershner, 1997).

If the EC decreases over a period of time and the cause is unknown, more intensive monitoring or research may be initiated to determine the cause of the decrease. If a cause for decrease is suspected, appropriate management intervention may be indicated (Elzinga *et al.*, 1998).

2.1.2 EcoSpecs and Thresholds of Potential Concern

EWRM must be undertaken within a structured Decision Support System (DSS) framework following the principles of Adaptive Management. The purpose of the DSS system is to provide a decision framework within which monitoring results can be interpreted in terms of the attainment of objectives set for the condition and integrity of the resource. This relates directly to EcoSpecs and Thresholds of Potential Concern (TPCs) (Bestbier and Rogers, 1997) formulated to assess attainment of an Ecological Category. Conclusions emanating from the DSS will provide guidance on the management of the resource (Cormier and Suter, 2008).

2.1.3 Different levels of monitoring

Due to capacity and resource limitations, all EWRM sites cannot always be monitored at the same and highest intensity that may be desirable. These restrictions necessitate different levels of monitoring and require the setting of TPCs for the different levels of monitoring. It follows that a relatively low intensity monitoring survey will provide TPCs with a larger margin of error than surveys done at a more intensive level. However, the results of TPC assessment from a lower to a higher level of monitoring must be linked. These concepts form the basis of the DSS system.

Within the Resource Directed Measures (RDM) "Operationalisation of the Reserve" project (DWA, 2009a), it was recognised that to ensure the effective implementation of EWRM, all efforts must be made to design a programme and methods that are as cost-effective as possible. The hierarchical approach within the DSS system supports this. The need for pragmatic and easy to apply methods to monitor instream habitat led to the development of the Rapid Habitat Assessment Method (RHAM). This method aims to provide a rapid approach to assess instream habitat conditions in wadeable and to a more limited degree, non-wadeable streams. RHAM data collected during the setting of the baseline (and the determination of the PES) is used to assess habitat suitability for

indicator instream biota (fish and macroinvertebrates) under the conditions prevailing during the survey and is fundamental to the development of EcoSpecs and in the setting of the accompanying TPCs that indicate the suitability of the habitat to sustain such biota. The premise of the RHAM is that suitable habitat conditions will indicate the likely presence, abundance and frequency of occurrence of particular biota. Baseline conditions are used to assess the possible future change in habitat conditions and the derived impact on the indicator biota. Available data and expert knowledge is used to associate particular habitat conditions with different indicator biota and the relevant ECs.

The RHAM is also supported with the development of a rapid approach to use diatoms as TPCs for physico-chemical changes. The diatom process is still in its infancy and must be tested. This approach was designed for a non-specialist and a manual is available.

The DSS system proposed for ecological water resource monitoring and management is based on monitoring and interpreting resource quality at five levels of detail. This framework is used to construct a DSS system based on baseline specification, EcoSpecs and TPCs. A prototype DSS is illustrated below (Figure 2-1).

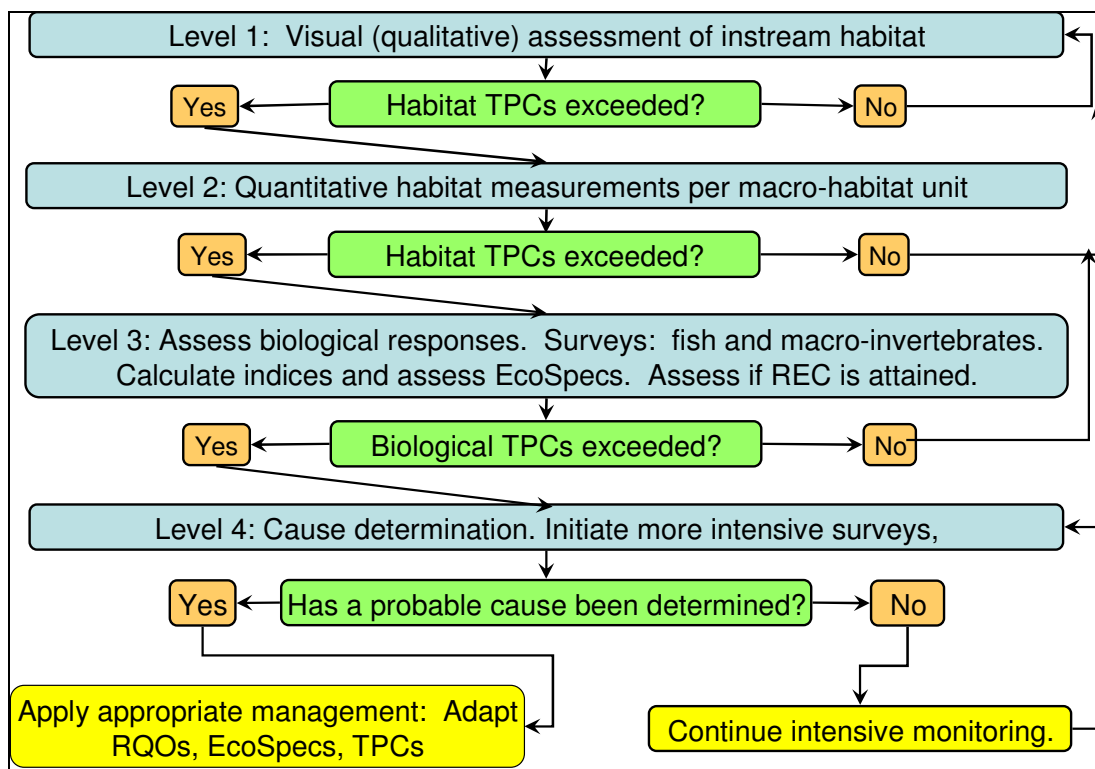


Figure 2–1 Elements of a prototype DSS

The following work is in development by DWA, Directorate: Resource Quality Services (D:RQS), and will be available later this year:

- DSS system.
- Using habitat information from the RHAM to determine fish EcoSpecs.
- Using habitat information from the RHAM to determine macroinvertebrate EcoSpecs.

Sufficient information on the baseline and the collection of data during monitoring is however available and it is strongly recommended that monitoring is implemented as soon as possible. It must also be pointed out that the information generated during an EWR

study should serve as the baseline. This means that monitoring must be initiated immediately after such a study ends, or else a new baseline will have to be collected at a later date.

2.2 ECOSPECS AND TPCs (SUMMARISED FROM DWA, 2009a)

EcoSpecs and TPCs are described in the Table 2.1 below.

Table 2.1 Purposes and principles of EcoSpecs and TPCs (from DWA, 2009a)

ECOSPECS	TPCs
PURPOSES	
<ul style="list-style-type: none"> • During EWR studies, EcoSpecs are developed and specified in terms of the RQOs as per the Resource Directed Measures and the EcoClassification process (Kleynhans and Louw, 2007). This encompasses biological specifications or Biocriteria that are numerical values or narrative statements that define a desired biological condition for a waterbody (Burton and Gerritsen, 2003). A certain level of habitat integrity (specified as Habitat criteria) is required to attain a particular biological condition for a water body. EcoSpecs then indicates the ecological detail that characterizes the EC. • To establish clear goals relating to the ecological quality of the relevant water resources. • Where resources, for instance, need a high level of protection, a strict set of objectives that will represent a low risk of damage, will be set. • Once the management class of a water resource has been decided, the objectives for protection of basic human needs and ecological integrity take precedence in cases where the objectives for other uses, or for impacts, may conflict with the requirements for protection. 	<p>TPCs indicate the values around the EcoSpecs that, if being approached would initiate more detailed investigation or even management action. TPCs are based on the acceptance that there is uncertainty as to accuracy or validity of EcoSpecs i.e. is deviation from EcoSpecs due to natural variation, sampling error, etc.</p> <p>In the context of EWRM, TPCs are regarded as early warning indicators of potential change from a particular EC to another (lower) EC.</p>
PRINCIPLES	
<p>EcoSpecs must be quantifiable, measurable, verifiable and enforceable and ensure protection of all components of the resource, which make up ecological integrity. The critical components of the EcoSpecs include:</p> <ul style="list-style-type: none"> • Requirements for water quantity. Flow requirements for a river reach, estuary, and/or water level requirements for standing water or ground water are included. Groundwater level requirements to maintain spring and base flow in rivers and other ecological features are also considered. • Biocriteria and Habitat criteria that are derived from RQOs and are clear and measurable specifications of ecological attributes (flow, physico-chemical attributes and biological integrity that reflect the health, community structure and distribution of aquatic biota). EcoSpecs define the EC and serve as an input to RQOs. EcoSpecs refer only to ecological information whereas RQOs include economic and social objectives 	<p>TPCs are upper and lower levels along a continuum of change in selected environmental indicators and are used and interpreted according to the following guidelines (Rogers and Bestbier, 1997):</p> <ul style="list-style-type: none"> • When a TPC level is reached (or when modelling predicts it will be reached), it prompts an assessment of the causes of the extent of the change. • Assessment of the causes provides the basis for deciding whether management action is needed or if the TPC needs to be recalibrated. TPCs provide management with strategic goals or endpoints within which to manage the system. • TPCs form the basis of an inductive approach to adaptive management, and are invariably hypotheses of limits of acceptable change in ecosystem structure, function and composition. • The validity and appropriateness of TPCs are always open to challenge and they must be adaptively modified as understanding and experience of the system being managed increases. <p>It follows that more detailed monitoring surveys would increase the confidence in the validity of a TPC (i.e. narrow the uncertainty). This principle is built into the DSS by considering different levels of monitoring surveys.</p>

2.3 APPROACH FOR APPLYING THE PRINCIPLES OF EWRM, ECOSPECS AND TPCs WITHIN THIS STUDY

The principles and conceptual approaches to EWRM have been under development since 2006 (DWAF, 2006). However, very few monitoring approaches have been tested and an appropriate DSS is still being developed. Proper testing within an adaptive management framework can only be done if EWRM for Reserves is implemented. Within this study, and with the guidance of the

developers of the methods in D:RQS, these conceptual approaches needed to be translated into a practical approach for defining DETAILED EcoSpecs that can be used in the monitoring process.

Ecological monitoring is the collection and analysis of repeated observations or measurements to evaluate changes in the condition of the resource and the progress towards meeting the management objective (Elzinga *et al.*, 1998). In terms of EWRM it is the measurement of EcoSpecs (ecological specifications) to determine if the REC is attained (Kleynhans *et al.*, 2009).

EWRM operates within the following concepts (based on Elzinga *et al.*, 1998):

- The reference condition is the natural or unimpaired condition of the system.
- The monitoring baseline is a series of measurements taken before the initiation of the impact or management activity and is used for comparison with the series of measurements taken after the management activity. If the PES of the resource is unimpaired (natural), the reference will also be the baseline.
- It is important to assess whether there is a trend in the baseline, i.e. is it stationary or changing in a particular direction at the time when it is determined.
- This is the standard (“benchmark”) against which future deviations can be compared.

Therefore the Present Ecological State (PES) of the system must be determined prior to management interventions. The PES will then serve as the baseline ecological state from which all changes can be measured and evaluated. i.e.:

PES = BASELINE = BASELINE ECOLOGICAL CATEGORY (BEC)

Management actions are designed to maintain, or attain (if different from the PES) the REC. These management actions relate to the management objectives which are described in terms of the flow and quality (physico-chemical) EcoSpecs. Additional land use objectives may also be described if these non-flow related aspects are contributing to the PES of the system.

During the EWR Scenario phase, different flow regimes are identified for a range of ECs. These serve as the flow RQOs or flow EcoSpecs for different ECs. Physico-chemical EcoSpecs for different ECs are also broadly defined during EcoClassification, but are quantified as far as possible during the EcoSpec phase of the study. During and after the testing of various operational and future development scenarios, as well as the Classification process or any surrogates of this, a final scenario will be signed off as the Reserve. If this scenario is to maintain or improve the EC in the system, the EcoSpecs associated with this scenario are used to describe the management objectives for the system.

Therefore one must clearly distinguish between setting management objectives in terms of the drivers to achieve/maintain certain Ecological Categories, and defining EcoSpecs for the biophysical response, that describes, in different level of detail, the Ecological Categories.

In essence, during an EWR study, flow requirements (main driver) are defined that could result in a certain ecological state defined through an Ecological Category. These flow **requirements (main driver) inform the management objectives supported by the other driver components**. Note that the word ‘could’ is used as the biological responses to driver conditions are all predicted and must be tested through monitoring.

Monitoring the ecological responses will test the predictions made during an EWR study. It furthermore will test whether adjustments to the EcoSpecs and TPCs are required and whether the overall management objective in terms of the REC (or class) is being achieved. It is therefore crucial that monitoring be driven by objectives as it forms the foundation of a monitoring project (cf. Elzinga *et al.*, 1998).

The condition and response of the resource is therefore monitored to determine if the REC has been attained or maintained.

2.4 ECOLOGICAL CATEGORIES: TERMINOLOGY RELEVANT TO EWRM (provided by CJ Kleynhans)

Present Ecological State (PES): The PES is based on the determination and integration of the condition of system drivers and the biological responses. This represents the ecological condition at the time of the survey. Logically there can only be one PES and that is the most recent determination.

Baseline Ecological Category (BEC): The baseline functions as a standard or benchmark against which future changes of the Ecological Category can be measured. The baseline is determined using the PES survey information that is collected during the EcoStatus determination for the EWR or RHP (EWRM). The PES used for this purpose is supplemented by historical data but the primary data source is the surveys and data collation for EcoClassification. The PES data collected and analyzed for this purpose is used to set or establish the baseline. The baseline is fixed as the Baseline Ecological Category (BEC).

Recommended Ecological Category (REC): This is the EC that is recommended based on the EIS and the attainability of the EIS.

Ecological Category (EC): The Ecological Category is a generic term that refers to the BEC or the REC. It should preferably only be used to refer to the process of Ecological Category determination.

2.5 ECOLOGICAL CATEGORIES: MONITORING DATA INTERPRETATION (provided by CJ Kleynhans)

The relationships described in 2.5.1 and 2.5.2 (between the BEC and the REC in terms of defining and quantifying EcoSpecs and TPCs) is illustrated in Figure 2-2 (provided by CJ Kleynhans).

2.5.1 Steps to follow when the REC is the same as the BEC (BEC (PES) = REC)

The EcoSpecs that represent the REC are directly derived from the BEC, e.g. both the biological indicator metrics and the particular associated physico-chemical metrics. EcoStatus models are run to indicate likely change points, e.g. where the REC may start to degrade to a lower category. This is done during the EcoClassification phase. These changes are linked with shifts in the numerical or index value of indicator metrics and are Thresholds of Potential Concern (TPCs). TPCs refers to upper and/or lower values around a metric that will preferably provide an early indication that the metric that represent an EcoSpec, may be deteriorating which may result in a degradation of the EC. The statement regarding the upper value must not be confused with the upper percentage value of an Ecological Category. The lower and upper value of a metric can refer to e.g. temperature where the increase in temperature can result in a lower EC.

2.5.2 Steps to follow when the REC is higher than the BEC (BEC (PES) < REC)

The BEC is used as the basis to derive the indicator metrics for EcoSpecs and TPCs by following the EcoClassification and running the relevant EcoStatus models for the REC. The relevant metrics are determined during the EcoClassification workshop.

- a) BEC improvement and attainment of REC: Define and quantify EcoSpecs and metric values that would indicate attainment of the REC or a trend in the improvement of the BEC (not TPCs) as determined during the EcoClassification workshop.
- b) BEC degradation: Define and quantify EcoSpecs and metric values that would indicate a decrease in the BEC. Define and quantify TPC maximum and/or minimum values that would indicate a decline in EcoSpec metrics and possible decline in the BEC.

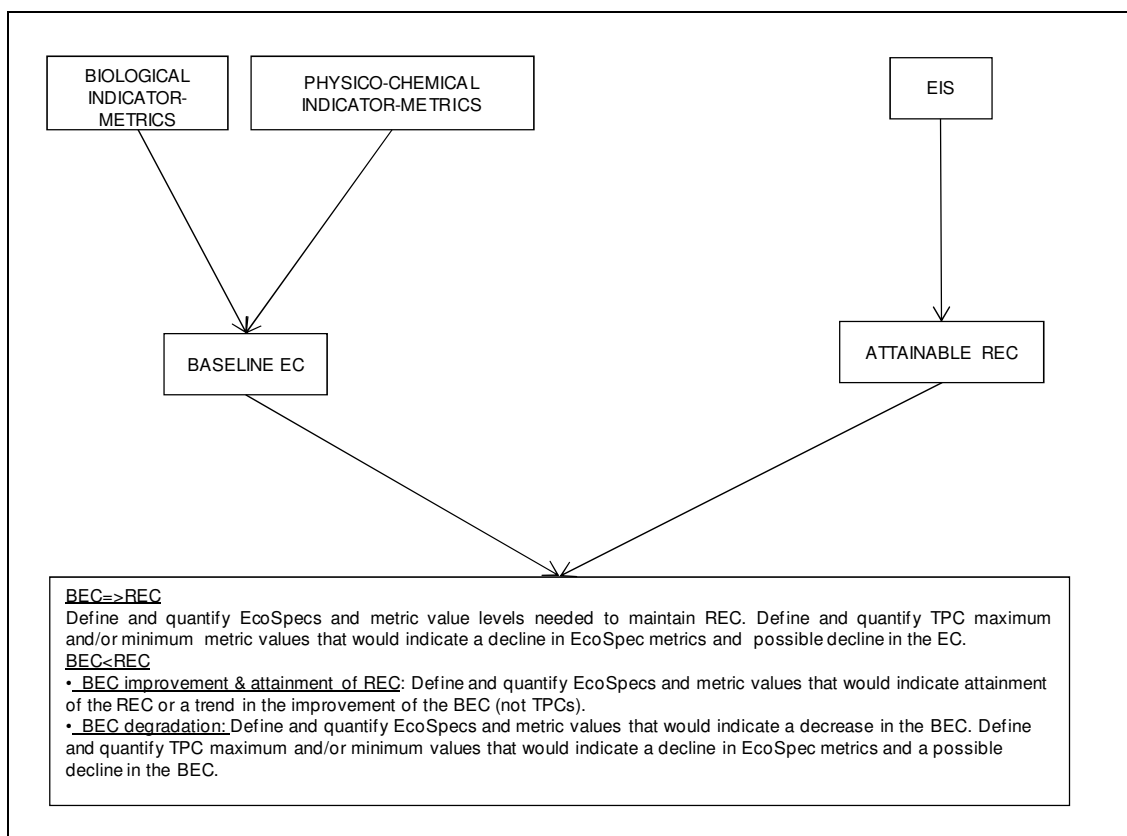


Figure 2–2 Relationship between BEC and the REC in terms of defining and quantifying EcoSpecs and TPCs

2.5.3 Implications of the Classification system and the Class on steps for setting EcoSpecs and TPCs

The ultimate Class determined through the application of the Classification System could be the BEC (PES), REC or a different EC. This Class is referred to as the Classification Ecological Category (CEC). The following scenarios could be relevant:

- BEC = CEC = REC
- BEC = CEC < REC
- BEC = REC > CEC

During EcoClassification an Alternative EC (AEC) is set and described and this caters for the situations where the CEC is a lower EC than the PES or BEC.

2.6 ECOSPEC DETERMINATION AS APPLIED IN THIS STUDY (written by D Louw)

Reference conditions, the Present Ecological State (PES), the Recommended Ecological Category (REC) and Alternative Ecological Categories (AECs) have been determined (DWA, 2009b) during the EcoClassification process. **This provides the broad level of EcoSpecs for the biophysical components for each EC addressed during EcoClassification. It also provides the information on the biological indicator metrics (see sections above). During the EWR scenario workshop, the flow EcoSpecs for each EC (the scenario refers to different ECs) is defined.**

What is required at this stage is to provide detailed EcoSpecs and TPCs for the baseline, i.e. the BEC for the biological responses, physico-chemical variables and geomorphology. As further clarification, the EcoStatus EC and component ECs that represent the BEC must be quantified to provide detail EcoSpecs to be used in the EWRM process. Irrespective of what the REC or the EC that will result from the implementation of the classification process is, what is being monitored is the baseline, i.e. the BEC. Therefore, to determine whether the BEC is changing, one needs to provide the detailed EcoSpecs and to define the TPC that will, within an EWRM DSS, indicate whether the BEC is being maintained, improved, or degrading.

The focus on this study is thus to provide the detailed EcoSpecs and to define the TPCs for (the BEC, i.e. the current or initial PES) at each EWR site on the Crocodile, Sabie and Sand River Systems. Note that **TPCs are set within the PES to indicate the probability or relative risk of the BEC changing to a lower EC. The purpose of this is to implement management actions** to prevent this degradation, unless the Classification system has resulted in a state worse than the PES (BASELINE EC) being selected as the CLASS.

The same level (qualitative/narrative to quantitative) of EcoSpecs is not set for the REC or any other EC as the focus is on the BEC. The level of EcoSpecs defined during the EcoClassification process will be sufficient during the initiation of monitoring. The EcoSpecs for ECs other than the PES are predictions and dependant on many driver variables and in essence, represents only one combination of driver conditions out of many that could result in this EC. (Note that during the EcoClassification process, only the most LIKELY hypothetical qualitative scenario is described in terms of changes in drivers). To define these EcoSpecs in more detail than the BEC would therefore be impractical, as these other ECs must be achieved first, before the detailed level of EcoSpecs can be defined. In the hypothetical case where the REC is an improvement of the BEC, the detailed EcoSpecs and a new TPC for this EC must be defined at that stage. Real conditions, data and specifications will then be available of how the biota has responded to the implementation of management objectives and this will allow for detailed EcoSpecs and a TPC to be set.

The concepts of the EcoSpecs and TPCs are described in a hypothetical example (Figure 2-3) where the PES (BEC) is a C and the REC a B.

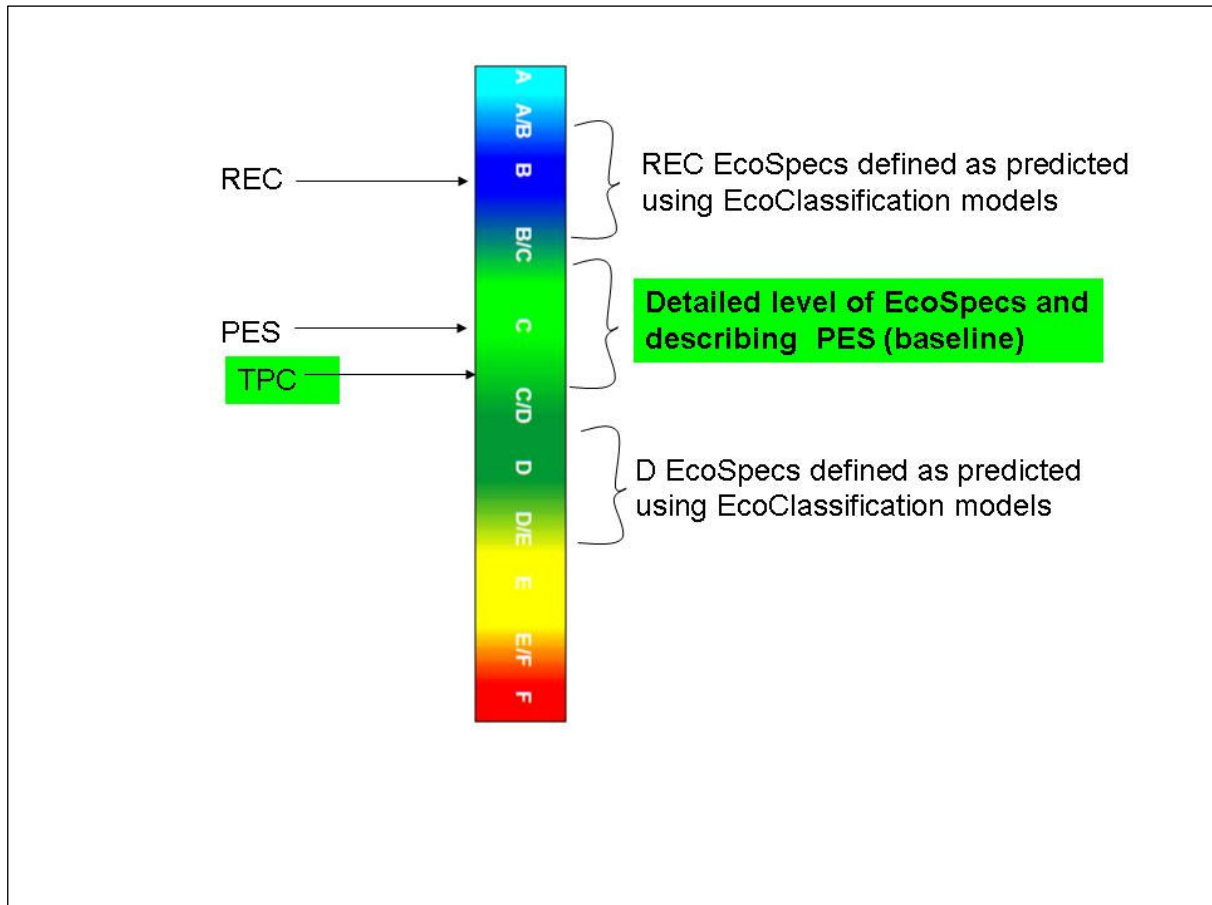


Figure 2–3 Example showing how the relationship between the EcoSpecs, TPCs and ECs

2.7 CONSTRAINTS

The RHAM provides information at the flow during the time of survey during the dry season. This flow could however be higher than the flows required to maintain the PES. The RHAM data represents a point within the PES range. It will not be possible (without a predictive hydraulic habitat model) to determine what the habitat conditions will be at the recommended flow if not similar to that which has been measured. It must therefore be acknowledged that the TPCs could often require adjustments within the adaptive management process. Once the RHAM has been monitored at a sufficient range of flows, the TPCs should be more stable.

3 METHODOLOGY

This section describes the methods and data that were used to identify metrics and TPCs to determine the EcoSpecs and TPCs for the different Reserve components.

3.1 GEOMORPHOLOGY

Authored by MW Rountree

At each EWR site there is usually a broad conceptual understanding of the Reference condition morphology and likely rates and ranges of changes of that state derived from expert knowledge of the area, the river reach (channel) type sensitivity and the historical aerial photographic record of the site. However the large spatial and long-term temporal scale of this understanding is difficult to scale down to the much more short-term, small (site specific) spatial scale understanding that is required setting and assessing EcoSpecs. The metrics identified for the EcoSpecs and TPCs are thus based on specialist interpretation of the expected rates and ranges of change of the baseline conditions at a site, these being inferred from expert judgement of site-specific susceptibility to change. Extensive historical aerial photographic analysis for numerous river reach types and their respective demonstrated rates and ranges of change (Parsons *et al.*, 2006; Rountree *et al.*, 2004; Rountree *et al.*, 2001) has been used to guide the estimates for EcoSpecs (both those derived from baselines RHAM and Geomorphology Assessment Index (GAI) metrics). Thus ***EcoSpecs for geomorphology***, described for each of the EWR sites, ***are based on expert assumptions of the likely acceptable range of change for a variety of metrics*** for a specific site.

The metrics identified for the generation of EcoSpecs and TPCs were selected based on the following criteria:

- 1) The expected critical, relatively rapid responding metrics that are
 - a. relevant for assessing and monitoring the condition of the river geomorphology; and/or
 - b. represent critical habitats for instream biota.
- 2) Variables that are being assessed as part of, or can be derived from, the RHAM data collection, or that were part of the EWR data collection (e.g. sediment size distributions).

This approach has been followed to minimise monitoring costs, since the RHAM monitoring will be conducted more frequently than detailed studies. If TPCs are exceeded, this could (pending the design of the Monitoring DSS) trigger more detailed biotic assessments. Only if these assessments confirm an undesirable change in the BEC will further assessments, which could include a geomorphological (GAI) study be undertaken to identify the extent and causes of the BEC change.

Two tiers of geomorphological TPCs are thus provided. The first relate to the data collected as part of the RHAM monitoring. This set of TPCs have been automated into the Comp-RHAM excel data sheets for each EWR site. This enables the monitoring data to be entered into the data sheet, Comp-RHAM to be run and the relevant geomorphology metrics calculated (on a new TPC sheet) and compared against the TPCs set for the site. The sampling design, from a geomorphology perspective, of the RHAM is such that ***to enable meaningful comparisons between RHAM monitoring intervals, the RHAM monitoring must be undertaken during the low flow season, ideally at a similar discharge to the baseline data collection period.***

The second set of TPCs is provided for the situation where subsequent GAI assessments are initiated as part of the monitoring follow-up surveys.

The EcoSpecs and TPCs usually describe or specify a range of acceptable values or conditions for a given metric. This is because, under Reference or natural conditions, the geomorphological condition of a specific metric would incorporate some degree of a natural range and rate of change over time. The ability to define the range and rate of change of expected natural condition depends heavily on the available baseline information which usually only consists of information collated during the EWR survey and historical aerial photo analysis.

Where the EcoSpecs relate to metrics being assessed as part of RHAM assessments, confidence of the EcoSpecs and TPCs is low to moderate as the RHAM is not a geomorphological-focussed assessment. Confidence in the GAI related TPCs is higher as it is a dedicated geomorphological assessment and survey conducted by a fluvial geomorphology expert.

Confidence in the EcoSpecs and TPCs derived from RHAM data is:

- MODERATE for the Active channel substrate change EcoSpecs as the sampling site is variable according to the flow conditions (sediment is only assessed in the wetted channel and this is obviously variable over time).
- VERY LOW for the In-channel habitat diversity EcoSpecs as the sampling site is variable according to the flow conditions, and the confidence in the expected range of change under natural conditions is low; and
- LOW for the Active channel geometry EcoSpecs as the sampling site is variable according to the flow conditions.

Confidence in the EcoSpecs and TPCs derived from GAI data is:

- HIGH for the In-channel sediment distribution EcoSpecs because the sampling approach is more consistent across different flow conditions, and the field data collection is being conducted by an expert fluvial geomorphologist;
- MODERATE for the Channel Morphology because although a geomorphology expert is involved, the analysis is relatively subjective; and
- HIGH for the GAI Level IV EcoSpec because a geomorphology expert is involved and the analysis is more reliable and objective.

It must be noted that ideally, the EWR geomorphological survey and RHAM survey will take place during site selection, i.e. the dry season. As the baseline data would be collated at the same time and for the same conditions, the confidence of both sets of TPCs should be high. However, in this case, the RHAM was developed after the EWR surveys and the RHAM baseline collated at a later stage, and therefore at mostly different flow conditions and not always at the exact EWR site. Therefore, TPCs set for the RHAM will be of lower confidence than those set for the GAI.

When describing sediment size distributions for the Active channel substrate change (RHAM EcoSpec) and In-channel sediment distribution (GAI EcoSpec), the following sediment diameter size ranges are implied:

Sediment Class	Diameter size range (mm)
Fines	0.0 - 0.2
Sand	0.2 - 6
Gravel	6 - 60
Cobble	60 - 250
Boulder	>250
Bedrock	N/A

3.2 PHYSICO-CHEMICAL VARIABLES

Authored by P-A Scherman

EcoSpecs and TPCs have been prepared for various levels of a monitoring (DSS). RHAM (or visual) water quality indicators are used at Level 1 of the DSS, with *in situ* physico-chemical parameters included at Level II, i.e. pH, Electrical Conductivity (EC), oxygen and temperature. Level III of the DSS includes the use of diatoms as biotic response indicators, using the Rapid Diatom Riverine Assessment Method (R-DRAM). Other biotic response indicators included at this level are fish and aquatic macroinvertebrates. Level IV and V of the DSS include more detailed physico-chemical analyses and detailed diatom analyses, involving the collection of data from relevant gauging weirs. The R-DRAM therefore serves as a water quality screening tool and indicates which physico-chemical variable(s) require further monitoring and more detailed data analyses.

Note that the broader terminology 'water quality' has been used to encompass not only physico-chemical data, but also visual and biotic responses to changing water quality conditions as used in the RHAM. Level descriptions are linked to documentation (December 2009).

This document assumes that the monitoring baseline has been set for the sites and that all evaluations are therefore relative to knowledge of the natural state of the catchment.

The approach followed for each site is therefore as follows:

- Data collected per site during the RHAM monitoring surveys (August 2009, i.e. at low flows) represents the first monitoring data.
- RHAM water quality indicator TPCs are then set for the following RHAM water quality indicators, i.e. monitoring a deterioration from present state:
 - Water odour.
 - Water colour.
 - Turbidity/clarity. Due to data limitations for this parameter, the TPC is set in terms of a RHAM water quality indicator only.
 - Water surface indicators
 - Algal cover on hard surfaces
 - Filamentous algae present in the water column.

Visible biotic response is not assessed as it should be covered during other strategic monitoring or management activities.

RHAM water quality indicator TPCs have been set for the following sites only, as these were the site assessed during the RHAM surveys: Crocodile River EWR Sites 1, 2, 3 and 6; Sabie River EWR Sites 1, 3, and 8. Any exceedences are shown as bold red text.

- TPCs are also set for physico-chemical parameters for the site i.e. to monitor deterioration from present state. TPCs are presented as 95th percentiles, i.e. values not to be exceeded more than 5% of the time, for inorganic salts, physical variables and toxics; and 50th percentiles for nutrients, i.e. Total Inorganic Nitrogen (TIN), Soluble Reactive Phosphorous (SRP) or ortho-phosphate and chlorophyll-a (chl-a). The TPC ranges are defined by the upper boundary of the PES category and 80% thereof for the lower boundary, e.g. if a B category for a PES EcoSpec is < 15 mg/L, the associated TPC would be 12 – 15 mg/L.

Note: Percentiles should be calculated within the framework of the current assessment method (DWA, 2008b), i.e. using the PES monitoring point as shown on the table for the relevant EWR site, and the most recent 3 to 5 years of data, equivalent to a minimum of 60 data points. Data used from the DWA gauging weir must be requested from DWA's Water Management System's (WMS) database.

- EcoSpecs, i.e. water quality specifications or objectives for the Recommended Ecological Category (REC), are set for physico-chemical parameters only, i.e. quantifiable measurable parameters.
- EcoSpecs, i.e. water quality specifications or objectives for the Present Ecological State (PES), are set for physico-chemical parameters only, i.e. quantifiable measurable parameters.

NB: Quality EcoSpecs are therefore related to attaining the water quality category of the overall REC or PES, and are presented as the range that each variable should be in to maintain the required category for that variable. The category specified per variable, and the composition of categories for all variables, will depend on the drivers of water quality per site.

3.3 DIATOMS

Authored by S Koekemoer. Method developed by S Koekemoer.

A Rapid Diatom Riverine Assessment Method (R-DRAM) was developed as part of the EWRM at a Level 3 assessment approach within the DSS framework (DWA, 2009a, c). At this level diatoms are used as a **WATER QUALITY SCREENING TOOL** to indicate if:

- A particular physico-chemical metric needs further monitoring to assess the cause of the extent of the change.
- Management action is needed.
- The TPC for the particular metric needs recalibration.

For the R-DRAM to function as an effective water quality screening tool the results generated should:

- Provide information on diatoms as an additional response variable to compliment the physico-chemical driver component of the monitoring programme.
- Provide additional information and interpretive results, especially at sites where physico-chemical data availability was poor or of low confidence.
- Give an indication of the current pollution levels at a monitoring site according to the defined water quality class limits of the Specific Pollution sensitivity Index (SPI).

Note: The R-DRAM is still under development and has **not** been tested. It is also important to note that the EcoSpecs and TPCs within the current R-DRAM are based on moderate water quality (C EC). Therefore the approach the defined EcoSpecs and TPCs for the Crocodile and Sabie-Sand River system is based purely on specialist opinion and would therefore need verification at some stage.

3.3.1 Approach

During comprehensive diatom assessments the diatom scoring (EC) is based on the SPI score generated by OMNIDIA (Lecoite *et al.*, 1993). Selected physico-chemical metrics are also assigned class values for certain physico-chemical metrics (according to different water quality conditions), based on the Van Dam index (Van Dam *et al.*, 1994) to derive an overall ecological classification of the site. The physico-chemical metrics include pH, nutrients, organics, oxygen saturation and salinity.

The EcoSpecs derived for the R-DRAM was based on these ecological values and were specified for biological water quality that falls within a C EC.

The R-DRAM TPC for each metric essentially has three tiers of indicator species occurrence (counts) that are linked to a specific action/result. This includes:

- Tier 1: A diatom count that falls between specified limits that indicates that there is no threat/impact to the current biological water quality.
- Tier 2: A diatom count that falls between specified limits that indicates a possible impact to the current biological water quality.
- Tier 3: A diatom count that falls between specified limits that detects a definite impact to the current biological water quality.

3.3.2 EcoSpecs and TPCs derived for this study

RHAM water quality indicator TPCs were set for the following site, as these were the site assessed during the RHAM surveys:

- Crocodile River EWR 1, 2, 3 and 6.
- Sabie River EWR 1, 3, and 8.

A summary of the diatom results as well as the physico-chemical EC for these sites are provided below in Table 3.1.

Table 3.1 Diatom and physico-chemical results

EWR site	Site name	River	SPI score	Class	Category	Physico-chemical EC
CROCODILE RIVER SYSTEM						
EWR 1	Valeyspruit	Crocodile	16.5	Good quality	B	A
EWR 2	Goedenhoop	Crocodile	15.3	Good quality	B	B
EWR 3	Poplar Creek	Crocodile	14.6	Good quality	B	C
EWR 6	Nkongoma	Crocodile	13.1	Moderate quality	B/C	C
SABIE-SAND RIVER SYTEM						
EWR 1	Upper Sabie	Sabie	13.1	Moderate quality	B/C	A/B
EWR 3	Kidney	Sabie	14.5	Good quality	B	B
EWR 8	Upper Sand	Sand	13.1	Moderate quality	B/C	B

As diatoms are used as a water quality screening tool for the physico-chemical component the EcoSpecs and TPC developed for diatoms were based on the physico-chemical EC. Based on the diatom and physico-chemical ECs at the sites, EcoSpecs and TPCs were set for a C BEC, based on professional judgement was set for EWR 3 and 6 in the Crocodile River and a B BEC were set for the rest of the sites. This included an analysis of the diatom communities of the different

samples taken at the sites and determining the present occurrence of the twenty indicator species used in the R-DRAM. As expected some of the indicator species were present in the diatom samples however at very low abundances (1 – 3% of the total diatom count per sample) at sites where the biological water quality was good. Therefore the TPCs were derived from adjusting the first tier of diatom counts of each metric used in the R-DRAM.

3.4 RIPARIAN VEGETATION

Authored by J Mackenzie. Method developed by J Mackenzie.

The following vegetation components, when assessed together, satisfactorily describe the overall state of any riparian site:

- Exotic invasion.
- Terrestrialisation.
- General vegetation structure as shown by proportions of riparian woody species, reeds and non-woody species (grasses, sedges and dicotyledonous forbs).

Please note the hypotheses on which EcoSpecs (and hence TPCs) are based (described in Section 3.4.1 – 3.4.5) and that these need to be refined within the DSS once triggered.

EWR 3 (Poplar Creek) was used as an example to illustrate the generic approach.

3.4.1 Exotic invasion

Ecological specifications were set for the proportion of exotic species invading the riparian zone (Table 3.2). Values were tested by assessing a number of existing sites where exotic aerial cover data were available.

Table 3.2 Hypothesis on which EcoSpecs for exotic species occurrence in the riparian zone is based

Category	% Cover (Perennial Exotics)
A	0
A/B	1 - 5
B	5 - 10
B/C	10 - 15
C	15 - 20
C/D	20 - 30
D	30 - 50
D/E	50 - 60
E	60 - 70
E/F	70 - 80
F	>80

The Vegetation Response Assessment Index (VEGRAI) assessment indicated that the PES was 77.3% (C) and the REC was set at B. Based on the EcoSpecs for exotic invasion (Table 3.2), exotic species cover of 15 - 20% is associated with a C EC. Measured data verified these proportions. The TPC would therefore be set at the lower level of the PES i.e. an increase in perennial exotic species cover of 20% or more, but since the assessment showed that this applied to the lower and upper zones specifically and that the marginal zone had less exotic invasion, a separate TPC was set for the marginal zone; an increase in perennial exotic species cover of 10% or more (Section 6.4.1). The specific EcoSpec associated with this site would therefore be

determined from Table 3.1 in order to describe an improved state and taking the REC into account i.e. to maintain cover (%) of perennial exotic species at 20% or lower within the riparian zone, which refers to an ecological category of a C or better.

3.4.2 Terrestrialisation

Based on EcoSpecs for terrestrialisation (Table 3.3), terrestrial species cover of 5 - 10 and 20 - 30% is associated with a C in the lower and upper zones respectively. The TPC was therefore set at the lower level of the PES i.e. an increase in woody terrestrial species cover of 20% or more (Section 6.4.1). The specific EcoSpec associated with this site would therefore be determined from Table 3.2 in order to describe an improved state and taking the REC into account i.e. to maintain cover (%) of woody terrestrial species at 15% or lower within the riparian zone, which refers to an ecological category of a B or better.

Table 3.3 Hypothesis for EcoSpecs concerning terrestrialisation of the riparian zone

Class	Marginal Zone	Lower Zone	Upper Zone	Note
A	0	0	0 - 5	This hypothesis is based on the phenomenon that terrestrial species occur naturally in the riparian zone, but are reduced in cover and abundance by increased flooding disturbance. Data of terrestrial:riparian plant ratios (on the Sabie River) showed a distinct reduction in terrestrial individuals with increasing exposure to flooding disturbance.
A/B	0	0	5 - 10	
B	0	0	10 - 15	
B/C	0	1 - 5	15 - 20	
C	0	5 - 10	20 - 30	
C/D	0	10 - 15	30 - 40	
D	1 - 5	15 - 20	40 - 50	
D/E	5 - 10	20 - 30	50 - 60	
E	10 - 15	30 - 40	60 - 70	
E/F	15 - 20	40 - 50	70 - 80	
F	> 20	> 50	> 80	

3.4.3 Indigenous Riparian woody cover

This site occurs in a section of river where the climax community of the macro-channel bank and alluvial-dominated bars will be indigenous woody riparian species (notably, *Combretum erythrophyllum*), with some *Gomphostigma virgatum* in the rocky or cobble areas of the marginal and lower portions of the lower zones. In the absence of unnatural disturbance the proportion (% cover) will tend to increase to values as high as 70 or 100% of suitable habitat. An increase beyond this range will reduce the ecological category of the site since it is then assumed that prevailing conditions favour woody species at the expense of non-woody species where the latter are expected to occur. RHAM data show an average of 48%, for indigenous woody cover while VEGRAI data show an average of 40% for PES. Woody vegetation removal for firewood is an impact at this site and a decrease in riparian woody cover below 20% would reduce the EC by a category. Similarly an increase above 70% cover may indicate loss of flooding disturbance, which would also reduce the EC.

Based on the EcoSpecs for this site (Table 3.4), the TPC was set to maintain the site at a C (PES) at least i.e. a decrease in riparian woody species cover below 20% or an increase in riparian woody species cover above 70% in the lower and upper zones. The specific EcoSpec for this site would refer to cover values for classes A, B, or C i.e. to maintain cover (%) of riparian woody species between 20 and 50% within the riparian zone.

Table 3.4 Hypotheses for EcoSpecs concerning indigenous riparian woody cover

Lowveld bushveld rivers				
Class	Marginal Zone	Lower Zone	Upper Zone	Note
A	10 - 20	20 - 40	40 - 50	This hypothesis for Lowveld Bushveld rivers (on granites) is based on a dynamic whereby riparian vegetation in the lower and upper zones will always tend towards increased woody cover with diminishing non-woody cover (including reeds), this being "reset" by large flood events. "Reset" here refers to the removal of woody plants by floods, the resulting open space being available for quick colonizing non-woody species (including reeds). The hypothesis assumes that if woody cover increases beyond a given value and remains high, that the flooding regime has been changed so that large floods are smaller or less frequent.
B	20 - 60; 5 - 10	10 - 20; 40 - 50	30 - 40; 50 - 60	
C	60 - 80; 1 - 5	- 10; 50 - 60	20 - 30; 60 - 70	
D	> 80; < 1	< 5; 60 - 70	10 - 20; 70 - 80	
E		70 - 80	- 10; 80 - 90	
F		> 80	< 5; > 90	

3.4.4 Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs)

The above interaction between woody and non-woody vegetation does not apply to this assessment of non-woody indigenous cover. The reason for this is the format in which data are collected in RHAM. When assessing woody vegetation, non-woody vegetation is an assessed class as part of the data whereas woody vegetation is ignored when non-woody vegetation classes are assessed. This is because there is usually an understory to woody vegetation which form part of the non-woody assessment. Thus it is possible to have 50% woody riparian cover in the lower zone, as well as 80% non-woody indigenous cover. This would be a class B river at EWR 3. Data collected during RHAM assessments showed an average of 31%, while those collected for the VEGRAI range from 20 - 60%. This is linked, mostly to woody cover (indigenous and exotic) by way of shading i.e. too much shading reduces cover and none allows for a situation where 100% cover is possible. This site occurs where a mix of woody and non-woody is always expected. Based on the PES of a C at this site, the EcoSpec is to maintain grass, sedge and dicotyledonous forb cover between 30% and 90% (Table 3.5). The associated TPC is a decrease in sedge, grass and dicotyledonous forb cover below 30% or an increase above 90%.

Table 3.5 Hypotheses for EcoSpecs concerning indigenous non-woody cover

Category	Non-woody indigenous cover (grasses, sedges and dicotyledonous forb)
A	70 - 80
B	50 - 70; 80 - 90
C	30 - 50; >90
D	20 - 30
E	10 - 20
F	<10

3.4.5 *Phragmites* (reeds) cover

In both VEGRAI and RHAM, reeds are classified as non-woody, and although they are a grass, their importance in riparian structure and function warrants their separate assessment in terms of EcoSpecs and TPCs. The EcoSpecs for reed cover would ordinarily be determined by a genera hypothesis as set out in Table 3.6. However, reeds did not occur in RHAM data and cover was low (< 10%) in VEGRAI data at this site, probably due to the gorge characteristics of the stream. The

EcoSpec was set to maintain reed cover below 10% with the TPC being an increase in reed cover above 10%.

Table 3.6 Hypotheses for EcoSpecs concerning *Phragmites* (reed) cover

Lowveld bushveld rivers				
Class	Marginal Zone	Lower Zone	Upper Zone	Note
A	40 - 80	40 - 70	20 - 30	This hypothesis for Lowveld Bushveld rivers (on granites) is a corollary to the riparian woody cover hypothesis i.e. it is based on a dynamic whereby riparian vegetation will always tend towards increased woody cover with diminishing reed cover, this being "reset" by large flood events. "Reset" here refers to the removal of woody plants by floods, the resulting open space being available for quick colonizing reeds. The hypothesis assumes that reeds will colonize open alluvium (similar to the pioneer species concept) created by floods, and will increase in cover until slowly replaced by woody vegetation as shading occurs. A natural flow regime will create a patch mosaic of woody vs. reeded areas, thus a mix is always expected (in the absence of very infrequent extreme events): an increase in reed cover beyond a specified value is seen to be a loss of riverine diversity and as such will begin to reduce the EC.
B	20 - 40, > 80	20 - 40; 70 - 80	< 20; 30 - 40	
C	10 - 20	10 - 20; 80 - 90	40 - 50	
D	< 10	< 10; > 90	50 - 60	
E			60 - 70	
F			> 70	

3.5 FISH

Authored: P Kotze and A Deacon

EcoSpec and TPC results are provided in an MS Excel format (Fish EcoSpec & TPCs) for the relevant site, which includes methodology and supporting data and information for future reference, especially during application of TPCs after monitoring. This data will be provided electronically (RDM Report 26/8/3/10/12/016) (DWA, 2010).

The approach for determining EcoSpecs and TPCs is described in sheet 1 of the Excel spreadsheet in a step-wise manner. These steps are listed below (Bold typeface) and further explained below.

- 1. Import information from FRAI model (PES and REC) into relevant sheets (sheet 5 to 10) and follow the instructions at the top of each spreadsheet.**
- 2. Select indicator taxa for each metric using sheets 7 to 10 and referring to sheet 5 determine whether a species was previously sampled at the relevant EWR site (only use species known to occur at the site). Use one or two of the highest ranked species (present at site) and list them in Column C (2-EcosSpecs&TPC' worksheet).**

The selection of indicator taxa for each metric is done using the 'monitoring indicator' sheet in the Fish Response Assessment Index (FRAI) model for each EWR site/reach. This sheet calculates an indicator value for each species in different variables (such as fast shallow habitats, cover type, etc.) based on the reference Frequency Of Occurrence (FROC) and relative intolerance rating of the species. Based on the indicator value determined by the model, species are ranked in order of importance to serve as indicator for a specific variable. The two highest ranked species that are known to occur at the EWR site was generally used as the indicator taxa for the specific metric. If there were uncertainty about the presence of an optimal indicator species (ranked 1 and 2) at a site, or if the species occurred in too low abundance and sampling may therefore be coincidental,

these species were excluded and replaced by lower ranked indicator taxa at the site. The two highest ranked indicator species for each metric was used as indicators for reach (automated in Excel spreadsheet) by default.

- 3. Describe PES EcoSpecs and TPCs for each metric per site and reach (columns D - G), and EcoSpec for the REC (reach only) (column H). This should be done using the spatial and temporal¹ FROC as well as relative abundance information in the worksheet labeled 5-FROC.**

Site versus reach EcoSpec assessment

Fish EcoSpecs and TPCs are described for each fish metric, differentiating between reach and EWR site where applicable. This was done due to the fact that the PES is determined for an entire reach within which the EWR site falls, while fish sampling is however often conducted only at the EWR site, and therefore merits site-specific EcoSpecs and TPCs. EcoSpecs were therefore described for the site to reflect the PES (baseline), while broad EcoSpecs were also given for the reach should detailed monitoring be performed where more than one site is sampled in the reach. EcoSpecs were also described for the reach in terms of the REC (if different from PES), providing a broad description of the expected change in FROC of selected species that would result in the attainment of (improvement towards) the REC.

Once site-specific EcoSpecs were described, TPCs were then derived for each of the selected metrics for the EWR site, giving measurable biotic TPCs for fish as well as conceptual habitat TPC. The habitat TPCs could be quantified using the RHAM once more information becomes available. The biotic (fish) TPCs described for the site should enable the detection of deterioration at the site that may result in a deterioration of the PES towards a lower category (deterioration). The EcoSpecs described for the reach should provide an indication of conditions when the PES is reaching the REC.

Spatial and temporal FROC of species, as well as their relative abundance (catch per unit effort) were used as units for the different variables or metrics. The calculation of the FROC and relative abundance is based on the results gained during the baseline (generally EWR) surveys, and sometimes also on other available data (important to note that EcoSpecs and TPCs should reflect the PES) and therefore historic data should be used with care in cases where changes could have occurred since the surveys were conducted. The use of data from other sites in a reach must also be applied with circumspection as it may not reflect the species composition and relative abundances of the specific EWR site. It is imperative to note that the recommended values given as TPCs should be tested and refined over time as more information becomes available. This is however the best available information at present and should serve as a good starting point. As the RHAM protocol is developed and applied further, these variables should be used to provide specific habitat TPCs in terms of the different fish metrics. Ideally a range of RHAM surveys at different base low flows should be conducted, and fish surveys should be done during these surveys. This would be the best applicable way to link the species composition and relative abundances directly to RHAM results, and allow for quantification of habitat TPCs based on RHAM. Ideally fish data should be gathered separately for each RHAM unit at the EWR site.

¹ Spatial FROC: presence of fish species at different sites within a reach or in different units/areas at a site (as used in FRAI).
Temporal FROC: Presence of species over time at a specific site (such as EWR site).

Relative abundance/Catch Per Unit Effort (CPUE): Calculated only for electro-fishing in number of individuals/minute (can be done for per site and per species) (if available for many surveys, use lowest observed CPUE to set TPCs).

4. In the "EcoSpecs & TPCs" worksheet rank the metrics in order of most sensitive (rated 1) to less sensitive to detect change (using sheet 6-metric group weights and professional judgement)

Various metrics were selected that would allow the use of fish to determine changes, specifically deterioration in biotic integrity of the aquatic ecosystem. A metric is a measurable component of biological systems, which show an empirical change in value along a gradient of human disturbance (USEPA, 1998). By default, various relevant metrics used in the FRAI model (such as FS habitats, overhanging vegetation, etc.) were selected.

The different metrics were then ranked based on FRAI metric group weighting, relative intolerance or sensitivity of the species to detect change and professional judgement. The purpose of the ranking of metrics is to indicate the metrics most probable (most sensitive) to detecting deterioration. Although different indicator species indicate different changes, the ranking aims to highlight which metrics will be the most sensitive to detect changes at the site.

5. Complete sheet 3 - Monitoring requirements

Recommendations were also made regarding monitoring requirements taking into consideration the Ecological Importance and Sensitivity metric - rare and endangered and unique fish species at the site. The monitoring recommendations included aspects such as frequency of monitoring, optimal sampling season, location (where and which habitats to focus on) as well as sampling techniques (including recommended effort that should be applied). The monitoring recommendation should also be verified and adapted over time once more information becomes available. It is of critical importance that the follow-up monitoring should be conducted during the same season as when baseline surveys were conducted, or TPCs should be refined for the specific season of the monitoring. The closer the flow (discharge) between monitoring and baseline survey, the more comparable the results and the more likely changes can be detected (it will exclude natural seasonal and habitat differences at the site, which is coupled with natural variation in fish diversity and abundance at the site).

When a TPC for a certain metric is reached, it must first be established whether that specific habitat type (such as SD, water column, overhanging vegetation) has been sampled adequately, to exclude the possibility that the TPC was reached as a result of sampling effort. This would therefore mean that sampling should be done when conditions are optimal. Indicator species can be identified before the actual survey at a site and sampling can then be aimed at specific habitats using the most appropriate sampling method that would give the highest probability of the indicator species being sampled if present. The most preferred sampling method for monitoring purposes is electro-fishing, as this method is very effective in especially flow sensitive habitats (Fast Shallow (FS)) as well as other shallow marginal habitats (such as undercut banks and overhanging vegetation). This method may also be the most reliable of all methods to calculate relative abundance of a species (CPUE). For the purpose of setting EcoSpecs and TPCs during this study, relative abundance was only determined using electro-fishing data and it was expressed as individuals per minute. Electro-fishing does not however have to be the only sampling method applied during the monitoring phase, as sampling methods should be determined by the indicator species.

Unfortunately due to factors such as cost efficiency, safety at site (presence of crocodiles and hippos) a range of sampling methods can sometimes not be applied. Under such circumstances,

the TPCs should be evaluated with caution, considering only those metrics that reflect habitats and species that could be sampled efficiently.

3.6 MACROINVERTEBRATES

Authored: AC Uys

A method to determine EcoSpecs and TPCs for macroinvertebrates was developed during 2006 (DWA, 2006). As EWRM has never been applied since then, these methods have not been tested or refined. The method was further refined during this study to cater for additional information collated in terms of habitat via the RHAM. As with all the components, all methods to determine EcoSpecs and TPCs must be applied and tested following Adaptive Management principles within EWRM.

EcoSpecs and TPCs for each site have been estimated on the basis of a set of physical and hydraulic-habitat criteria, a suite of existing data, and specialist knowledge.

The physical and hydraulic-habitat criteria are considered to be those of relevance to the site's indicator taxa (macroinvertebrate families with a preference for fast-flowing water (Flow Dependant invertebrates - FDI) or marginal vegetation (marginal vegetation invertebrates - MVI)). These criteria include discharge, width, average and maximum depth, average and maximum velocity, substrate type, substrate embeddedness, proportion of different habitat/flow classes across the channel, and algal cover.

An MS Excel spreadsheet format is used. For each site, the afore-mentioned criteria are listed in rows, and each data source is presented as a separate column:

- "RHAM" – the hydraulic parameters associated with the RHAM monitoring data, sourced from COMP-RHAM.
- "PES" – the hydraulic parameters associated with the discharge requested for the PES for MAINTENANCE DRY at the relevant percentage exceedance during the determination of EWR scenarios (DWA, 2009b).
- "REC" – the hydraulic parameters associated with the discharge requested for the REC for MAINTENANCE DRY at the relevant percentage exceedance during the determination of EWR scenarios (DWA 2009b).

The intention of presenting data in this format is to provide, at a glance, a context to aid the setting of appropriate and valid TPCs and EcoSpecs for the site, and to assist interpretation of future RHAM monitoring data. The spreadsheets for each site are provided electronically with this report (RDM Report 26/8/3/10/12/016) (DWA, 2010).

The actual setting of TPCs and EcoSpecs was guided by the data described above. For each of the hydraulic-habitat criteria (e.g. minimum depth), the associated values from each data source (column) were considered. This, in combination with an understanding of the minimum requirements (or preferences) of the indicator taxa, the site morphology, and the likely change in habitat availability at different flows, was used to come up with a minimum value per hydraulic-habitat criterion for the TPC, and the EcoSpec.

Note that the baseline or survey data ("PES" column) relates to the *EWR survey* cross-section which is, at a number of sites, located at a different point or points along the river from the

monitoring cross section or reach (“RHAM” data column). In the case of the EWR survey data, key hydraulic habitat parameters linked to any discharge can be sourced in the hydraulic look-up table for the site. This table is referred to throughout the Reserve Determination process. In the case of the monitoring data however, these are sourced from the COMP-RHAM outputs, which are only applicable to the discharge at the time of sampling (i.e. one cannot alter discharge and see what the resulting change in hydraulic habitat will be). This made the determination of EcoSpecs and TPCs complex. Cognizance was however been taken of the difficulties associated with the use of data from different cross-sections and different discharges, and cautious minimum values were set. In order to cater for the RHAM monitoring, baseline data (i.e. that acquired during EWR surveys) should be collected at the **same** hydraulic cross-section as subsequent monitoring data.

It should also be mentioned that no standard method exists for the setting of EcoSpecs and TPCs for macroinvertebrates, and there was thus a requirement to “create” and test a method for this task during the workshop itself. This output is considered preliminary and conservative. Further research and development is required to establish a standard approach to this task.

3.7 DATA USED FOR DETERMINING ECOSPECS AND TPC

The following data was used for determining EcoSpecs and TPCs:

- Data collected during the EWR site visits; September and October 2007.
- Data collected during the RHAM site visit; August 2009.
- Relevant historic data and observations from surveys in the catchment.

EWR and RHAM data is available as part of the electronic information and data of this study (RDM Report 26/8/3/10/12/016) (DWA, 2010).

4 RESULTS: ECOSPECS AND TPCs FOR EWR 1: VALEYSPRUIT (CROCODILE RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

4.1 ECOCLASSIFICATION SUMMARY OF EWR 1

EWR 1 Valeyspruit (Crocodile River)																																									
<p>EIS: MODERATE Highest scoring metric were diversity of sensitive habitat types present e.g. wetlands, oxbows, sponges.</p> <p>PES: A/B Minor impacts due to farming, exotic vegetation species, trout. Impacts mostly non-flow related</p> <p>REC: A/B Maintain the PES as only moderate EIS.</p> <p>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.</p>	<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES & REC Category</th> <th>Trend</th> <th>AEC↓</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>A/B</td> <td></td> <td>B</td> </tr> <tr> <td>WATER QUALITY</td> <td>A</td> <td></td> <td>B</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>B</td> <td>Stable</td> <td>C</td> </tr> <tr> <th>Response Components</th> <th>PES & REC Category</th> <th>Trend</th> <th>AEC↓</th> </tr> <tr> <td>FISH</td> <td>A</td> <td>Stable</td> <td>B/C</td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>B</td> <td>Negative</td> <td>B/C</td> </tr> <tr> <td>INSTREAM</td> <td>A/B</td> <td></td> <td>B/C</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>A</td> <td>Stable</td> <td>B</td> </tr> <tr> <td>ECOSTATUS</td> <td>A/B</td> <td></td> <td>B/C</td> </tr> </tbody> </table>	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	Negative	B/C	INSTREAM	A/B		B/C	RIPARIAN VEGETATION	A	Stable	B	ECOSTATUS	A/B		B/C
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	Negative	B/C																																						
INSTREAM	A/B		B/C																																						
RIPARIAN VEGETATION	A	Stable	B																																						
ECOSTATUS	A/B		B/C																																						

EcoSpecs and TPCs for the PES and REC are provided for the different components in Section 4.2 to 4.7.

4.2 GEOMORPHOLOGY

The REC is the same as the PES. There has been some channel incision and straightening which are the main reasons for the change from reference condition and this is the focus of the EcoSpecs and TPCs. EcoSpecs and TPCs are provided for RHAM monitoring data in Section 5.2.1 and GAI monitoring data in Section 5.2.2.

4.2.1 EcoSpecs and TPCs relating to RHAM monitoring data

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Fines should not exceed 25%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 23%. Sand (< 6 mm) should not exceed 10%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 6%. Cobbles should exceed 25%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 27%. Within all of the fast habitats: Neither sands nor fines should exceed 5%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 3% fines and 1% sands. Cobbles should exceed 5%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 10%. </p>
The percentage substrate type within the active channel at the RHAM site is provided below.		

Metric	EcoSpec	TPCs																								
<table border="1"> <caption>Approximate data from the bar chart</caption> <thead> <tr> <th>Substrate</th> <th>Overall site (%)</th> <th>Fast habitats (%)</th> </tr> </thead> <tbody> <tr> <td>Roots</td> <td>1</td> <td>0.5</td> </tr> <tr> <td>Fines</td> <td>23</td> <td>2</td> </tr> <tr> <td>Sand</td> <td>6</td> <td>1</td> </tr> <tr> <td>Gravel</td> <td>6</td> <td>3</td> </tr> <tr> <td>Cobbles</td> <td>27</td> <td>10</td> </tr> <tr> <td>Boulders</td> <td>32</td> <td>12</td> </tr> <tr> <td>Bedrock</td> <td>3</td> <td>1.5</td> </tr> </tbody> </table>			Substrate	Overall site (%)	Fast habitats (%)	Roots	1	0.5	Fines	23	2	Sand	6	1	Gravel	6	3	Cobbles	27	10	Boulders	32	12	Bedrock	3	1.5
Substrate	Overall site (%)	Fast habitats (%)																								
Roots	1	0.5																								
Fines	23	2																								
Sand	6	1																								
Gravel	6	3																								
Cobbles	27	10																								
Boulders	32	12																								
Bedrock	3	1.5																								
Proportion of embedded sediments.	Maintain minimum embeddedness to ensure bed mobility and create habitat for instream biota.	<p>Overall for the in-channel sediments: Most of the embedded material should be found in the shallow habitats.</p> <p>Per substrate type: Proportion of GRAVELS that are embedded should be less than 25%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 23%. Proportion of COBBLES that are embedded should be less than 40%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 34%. Proportion of BOULDERS that are embedded should be less than 50%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 42%. </p>																								
<p>IN-CHANNEL HABITAT DIVERSITY</p> <p>The percentage mobile sediment per macroinvertebrate velocity class is given below.</p>																										
<p>ACTIVE CHANNEL GEOMETRY</p>																										
Active channel width.	Maintain channel width.	For discharges around 0.1 m ³ /s the average width of the active channel should be between 4 and 6 m wide. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 5.5 m. 																								
Lower bank stability.	Extent of undercut banks.	Overall for the site, the proportion of undercut banks should not exceed 50%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 42%. 																								

4.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Sediment size distribution was measured in 2003 as part the sediment transport analyses for the Crocodile River and GAI information is therefore based on these results. This is applicable to all EWR sites in the Crocodile River unless otherwise stated.

Metric	EcoSpec	TPCs
<p>ACTIVE CHANNEL SUBSTRATE CHANGES</p>		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	At approximate discharge of 0.1 m ³ /s and average width of 5 m, bed sediment within the active channel riffle should be distributed as follows: Fines and sands (< 2 mm diameter) should not exceed 20%. <ul style="list-style-type: none"> GAI in 2007 measured 16%. Gravels (< 60 mm) should not be less than 30%.

Metric	EcoSpec	TPCs
		<ul style="list-style-type: none"> GAI in 2007 measured 33%. Sampling protocol: Sediment is to be sampled in the active channel riffle.
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the reach as an alluvial meandering channel type.	This is a typically meandering floodplain – cut banks, advancing point bars and cut-off meanders on the floodplain. An oxbow lake is evident on the eastern flank of the floodplain. This channel pattern and associated dynamics should be maintained. If the extent of cut banks increases so as to indicate extensive incision of the active channel, this would be undesirable for the dynamics of the floodplain.
GAI level IV EC		
GAI level IV PES score.	PES score from the GAI level IV should equal or exceed 85%.	

4.3 PHYSICO-CHEMICAL VARIABLES

TPCs relating to the RHAM water quality indicators are provided in Section 4.3.1 and EcoSpecs and TPCs for the PES and REC in Section 4.3.2 – 4.3.3. Detailed information on the rankings used in this table is available in the RHAM document (DWA, 2009a).

4.3.1 TPCs relating to RHAM water quality indicators

	RHAM indicators					
	Water odour type and extent	Filamentous algae in water column	Water colour and extent	Turbidity/clarity	Water surface indicator and extent	Algal cover on hard surfaces
PES/baseline (RHAM survey)	None	0.5	Green, 0.5	1	Scum, 1	4
TPC	Cattle: ≥ 3 Chemical pollution: ≥ 1 Other sources: ≥ 2 Trigger R-DRAM.	> 3	Green: ≥ 3. All other colours: ≥ 1 Trigger R-DRAM*	≥ 2 Trigger R-DRAM **	All indicators: ≥ 2 Salt deposits: ≥ 1 Trigger R-DRAM	> 4
Activity at site: Run-off from trout farming: Extent = 1						

* R-DRAM:
Orange water: pH metric
Milky water: Salt and organic metrics
Green: Nutrient metric

** R-DRAM:
Turbidity indicators

4.3.2 EcoSpecs relating to physico-chemical data: PES and REC

River: Crocodile	EWR 1	Monitoring site: X2H074Q01
Water quality metrics	ECOSPEC: PES and REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95 th percentile of the data must be ≤ 30 mS/m.
	pH	The 5 th and 95 th percentiles of the data must range from 6.5 to 8.0.
	Temperature	Small deviation from the natural temperature range.
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.

Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.25 mg/L.
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.015 mg/L.
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be <10 μ g/L.
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .
	Toxics	The 95 th percentile of the data must be within the TWQR as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

4.3.3 TPCs relating to physico-chemical data: PES

River: Crocodile		EWR 1	Monitoring site: X2H074Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 13 – 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	
	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 24 – 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must be < 6.7 and > 7.8 .	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.8 – 7.5 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.2 – 0.25 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.012 – 0.015 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 μ g/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 17 – 21 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

4.4 DIATOMS

EcoSpecs and TPCs relating to the RHAM water quality indicators are provided in Section 4.3.1.

4.4.1 Diatom EcoSpecs and TPCs relating to RHAM water quality indicators: PES

Based on the diatom results from the October 2007 survey, EcoSpecs and TPCs for a B EC were derived. Therefore if a live sample count is needed that includes all metrics, the EcoSpecs and TPCs provided below will apply. Detailed information on the rankings used in this table is available in the R-DRAM document (DWA, 2009b).

Physico-chemical metric	EcoSpecs	Class rank*	TPC
pH	6 - 8 Circumneutral	3	≥ 2 ; ≤ 4
Salinity	Fresh brackish (100 - 500 μ S/cm)	2	< 2
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	1	≤ 2
Organics	β -mesosaprobic: BOD ₅ < 4 mg/l, O ₂ deficit $< 30\%$	2	< 2
SPI score	≤ 13.3 - ≥ 16.8	B EC	≥ 13.3

* According to Van Dam *et al.* (1994) in OMNIDIA (Leconte *et al.*, 1993).

RHAM Water Quality			Diatoms (R-DRAM)			
RHAM indicator	Trigger/Water quality indicator	TPC	Considered metric/species	EcoSpec Class ranking	TPC ¹	TPC ²
Water odour type and extent	Chemical	≥1	pH	3	≥2; ≤4	Live sample count: <i>Frustulia</i> and <i>Eunotia</i> spp. count above 75
	Chemical	≥1	Salinity	2	<2	Live sample count for all species included in this metric is <40
	Cattle	≥3	Nutrients	1	≤2	Live sample count for all species included in this metric is <30
	Cattle	≥3	Organics	2	<2	Live sample count for all species included in this metric is <20
	Other sources	≥2	SPI score	B EC	≥ 13.3	≥ 13.3
Water colour	Orange water (Iron-oxidizing bacteria or acid mine drainage)	≥1	pH	3	≥2; ≤4	Live sample count: <i>Frustulia</i> and <i>Eunotia</i> spp. count above 75
	Milky water (Chemical pollution)	≥1	Salinity	2	<2	Live sample count for all species included in this metric is <40
			Organics	2	<2	Live sample count for all species included in this metric is <20
Green (Algae, eutrophication)	≥3	Nutrients	1	≤2	Live sample count for all species included in this metric is <30	
Turbidity/Clarity	Moderately turbid	≥2	<i>Epithemia adnata</i> (EADN)	>30	N/A	Live sample count for EADN is <30
Extent of algal growth on rocks	Algal cover on hard surfaces	≥2	Nutrients	1	≤2	Live sample count for all species included in this metric is <30
Water surface and riparian bank and vegetation clues	Salt deposits on bank	≥1	Salinity	2	≤2	Live sample count for all species included in this metric is <40
	Scum	≥2	Organics	2	<2	Live sample count for all species included in this metric is <20
	Foam	≥2	Nutrients	1	≤2	Live sample count for all species included in this metric is <30

1 Based on total live sample count.

2 Based on live sample counts per metric.

4.5 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the RHAM and VEGRAI data are provided Section 4.5.1. The confidence for is high in general RHAM and VEGRAI data were available.

4.5.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	Note
A	A	Exotic Invasion (perennial exotics).	Marginal zone.	Maintain an absence of perennial exotic species.	An occurrence of perennial exotic species.	The marginal zone was (under baseline conditions) free of exotic species; the presence of which would reduce the EC.
			Non-marginal zone.	Maintain cover (%) of perennial exotic species at 1% or lower.	An increase in perennial exotic species cover > 5%.	Exotic species cover was observed at < 1% in the non-marginal zone. This is the level at which it should be maintained, or reduced, but an increase above 5% is likely to reduce the EC.
		Terrestrialisation.	Riparian zone.	Maintain absence of terrestrial woody species.	An increase in terrestrial woody species cover > 2%.	Grass dominated vegetation type, should not have woody terrestrial species, even beyond the riparian zone.
			Marginal zone.	Maintain cover (%) of terrestrial grasses at 5% or lower.	An increase in terrestrial grass species cover > 10%.	<i>Miscanthus junceus</i> (endemic) not considered terrestrial; terrestrial grasses only expected to occur in the non-marginal zone.

		Indigenous Riparian Woody Cover.	Riparian zone.	Maintain cover (%) of riparian woody species below 5%.	An increase in riparian woody species cover above 10%.	RHAM data show current value at 5%; but an increase beyond 10% would reduce the EC because the site occurs in a grass-dominated system where indigenous riparian woody species are expected to be scattered, with low cover and abundance.
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Riparian zone.	Maintain grass, sedge and dicotyledonous forb cover between 80% and 100%.	A decrease in sedge, grass and dicotyledonous forb cover below 70%.	80 - 90% non-woody in RHAM woody data; 81% average for non-woody data.
		<i>Phragmites</i> (reed) cover.	Riparian zone.	Maintain absence of reed cover.	An increase in reed cover above 5%.	<i>Phragmites</i> sp. do not and should not occur at this site, hence colonization by reeds would change the riparian characteristics of the site and reduce the EC.

4.6 FISH

EcoSpecs and TPCs are provided for RHAM monitoring and FRAI data in Section 4.6.1. The spatial FROC of EWR 1 is provided in Section 4.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

4.6.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES

RANK	Metric	Indicator spp.	PES				REC	
			EWR Site		Reach		REACH	
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
4	Species richness	All species	1 indigenous fish species has been sampled at site EWR 1.	Not applicable due to the fact that only one species is present.	Loss in optimal habitat for BANO (to be quantified by RHAM).	All species.	Any decreased FROC (< 5) in reach of BANO (refer to sheet 5-FROC, Table 2 ¹) OR FRAI scores decreasing below 87% (B EC).	N/A PES = REC
3	Relative abundance	N/A	During recent surveys BANO were sampled at 0.75 individual/s per minute (ind/min).	Relative abundance of less than 0.5 BANO ind/min sampled at the site (during same season as baseline data).		N/A.	N/A.	
2	Alien fish species	Any alien/introduced spp	No alien fish species sampled at site during recent surveys.	Presence of any alien/introduced fish species at site during any survey.	N/A	Any alien/introduced spp.	Presence of any alien/introduced fish species at sites in the reach during any survey.	
1	SD ² habitats	BANO	BANO will be most appropriate indicator of SD, SS, overhanging vegetation and instream vegetation habitats at the site. BANO should under present conditions be present at site 100% of time at relative abundance of > 0.5 ind/min.	BANO absent during any survey or with relative abundance < 0.5 ind/min.	Reduced suitability of SD, SS, overhanging and instream vegetation habitats (to be quantified with RHAM).	BANO	Any decreased FROC in reach of BANO (refer to Table 2 -FROC, column F)	
	SS ³ habitats							
	Overhanging vegetation							
	Instream vegetation							

¹ Refer to electronic data (DWA, 2010).

² Slow Deep

³ Slow Shallow

4.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (A)		REC (A)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
BANO	<i>Barbus anoplus</i> (Weber, 1897)	5	5	4	N/A

4.7 MACROINVERTEBRATES

4.7.1 Baseline description

The baseline data for the biota is based on an EWR site visit in October 2007, at a flow of 0.05 m³/s. The SASS5 total score for the site was 215 with an ASPT of 6.3. The PES and the REC is a B (DWA, 2009b). The reference conditions used to derive the EcoStatus (MIRAI) were based on historical data at three sites in the same EcoRegion and geomorphological zone as the EWR site (Thirion, *pers. comm.*). The reference total SASS5 score for the site is 240 with an ASPT of 7.5. The baseline results are presented in the electronic information that accompanies this Report series (DWA, 2010).

4.7.2 Indicator taxa

Although a variety of flow-dependent taxa were collected at this site there are basically 4 groups of indicator taxa. The habitat preferences for the indicator taxa groups are as follows:

Indicator group	Families	Velocity (m/s)	Substratum	Water Quality
1	Tricorythidae, Philopotamidae	> 0.6	Cobbles	Moderate
2	Prosopistomatidae, Psephenidae	> 0.6	Cobbles	High
3	Heptageniidae	0.3 - 0.6	Cobbles	High
4	Elmidae	0.3 - 0.6	Cobbles	Moderate

Tricorythidae mayflies require velocities of > 0.6 m/s, but may persist at lower velocities (> 0.1 m/s); Heptageniidae mayflies require velocities of 0.3 - 0.6 m/s but will also survive at faster velocities (> 0.6 m/s), they might persist at slower velocities (0.1 - 0.3 m/s). Elmidae beetles also require velocities of 0.3 - 0.6 m/s and may persist at slower (0.1 - 0.3m/s) and faster velocities. All three taxa occur mostly on cobbles but are able to survive on vegetation and bedrock. The Heptageniidae are highly sensitive and the Tricorythidae and Elmidae moderately sensitive to water quality conditions. These taxa are not expected to tolerate wide fluctuations in flow and water quality.

4.7.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

HABITAT ECOSPECS	HABITAT TPCs
To ensure that the maximum depth over the riffle area is greater than 15 cm.	The maximum depth over the riffle area is less than 16 cm.
To ensure that the average depth over the riffle area is greater than 8 cm.	The average depth over the riffle area is less than 9 cm.
To ensure that the maximum velocity over the riffle area is greater than 0.5 m/s.	The maximum velocity over the riffle area is less than 0.53 m/s.
To ensure that the average width of the river in the riffle area is greater than 4.5 m.	The average width of the river in the riffle area is less than 4.6 m.
To ensure that there are at least 8% fast flow over coarse substrate.	There is less than 9% fast flow over coarse substrate.
To ensure that less than 20% of the coarse substrates are embedded.	More than 18% of the coarse substrates are embedded.
To ensure that less than 20% of the coarse substrates are covered with algae.	More than 18% of the coarse substrates are covered with algae.
BIOTA ECOSPECS	BIOTA TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 180; ASPT value: > 6.2.	SASS5 scores below 190 and ASPT below 6.3.
To ensure that the MIRAI score remains within the range of a B category (82% – 88%), using the same reference data used in this study.	A MIRAI score of 83% or less.
To maintain suitable flow velocity(maximum > 0.6 m/s) and clean, unembedded surface area (cobble) to support the following flow-dependent taxa in the VFCS (Very fast flow over coarse sediment) biotope: <ul style="list-style-type: none"> • Philopotamidae (Abundance A) • Tricorythidae (Abundance A) • Prosopistomatidae (Abundance A) • Psephenidae (Abundance A) 	Any one of these taxa missing or present as a single individual in any two consecutive surveys.
To maintain suitable flow velocity (0.3 - 0.6 m/s) and clean, unembedded surface area (cobble) to support the following flow-dependent taxa in the FFCS (Fast flow over coarse sediment) biotope: <ul style="list-style-type: none"> • Heptageniidae (Abundance B) • Elmidae (Abundance B) 	Any one of these taxa missing or present in an A abundance or less for two consecutive surveys.
To maintain suitable water quality, shading, temperature and habitat conditions for the following six key taxa: <ul style="list-style-type: none"> • Psephenidae • Tricorythidae • Philopotamidae • Elmidae • Heptageniidae • Prosopistomatidae 	Presence of less than five of the six key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as D abundance (> 1000).	Any taxon occurring in an abundance of > 500 for two consecutive surveys.
The REC is the same as the PES thus these values also refer to the REC.	

5 RESULTS: ECOSPECS AND TPCs FOR EWR 2: GOEDEHOOP (CROCODILE RIVER)

5.1 ECOCLASSIFICATION SUMMARY OF EWR 2

A summary of the site EcoClassification is provided below (DWA, 2009b).

EWR 2 Goedehoop (Crocodile River)					
<p>EIS: HIGH Rare and endangered fish sp which are sensitive to flow and quality changes. High species diversity.</p> <p>PES: B Impacts as for EWR 1 with increased agricultural activities and decreased flows. However, impacts mostly still non-flow related.</p> <p>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.</p> <p>AEC down: C See EWR 1. Possible zero flow situations and additional impacts on moderate events.</p>		Driver Components	PES & REC Category	Trend	AEC _d
		HYDROLOGY	B		C
		WATER QUALITY	B		C
		GEOMORPHOLOGY	B	Stable	B/C
		Response Components	PES & REC Category	Trend	AEC _d
		FISH	B	Stable	C
		MACRO INVERTEBRATES	B	Negative	C
		INSTREAM	B		C
		RIPARIAN VEGETATION	A/B	Negative	B
		ECOSTATUS	B		C

EcoSpecs and TPCs for the PES and REC are provided for the different components in Section 5.2 to 5.7.

5.2 GEOMORPHOLOGY

The REC is the same as the PES. Some slight changes in sediment supply (increased fines) and channel incision which is the main reasons for the change from reference condition and this is the focus of the EcoSpecs and TPCs. EcoSpecs and TPCs are provided for RHAM monitoring data in Section 5.2.1 and GAI monitoring data in Section 5.2.2.

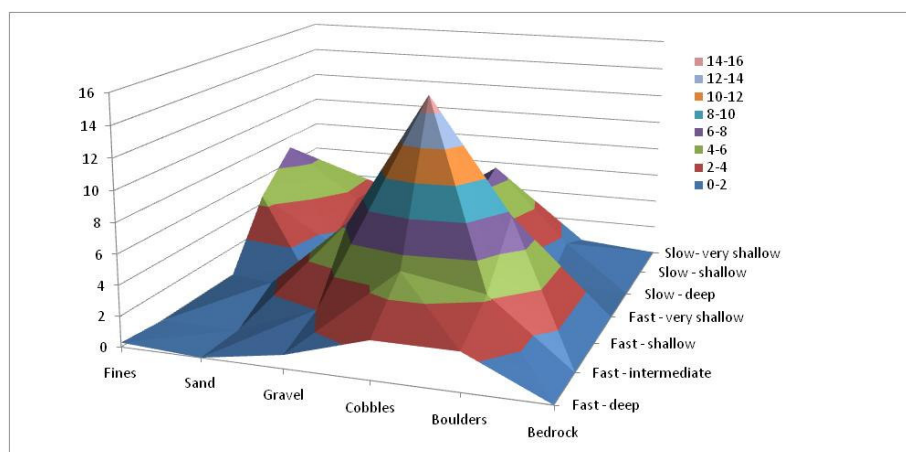
5.2.1 EcoSpecs and TPCs relating to RHAM monitoring data

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Fines should not exceed 20%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 16%. Sand should not exceed 15%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 11%. Cobbles should exceed 30%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 39%. </p> <p>Within all of the fast habitats: Neither sands nor fines should exceed 5%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 3%. Cobbles should exceed 20%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 23%. </p>

Metric	EcoSpec	TPCs																								
The percentage substrate type within the active channel at the RHAM site is provided below.																										
<table border="1"> <caption>Substrate Percentage Data</caption> <thead> <tr> <th>Substrate Type</th> <th>Overall site (%)</th> <th>Fast habitats (%)</th> </tr> </thead> <tbody> <tr> <td>Roots</td> <td>~1</td> <td>0</td> </tr> <tr> <td>Fines</td> <td>~15</td> <td>~1</td> </tr> <tr> <td>Sand</td> <td>~10</td> <td>~2</td> </tr> <tr> <td>Gravel</td> <td>~15</td> <td>~10</td> </tr> <tr> <td>Cobbles</td> <td>~38</td> <td>~22</td> </tr> <tr> <td>Boulders</td> <td>~16</td> <td>~14</td> </tr> <tr> <td>Bedrock</td> <td>0</td> <td>0</td> </tr> </tbody> </table>			Substrate Type	Overall site (%)	Fast habitats (%)	Roots	~1	0	Fines	~15	~1	Sand	~10	~2	Gravel	~15	~10	Cobbles	~38	~22	Boulders	~16	~14	Bedrock	0	0
Substrate Type	Overall site (%)	Fast habitats (%)																								
Roots	~1	0																								
Fines	~15	~1																								
Sand	~10	~2																								
Gravel	~15	~10																								
Cobbles	~38	~22																								
Boulders	~16	~14																								
Bedrock	0	0																								
Proportion of embedded sediments.	Maintain minimum embeddedness to ensure bed mobility and create habitat for instream biota.	<p>Overall for the in-channel sediments: Most of the embedded material should be found in the shallow habitats.</p> <p>And per substrate type: Proportion of GRAVELS that are embedded should be less than 20%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 12%. Proportion of COBBLES that are embedded should be less than 30%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 22%. Proportion of BOULDERS that are embedded should be less than 15%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 9%. </p>																								

IN-CHANNEL HABITAT DIVERSITY

The percentage substrate type within the active channel at the RHAM site is provided below.



ACTIVE CHANNEL GEOMETRY

Active channel width.	Maintain channel width.	For discharges around 0.7 m ³ /s the average width of the active channel should be between 8 and 11 m wide. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 8.9 m.
Lower bank stability.	Extent of undercut banks.	Overall for the site, the proportion of undercut banks should not exceed 50%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 49%.

5.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	At approximate discharge of 0.1 m ³ /s and average width of 5 m, bed sediment within the active channel riffle should be distributed as follows: Fines and sands (< 6 mm diameter) should not exceed 10%. <ul style="list-style-type: none"> GAI in 2007 measured 5%. Gravels (< 60 mm) should not be less than 40%. <ul style="list-style-type: none"> GAI in 2007 measured 58%.

		<p>Cobbles and boulders (> 60 mm) should not be less than 25%.</p> <ul style="list-style-type: none"> GAI in 2007 measured 37%. <p>Sampling protocol: Sediment is to be sampled in the active channel riffle.</p>
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the reach as an alluvial meandering channel type.	<p>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.</p> <p>If the extent of cut banks were to increase further so as to indicate extensive incision of the majority of the active channel, this would be undesirable for the dynamics of the floodplain since overtopping and floodplain inundation would decrease.</p>
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 85%.	

5.3 PHYSICO-CHEMICAL VARIABLES

TPCs relating to the RHAM water quality indicators are provided in Section 5.3.1 and EcoSpecs and TPCs for the PES and REC in Section 5.3.2 – 5.3.3.

5.3.1 TPCs relating to RHAM water quality indicators

	RHAM indicators					
	Water odour type and extent	Filamentous algae in water column	Water colour and extent	Turbidity/clarity	Water surface indicator and extent	Algal cover on hard surfaces
PES/baseline (RHAM survey)	None	2	None	None	None	3
TPC	Cattle: ≥ 3 Chemical pollution: ≥ 1 Other sources: ≥ 2 Trigger R-DRAM	>3	Green: ≥ 3 All other colours: ≥ 1 Trigger R-DRAM*	≥ 2 Trigger R-DRAM**	All indicators: ≥ 2 Salt deposits: ≥ 1 Trigger R-DRAM	> 4
Activity at site: Return flows from agriculture and trout farming: Extent = 2.						

* R-DRAM:

Orange water: pH metric

Milky water: Salt and organic metrics

Green: Nutrient metric

** R-DRAM:

Turbidity indicators

5.3.2 EcoSpecs relating to physico-chemical data: PES and REC

River: Crocodile		EWR Site 2	Monitoring site: X2H074Q01
Water quality metrics		ECOSPEC: PES and REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 27 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 22 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 39 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 118 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 43 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must range from 6.5 to 8.0.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	

Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.25 mg/L.
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.015 mg/L.
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 μ g/L.
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .
	Toxics	The 95 th percentile of the data must be within the TWQR as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

5.3.3 TPCs relating to physico-chemical data: PES

River: Crocodile		EWR 2	Monitoring site: X2H074Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 22 – 27 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 18 – 22 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 32 – 39 mg/L.	
	NaCl	The 95 th percentile of the data must be 95 – 118 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 35 – 43 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must be < 6.7 and > 7.8 .	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.8 – 7.5 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.2 – 0.25 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.012 – 0.015 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 μ g/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 17 – 21 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

NOTE:

- Data for EWR 1 and 2 is low confidence due to poor data records. The same data record was used for both sites.
- Although ecological specifications are provided per site for EWR 1 and EWR 2, the resolution is low and it is likely that the same set of objectives can be used for both sites. This is reinforced due to the poor data quality used to represent the sites. Monitoring would therefore be essential to improve the database and assess whether conditions are different between the two sites. Due to the good water quality suggested by the small amount of available data, biotic responses at the site are probably driven by other drivers (which may result in a concomitant change in physico-chemistry).

5.4 DIATOMS

EcoSpecs and TPCs relating to the RHAM water quality indicators are the same as for EWR 1 (Section 4.4.1).

5.5 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the RHAM and VEGRAI data are provided Section 5.5.1. The confidence is high since RHAM and VEGRAI data were available.

5.5.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	Note
A/B	A/B	Exotic Invasion (perennial exotics).	Marginal zone.	Maintain an absence of perennial exotic species.	An occurrence of perennial exotic species.	The marginal zone was (under baseline conditions) free of perennial exotic species; the presence of which would reduce the EC.
			Non-marginal zone.	Maintain cover (%) of perennial exotic species at 1% or lower.	An increase in perennial exotic species cover > 5%.	Exotic species cover was observed at < 1% (RHAM data) in the non-marginal zone. This is the level at which it should be maintained, or reduced, but an increase above 5% is likely to reduce the EC.
		Terrestrialisation.	Riparian zone.	Maintain absence of terrestrial woody species.	An increase in terrestrial woody species cover > 2%.	Grass dominated vegetation type, should not have woody terrestrial species.
			Marginal zone.	Maintain cover (%) of terrestrial grasses at 5% or lower.	An increase in terrestrial grass species cover > 10%.	Miscanthus junceus not considered terrestrial; terrestrial grasses only expected to occur in the non-marginal zone.
		Indigenous Riparian Woody Cover.	Riparian zone.	Maintain cover (%) of riparian woody species below 5%.	An increase in riparian woody species covers above 15% (15% based on VEGRAI max).	RHAM data show current value at 2.5%; but an increase beyond 10% would reduce the EC because the site occurs in a grass-dominated system where indigenous riparian woody species are expected to be scattered, with low cover and abundance.
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Riparian zone.	Maintain grass, sedge and dicotyledonous forb cover between 80% and 100%.	A decrease in sedge, grass and dicotyledonous forb cover below 70%.	85 - 95% non-woody in RHAM woody data; 93% average for non-woody data. Trampling of the marginal zone was a major impact at this site: should trampling reduce value below 70% then EC would reduce.
<i>Phragmites</i> (reed) cover.	Riparian zone.	Maintain reed cover at 2% or lower.	An increase in reed cover above 5%.	On average, <i>Phragmites</i> sp. comprised 1% of vegetation in the riparian zone (RHAM data), which is keeping with the grassland characteristics of this site, hence expansion of reeds would change the riparian characteristics of the site and reduce the EC.		

5.6 FISH

EcoSpecs and TPCs are provided for RHAM monitoring and FRAI data in Section 5.6.1. The spatial FROC of EWR 2 is provided in Section 5.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

5.6.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES

RANK	Metric	Indicator spp.	PES					REC
			EWR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
6	Species richness.	All species.	5 indigenous fish species have been sampled during the baseline survey (PES determination).	Less than 5 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All species.	Any decreased FROC in reach of indicator species (refer to sheet 5-FROC, column F: Table 2 ¹) OR FRAI scores decreasing below 77% (B/C EC).	N/A PES = REC
5	Relative abundance.	N/A.	During recent surveys (baseline/PES) fish were sampled at 2.2 ind/min electrofishing.	Relative abundance of less than 1.5 ind/min electrofishing at the site (during same season as baseline data).		N/A.		
4	Alien fish species.	Any alien/introduced spp.	No alien fish species sampled at site during baseline surveys.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien / introduced spp.	OMYK potentially present in reach under baseline condition. Presence of more than 1 alien/introduced fish species in reach during any survey (or increased spatial FROC or abundance of OMYK).	
1	FD ² Habitats.	CPRE, ANAT	During baseline survey CPRE was present at site at relative abundance of 1.4 ind/min electrofishing, while ANAT was present at 0.2 ind/min.	CPRE and ANAT present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of CPRE below 1 ind/min electrofishing, and < 0.1 ind/min for ANAT.	Reduced suitability (abundance & quality) of FD & FS habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).	AURA	CPRE		Any decreased FROC in reach of AURA & CPRE (refer to sheet 5-FROC, column F: Table 2).
	FS ³ habitats.					CPRE	AURA	
	Flow dependant spp (flow alteration).					AURA	CPRE	
	Water quality intolerance.					AURA	CPRE	
2	Substrate.	CPRE, BNEE	During baseline survey CPRE was present at site at relative abundance of 1.4 ind/min electrofishing, while BNEE was present at 0.24 ind/min.	CPRE & BNEE present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of CPRE below 1 ind/min electrofishing, and < 0.1 ind/min for BNEE.	Reduced suitability (abundance & quality) of substrates (i.e. excessive algal growth on substrates, sedimentation) (to be quantified with RHAM).	AURA	BARG	Any decreased FROC in reach of AURA & BARG (refer to sheet 5-FROC, column F table 2)
3	SD habitats.	BNEE	During baseline survey BNEE was present at 0.24 ind/min.	BNEE present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.1 ind/min for BNEE.	Reduced suitability (abundance & quality) of substrates (i.e. excessive algal growth on substrates, sedimentation) (to be quantified with RHAM).	BANO	BNEE	Any decreased FROC in reach of BANO & BNEE (refer to Table 2 -FROC, column F).
	SS habitats.					BNEE	BANO	
7	Overhanging vegetation.	PPHI & BNEE	During baseline survey PPHI was present at site at relative abundance of 0.29 ind/min electrofishing, while BNEE was present at 0.24 ind/min.	PPHI and BNEE present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of PPHI below	Reduced suitability (abundance & quality) of overhanging vegetation habitats (to be quantified with RHAM).	KAUR	PPHI	Any decreased FROC in reach of KAUR & PPHI (refer to Table 2 -FROC, column F: Table 2).

RANK	Metric	Indicator spp.	PES					REC	
			EWR SITE			REACH		REACH	
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
	Undercut banks.	PPHI & BNEE		0.15 ind/min electrofishing, and < 0.1 ind/min for BNEE.	Significant change in undercut bank habitats (to be quantified with RHAM).	BNEE	PPHI	Any decreased FROC in reach of BNEE & PPHI (refer to sheet 5-FROC, column F: Table 2).	
8	Instream vegetation.	None available at site.				BANO		Any decreased FROC in reach of BANO & TSPA (refer to sheet 5-FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010).

2 Fast Deep

3 Fast Shallow

5.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ANAT	<i>Amphilius natalensis</i> (Boulenger, 1917)	4	4	3	Same as PES
AURA	<i>Amphilius uranoscopus</i> (Pfeffer, 1889)	5	3	2	
BANO	<i>Barbus anoplus</i> (Weber, 1897)	5	4	3	
BARG	<i>Barbus argenteus</i> (Günther, 1868)	5	3	2	
BNEE	<i>Barbus neefi</i> (Greenwood, 1962)	5	5	4	
CBIF	<i>Chiloglanis bifurcus</i> (Jubb & Le Roux, 1969)	3	1	0	
CPRE	<i>Chiloglanis pretoriae</i> (Van der Horst, 1931)	5	5	4	
KAUR	<i>Kneria auriculata</i> (Pellegrin, 1905)	5	3	2	
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	5	5	4	
TSPA	<i>Tilapia sparrmanii</i> (Smith, 1840)	4	4	3	

5.7 MACROINVERTEBRATES

5.7.1 Baseline description

The baseline data for the biota is based on an EWR site visit in October 2007, at a flow of 0.1 m³/s. The original SASS5 total score for the site was 228 with an ASPT of 6.4. The REC is the same as the PES (B EC) (DWA, 2009b). The reference conditions used to derive the EcoStatus (MIRAI) were based on historical data at the EWR site (Thirion, *pers. comm.*). The reference total SASS5 score for the site is 260 with an ASPT of 7. The baseline results are presented in the electronic information that accompanies this report series (DWA, 2010).

5.7.2 Indicator taxa

See EWR 1, section 4.7.2.

5.7.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

HABITAT ECOSPECS	HABITAT TPCs
To ensure that the maximum depth over the riffle area is greater than 20 cm.	The maximum depth over the riffle area is less than 21 cm.
To ensure that the average depth over the riffle area is greater than 10 cm.	The average depth over the riffle area is less than 11 cm.
To ensure that the maximum velocity over the riffle area is greater than 0.7m/s.	The maximum velocity over the riffle area is less than 0.6 m/s.
To ensure that the average width of the river in the riffle area is greater than 11 m.	The average width of the river in the riffle are is less than 11.5 m.
To ensure that there are at least 10% fast flow over coarse substrate.	There is less than 11% fast flow over coarse substrate.
To ensure that less than 20% of the coarse substrates are embedded.	More than 18% of the coarse substrates are embedded.
To ensure that less than 20% of the coarse substrates are covered with algae.	More than 18% of the coarse substrates are covered with algae.

BIOTA ECOSPECS	BIOTA TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 180; ASPT value: > 6.2.	SASS5 scores below 190 and ASPT below 6.3.
To ensure that the MIRAI score remains within the range of a B category (82% – 88%), using the same reference data used in this study.	A MIRAI score of 83% or less.
To maintain suitable flow velocity(maximum > 0.6m/s) and clean, unembedded surface area (cobble) to support the following flow-dependent taxa in the VFCS biotope: <ul style="list-style-type: none"> • Perlidae (Abundance B) • Tricorythidae (Abundance B) • Prosopistomatidae (Abundance A) 	Any one of these taxa missing or present in an A abundance or less in any two consecutive surveys.
To maintain suitable flow velocity (0.3 - 0.6 m/s) and clean, unembedded surface area (cobble) to support the following flow-dependent taxa in the FFCS: <ul style="list-style-type: none"> • Heptageniidae (Abundance B) • Elmidae (Abundance B) 	Any one of these taxa missing or present in an A abundance or less for two consecutive surveys.
To maintain suitable water quality, shading, temperature and habitat conditions for the following five key taxa: <ul style="list-style-type: none"> • Perlidae • Tricorythidae • Elmidae • Heptageniidae • Prosopistomatidae 	Presence of less than four of the five key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as D abundance (> 1000) over more than two consecutive surveys.	Any taxon occurring in an abundance of > 500 for two consecutive surveys.
The REC is the same as the PES thus these values also refer to the REC.	

6 RESULTS: ECOSPECS AND TPCs FOR EWR 3: POPLAR CREEK (CROCODILE RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

6.1 ECOCLASSIFICATION SUMMARY OF EWR 3

EWR 3 Poplar Creek (Crocodile River)					
<p>EIS: HIGH Rare and endangered fish, vegetation and bird species, some of which are sensitive to flow and quality changes.</p> <p>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.</p> <p>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.</p> <p>AEC down: C/D Lower flows than natural in both the dry and wet season leading to an impact of the seasonal distribution of the low flows. Associated increase in temperature and oxygen.</p>	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

EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 6.2 to 6.7.

6.2 GEOMORPHOLOGY

The REC is the same as the PES. Scouring of the bed and banks due to elevated flows and clean water releases from Kwena Dam which is the main reasons for the change from reference condition and this is the focus of the EcoSpecs and TPCs. EcoSpecs and TPCs are provided for RHAM monitoring data in Section 6.2.1 and GAI monitoring data in Section 6.2.2.

6.2.1 EcoSpecs and TPCs relating to RHAM monitoring data

Metric	EcoSpec	TPCs																								
ACTIVE CHANNEL SUBSTRATE CHANGES																										
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Sand should NOT BE LESS THAN 5%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 8%. Cobbles should NOT BE LESS THAN 5%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 8%. </p>																								
The percentage substrate type within the active channel at the RHAM site is provided below.																										
<table border="1"> <caption>Substrate Type Distribution Data</caption> <thead> <tr> <th>Substrate Type</th> <th>Overall site (%)</th> <th>Fast habitats (%)</th> </tr> </thead> <tbody> <tr> <td>Roots</td> <td>~2</td> <td>~1</td> </tr> <tr> <td>Fines</td> <td>~3</td> <td>~1</td> </tr> <tr> <td>Sand</td> <td>~8</td> <td>~2</td> </tr> <tr> <td>Gravel</td> <td>~3</td> <td>~1</td> </tr> <tr> <td>Cobbles</td> <td>~8</td> <td>~5</td> </tr> <tr> <td>Boulders</td> <td>~30</td> <td>~20</td> </tr> <tr> <td>Bedrock</td> <td>~45</td> <td>~35</td> </tr> </tbody> </table>			Substrate Type	Overall site (%)	Fast habitats (%)	Roots	~2	~1	Fines	~3	~1	Sand	~8	~2	Gravel	~3	~1	Cobbles	~8	~5	Boulders	~30	~20	Bedrock	~45	~35
Substrate Type	Overall site (%)	Fast habitats (%)																								
Roots	~2	~1																								
Fines	~3	~1																								
Sand	~8	~2																								
Gravel	~3	~1																								
Cobbles	~8	~5																								
Boulders	~30	~20																								
Bedrock	~45	~35																								

Metric	EcoSpec	TPCs
IN-CHANNEL HABITAT DIVERSITY		
The percentage mobile sediment per macroinvertebrate velocity class is given below.		
ACTIVE CHANNEL GEOMETRY		
Active channel width.	Maintain channel width.	For discharges around 1.1 m ³ /s the average width of the active channel should be between 18 and 24 m wide. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 21.5 m.

6.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	At approximate discharge of 1.1 m ³ /s and average width of 21 m, bed sediment within the active channel riffle should be distributed as follows: <ul style="list-style-type: none"> Fines and sands (< 6 mm diameter) should not be less than 5%. <ul style="list-style-type: none"> GAI in 2007 measured 8%. Gravels (6 – 60 mm) should not be less than 30%. <ul style="list-style-type: none"> GAI in 2003 measured 35%. Cobbles and boulders (> 60 mm) should not be less than 50%. <ul style="list-style-type: none"> GAI in 2007 measured 57%. <p>Sampling protocol: Sediment is to be sampled in the active channel riffle.</p>
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the reach as an alluvial meandering channel type.	Cut banks on both banks (and 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 the large Kwena Dam upstream. <p>Further incision and narrowing of the channel will reduce habitat diversity and reduce overtopping and the condition of the riparian vegetation.</p>
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 64%.	

6.3 PHYSICO-CHEMICAL VARIABLES

TPCs relating to the RHAM water quality indicators are provided in Section 4.3.1 and EcoSpecs and TPCs for the PES and REC in Section 6.3.2 – 6.3.4.

6.3.1 TPCs relating to RHAM water quality indicators

	RHAM indicators					
	Water odour type and extent	Filamentous algae in water column	Water colour and extent	Turbidity/clarity	Water surface indicator and extent	Algal cover on hard surfaces
PES/baseline (RHAM survey)	None	1	Green, 0.5	1	None	5 ¹
TPC	Cattle: ≥ 3 Chemical pollution: ≥ 1 Other sources: ≥ 2 Trigger R-DRAM	> 3	Green: ≥ 3 All other colours: ≥ 1 Trigger R-DRAM*	≥ 2 Trigger R-DRAM**	All indicators: ≥ 2 Salt deposits: ≥ 1 Trigger R-DRAM	> 4
Activity at site: Footpaths and movement of people and animals; riparian vegetation removal: Extent = 2						

* R-DRAM:

Orange water: pH metric

Milky water: Salt and organic metrics

Green: Nutrient metric

1 The TPC was exceeded during the RHAM monitoring survey.

** R-DRAM:

Turbidity indicators

6.3.2 EcoSpecs relating to physico-chemical data: PES

River: Crocodile		EWR 3	Monitoring site: X2H013Q01
Water quality metrics		ECOSPEC: PES	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must range from 6.5 to 8.0.	
	Temperature	Small to moderate deviation from the natural temperature range. Some highly temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 6 mg/L.	
	Turbidity	Moderate changes to the catchment land-use resulting in <u>temporary</u> unnaturally high sediment loads and high turbidities.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.25 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.025 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 52.5 mg/m ² .**	
	Toxics	The 95 th percentile of the data must be within the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** Periphyton (29.81 mg/m²) is actually in a C/D category (C = 12 - 21 and D = 21 - 84 mg/m², DWAF, 2008b), so have defined the upper boundary of a C/D as the EcoSpec for PES.

6.3.3 EcoSpecs relating to physico-chemical data: REC

River: Crocodile		EWR 3	Monitoring site: X2H013Q01
Water quality metrics		ECOSPEC: REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	

Physical variables	EC	The 95 th percentile of the data must be ≤ 30 mS/m.
	pH	The 5 th and 95 th percentiles of the data must range from 6.5 to 8.0.
	Temperature	Small deviation from the natural temperature range, with lower abundances and frequencies of some highly temperature sensitive species.
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 6.5 mg/L
	Turbidity	Moderate changes to the catchment land-use resulting in <u>temporary</u> unnaturally high sediment loads and high turbidities.
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.25 mg/L.
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.025 mg/L.
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 μ g/L.
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 52.5 mg/m ² .**
	Toxics	The 95 th percentile of the data must be within the TWQR as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** Periphyton (29.81 mg/m²) is actually in a C/D category (C = 12 - 21 and D = 21 - 84 mg/m², DWAF, 2008b), so have defined the upper boundary of a C/D as the EcoSpec for PES.

6.3.4 TPCs relating to physico-chemical data: PES

River: Crocodile		EWR 3	Monitoring site: X2H013Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 13 – 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	
	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 24 – 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must be < 6.7 and > 7.8 .	
	Temperature	Vary by more than 2°C, i.e. a large change to the temperature regime occurs often. Most moderately temperature sensitive species would be in lower abundances and frequency of occurrence than expected for reference. Biological assessments therefore recommended and initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 6.2 – 6 mg/L. Biological assessments recommended and initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.2 – 0.25 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.012 – 0.015 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 μ g/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 42 – 52 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

6.4 DIATOMS

EcoSpecs and TPCs relating to the RHAM water quality indicators are provided in Section 6.3.1.

6.4.1 Diatom EcoSpecs and TPCs relating to RHAM water quality indicators

Based on the diatom results, EcoSpecs and TPCs for a C EC were derived. Therefore if a live sample count is needed that includes all metrics, the EcoSpecs and TPCs provided below will apply.

Physico-chemical metric	EcoSpecs	Class rank*	TPC
pH	6 - 8 Circumneutral	3	≥2; ≤4
Salinity	Fresh brackish (100 - 500 µS/cm)	2	<2
Nutrients	Elevated concentrations of organically bound nitrogen.	2	≤3
Organics	β-α-mesosaprobic: BOD <7 (10), O2 deficit <50%	3	<3
SPI score	≤8.9 - ≥13	C EC	≥ 8.8

* According to Van Dam *et al.* (1994) in OMNIDIA (Lecointe *et al.*, 1993).

RHAM Water Quality			Diatoms (R-DRAM)			
RHAM indicator	Trigger/Water quality indicator	TPC	Considered metric/species	EcoSpec Class ranking	TPC ¹	TPC ²
Water odour type and extent	Chemical	≥1	pH	3	≥2; ≤4	Live sample count: <i>Frustulia</i> and <i>Eunotia</i> spp. count above 80.
	Chemical	≥1	Salinity	2	<2	Live sample count for all species included in this metric is between 50 – 100.
	Cattle	≥3	Nutrients	2	≤3	Live sample count for all species included in this metric is between 40 – 80.
	Cattle	≥3	Organics	3	<3	Live sample count for all species included in this metric is between 30 – 90.
	Other sources	≥2	SPI score	C EC	≥ 8.8	≥ 8.8
Water colour	Orange water (Iron-oxidizing bacteria or acid mine drainage)	≥1	pH	3	≥2; ≤4	Live sample count: <i>Frustulia</i> and <i>Eunotia</i> spp. count above 80.
	Milky water (Chemical pollution)	≥1	Salinity	2	<2	Live sample count for all species included in this metric is between 50 – 100.
			Organics	3	<3	Live sample count for all species included in this metric is between 30 – 90.
Green (Algae, eutrophication)	≥3	Nutrients	2	≤3	Live sample count for all species included in this metric is between 40 – 80.	
Turbidity/Clarity	Moderately turbid	≥2	<i>Epithemia adnata</i> (EADN)	>50	N/A	Live sample count for EADN is <30.
Extent of algal growth on rocks	Algal cover on hard surfaces	≥2	Nutrients	2	≤3	Live sample count for all species included in this metric is between 40 – 80.
Water surface and riparian bank and vegetation clues	Salt deposits on bank	≥1	Salinity	2	≤2	Live sample count for all species included in this metric is between 50 – 100.
	Scum	≥2	Organics	3	<3	Live sample count for all species included in this metric is between 30 – 90.
	Foam	≥2	Nutrients	2	≤3	Live sample count for all species included in this metric is between 40 – 80.

¹ Based on total live sample count ² Based on live sample counts per metric

6.5 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the RHAM and VEGRAI data are provided Section 6.5.1. Confidence was high since RHAM and VEGRAI data were available.

6.5.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	Note
C	B	Exotic Invasion (perennial exotics).	Marginal zone.	Maintain cover (%) of perennial exotic species at 5% or lower.	An increase in perennial exotic species cover > 10%.	Exotic perennial species cover was low in marginal zone (< 10% in VEGRAI data and ave 7.5% in RHAM data). Since the marginal

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	Note
						zone has less exotic species than the remainder of the riparian zone and is also directly more important for aquatic habitat, the aim is to keep exotic cover low.
			Lower & Upper zones.	Maintain cover (%) of perennial exotic species at 15% or lower.	An increase in perennial exotic species cover > 20%.	Higher cover on lower and upper zones should be kept in check at observed average (VEGRAI and RHAM), but expansion above 20% likely to reduce EC to C/D.
		Terrestrialisation.	Lower & Upper zones.	Maintain cover (%) of terrestrial woody species at 25% or lower.	An increase in terrestrial woody species cover > 40%.	RHAM data show average cover of 28%. An increase above 40% is likely to reduce EC by a category due to the reduction of indigenous riparian species.
		Indigenous Riparian Woody Cover.	Lower & Upper zones.	Maintain cover (%) of riparian woody species between 20 and 70% within the riparian zone.	A decrease in riparian woody species cover below 20% OR an increase above 70%.	RHAM data show average of 48%, VEGRAI data show average of 40% for PES. Woody vegetation removal for firewood is an impact at this site and a decrease in riparian woody cover below 20% would reduce the EC by a category. Similarly an increase above 70% cover may indicate loss of flooding disturbance, which would also reduce the EC.
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Riparian zone.	Maintain grass, sedge and dicotyledonous forb cover between 30% and 90%.	A decrease in sedge, grass and dicotyledonous forb cover below 30% OR above 90%.	RHAM average: 31%; VEGRAI range 20 - 60%. Linked mostly to woody cover (indigenous and exotic) by way of shading i.e. too much shading reduces cover and none allows for a situation where 100% cover is possible. This site occurs where a mix of woody and non-woody is always expected.
		<i>Phragmites</i> (reed) cover.	Marginal Zone.	Maintain reed cover below 10%.	An increase in reed cover above 10% on the marginal zone.	Reeds did not occur in RHAM data and cover was low < 10% in VEGRAI. An increase in reeds would trap sediment and change instream habitat types

6.6 FISH

EcoSpecs and TPCs are provided for RHAM monitoring and FRAI data in Section 6.6.1. The spatial FROC of EWR 3 is provided in Section 6.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

6.6.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES					REC	
			EWR SITE			REACH		REACH	
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS	
4	Species richness.	All indigenous species.	Six naturally occurring indigenous fish species have been sampled during the baseline (EWR-PES) survey.	Less than 4 naturally occurring indigenous fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All indigenous species, esp. CPRE, AURA.	Baseline FRAI score of 84.7% calculated for reach. Any decreased FROC in reach of especially AURA, CPRE (refer to sheet 5-FROC: Table 2 ¹) OR FRAI scores decreasing below 80% (B/C EC).	N/A PES = REC	
2	Relative abundance.	N/A.	During baseline (EWR/PES) surveys fish were sampled at 1.3 ind/min electrofishing.	Relative abundance of less than 0.9 ind/min sampled at the site (during same season as baseline data).		N/A			
5	Alien fish species.	Any alien/introduced spp.	No alien fish species sampled at site during recent surveys, but one introduced species CGAR present at relative abundance of 0.03 ind/min electrofishing.	Presence of any alien/introduced fish species at site during any survey or increased abundance (> 0.06 ind/min) of CGAR.	N/A.	Any alien/introduced spp.	Presence of any alien/introduced fish species at site during any survey or increased FROC and abundance of CGAR.		
1	FD Habitats.	CPRE, AURA	During baseline survey CPRE was present at site at relative abundance of 0.63 ind/min electrofishing, while AURA was present at 0.6 ind/min.	CPRE & AURA present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.3 ind/min for CPRE or AURA.	Reduced suitability (abundance & quality) of FD & FS habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on (to be quantified with RHAM). Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	AURA	CPRE		Any decreased FROC in reach of AURA & CPRE (refer to sheet 5-FROC, column F: Table 2).
	FS habitats.					CPRE	AURA		
	Flow dependant spp (flow alteration).					AURA	CPRE		
	Water quality intolerance.					AURA	CPRE		
1	Substrate.	AURA, BARG & CPRE	During baseline survey CPRE was present at site at relative abundance of 0.63 ind/min electrofishing, while AURA was present at 0.6 ind/min. BARG were only sampled with cast net.	CPRE & AURA present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.3 ind/min for CPRE or AURA. Absence of BARG during 2 consecutive surveys.	Reduced suitability (abundance & quality) of substrates, increased sedimentation, and excessive algal growth on (to be quantified with RHAM).	AURA	BARG		Any decreased FROC in reach of AURA & BARG (refer to sheet 5-FROC, column F: Table 2).
7	SD habitats.	AMOS	AMOS the only indicator species for SD habitats. The sampling of this species is however generally coincidental and it will therefore not be a useful indicator species.			AMOS			Any decreased FROC in reach of AMOS (refer to sheet 5-FROC, column F: Table 2) (AMOS generally coincidentally sampled,

Flank	Metric	Indicator spp.	PES					REC	
			EWR SITE			REACH		REACH	
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS	
								therefore not good indicator species).	
3	SS habitats.	PPHI	PPHI is the best indicators of SS, overhanging and undercut banks and was be present at site during the baseline (EWR-PES) survey at a relative abundance > 0.05 ind/min.	PPHI absent more than 50% of time (absent during 2 consecutive surveys) or present with relative abundance < 0.03 ind/min.	Significant change in SS, overhanging vegetation and undercut bank habitats (to be quantified with RHAM).	PPHI	TSPA	Any decreased FROC in reach of PPHI & TSPA (refer to sheet 5-FROC, column F: Table 2).	
	Overhanging vegetation.	PPHI				PPHI	TSPA		
	Undercut banks.	PPHI				PPHI				Any decreased FROC in reach of PPHI (refer to sheet 5-FROC, column F: Table 2).
6	Instream vegetation.	TSPA	TSPA the only indicator species for instream vegetation in this reach. This species was however not sampled during the baseline (EWR PES) surveys, and therefore EcoSpecs and TPCs cannot be derived at present.			TSPA		Any decreased FROC in reach of TSPA (refer to sheet 5-FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010).

6.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	4	3	2	Same as PES
AURA	<i>Amphilius uranoscopus</i> (Pfeffer, 1889)	5	5	4	
BARG	<i>Barbus argenteus</i> (Günther, 1868)	5	4	3	
CBIF	<i>Chiloglanis bifurcus</i> (Jubb & Le Roux, 1969)	3	3	2	
CPRE	<i>Chiloglanis pretoriae</i> (Van der Horst, 1931)	5	5	4	
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	3	3	2	
TSPA	<i>Tilapia sparrmanii</i> (Smith, 1840)	3	1	0	

6.7 MACROINVERTEBRATES

6.7.1 Baseline description

The baseline data for the biota is based on an EWR site visit in October 2007, at a flow of 2.7 m³/s. The original SASS5 total score for the site was 204 with an ASPT of 6.8. The REC is a B category (DWA, 2009b). The reference conditions used to derive the EcoStatus (MIRAI) were based on historical data at two sites in the same EcoRegion and geomorphological zone (Thirion, *pers. comm.*). The reference total SASS5 score for the site is 240 with an ASPT of 7.5. The baseline results are presented in the electronic information that accompanies this report series (DWA, 2010).

6.7.2 Indicator taxa

See EWR 1, Section 4.7.2.

6.7.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

HABITAT ECOSPECS	HABITAT TPCs
To ensure that the maximum depth over the riffle area is greater than 50 cm.	The maximum depth over the riffle area is less than 53 cm.
To ensure that the average depth over the riffle area is greater than 25 cm.	The average depth over the riffle area is less than 27 cm.
To ensure that the maximum velocity over the riffle area is greater than 0.7m/s.	The maximum velocity over the riffle area is less than 0.6 m/s.
To ensure that the average width of the river in the riffle area is greater than 23 m.	The average width of the river in the riffle are is less than 24 m.
To ensure that there are at least 15% fast flow over coarse substrate.	There is less than 16% fast flow over coarse substrate.
To ensure that less than 15% of the coarse substrates are embedded.	More than 13% of the coarse substrates are embedded.
To ensure that less than 25% of the coarse substrates are covered with algae.	More than 23% of the coarse substrates are covered with algae.
BIOTA ECOSPECS	BIOTA TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 150; ASPT value: > 6.4.	SASS5 scores below 160 and ASPT below 6.5.
To ensure that the MIRAI score remains within the range of a C category (62% – 78%), using the same reference data used in this	A MIRAI score of 64% or less.

study.	
To maintain suitable flow velocity(maximum > 0.6 m/s) and clean, unembedded surface area (cobble) to support the following flow-dependent taxa in the VFCS: <ul style="list-style-type: none"> • Perlidae (Abundance A) • Tricorythidae (Abundance B) • Psephenidae (Abundance B) 	Any one of these taxa missing or present as a single individual in any two consecutive surveys. Tricorythidae and/or Psephenidae present in an A abundance in any two consecutive surveys.
To maintain suitable flow velocity (0.3 - 0.6 m/s) and clean, unembedded surface area (cobble) to support the following flow-dependent taxa in the FFCS biotope: <ul style="list-style-type: none"> • Heptageniidae (Abundance B) • Elmidae (Abundance B) 	Any one of these taxa missing or present in an A abundance or less for two consecutive surveys.
To maintain suitable water quality, shading, temperature and habitat conditions for the following five key taxa: <ul style="list-style-type: none"> • Perlidae • Tricorythidae • Elmidae • Heptageniidae • Psephenidae 	Presence of less than four of the five key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as D abundance (> 1000) over more than two consecutive surveys.	Any taxon occurring in an abundance of > 500 for two consecutive surveys.

7 RESULTS: ECOSPECS AND TPCs FOR EWR 4: KANYAMAZANE (CROCODILE RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

7.1 ECOCLASSIFICATION SUMMARY OF EWR 4

EWR 4 KaNyamazane (Crocodile River)					
<p>EIS: HIGH Rare and endangered sp sensitive to flow and quality changes. High species taxon richness and diversity of habitat types.</p> <p>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. Abstraction, return flows, landuse mismanagement, water quality issues, and sedimentation.</p> <p>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.</p> <p>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.</p>	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

EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 7.2 to 7.6.

7.2 GEOMORPHOLOGY

The REC is higher than the PES. Reduced flows and increased sediment inputs have combined to reduce the ecological condition. The REC aims to reverse some of these negative changes, and EcoSpecs and TPCs have been set to achieve this. There was no available baseline RHAM data for this site, so EcoSpecs and TPCs tied to this format of data could not be generated. EcoSpecs and TPCs are provided for GAI monitoring data in Section 7.2.1.

7.2.1 EcoSpecs and TPCs relating to GAI monitoring data: REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Fines and Sands (< 6 mm diameter) should not exceed 10%. <ul style="list-style-type: none"> GAI level IV in 2007 measured 7%. Gravels (6 – 60 mm diameter) should not be less than 10%. <ul style="list-style-type: none"> GAI level IV in 2007 measured 13%. Cobbles (< 60 mm) should not be less than 60%. <ul style="list-style-type: none"> GAI level IV in 2007 measured 80%. </p> <p>Sampling protocol: Sediment is to be sampled in the active channel riffle.</p>
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	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 at the site, but increased erosion in the catchment has increased the fines load. Filling in of pools by sediment would represent

Metric	EcoSpec	TPCs
		an undesirable trend. Monitoring could take place through occasional (5 - 10 year) resurveyed cross-sections at the EWR site.
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should exceed 81%.	

7.3 PHYSICO-CHEMICAL VARIABLES

There was no available baseline RHAM data for this site. EcoSpecs and TPCs relating for the PES and REC are provided in Section 7.3.1 – 7.3.3.

7.3.1 EcoSpecs relating to physico-chemical data: PES

River: Crocodile		EWR 4	Monitoring site: X2H032Q01
Water quality metrics		ECOSPEC: PES	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 38 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 191 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 55 mS/m	
	pH	The 5 th percentile of the data must be 5.9 – 6.5, and the 95 th percentile 8.0 – 8.8.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 1.0 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.125 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .**	
	Toxics	The 95 th percentile of the data must be within the CEV as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** No periphyton data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

7.3.2 EcoSpecs relating to physico-chemical data: REC

River: Crocodile		EWR: 4	Monitoring site: X2H032Q01
Water quality metrics		ECOSPEC: REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 38 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 191 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 55 mS/m.	
	pH	The 5 th percentile of the data must be 5.9 – 6.5, and the 95 th percentile 8.0 – 8.8.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	

Nutrients	TIN	The 50 th percentile of the data must be ≤ 1.0 mg/L.
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.050 mg/L.**
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 $\mu\text{g/L}$.
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/ m ² .***
	Toxics	The 95 th percentile of the data must be within the TWQR as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** EcoSpec for the REC generated to improve conditions. Boundaries for the relevant category are 0.025 – 0.125 mg/L, but the upper boundary was considered too high to ensure improvement.

*** No periphyton data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

7.3.3 TPCs relating to physico-chemical data: PES

River: Crocodile		EWR 4	Monitoring site: X2H032Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 30 – 38 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	
	NaCl	The 95 th percentile of the data must be 45 – 191 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 44 – 55 mS/m.	
	pH	The 5 th percentile of the data must be < 6.1 and > 6.3 , and the 95 th percentile must be ≤ 8.2 and ≥ 8.6 .	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.8 – 7.5 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.8 – 1.0 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.1 – 0.125 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 $\mu\text{g/L}$.	
	Chl-a periphyton	The 50 th percentile of the data must be 17 – 21 mg/m ² . Initiate baseline monitoring for this variable depending on biotic responses.	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the Chronic Effects Value (CEV) as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

7.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 7.4.1. Confidence medium since only VEGRAI data were available.

7.4.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	Note
C	B	Exotic Invasion (perennial exotics).	Non-marginal zone.	Maintain cover (%) of perennial exotic species at 20% or lower.	An increase in perennial exotic species cover $> 30\%$.	VEGRAI data average of 20 - 40% on all zones. Exotic invasion is a major impact on the PES at this site.
		Terrestrialisation.	Lower zone.	Maintain cover (%) of terrestrial woody species at 10% or lower within the riparian zone.	An increase in terrestrial woody species cover $> 10\%$.	More than 10% cover by woody terrestrial species likely to reduce EC to a lower category.
			Upper zone.	Maintain cover (%) of terrestrial woody species at 30% or lower within the riparian zone.	An increase in terrestrial woody species cover $> 30\%$.	More than 30% cover by woody terrestrial species likely to reduce EC to a lower category.

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	Note
		Indigenous Riparian Woody Cover.	Lower zone.	Maintain cover (%) of riparian woody species between 5 and 60%.	A decrease in riparian woody species cover below 5% OR above 60%.	VEGRAI data average of 10 - 20%, this is within the lower range due to high exotic species cover. .
			Upper zone.	Maintain cover (%) of riparian woody species between 20 and 70%.	A decrease in riparian woody species cover below 20% OR above 70%.	VEGRAI data average of 20 - 40%. This is within the lower range due to high exotic species cover.
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Upper zone.	Maintain grass, sedge and dicotyledonous forb cover above 30%.	A decrease in sedge, grass and dicotyledonous forb cover below 30%.	VEGRAI data average 20 - 40% cover. Used upper zone only so that VEGRAI data would be applicable (non-woody data predominantly non-reed).
		<i>Phragmites</i> (reed) cover.	Marginal zone.	Maintain reed cover between 10% and 20%.	An increase in reed cover above 80% or a decrease below 40%.	VEGRAI data average 40 - 60% cover. Used marginal and lower zones only so that VEGRAI data would be applicable (non-woody data predominantly reed). EcoSpec set for EC of C, hence low, but TPC set to maintain current state or improve. The EC would then be better than PES in terms of reeds only, but should reeds decrease to the EcoSpec level, degradation would be compounding due to currently high cover of exotics which would likely colonise space should reeds decline.
			Lower zone.	Maintain reed cover between 10% and 20% OR between 80% and 90%.	An increase in reed cover above 70% or a decrease below 40%.	As above.

7.5 FISH

EcoSpecs and TPCs are provided for the FRAI data in Section 7.5.1. The spatial FROC of EWR 4 is provided in Section 7.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

7.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES					REC	
			EWR SITE			REACH		REACH	
			ECOSPECS*	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS	
7	Species richness.	All indigenous species.	Eight of the 20 expected indigenous fish species were sampled during the baseline (EWR) survey. Sampling conditions were not optimal due to high flows and crocodiles, and it can be expected that more species are present at the site.	Less than 10 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All indigenous species.	Any decreased FROC in reach of especially CPRE, OPER, BMAR, LCYL (refer to Table 2 ¹ -FROC) <u>OR</u> FRAI scores decreasing below 77% (B/C EC).	N/A REC = PES	
5	Relative abundance.	N/A.	During the baseline (EWR-PES) surveys fish were sampled at 0.9 ind/min (should be higher during optimal sampling conditions).	Relative abundance of less than 1 ind/min sampled at the site (during optimal sampling conditions).	N/A.	N/A.			
6	Alien fish species.	Any alien/introduced spp.	No alien fish species sampled at site during recent surveys.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien/introduced spp.	XHEL sampled in reach previously. Presence of any other alien/introduced fish species at any site during any survey or evident increase in FROC or abundance of XHEL.		
2	FD habitats.	CPRE, BMAR	During the baseline survey CPRE was present at site at relative abundance of 0.13 ind/min electrofishing, while BMAR was present at 0.32 ind/min.	CPRE and BMAR absent from site during any survey <u>AND/OR</u> present at relative abundance < 0.1 ind/min for CPRE and < 0.2 ind/min for BMAR.	Reduced suitability (abundance & quality) of FD & FS habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).	CPRE	BMAR		Any decreased FROC in reach of CPRE & BMAR (refer to table 2 -FROC, column F).
	FS habitats.	CPRE, BMAR & LCYL if present at site).				CPRE	LCYL		
2	Substrate.	CPRE & LMOL (LCYL if present).	During the baseline survey CPRE was present at site at relative abundance of 0.13 ind/min electrofishing, while LMOL was present at 0.05 ind/min electrofishing.	CPRE and LMOL absent from site during any survey <u>AND/OR</u> present at relative abundance < 0.1 ind/min for CPRE and < 0.03 ind/min for LMOL.		CPRE	LCYL		Any decreased FROC in reach of CPRE & LCYL (refer to table 2 -FROC, column F).
1	Flow dependant spp (flow alteration).	OPER, CPRE	OPER & CPRE will be most appropriate indicators of flow at the site. Both species were present during baseline (EWR-PES) survey) with OPER at relative abundance of 0.26 ind/min and CPRE at 0.13 ind/min.	OPER <u>and</u> CPRE absent during any survey or with relative abundance < 0.15 ind/min for OPER and < 0.1 ind/min for CPRE.		OPER	CPRE		Any decreased FROC in reach of OPER & CPRE (refer to table 2 -FROC, column F).
	Water quality intolerance.					CPRE	OPER		

Rank	Metric	Indicator spp.	PES					REC
			EWR SITE			REACH		REACH
			ECOSPECS*	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
4	SD habitats.	BMAR, LMOL	BMAR & LMOL will be most appropriate indicators of SD habitats at the site. Both species should under baseline conditions be present at site 100% of time, with BMAR sampled during baseline survey at relative abundance of 0.32 ind/min, while LMOL were present 0.05 ind/min.	BMAR & LMOL absent during any survey or with relative abundance < 0.2 ind/min for BMAR and < 0.03 ind/min for LMOL.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).	BMAR	BUNI	Any decreased FROC in reach of BMAR & BUNI (refer to table 2 -FROC, column F).
3	Water column.	OPER, BMAR	OPER & BMAR are the best indicators of water column habitats and were present during the baseline survey at relative abundance of 0.26 ind/min for OPER and 0.32 ind/min for BMAR.	OPER &/or BMAR absent during any survey or present at relative abundance < 0.15 ind/min for OPER and < 0.2 ind/min for BMAR.	Reduction in suitability of water column (i.e. increased sedimentation of pools).	OPER	BMAR	Any decreased FROC in reach of OPER & BMAR & MACU (refer to table 2 - FROC, column F).
8	SS habitats.	PPHI, BMAR	PPHI & BMAR will be most appropriate indicators of SS habitats at the site. Both species were present during the baseline survey at relative abundance of 0.08 ind/min for PPHI and 0.32 ind/min for BMAR.	PPHI & BMAR absent during any survey or PPHI present at relative abundance < 0.04 ind/min and BMAR at < 0.2 ind/min.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).	BVIV	BUNI	Any decreased FROC in reach of BVIV & BUNI (refer to table 2 -FROC, column F).
9	Overhanging vegetation.	PPHI, BPAU	PPHI & BPAU are the best indicators of overhanging vegetation habitats and was present at site during the baseline survey. PPHI was sampled at abundance of 0.08 ind/min, while BPAU occurred at 0.03 ind/min.	PPHI &/or BPAU absent during any survey or PPHI present with relative abundance < 0.04 ind/min and BPAU < 0.01 ind/min.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BVIV	BUNI	
11	Undercut banks.	PPHI	PPHI is the best indicators of undercut banks, it was present during baseline surveys at a relative abundance of 0.08 ind/min.	PPHI absent during any survey or present with relative abundance < 0.04 ind/min.	Significant change in undercut bank habitats (to be quantified with RHAM).	MMAC	BEUT	Any decreased FROC in reach of MMAC & BEUT (refer to table 2 -FROC, column F).
10	Instream vegetation.	BPAU	Species with high indicator value for instream vegetation is BPAU. BPAU should be present 100%, sampled during baseline surveys at 0.03 ind/min.	BPAU absent during any survey or with relative abundance < 0.01 ind/min.	Significant change in instream vegetation habitats (to be quantified with RHAM).	BVIV	TREN	Any decreased FROC in reach of BVIV & TREN (refer to table 2 -FROC, column F).

* Relative abundance in individuals per minute sampled using electrofishing unless stated for other sampling method.

1 Refer to electronic data (DWA, 2010).

7.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	3	2	1	Same as PES
AURA	<i>Amphilius uranoscopus</i> (Pfeffer, 1889)	2	1	0	
BEUT	<i>Barbus eutaenia</i> (Boulenger, 1904)	4	3	2	
BMAR	<i>Labeobarbus marequensis</i> (Smith, 1841)	5	5	4	
BPAU	<i>Barbus paludinosus</i> (Peters, 1852)	3	3	2	
BTRI	<i>Barbus trimaculatus</i> (Peters, 1852)	4	3	2	
BUNI	<i>Barbus unitaeniatus</i> (Günther, 1866)	4	3	2	
BVIV	<i>Barbus viviparus</i> (Weber, 1897)	4	3	2	
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	4	4	3	
CPRE	<i>Chiloglanis pretoriae</i> (Van der Horst, 1931)	5	5	4	
LCYL	<i>Labeo cylindricus</i> (Peters, 1852)	5	5	4	
LMOL	<i>Labeo molybdinus</i> (Du Plessis, 1963)	5	5	4	
MACU	<i>Micralestes acutidens</i> (Peters, 1852)	3	3	2	
MMAC	<i>Marcusenius macrolepidotus</i> (Peters, 1852)	4	3	2	
OMOS	<i>Oreochromis mossambicus</i> (Peters, 1852)	4	4	3	
OPER	<i>Opsaridium peringueyi</i> (Gilchrist & Thompson, 1913)	5	4	3	
PCAT	<i>Petrocephalus wesselsi</i> (Kramer & Van der Bank, 2000)	3	2	1	
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	4	4	3	
TREN	<i>Tilapia rendalli</i> (Boulenger, 1896)	3	3	2	
TSPA	<i>Tilapia sparrmanii</i> (Smith, 1840)	3	3	2	

7.6 MACROINVERTEBRATES

7.6.1 Baseline description

The baseline data for the biota is based on an EWR site visit during October 2007, at a flow of 10.14 m³/s. The PES for this site is a high C (75.9%) and the REC is a B (82 - 88%). The original SASS5 total score for the site was 153 with an ASPT of 5.9. The REC is a B category (DWA, 2009b). The reference conditions used to derive the EcoStatus (MIRAI) were based on historical data at two sites in the same EcoRegion and geomorphological zone (Thirion, *pers. comm.*). The reference total SASS5 score for the site is 270 with an ASPT of 7. The baseline results are presented in the electronic information that accompanies this report series (DWA, 2010).

7.6.2 Indicator taxa

Although a variety of flow-dependent taxa were collected at this site there are basically 3 groups of indicator taxa. The habitat preferences for the indicator taxa groups are as follows:

Indicator group	Families	Velocity (m/s)	Substratum	Water Quality
1	Perlidae	> 0.6	Cobbles	High
2	Heptageniidae	0.3 - 0.6	Cobbles	High
3	Elmidae	0.3 - 0.6	Cobbles	Moderate

Perlidae mayflies require velocities of > 0.6 m/s, but may persist at lower velocities (> 0.1 m/s). Heptageniidae mayflies and Elmidae beetles require velocities of 0.3 - 0.6 m/s but will also survive at faster velocities (> 0.6 m/s), they might persist at slower velocities (0.1 - 0.3 m/s). All three taxa occur mostly on cobbles. Tricorythidae and Heptageniidae are able to survive on vegetation and bedrock. The Heptageniidae are highly sensitive and the Tricorythidae moderately sensitive to water quality conditions. These taxa are not expected to tolerate wide fluctuations in flow and water quality conditions. Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population.

7.6.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

HABITAT ECOSPECS	HABITAT TPCs
To ensure that the maximum depth over the riffle area is greater than 25 cm.	The maximum depth over the riffle area is less than 27 cm.
To ensure that the average depth over the riffle area is greater than 15 cm.	The average depth over the riffle area is less than 17 cm.
To ensure that the maximum velocity over the riffle area is greater than 0.7 m/s.	The maximum velocity over the riffle area is less than 0.6 m/s.
To ensure that the average width of the river in the riffle area is greater than 14.5 m.	The average width of the river in the riffle area is less than 15 m.
To ensure that there are at least 14% fast flow over coarse substrate.	There is less than 15% fast flow over coarse substrate.
To ensure that less than 15% of the coarse substrates are embedded.	More than 13% of the coarse substrates are embedded.
To ensure that less than 25% of the coarse substrates are covered with algae.	More than 23% of the coarse substrates are covered with algae.
BIOTA ECOSPECS	BIOTA TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 155; ASPT value: > 5.8.	SASS5 scores below 160 and ASPT below 5.9.
To ensure that the MIRAI score remains within the range of a C category (62% – 78%), using the same reference data used in this study.	A MIRAI score of 64% or less.
To maintain suitable flow velocity (maximum > 0.6m/s) and clean, unembedded surface area (cobbles) to support the Perlidae (A abundance) in the VFCS biotope:	Perlidae missing or present as a single individual in any two consecutive surveys.
To maintain suitable flow velocity (0.3 - 0.6 m/s) and clean, unembedded surface area (cobbles) to support the following flow-dependent taxa in the FFCS biotope: <ul style="list-style-type: none"> • Heptageniidae (Abundance A) • Elmidae (Abundance A) 	Any one of these taxa missing or present as a single individual for two consecutive surveys.
To maintain suitable water quality, shading, temperature and habitat conditions for the following five key taxa: <ul style="list-style-type: none"> • Perlidae • > 2 spp of Hydropsychidae • Elmidae • Heptageniidae • Coenagrionidae 	Presence of less than four of the five key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as D abundance (> 1000) over more than two consecutive surveys.	Any taxon occurring in an abundance of > 500 for two consecutive surveys.

8 RESULTS: ECOSPECS AND TPCs FOR EWR 5: MALELANE (CROCODILE RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

8.1 ECOCLASSIFICATION SUMMARY OF EWR 5

EWR 5 Malelane (Crocodile River)																																																			
<p>EIS: VERY HIGH Rare and endangered sp sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on LB.</p> <p>PES: C Change in low flows, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.</p> <p>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.</p> <p>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, and loss of deeper channel sections, increased reed and vegetation growth.</p>	<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC_↓</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>C</td> <td></td> <td>B</td> <td>D</td> </tr> <tr> <td>WATER QUALITY</td> <td>C</td> <td></td> <td>B</td> <td>D</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>C/D</td> <td>Negative</td> <td>C</td> <td>D</td> </tr> <tr> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC_↓</th> </tr> <tr> <td>FISH</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td>INSTREAM</td> <td>C</td> <td></td> <td>B</td> <td>D</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>C</td> <td>Negative</td> <td>B</td> <td>D</td> </tr> <tr> <td>ECOSTATUS</td> <td>C</td> <td></td> <td>B</td> <td>D</td> </tr> </tbody> </table>	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
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																																															

EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 8.2 to 8.7.

8.2 GEOMORPHOLOGY

The REC is higher than the PES. Flow stabilisation and significant flow reductions have caused the channel to narrow, and the REC aims to reverse some of these negative changes. There was no available baseline RHAM data for this site, so EcoSpecs and TPCs tied to this format of data could not be generated. EcoSpecs and TPCs are provided for GAI monitoring data in Section 8.2.1.

8.2.1 EcoSpecs and TPCs relating to GAI monitoring data: REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Fines and Sands (< 6 mm diameter) should not exceed 85%.</p> <ul style="list-style-type: none"> GAI level IV in 2007 measured 78%. Gravels (6 – 60 mm) should not be less than 10%. GAI level IV in 2007 measured 15%. <p>Sampling protocol: Sediment is to be sampled across the active channel.</p>
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	Increased erosion in the catchment has increased the fines load and could lead to filling in of pools and loss of bedrock influence. This would represent an undesirable trend. Monitoring could take place through occasional (5 - 10 year) resurveyed cross-sections at the EWR site.
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should exceed 60%.	

8.3 PHYSICO-CHEMICAL VARIABLES

There was no available baseline RHAM data for this site. EcoSpecs and TPCs relating for the PES and REC are provided in Section 8.3.1 – 8.3.3.

8.3.1 Physico-chemical data: EcoSpecs: PES

River: Crocodile		EWR 5	Monitoring site: X2H017Q01
Water quality metrics		ECOSPEC: PES	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 45 mg/L.**	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 70 mS/m.***	
	pH	The 5 th percentile of the data must be 5.9 – 6.5, and the 95 th percentile 8.0 – 8.8.	
	Temperature	Moderate deviation from the natural temperature range. Most highly temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.125 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .****	
	Toxics	The 95 th percentile of the data must be within the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** MgSO₄ concentration was 52 mg/L, i.e. an F category. The minimum category accepted would be a D category of 37 – 45 mg/L.

*** EcoSpec for the PES generated. Although the PES value was 57.75 mS/m, boundaries for the relevant category are 55.1 – ≤ 85 mg/L. As the upper boundary was considered too high to maintain the present state for salts, a lower boundary was used.

**** No periphyton or phytoplankton data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

8.3.2 Physico-chemical data: EcoSpecs: REC

River: Crocodile		EWR 5	Monitoring site: X2H017Q01
Water quality metrics		ECOSPEC: REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 45 mg/L.**	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 55 mS/m.	
	pH	The 5 th percentile of the data must be 5.9 – 6.5, and the 95 th percentile 8.0 – 8.8.	
	Temperature	Small deviation from the natural temperature range, with lower abundances and frequencies of some highly temperature sensitive species.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.025 mg/L.	

Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be <10 µg/L.
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/ m ² .***
	Toxics	The 95 th percentile of the data must be within the TWQR as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** MgSO₄ concentration was 52 mg/L, i.e. an F category. The minimum category accepted would be a D category of 37 – 45 mg/L.

*** No periphyton or phytoplankton data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

8.3.3 TPCs relating to physico-chemical data: PES

River: Crocodile		EWR 5	Monitoring site: X2H017Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 40 – 45 mg/L.**	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	
	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 70 – 85 mS/m.	
	pH	The 5 th percentile of the data must be < 6.1 and > 6.3, and the 95 th percentile must be < 8.2 and > 8.6.	
	Temperature	Vary by more than 2°C, i.e. a large change to the temperature regime occurs often. Most moderately temperature sensitive species would be in lower abundances and frequency of occurrence than expected for reference. Biological assessments therefore recommended and initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.2 – 7 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.55 – 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.02 – 0.025 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 17 – 21 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** Although the PES for MgSO₄ is an F category, the TPC is linked to a D category as the minimum requirement for this variable.

8.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 8.4.1. Confidence medium since only VEGRAI data were available.

8.4.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	Note
C	B	Exotic Invasion (perennial exotics).	Lower & Upper zones.	Maintain cover (%) of perennial exotic species at 10% or lower.	An increase in perennial exotic species cover > 15%.	VEGRAI data average of 20 - 40% in the marginal zone, but comprised of annuals. Exotic invasion low in lower and upper zones (< 10%).
		Terrestrialisation.	Lower zone.	Maintain cover (%) of terrestrial woody species at 10% or lower within the riparian zone.	An increase in terrestrial woody species cover > 10%.	More than 10% cover by woody terrestrial species likely to reduce EC to a lower category
			Upper zone.	Maintain cover (%) of terrestrial woody species at 30% or lower within the riparian zone.	An increase in terrestrial woody species cover > 30%.	More than 30% cover by woody terrestrial species likely to reduce EC to a lower category.

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	Note
		Indigenous Riparian Woody Cover.	Lower zone.	Maintain cover (%) of riparian woody species between 5 and 60%.	A decrease in riparian woody species covers below 5% OR above 60%.	VEGRAI data average of < 10%, this is within the lower range due to high exotic species cover.
			Upper zone.	Maintain cover (%) of riparian woody species between 20 and 70%.	A decrease in riparian woody species covers below 20% OR above 70%.	VEGRAI data average of 10 - 20%. This is within the lower range due to high exotic species cover.
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Marginal zone.	Maintain grass, sedge and dicotyledonous forb cover above 40% (in summer).	A decrease in sedge, grass and dicotyledonous forb cover below 30%.	VEGRAI data average 40 - 60% cover.
		<i>Phragmites</i> (reed) cover.	Marginal zone.	Maintain reed cover above 10%.	A decrease in reed cover below 10%.	VEGRAI data average < 10%.
			Lower zone.	Maintain reed cover between 10% and 90%.	An increase in reed cover above 90% or a decrease below 10%.	VEGRAI data show value around 20%.
			Upper zone.	Maintain reed cover below 50%.	An increase in reed cover above 50%.	VEGRAI data show value around 30%.

8.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 8.5.1. The spatial FROC of EWR 5 is provided in Section 8.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

8.5.1 EcoSpecs and TPCs relating to FRAI data: PES

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	
11	Species richness.	All indigenous species.	During the baseline survey CPRE was not sampled, but it is expected to be present at site. OPER was present during baseline EWR survey at relative abundance of 0 ind/min electrofishing.	Less than 10 fish species sampled using electrofishing during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All indigenous species.		Baseline (PES) FRAI score of 66.1 calculated for reach. Any decreased FROC in reach of especially CPAR, CPRE, BMAR, OPER, MMAC & PCAT (refer to table 2 ¹ -FROC) <u>OR</u> FRAI scores decreasing below 63% (low C).
4	Relative abundance.	N/A.		Relative abundance of less than 1.5 ind/min sampled at the site (during optimal sampling conditions).	N/A.	N/A.		
12	Alien fish species.	Any alien/introduced spp.	One alien fish species (CCAR) sampled at site during baseline (EWR) survey at relative abundance of 0.02 ind/min electrofishing.	Presence of more than 1 (CCAR) alien/introduced fish species at site during any survey, <u>AND/OR</u> an increase in relative abundance of CCAR becoming > 0.02 ind/min electrofishing.	N/A.	Any alien/introduced spp.		Presence of more than 1 (CCAR) alien/introduced fish species in reach during any survey, or increase in abundance and FROC of CCAR.
3	FD habitats.	CPAR & BMAR	During the baseline survey CPAR was not sampled, but it is expected to be present at site. BMAR was present during baseline EWR survey at relative abundance of 0.93 ind/min electrofishing.	CPAR present less than 50% of time (not sampled for more than 2 consecutive surveys) and BMAR absent during any survey <u>AND/OR</u> decrease in relative abundance below 0.5 ind/min for BMAR.	Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows), (to be quantified with RHAM).	CPAR	BMAR	Any decreased FROC in reach of CPAR & BMAR (refer to table 2 - FROC, column F).
2	FS habitats.	CPAR & LCYL	During the baseline survey CPAR & LCYL were not sampled, but it is expected to be present at site.	CPAR & LCYL present less than 50% of time (not sampled for more than 2 consecutive surveys).	Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows), Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).	CPAR	LCYL	Any decreased FROC in reach of CPAR & LCYL (refer to table 2 - FROC, column F).
	CPAR					LCYL		
1	Flow dependant spp (flow alteration).	OPER, CPRE	During the baseline survey CPRE was not sampled, but it is expected to be present at site. OPER was present during baseline EWR survey at relative abundance of 0.03 ind/min electrofishing.	CPRE & OPER present less than 33% of time (not sampled for more than 3 consecutive surveys) <u>AND/OR</u> OPER present at relative abundance below 0.02 ind/min.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	OPER	CPRE	Any decreased FROC in reach of OPER & CPRE (refer to table 2- FROC, column F).
	Water quality intolerance.					OPER	CPRE	

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)
9	SD habitats.	OMOS, BMAR	OMOS & BMAR will be most appropriate indicators of SD habitats at the site. Both species were sampled during baseline survey, OMOS being present at 0.28 ind/min electrofishing, and BMAR at 0.93 ind/min electrofishing.	OMOS & BMAR absent during any survey <u>AND/OR</u> OMOS present at relative abundance < 0.15 ind/min and < 0.5 ind/min for BMAR.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).	OMOS	BMAR	Any decreased FROC in reach of OMOS & BMAR (refer to table 2 - FROC, column F).
6	Water column.	BMAR, MBRE	During the baseline survey MBRE was not sampled, but it is expected to be present at site. BMAR was present during baseline EWR survey at relative abundance of 0.93 ind/min electrofishing.	MBRE present less than 50% of time (not sampled for more than 2 consecutive surveys) and BMAR absent during any survey <u>AND/OR</u> decrease in relative abundance below 0.5 ind/min for BMAR.	Reduction in suitability of water column (i.e. increased sedimentation of pools).	BMAR	MBRE	Any decreased FROC in reach of BMAR & MBRE (refer to table 2 - FROC, column F).
7	SS habitats.	BVIV, BRAD	During the baseline survey BRAD was not sampled, but it is expected to be present at site. BVIV was present during baseline EWR survey at relative abundance of 0.4 ind/min electrofishing.	BRAD present less than 50% of time (not sampled for more than 2 consecutive surveys) and BVIV absent during any survey <u>AND/OR</u> decrease in relative abundance below 0.3 ind/min for BVIV.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).	BVIV	BRAD	Any decreased FROC in reach of BVIV & BRAD (refer to table 2 - FROC, column F).
8	Overhanging vegetation.	BVIV, BTRI	During the baseline survey BTRI was not sampled, but it is expected to be present at site. BVIV was present during baseline EWR survey at relative abundance of 0.4 ind/min electrofishing.	BTRI present less than 75% of time and BVIV absent during any survey <u>AND/OR</u> decrease in relative abundance below 0.3 ind/min for BVIV.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BVIV	BTRI	Any decreased FROC in reach of BVIV & BTRI (refer to table 2 - FROC, column F).
5	Undercut banks.	MMAC & PCAT	During the baseline survey MMAC & PCAT were not sampled, but it is expected to be present (at low abundance) at site.	MMAC & PCAT present less than 33% of time (not sampled for more than 3 consecutive surveys).	Significant change in undercut bank habitats (to be quantified with RHAM).	MMAC	PCAT	Any decreased FROC in reach of MMAC & PCAT (refer to table 2 - FROC, column F).
10	Instream vegetation.	TREN & BVIV	During the baseline survey TREN was not sampled, but it is expected to be present at site. BVIV was present during baseline EWR survey at relative abundance of 0.4 ind/min electrofishing.	TREN & BVIV absent during any survey <u>AND/OR</u> decrease in relative abundance below 0.3 ind/min for BVIV.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	TREN	BVIV	Any decreased FROC in reach of BVIV & TREN (refer to table 2 - FROC, column F).

1 Refer to electronic data (DWA, 2010).

8.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMAR	<i>Anguilla marmorata</i> (Quoy & Gaimard 1824)	1	1	0	1
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	1	1	0	1
BANN	<i>Barbus annectens</i> (Gilchrist & Thompson, 1917)	3	1	0	1
BEUT	<i>Barbus eutaenia</i> (Boulenger, 1904)	3	2	1	2
BFRI	<i>Barbus afrohamiltoni</i> (Crass, 1960)	1	1	0	1
BIMB*	<i>Brycinus imberi</i> (Peters, 1852)	4	3	2	3
BMAR	<i>Labeobarbus marequensis</i> (Smith, 1841)	5	5	4	5
BPAU	<i>Barbus paludinosus</i> (Peters, 1852)	3	2	1	3
BRAD	<i>Barbus radiatus</i> (Peters, 1853)	4	3	2	4
BTOP	<i>Barbus toppini</i> (Boulenger, 1916)	3	2	1	2
BTRI	<i>Barbus trimaculatus</i> (Peters, 1852)	5	4	3	5
BUNI	<i>Barbus unitaeniatus</i> (Günther, 1866)	4	4	3	4
BVIV	<i>Barbus viviparus</i> (Weber, 1897)	5	5	4	5
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	5	5	4	5
CPAR	<i>Chiloglanis paratus</i> (Crass, 1960)	5	3	2	4
CPRE	<i>Chiloglanis pretoriae</i> (Van der Horst, 1931)	4	2	1	3
CSWI	<i>Chiloglanis swierstrai</i> (Van der Horst, 1931)	3	2	1	2
GGIU	<i>Glossogobius giuris</i> (Hamilton-Buchanan, 1822)	3	2	1	2
HVIT	<i>Hydrocynus vittatus</i> (Castelnau, 1861)	2	2	1	2
LCON	<i>Labeo congoro</i> (Peters, 1852)	4	2	1	3
LCYL	<i>Labeo cylindricus</i> (Peters, 1852)	5	3	2	4
LMOL	<i>Labeo molybdinus</i> (Du Plessis, 1963)	5	4	3	5
LROS	<i>Labeo rosae</i> (Steindachner, 1894) (<i>Labeo alteviliis</i>)	3	2	1	2
LRUD	<i>Labeo ruddi</i> (Boulenger, 1907)	1	1	0	1
MACU	<i>Micralestes acutidens</i> (Peters, 1852)	4	3	2	3
MBRE	<i>Mesobola brevianalis</i> (Boulenger, 1908)	4	3	2	3
MMAC	<i>Marcusenius macrolepidotus</i> (Peters, 1852)	3	2	1	2
OMOS	<i>Oreochromis mossambicus</i> (Peters, 1852)	5	5	4	5
OPER	<i>Opsaridium peringueyi</i> (Gilchrist & Thompson, 1913)	4	2	1	3
PCAT	<i>Petrocephalus wesselsi</i> (Kramer & Van der Bank, 2000)	3	1	0	1
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	3	3	2	3
SINT	<i>Schilbe intermedius</i> (Rüppell, 1832)	3	2	1	2
SZAM	<i>Synodontis zambezensis</i> (Peters, 1852)	2	1	0	1
TREN	<i>Tilapia rendalli</i> (Boulenger, 1896)	4	4	3	4
TSPA	<i>Tilapia sparrmanii</i> (Smith, 1840)	1	1	0	1

* EWR sampling was done during relative high flow, so optimal sampling could not be performed. Based on a previous survey in the reach the species that could be sampled under optimal sampling conditions are indicated in yellow.

8.6 MACROINVERTEBRATES

8.6.1 Baseline description

The baseline data for the biota is based on an EWR site visit in October 2007, at a flow of 7 m³/s. The original SASS5 total score for the site was 131 with an ASPT of 5.1. The REC is a B category (DWA, 2009b). The reference conditions used to derive the EcoStatus (MIRAI) were based on historical data at sites in the same EcoRegion and Geomorphological zone (Thirion, *pers. comm.*). The reference total SASS5 score for the site is 180 with an ASPT of 6. The baseline results are presented in the electronic information that accompanies this Report series (DWA, 2010).

8.6.2 Indicator taxa

The habitat at this site is rather poor for flow-dependent taxa, the vegetation provides better habitat. There are basically 4 groups of indicator taxa. The habitat preferences for the indicator taxa groups are as follows:

Indicator group	Families	Velocity (m/s)	Substratum	Water Quality
1	Libellulidae	0.3 - 0.6	Cobbles	Low
2	Elmidae	0.3 - 0.6	Cobbles	Moderate
3	Atyidae	N/A.	Vegetation	Moderate
4	Coenagrionidae	0.3 - 0.6	Vegetation	Low

The flow dependent cobble dwelling macroinvertebrate taxa used for this site (Elmidae and Libellulidae) both prefer velocities between 0.3 and 0.6 m/s although they can also survive at other velocity categories and live on other substrates. Elmidae are moderately sensitive to water quality whereas the Libellulidae have a low sensitivity to water quality. Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.36 m/s (macroinvertebrate stress of 5) will ensure that this takes place. The vegetation dwelling macroinvertebrate taxa used for this site (Coenagrionidae and Atyidae) are both able to also survive on other substrata such as Cobbles. Atyidae are moderately sensitive to water quality changes while Coenagrionidae have a low sensitivity to water quality changes. Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can overwinter without significant detrimental impacts on the overall population. At a macroinvertebrate stress of 7 only 1% fringing vegetation is inundated but enough aquatic vegetation will be available to provide adequate habitat for the selected taxa.

8.6.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

HABITAT ECOSPECS	HABITAT TPCs
To ensure that the maximum depth over the riffle area is greater than 15 cm.	The maximum depth over the riffle area is less than 16 cm.
To ensure that the average depth over the riffle area is greater than 10 cm.	The average depth over the riffle area is less than 11 cm.
To ensure that the maximum velocity over the riffle area is greater than 0.8 m/s.	The maximum velocity over the riffle area is less than 0.6 m/s.
To ensure that the average width of the river is greater than 35 m.	The average width of the river in the riffle area is less than 36 m.
To ensure that there are at least 14% fast flow over coarse substrate.	There is less than 15% fast flow over coarse substrate.
To ensure that less than 15% of the coarse substrates are embedded.	More than 13% of the coarse substrates are embedded.
To ensure that less than 25% of the coarse substrates are covered with	More than 23% of the coarse substrates are covered with

HABITAT ECOSPECS	HABITAT TPCs
algae.	algae.
To ensure that at least 1% of the marginal area contains inundated vegetation.	Less than 2% of the marginal area contains inundated vegetation.
BIOTA ECOSPECS	BIOTA TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 110; ASPT value: > 5.	SASS5 scores below 120 and ASPT below 5.1.
To ensure that the MIRAI score remains within the range of a C category (62% – 78%), using the same reference data used in this study.	A MIRAI score of 64% or less.
To maintain suitable flow velocity (0.3 - 0.6 m/s) and clean, unembedded surface area (cobble) to support the following flow-dependent taxa in the FFCS biotope: <ul style="list-style-type: none"> • Libellulidae (Abundance A) • Elmidae (Abundance A) 	Any one of these taxa missing in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation dwelling taxa: <ul style="list-style-type: none"> • Atyidae • Coenagrionidae 	Any one of these taxa missing in two consecutive surveys.
To maintain suitable water quality, shading, temperature and habitat conditions for the following five key taxa: <ul style="list-style-type: none"> • Tricorythidae • Elmidae • Libellulidae • Atyidae • Coenagrionidae 	Presence of less than four of the five key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as D abundance (> 1000) over more than two consecutive surveys.	Any taxon occurring in an abundance of > 500 for two consecutive surveys.

9 RESULTS: ECOSPECS AND TPCs FOR EWR 6: NKONGOMA (CROCODILE RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

9.1 ECOCLASSIFICATION SUMMARY OF EWR 6

EWR 6 Nkongoma (Crocodile River)																																																						
<p>EIS: VERY HIGH Rare and endangered sp sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on LB.</p> <p>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.</p> <p>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.</p> <p>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, and loss of deeper channel sections, increased reed and vegetation growth.</p>	<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC↓</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>D</td> <td></td> <td>B</td> <td>D</td> </tr> <tr> <td>WATER QUALITY</td> <td>C</td> <td></td> <td>B</td> <td>D</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>C</td> <td>Negative</td> <td>C</td> <td>C/D</td> </tr> <tr> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC↓</th> </tr> <tr> <td>FISH</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>C</td> <td>Stable</td> <td>B</td> <td>C/D</td> </tr> <tr> <td>INSTREAM</td> <td>C</td> <td></td> <td>B</td> <td>D</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>C</td> <td>Negative</td> <td>B</td> <td>D</td> </tr> <tr> <td>ECOSTATUS</td> <td>C</td> <td></td> <td>B</td> <td>D</td> </tr> </tbody> </table>				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
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																																																		

EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 9.2 to 9.7.

9.2 GEOMORPHOLOGY

The REC is the same as the PES. Accumulation of fines and reduced scour/flushing of the channel is the focus of the EcoSpecs and TPCs. EcoSpecs and TPCs are provided for RHAM monitoring data in Section 9.2.1 and GAI monitoring data in Section 9.2.2.

9.2.1 EcoSpecs and TPCs relating to RHAM monitoring data

Metric	EcoSpec	TPC																								
ACTIVE CHANNEL SUBSTRATE CHANGES																										
In-channel sediment (substrate) distribution.	Maintain the physical habitat diversity; specifically preventing the loss of bedrock habitat through smothering by sands.	<p>Overall for the site: Bedrock should be more than 30%.</p> <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 42%. 																								
The percentage substrate type within the active channel at the RHAM site is provided below.																										
<table border="1"> <caption>Substrate Percentage Data</caption> <thead> <tr> <th>Substrate Type</th> <th>Overall site (%)</th> <th>Fast habitats (%)</th> </tr> </thead> <tbody> <tr> <td>Roots</td> <td>~5</td> <td>0</td> </tr> <tr> <td>Fines</td> <td>~5</td> <td>0</td> </tr> <tr> <td>Sand</td> <td>~45</td> <td>~10</td> </tr> <tr> <td>Gravel</td> <td>0</td> <td>0</td> </tr> <tr> <td>Cobbles</td> <td>0</td> <td>0</td> </tr> <tr> <td>Boulders</td> <td>~5</td> <td>0</td> </tr> <tr> <td>Bedrock</td> <td>~42</td> <td>~15</td> </tr> </tbody> </table>			Substrate Type	Overall site (%)	Fast habitats (%)	Roots	~5	0	Fines	~5	0	Sand	~45	~10	Gravel	0	0	Cobbles	0	0	Boulders	~5	0	Bedrock	~42	~15
Substrate Type	Overall site (%)	Fast habitats (%)																								
Roots	~5	0																								
Fines	~5	0																								
Sand	~45	~10																								
Gravel	0	0																								
Cobbles	0	0																								
Boulders	~5	0																								
Bedrock	~42	~15																								

IN-CHANNEL HABITAT DIVERSITY		
The percentage mobile sediment per macroinvertebrate velocity class is given below.		
ACTIVE CHANNEL GEOMETRY		
Active channel width.	Maintain channel width.	The site is bedrock controlled and little adjustment of the channel can occur. No TPC has been set for this metric.

9.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel mobile sediments: Sand (< 6 mm diameter) should not exceed 95%. • GAI level IV in 2007 measured 93%.</p> <p>Sampling protocol: Sediment is to be sampled in the active channel.</p>
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	<p>EWR 6 is a mixed anastomosing channel type and is representative of the macro-reach. 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.</p> <p>A change to a single channel would represent a loss of in-channel diversity and reduced geomorphological condition and thus represents an undesirable trend.</p>
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 66%.	

9.3 PHYSICO-CHEMICAL VARIABLES

TPCs relating to the RHAM water quality indicators are provided in Section 9.3.1 and EcoSpecs and TPCs for the PES and REC in Section 9.3.2 – 9.3.4.

9.3.1 TPCs relating to RHAM water quality indicators

	RHAM indicators					
	Water odour type and extent	Filamentous algae in water column	Water colour and extent	Turbidity/clarity	Water surface indicator and extent	Algal cover on hard surfaces
PES/baseline (RHAM survey)	None	2	Green, 0.5	2 ¹	None	4
TPC	Cattle: ≥ 3 Chemical pollution: ≥ 1	>3	Green: ≥ 3. All other colours: ≥1	≥ 2 Trigger R-DRAM**	All indicators: ≥ 2 Salt deposits: ≥ 1	> 4

	RHAM indicators					
	Water odour type and extent	Filamentous algae in water column	Water colour and extent	Turbidity/clarity	Water surface indicator and extent	Algal cover on hard surfaces
	Other sources: ≥ 2 Trigger R-DRAM		Trigger R-DRAM *		Trigger R-DRAM	
	Activity at site: Run-of-river abstraction upstream of the site and irrigation return flows: Extent = 4.					

* R-DRAM:

Orange water: pH metric

Milky water: Salt and organic metrics

Green: Nutrient metric

1 The TPC was exceeded during the RHAM monitoring survey.

** R-DRAM:

Turbidity indicators

9.3.2 EcoSpecs relating to physico-chemical data: PES

River: Crocodile		EWR 6	Monitoring site: X2H016Q01
Water quality metrics		ECOSPEC: PES	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 45 mg/L**	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 30 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 57 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 85 mS/m.	
	pH	The 5 th percentile of the data must be 5.9 – 6.5, and the 95 th percentile 8.0 – 8.8.	
	Temperature	Small to moderate deviation from the natural temperature range. Some highly temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7 mg/L.	
Nutrients	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
Response variables	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.125 mg/L.	
	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 μ g/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .***	
	Toxics	The 95 th percentile of the data must be within the CEV as stated in DWAF (1996).****	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** Although the PES for MgSO₄ is an F category, the TPC is linked to a D category as the minimum requirement for this variable.

*** No periphyton or phytoplankton data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

**** Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008b) for a number of toxicants (e.g. Cd, found at this site), adherence to the CEV (DWAF, 1996) is recommended for the present state, with an improvement to meet the TWQR under the REC. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

9.3.3 EcoSpecs relating to physico-chemical data: REC

River: Crocodile		EWR Site: 6	Monitoring site: X2H016Q01
Water quality metrics		ECOSPEC: REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 45 mg/L.**	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 22 mg/L (A/B category).	
	CaCl ₂	The 95 th percentile of the data must be ≤ 57 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 85 mS/m.	
	pH	The 5 th percentile of the data must be 5.9 – 6.5, and the 95 th percentile 8.0 – 8.8.	
	Temperature	Small deviation from the natural temperature range, with lower abundances and frequencies of some highly temperature sensitive species.	

	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.7 mg/L.
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be ≤ 0.025 mg/L.
	Chl-a periphyton	The 95 th percentile of the data must be ≤ 45 mg/L.**
	Toxics	The 95 th percentile of the data must be ≤ 20 mg/L.

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** MgSO₄ concentration was 50 mg/L, i.e. an F category. The minimum category accepted would be a D category of 37 – 45 mg/L.

*** No periphyton or phytoplankton data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

9.3.4 TPCs relating to physico-chemical data: PES

River: Crocodile		EWR 6	Monitoring site: X2H016Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 40 – 45 mg/L.**	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 24 – 30 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 46 – 57 mg/L.	
	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 68 – 85 mS/m.	
	pH	The 5 th percentile of the data must be < 6.1 and > 6.3 , and the 95 th percentile must be < 8.2 and > 8.6 .	
	Temperature	Vary by more than 2°C, i.e. a large change to the temperature regime occurs often. Most moderately temperature sensitive species would be in lower abundances and frequency of occurrence than expected for reference. Biological assessments therefore recommended and initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.2 – 7 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.55 – 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.06 – 0.075 mg/L.***	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 17 – 21 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the CEV as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** Although the PES for MgSO₄ is an F category, the TPC is linked to a D category as the minimum requirement for this variable.

*** Although the upper boundary for the relevant phosphate category is 0.125 mg/L, the TPC has been set at 0.075 mg/L as deterioration beyond this would be problematic at this site, where nutrients levels are already quite high.

9.4 DIATOMS

EcoSpecs and TPCs relating to the RHAM water quality indicators are the same as for EWR 3 (Section 6.4.1).

9.5 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the RHAM and VEGRAI data are provided Section 9.5.1. Both RHAM and VEGRAI data support observation (high confidence).

9.5.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	Note
C	B	Exotic Invasion (perennial exotics).	Riparian zone.	Maintain the absence of perennial exotic species.	An increase in perennial exotic species cover > 5%.	Currently exotic species cover < 10% of the riparian zone, all species are non-perennial however. No perennial exotic species were observed.
		Indigenous Riparian Woody Cover.	Lower zone.	Maintain cover (%) of riparian woody species between 5 and 60%.	A decrease in riparian woody species covers below 5% OR above 60%.	VEGRAI data showed cover of 10 - 20%. RHAM data showed cover at 0%, expected to be naturally low and patchy, but with higher species richness than the marginal zone (<i>Nuxia oppositifolia</i> , <i>Flugea virosa</i> , <i>Acacia robusta</i> , <i>Breonadia salicina</i> , <i>Ficus caprefolia</i>).
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Marginal zone.	Maintain grass, sedge and dicotyledonous forb cover above 30% (in summer).	A decrease in sedge, grass and dicotyledonous forb cover below 30%.	RHAM data showed an average cover of 16% overall, and 49% on the marginal zone.
		<i>Phragmites</i> (reed) cover.	Marginal zone.	Maintain reed cover above 10%.	A decrease in reed cover below 10%.	RHAM data showed an average cover of 20% overall, 13% on the marginal zone and 20% on the lower zone.
			Lower zone.	Maintain reed cover between 10% and 90%.	An increase in reed cover above 90% or a decrease below 10%.	As above.
			Upper zone.	Maintain reed cover below 50%.	An increase in reed cover above 50%.	No data available for upper zone.

9.6 FISH

EcoSpecs and TPCs are provided for RHAM monitoring and FRAI data in Section 9.6.1. The spatial FROC of EWR 6 is provided in Section 9.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

9.6.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	
10	Species richness.	All indigenous species.	Four of the 34 expected indigenous fish species were sampled during the baseline (EWR) survey. Sampling conditions were not optimal due to high flows and crocodiles, and it can be expected that more species (approx. 21) should be present at the site (highlighted in yellow in Section 9.5.2) (approx. 13 spp. should be sampled using electrofishing).	Less than 10 fish species sampled using electrofishing during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All species.	Baseline (PES) FRAI score of 67.3 calculated for reach. Any decreased FROC in reach of especially CPAR, LCON, BMAR, (refer to table 2 ¹ -FROC) <u>OR</u> FRAI scores decreasing below 63% (low C).	
5	Relative abundance.	N/A.	During previous surveys (not baseline EWR survey) conducted under optimal sampling conditions, fish were sampled at > 10 ind/min.	Relative abundance of less than 7 ind/min sampled at the site (during optimal sampling conditions).		N/A.		
11	Alien fish species.	Any alien/introduced spp.	No alien species previously sampled at site.	Presence of any alien fish species during any survey.	N/A.	Any alien/introduced spp.	Previous observations of HMOL in lower section of Reach. Any increase in the number of alien species or increased FROC and abundance of HMOL.	
3	FD Habitats.	CPAR & BMAR (LCON)	CPAR and BMAR should always be present at the site under baseline conditions (based on available data for site: CPAR sampled 67% of time and BMAR 100% of time).	CPAR present less than 50% of time (not sampled for more than 2 consecutive surveys) and BMAR absent during any survey.	Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows) (to be quantified with RHAM).	LCON	CPAR	Any decreased FROC in reach of CPAR & LCON (refer to table 2 - FROC, column F).
1	FS habitats.	CPAR & LCYL (LCON)	CPAR and LCYL should always be present at the site under baseline conditions (based on available data for site: CPAR and LCYL sampled 67% of time).	CPAR & LCYL present less than 50% of time (not sampled for more than 2 consecutive surveys).	Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows), (to be quantified with RHAM).	CPAR	LCYL	Any decreased FROC in reach of CPAR & LCYL (refer to table 2 - FROC, column F).
	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).				LCON	CPAR	Any decreased FROC in reach of CPAR & LCON (refer to table 2 -- FROC, column F).	
4	Flow dependant spp (flow alteration).	LMOL & BMAR (& LCON)	LMOL and BMAR should always be present at the site under baseline conditions (based on available data for site: LMOL sampled 33% of time and BMAR 100% of time).	LMOL and BMAR absent during any survey.		CSWI	CPRE	Any decreased FROC in reach of CSWI & CPRE (refer to table 2- FROC, column F).
2	Water quality intolerance.	LMOL & CPAR	LMOL and CPAR should always be present at the site under baseline conditions (based on available data for site: LMOL sampled 33% of time and CPAR 67% of time).	LMOL and CPAR absent during any survey.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	CPRE	BIMB	Any decreased FROC in reach of CPRE & BIMB (refer to table 2- FROC, column F).
9	SD habitats.	TREN & OMOS (LCON)	TREN and OMOS should always be present at the site under baseline conditions (based	TREN and OMOS absent during any survey.	Reduced suitability of SD habitats (i.e. increased flows in	LCON	TREN	Any decreased FROC in reach of LCON & TREN (refer to table 2-

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)
			on available data for site: TREN sampled 100% of time and OMOS 67% of time).		dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).			FROC, column F).
6	Water column.	HVIT, BIMB	HVIT and BIMB should be present at the site in deep pools (based on available data for site both species sampled 33% of time).	HVIT & BIMB present less than 33% of time (not sampled for more than 2 consecutive surveys).	Reduction in suitability of water column (i.e. increased sedimentation of pools).	HVIT	BIMB	Any decreased FROC in reach of HVIT & GGIU (refer to table 2-FROC, column F).
7	SS habitats.	BVIV, GGIU	BVIV and GGIU should always be present at the site under baseline conditions (based on available data for site: BVIV sampled 67% of time and GGIU 33% of time).	BVIV present < 100% of time and GGIU present less than 50% of time (not sampled for more than 2 consecutive surveys).	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).	BVIV	GGIU	Any decreased FROC in reach of BVIV & GGIU (refer to table 2-FROC, column F).
8	Overhanging vegetation.	BVIV, TREN	BVIV and TREN should always be present at the site under baseline conditions (based on available data for site: BVIV sampled 67% of time and TREN 100% of time).	BVIV & TREN absent during any survey.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BVIV	TREN	Any decreased FROC in reach of BVIV & TREN (refer to table 2 - FROC, column F).
	Instream vegetation.	BVIV, TREN			Significant change in instream vegetation habitats (to be quantified with RHAM).	TREN	BVIV	
12	Undercut banks.	None.	No indicator species of undercut banks previous sampled at site.			MMAC	SZAM	Any decreased FROC in reach of MMAC & SZAM (refer to table 2-FROC, column F).

NB: Flow conditions during baseline (EWR) survey (high flows) resulted in poor sampling of site. Data gathered during this survey was therefore not adequate to use determining accurate species composition and relative abundances at site.

1 Refer to electronic data (DWA, 2010).

9.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ABER	<i>Acanthopagrus berda</i> (Forsskål, 1775)	2	1	0	1
ALAB	<i>Anguilla bengalensis labiata</i> (Peters, 1852)	1	1	0	1
AMAR	<i>Anguilla marmorata</i> (Quoy & Gaimard 1824)	2	1	0	1
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	2	1	0	2
BANN	<i>Barbus annectens</i> (Gilchrist & Thompson, 1917)	1	1	0	1
BFRI*	<i>Barbus afrohamiltoni</i> (Crass, 1960)	3	2	1	2
BIMB	<i>Brycinus imberi</i> (Peters, 1852)	5	3	2	3
BMAR	<i>Labeobarbus marequensis</i> (Smith, 1841)	5	4	3	5
BPAU	<i>Barbus paludinosus</i> (Peters, 1852)	3	2	1	3
BRAD	<i>Barbus radiatus</i> (Peters, 1853)	3	2	1	3
BTRI	<i>Barbus trimaculatus</i> (Peters, 1852)	4	3	2	3
BUNI	<i>Barbus unitaeniatus</i> (Günther, 1866)	3	2	1	2
BVIV	<i>Barbus viviparus</i> (Weber, 1897)	5	4	3	5
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	4	3	2	3
CPAR	<i>Chiloglanis paratus</i> (Crass, 1960)	5	3	2	4
CPRE	<i>Chiloglanis pretoriae</i> (Van der Horst, 1931)	1	1	0	1
CSWI	<i>Chiloglanis swierstrai</i> (Van der Horst, 1931)	4	3	2	4
GCAL	<i>Glossogobius callidus</i> (Smith, 1937)	2	1	0	1
GGIU	<i>Glossogobius giuris</i> (Hamilton-buchanan, 1822)	5	4	3	4
HVIT	<i>Hydrocynus vittatus</i> (Castelnau, 1861)	5	3	2	4
LCON	<i>Labeo congoro</i> (Peters, 1852)	5	3	2	5
LCYL	<i>Labeo cylindricus</i> (Peters, 1852)	5	4	3	4
LMOL	<i>Labeo molybdinus</i> (Du Plessis, 1963)	5	4	3	4
LROS	<i>Labeo rosae</i> (Steindachner, 1894) (<i>Labeo altevilis</i>)	4	3	2	3
LRUD	<i>Labeo ruddi</i> (Boulenger, 1907)	1	1	0	1
MACU	<i>Micralestes acutidens</i> (Peters, 1852)	5	3	2	4
MBRE	<i>Mesobola brevianalis</i> (Boulenger, 1908)	4	3	2	3
MMAC	<i>Marcusenius macrolepidotus</i> (Peters, 1852)	4	2	1	3
OMOS	<i>Oreochromis mossambicus</i> (Peters, 1852)	5	5	4	5
PCAT	<i>Petrocephalus wesselsi</i> (Kramer & Van der Bank, 2000)	2	1	0	1
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	3	3	2	3
SINT	<i>Schilbe intermedius</i> (Rüppell, 1832)	4	2	1	2
SZAM	<i>Synodontis zambezensis</i> (Peters, 1852)	3	1	0	1
TREN	<i>Tilapia rendalli</i> (Boulenger, 1896)	5	5	4	5

* EWR sampling was done during relative high flow, so optimal sampling could not be performed. Based on a previous survey in the reach the species that could be sampled under optimal sampling conditions are indicated in yellow.

9.7 MACROINVERTEBRATES

9.7.1 Baseline description

The baseline data for the biota is based on an EWR site visit in October 2007, at a flow of 3.3 m³/s. The original SASS5 total score for the site was 121 with an ASPT of 4.8. The REC is a B category

(DWA, 2009b). The reference conditions used to derive the EcoStatus (MIRAI) were based on historical data at the EWR site (Thirion, *pers. comm.*). The reference total SASS5 score for the site is 230 with an ASPT of 6. The baseline results are presented in the electronic information that accompanies this Report series (DWA, 2010).

9.7.2 Indicator taxa

A limited number of flow-dependent taxa were collected at this site there are basically 4 groups of indicator taxa. The habitat preferences for the indicator taxa groups are as follows:

Indicator group	Families	Velocity (m/s)	Substratum	Water Quality
1	Tricorythidae	> 0.6	Cobbles	Moderate
2	Libellulidae	0.3 - 0.6	Cobbles	Low
3	Elmidae	0.3 - 0.6	Cobbles	Moderate
4	Coenagrionidae	0.3 - 0.6	Vegetation	Low

Tricorythidae mayflies require velocities of > 0.6 m/s, but may persist at lower velocities (> 0.3 m/s), while the other flow dependent indicator taxa used for this site (Elmidae and Libellulidae) both prefer velocities between 0.3 and 0.6 m/s although they can also survive at other velocity categories and live on other substrates. Tricorythidae and Elmidae are moderately sensitive to water quality whereas the Libellulidae have a low sensitivity to water quality. Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population.

9.7.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

HABITAT ECOSPECS	HABITAT TPCs
To ensure that the maximum depth over the bedrock area is greater than 50 cm.	The maximum depth over the bedrock area is less than 52 cm.
To ensure that the average depth over the riffle area is greater than 25 cm.	The average depth over the riffle area is less than 26 cm.
To ensure that the maximum velocity over the riffle area is greater than 0.4 m/s.	The maximum velocity over the riffle area is less than 0.45 m/s.
To ensure that the average width of the river is greater than 50 m.	The average width of the river in the riffle area is less than 51 m.
To ensure that there are at least 5% fast flow over bedrock.	There is less than 6% fast flow over bedrock.
To ensure that less than 60% of the bedrock is covered with algae.	More than 65% of the bedrock is covered with algae.
To ensure that at least 3% of the marginal area contains inundated vegetation.	Less than 4% of the marginal area contains inundated vegetation.
BIOTA ECOSPECS	BIOTA TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 120; ASPT value: > 4.8.	SASS5 scores below 125 and ASPT below 4.8.
To ensure that the MIRAI score remains within the range of a C category (62% – 78%), using the same reference data used in this study.	A MIRAI score of 64% or less.
To maintain suitable flow velocity(maximum > 0.6 m/s) and clean, unembedded surface area (cobbles) to support the Tricorythidae in the VFCS (Very fast flow over coarse sediment) biotope:	Tricorythidae missing in any two consecutive surveys.
To maintain suitable flow velocity (0.3 - 0.6 m/s) and clean, unembedded surface area (cobbles) to support the following flow-dependent taxa in the FFCS biotope: <ul style="list-style-type: none"> • Libellulidae (Abundance A) • Elmidae (Abundance A) 	Any one of these taxa missing in two consecutive surveys.
• To maintain sufficient quantity and quality of inundated vegetation to support the Coenagrionidae.	Coenagrionidae missing in two consecutive surveys.

To maintain suitable water quality, shading, temperature and habitat conditions for the following four key taxa: <ul style="list-style-type: none">• Tricorythidae• Elmidae• Libellulidae• Coenagrionidae	Presence of less than three of the six key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as D abundance (> 1000) over more than two consecutive surveys.	

10 RESULTS: ECOSPECS AND TPCs FOR EWR 7: HONEYBIRD (CROCODILE RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

10.1 ECOCLASSIFICATION SUMMARY OF EWR 7

EWR 7 Kaap (Kaap River)																																																						
<p>EIS: HIGH Rare and endangered sp sensitive to flow and quality changes. High species taxon richness and habitat types sensitive to flow and quality changes.</p> <p>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.</p> <p>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.</p> <p>AEC down 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.</p>		<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC↓</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>D</td> <td></td> <td>C</td> <td>D</td> </tr> <tr> <td>WATER QUALITY</td> <td>B</td> <td></td> <td>B</td> <td>C</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>B</td> <td>Negative</td> <td>B</td> <td>C</td> </tr> <tr> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC↓</th> </tr> <tr> <td>FISH</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>B</td> <td>Stable</td> <td>B</td> <td>C</td> </tr> <tr> <td>INSTREAM</td> <td>B/C</td> <td></td> <td>B</td> <td>C</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>C/D</td> <td>Negative</td> <td>B/C</td> <td>D</td> </tr> <tr> <td>ECOSTATUS</td> <td>C</td> <td></td> <td>B</td> <td>D</td> </tr> </tbody> </table>			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
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																																																		

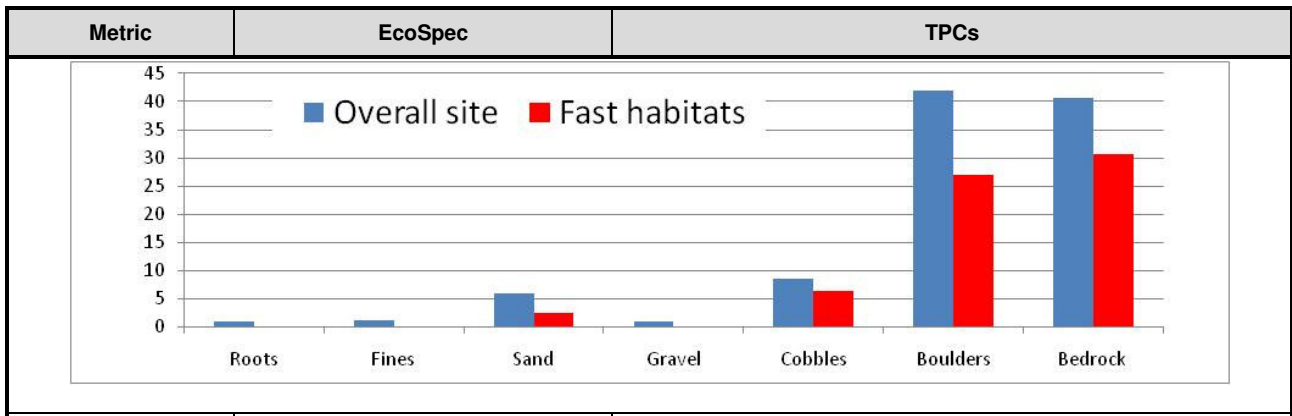
EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 10.2 to 10.6.

10.2 GEOMORPHOLOGY

The REC is the same as the PES. The site is stable and fairly resistant to flow changes. EcoSpecs and TPCs are provided for RHAM monitoring data in Section 10.2.1 and GAI monitoring data in Section 10.2.2.

10.2.1 EcoSpecs and TPCs relating to RHAM monitoring data

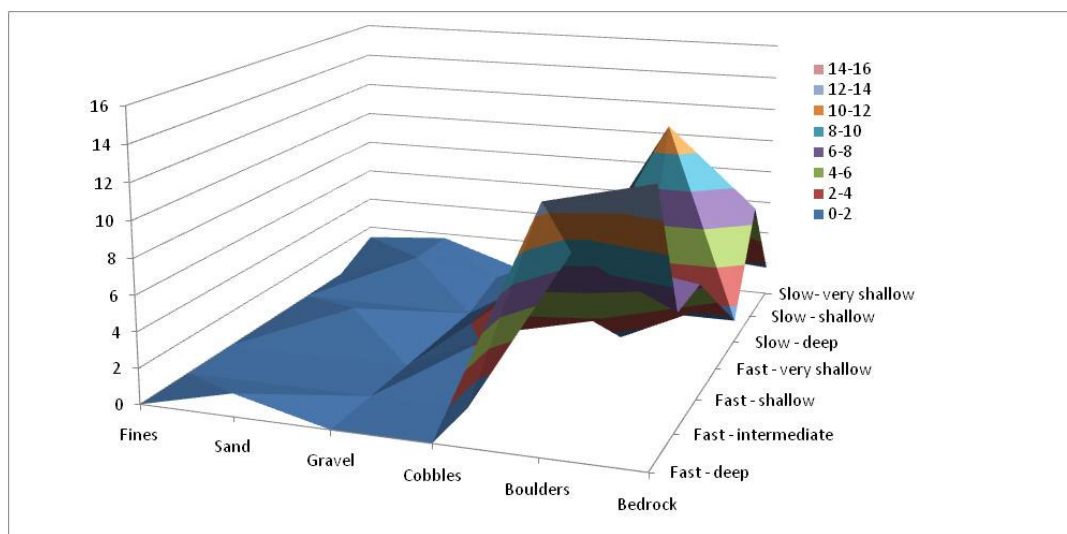
Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Sand should not exceed 10%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 6%. Cobbles should exceed 5%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 9%. Within all of the fast habitats: Sands should not exceed 5%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 3%. Cobbles should exceed 5%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 6%. </p>
The percentage substrate type within the active channel at the RHAM site is provided below.		



Proportion of embedded sediments.	Maintain minimum embeddedness to ensure bed mobility and create habitat for instream biota.	Embedded cobbles or gravels should be less than 5% of the site. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 0%.
-----------------------------------	---	--

IN-CHANNEL HABITAT DIVERSITY

The percentage mobile sediment per macroinvertebrate velocity class is given below.



ACTIVE CHANNEL GEOMETRY

Active channel width.	Maintain channel width.	For discharges around 0.9 m ³ /s the average width of the active channel should be between 5 and 8 m wide. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 6.2 m.
Lower bank stability.	Extent of undercut banks.	Overall for the site, the proportion of undercut banks should not exceed 20%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 0%.

10.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments:</p> <p>Sands and Gravels (< 60 mm diameter) should not exceed 20%.</p> <ul style="list-style-type: none"> GAI level IV in 2007 measured 18%. <p>Cobbles and boulders should not be less than 70%.</p> <ul style="list-style-type: none"> GAI level IV in 2007 measured 82%. <p>Sampling protocol:</p> <p>Sediment is to be sampled in the active channel riffle.</p>
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	EWR is classified as a bedrock gorge channel type and is representative of the Kaap River. The cross-section traverses a riffle. 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. This is a highly bedrock influenced site, and is therefore relatively insensitive to flow changes in terms of morphological adjustment.
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 86%.	

10.3 PHYSICO-CHEMICAL VARIABLES

There was no available baseline RHAM data for this site. EcoSpecs and TPCs relating for the PES and REC are provided in Section 10.3.1 – 10.3.3.

10.3.1 EcoSpecs relating to physico-chemical data: PES and REC

River: Kaap		EWR 7	Monitoring site: X2H022Q01
Water quality metrics		ECOSPEC: PES and REC	
Inorganic salts*	ALL	-	
Physical variables	EC	The 95 th percentile of the data must be ≤ 100 mS/m.**	
	pH	The 5 th percentile of the data must range from 6.5 to 8.0, and the 95 th percentile from 8.0 to 8.8.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 8 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 1.0 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.125 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 52.5 mg/m ² .***	
	Toxics	The 95 th percentile of the data must be within the TWQR as stated in DWAF (1996).	

*: To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** : The system seems naturally saline (PES: 90.8 mS/m; RC: 70.15 mS/m (data record: 1977 = 1981)), so the upper boundary of the relevant category has been adjusted from ≤ 85 mS/m to ≤ 100 mS/m.

***: Periphyton (31.42 mg/m²) is actually in a C/D category (C = 12 - 21 and D = 21 - 84 mg/m², DWAF 2008b), so have defined the upper boundary of a C/D as the EcoSpec for PES.

-: no data.

10.3.2 TPCs relating to physico-chemical data: PES

River: Kaap		EWR 7	Monitoring site: X2H022Q01
Water quality metrics		TPC	
Inorganic salts*	ALL	-	
Physical variables	EC	The 95 th percentile of the data must be 90 – 100 mS/m.**	
	pH	The 5 th percentile of the data must be < 6.7 and > 7.8, and the 95 th percentile must be < 8.2 and > 8.6.	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 8.2 – 8 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.8 – 1.0 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.06 – 0.075 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 42 – 52 mg/m ² .***	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the CEV as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** Although the upper boundary for the relevant phosphate category is 0.125 mg/L, the TPC has been set at 0.075 mg/L as deterioration beyond this would be problematic at this site, where nutrients levels are already elevated.

*** Periphyton (31.42 mg/m²) is actually in a C/D category (C = 12 - 21 and D = 21 - 84 mg/m², DWAF, 2008b), so have defined the upper boundary of a C/D as the EcoSpec for PES.

∴ no data.

NOTE:

As data for aggregated salts were not available but EC is elevated at the site, aggregated salts would have to be produced using TEACHA before EcoSpecs and TPCs can be generated.

10.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the RHAM and VEGRAI data are provided Section 10.4.1. As both VEGRAI and RHAM data were available, the confidence is high.

10.4.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	Note
C/D	B/C	Exotic Invasion (perennial exotics).	Lower & Upper zones.	Maintain cover (%) of perennial exotic species at 30% or lower.	An increase in perennial exotic species cover > 30%.	RHAM data show 43% average in the riparian zone. VEGRAI data recorded 40 - 60% on the lower zone and 60 - 80% on the upper zone.
		Terrestrialisation.	Lower zone.	Maintain cover (%) of terrestrial woody species at 15% or lower.	An increase in terrestrial woody species cover > 10%.	RHAM data show an average of 6% cover by terrestrial woody species.
		Indigenous Riparian Woody Cover.	Marginal zone.	Maintain cover (%) of riparian woody species below 70%, but always present.	An increase in riparian woody species cover above 70% OR below 1%.	RHAM average of 20% cover, VEGRAI average around 10%.
			Lower zone.	Maintain cover (%) of riparian woody species between 5 and 60%.	A decrease in riparian woody species covers below 5% OR above 60%.	RHAM average of 4% cover, VEGRAI observed < 10%.
			Upper zone.	Maintain cover (%) of riparian woody species between 20 and 70%.	A decrease in riparian woody species covers below 20% OR above 70%.	VEGRAI observed range between 10 - 20%.
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Marginal & Lower zone.	Maintain grass, sedge and dicotyledonous forb cover above 30% (in summer).	A decrease in sedge, grass and dicotyledonous forb cover below 30%.	RHAM average of 30% on the marginal zone and 23% on the lower zone.
		<i>Phragmites</i> (reed) cover.	Marginal zone.	Maintain reed cover above 10%.	A decrease in reed cover below 10%.	RHAM average 90% cover.
			Lower zone.	Maintain reed cover between 10% and 90%.	An increase in reed cover above 90% or a decrease below 10%.	RHAM average 10% cover.
			Upper zone.	Maintain reed cover below 50%.	An increase in reed cover above 50%.	

10.5 FISH

EcoSpecs and TPCs are provided for RHAM monitoring and FRAI data in Section 10.5.1. The spatial FROC of EWR 7 is provided in Section 10.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

10.5.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS*	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	
5	Species richness.	All indigenous species.	Twelve of an expected 17 expected indigenous fish species were sampled during the baseline (EWR) survey.	Less than 8 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All species.	Baseline (PES) FRAI score of 76.8 calculated for reach. Any decreased FROC in reach of especially CPRE, BEUT, BMAR, OPER (refer to table 2 ¹ -FROC) OR FRAI scores decreasing below 70%.	
4	Relative abundance.	N/A.	During recent baseline survey fish were sampled at 2.6 ind/min.	Relative abundance of less than 1.8 ind/min sampled at the site (during same season as baseline data).	N/A.	N/A.		
6	Alien fish species.	Any alien/introduced spp.	No alien /introduced fish species sampled at site during recent baseline survey.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien/introduced spp.	Presence of any alien/introduced fish species at site during any survey.	
1	FD Habitats.	BEUT, CPRE	During the recent baseline survey BEUT was present at relative abundance of 0.13 ind/min and CPRE at relative abundance of 0.75 ind/min.	BEUT and CPRE absent from the site during any survey OR present at relative abundance < 0.09 for BEUT and < 0.5 for CPRE.	Reduced suitability (abundance & quality) of FD & FS habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).	BEUT	CPRE	Any decreased FROC in reach of BEUT & CPRE (refer to table 2 - FROC, column F).
	FS habitats.					CPRE	BEUT	
	Flow dependant spp (flow alteration).					CPRE	BEUT	
2	Substrate.	BMAR, CPRE	During recent baseline survey BMAR was present at a relative abundance of 1.27 ind/min and CPRE at relative abundance of 0.75 ind/min.	BMAR and CPRE absent from a site during any survey and/or present at relative abundance < 1 ind/min for BMAR and < 0.5 for CPRE.		CPRE	BMAR	Any decreased FROC in reach of BMAR & CPRE (refer to table 2 - FROC, column F).
1	Water quality intolerance.	BEUT, CPRE	BEUT & CPRE will be most appropriate indicators of water quality at the site. Both species should under present conditions be present at site 100% of the time. During the recent baseline survey BEUT was present at relative abundance of 0.13 ind/min and CPRE at 0.75 ind/min.	BEUT and CPRE absent during any survey or BEUT with relative abundance < 0.09 ind/min and CPRE < 0.5 ind/min.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BEUT	CPRE	Any decreased FROC in reach of BEUT & CPRE (refer to table 2 - FROC, column F).
3	SD habitats.	BUNI, BMAR	BUNI & BMAR will be most appropriate indicators of SD habitats at the site. During the recent baseline survey BUNI was present at a relative abundance of 0.1 ind/min and BMAR at	BMAR absent during any survey or with relative abundance < 1 ind/min and or BUNI present less than 50% of time (absent for 2 consecutive	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of	BUNI	BMAR	Any decreased FROC in reach of BUNI & BMAR (refer to table 2 - FROC, column F).

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS*	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)
			1.27 ind/min.	surveys) or present with relative abundance of < 0.06 ind/min.	pools) (to be quantified with RHAM).			
3	Water column.	BMAR, MACU	BMAR & MACU are the best indicators of water column habitats at the site. During the recent baseline survey BMAR was present at a relative abundance of 1.27 ind/min and MACU at 0.05 ind/min.	BMAR absent during any survey or present at relative abundance < 1 ind/min, and MACU present less than 50% of time (absent for 2 consecutive surveys) or with relative abundance of < 0.02 ind/min.	Reduction in suitability of water column (i.e. increased sedimentation of pools).	BMAR	OPER	Any decreased FROC in reach of BMAR & OPER (refer to table 2 - FROC, column F).
3	SS habitats.	BUNI, BMAR	BUNI & BMAR are the species with most indicator value for SS. BUNI was present during the recent baseline survey at a relative abundance of 0.1 ind/min., while BMAR was present at 1.27 ind/min.	BUNI present less than 50% of time (absent for 2 consecutive surveys) or with relative abundance of < 0.06 ind/min AND/OR MAR absent during any survey or present at relative abundance < 1 ind/min.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).	BVIV	BUNI	Any decreased FROC in reach of BUNI & BVIV (refer to table 2 - FROC, column F).
2	Overhanging vegetation.	BUNI, BEUT	BUNI & BEUT are the species with most indicator value for overhanging vegetation at the site. BUNI was present during the recent baseline survey at a relative abundance of 0.1 ind/min, and BEUT at 0.13 ind/min.	BUNI & BEUT present less than 50% of time (absent for 2 consecutive surveys) or BUNI with relative abundance of < 0.06 ind/min and BEUT with relative abundance of < 0.09 ind/min.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BVIV	BUNI	
2	Undercut banks.	BEUT	BEUT will be the most appropriate indicator of undercut banks at site EWR 7 and should be present 100%. It was sampled during baseline survey at 0.13 ind/min.	BEUT present less than 50% of time (absent for 2 consecutive surveys) | with relative abundance of < 0.09 ind/min.	Significant change in undercut bank habitats (to be quantified with RHAM).	BEUT	PPHI	Any decreased FROC in reach of PPHI & BEUT (refer to table 2 - FROC, column F).

* Relative abundance in individuals per minute sampled using electrofishing unless stated for other sampling method.

1 Refer to electronic data (DWA, 2010).

10.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	3	2	1	2
BEUT	<i>Barbus eutaenia</i> (Boulenger, 1904)	5	4	3	4
BMAR	<i>Labeobarbus marequensis</i> (Smith, 1841)	5	4	3	5
BTRI	<i>Barbus trimaculatus</i> (Peters, 1852)	5	4	3	5
BUNI	<i>Barbus unitaeniatus</i> (Günther, 1866)	5	4	3	5
BVIV	<i>Barbus viviparus</i> (Weber, 1897)	5	4	3	5
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	3	3	2	3
CPAR	<i>Chiloglanis paratus</i> (Crass, 1960)	4	3	2	4
CPRE	<i>Chiloglanis pretoriae</i> (Van der Horst, 1931)	5	4	3	4
CSWI	<i>Chiloglanis swierstrai</i> (Van der Horst, 1931)	3	2	1	2
LCYL	<i>Labeo cylindricus</i> (Peters, 1852)	4	4	3	4
LMOL	<i>Labeo molybdinus</i> (Du Plessis, 1963)	4	4	3	4
LROS	<i>Labeo rosae</i> (Steindachner, 1894) (<i>Labeo altevilis</i>)	2	1	0	1
MACU	<i>Micralestes acutidens</i> (Peters, 1852)	3	3	2	3
OPER	<i>Opsaridium peringueyi</i> (Gilchrist & Thompson, 1913)	3	1	0	2
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	4	3	2	3
TREN	<i>Tilapia rendalli</i> (Boulenger, 1896)	3	2	1	2

10.6 MACROINVERTEBRATES

10.6.1 Baseline description

The baseline data for the biota is based on an EWR site visit in October 2007, at a flow of 0.43 m³/s. The original SASS5 total score for the site was 194 with an ASPT of 5.7. The PES and REC is a B category (DWA, 2009b). The reference conditions used to derive the EcoStatus (MIRAI) were based on historical data at the EWR site (Thirion, *pers. comm.*). The reference total SASS5 score for the site is 250 with an ASPT of 7. The baseline results are presented in the electronic information that accompanies this Report series (DWA, 2010).

10.6.2 Indicator taxa

A limited number of flow-dependent taxa were collected at this site there are basically 4 groups of indicator taxa. The habitat preferences for the indicator taxa groups are as follows:

Indicator group	Families	Velocity (m/s)	Substratum	Water Quality
1	Perlidae	> 0.6	Cobbles	High
2	Psephenidae, Philopotamidae	> 0.6	Cobbles	Moderate
3	Heptageniidae	0.3 - 0.6	Cobbles	High
4	Elmidae	0.3 - 0.6	Cobbles	Moderate

Psephenidae beetles and Perlidae stoneflies require velocities of > 0.6 m/s, but may persist at lower velocities (> 0.3 m/s). Heptageniidae mayflies and Elmidae beetles require velocities of 0.3 -

0.6 m/s but will also survive at faster velocities (> 0.6 m/s, they might persist at slower velocities (0.1 - 0.3 m/s). All four taxa occur mostly on cobbles but can also survive on bedrock and/or. The Heptageniidae and Perlidae are highly sensitive and the Elmidae and Psephenidae moderately sensitive to water quality conditions. Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population.

10.6.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

HABITAT ECOSPECS	HABITAT TPCs
To ensure that the maximum depth over the riffle/rapid area is greater than 30 cm.	The maximum depth over the riffle/rapid area is less than 32 cm.
To ensure that the average depth over the riffle/rapid area is greater than 15 cm.	The average depth over the riffle/rapid area is less than 16 cm.
To ensure that the maximum velocity over the riffle/rapid area is greater than 0.8 m/s.	The maximum velocity over the riffle/rapid area is less than 0.6 m/s.
To ensure that the average width of the river is greater than 3 m.	The average width of the river in the riffle area is less than 3.2 m.
To ensure that there are at least 25% fast flow over bedrock substrate.	There is less than 26% fast flow over bedrock.
To ensure that less than 50% of the bedrock substrates are covered with algae.	More than 51% of the bedrock is covered with algae.
BIOTA ECOSPECS	BIOTA TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 185; ASPT value: > 5.7.	SASS5 scores below 190 and ASPT below 5.8.
To ensure that the MIRAI score remains within the range of a B category (82% – 88%), using the same reference data used in this study.	A MIRAI score of 84% or less.
To maintain suitable flow velocity (maximum > 0.6 m/s) and clean, unembedded surface area (cobbles) to support the following flow-dependent taxa in the VFCS biotope: <ul style="list-style-type: none"> • Perlidae (Abundance A) • Psephenidae (Abundance A) • Philopotamidae (Abundance A) 	Any one of these taxa missing or present as a single individual in any two consecutive surveys.
To maintain suitable flow velocity (0.3 - 0.6 m/s) and clean, unembedded surface area (cobbles) to support the following flow-dependent taxa in the FFCS biotope: <ul style="list-style-type: none"> • Heptageniidae (Abundance A) • Elmidae (Abundance A) 	Any one of these taxa missing or present as a single individual in two consecutive surveys.
To maintain suitable water quality, shading, temperature and habitat conditions for the following five key taxa: <ul style="list-style-type: none"> • Perlidae • Psephenidae • Philopotamidae • Elmidae • Heptageniidae 	Presence of less than four of the five key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as D abundance (> 1000) over more than two consecutive surveys.	
The REC is the same as the PES thus these values also refer to the REC.	

11 EWR 1: UPPER SABIE (SABIE RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009).

11.1 ECOCLASSIFICATION SUMMARY OF EWR 1

EWR 1: Upper Sabie (Sabie River)					
<p>EIS: HIGH Rare and endangered fish and vegetation species. Fish species present that are intolerant to flow and flow related water quality changes. .</p> <p>PES: B/C Impacts due to forestry, exotic vegetation species, and abstraction. Impacts largely non-flow related.</p> <p>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.</p> <p>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.</p>					
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	

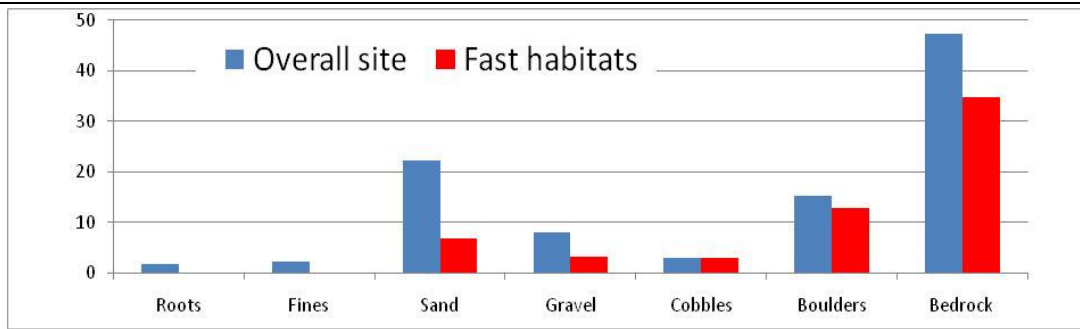
EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 11.2 to 11.7.

11.2 GEOMORPHOLOGY

The REC is the same as the PES. This pool-riffle system is a boulder/cobble bed with gravel and large sand component; the sands having been increased due to upstream forestry activities. The riparian zone is also heavily infested with exotic vegetation. To maintain the REC, the accumulation of fines and sands within the active channel is a potential problem and this is the focus of the EcoSpecs and TPCs. EcoSpecs and TPCs are provided for RHAM monitoring data in Section 11.2.1 and GAI monitoring data in Section 11.2.2.

11.2.1 EcoSpecs and TPCs relating to RHAM monitoring data

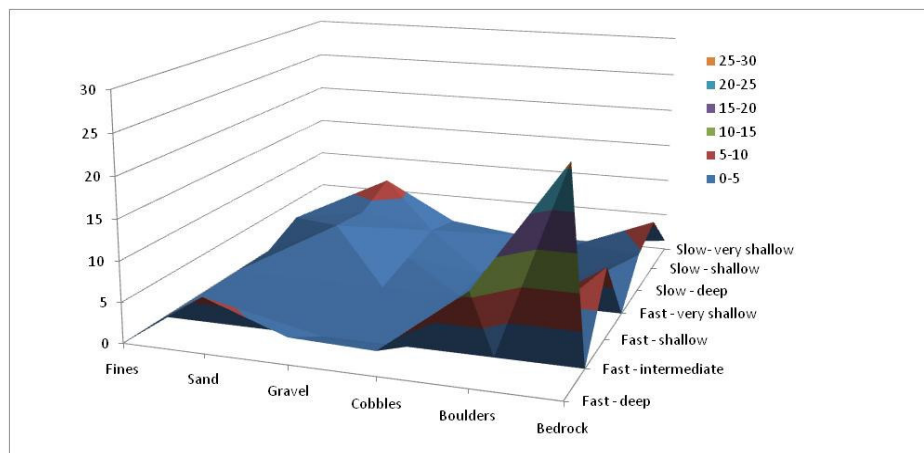
Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Sand (< 6 mm) should not exceed 25%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 22%. Gravels should be more than 5%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 8%. </p> <p>And within all of the fast habitats: Sand should not exceed 10%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 7%. </p>
The percentage substrate type within the active channel at the RHAM site is provided below.		



Proportion of embedded sediments.	Maintain minimum embeddedness to ensure bed mobility and create habitat for instream biota.	Embedded cobbles or gravels should be less than 5% of the site. • RHAM monitoring in 2009 measured 0%.
-----------------------------------	---	---

IN-CHANNEL HABITAT DIVERSITY

Percentage of instream habitat per depth-velocity class and per substrate type is provided below.



ACTIVE CHANNEL GEOMETRY

Active channel width.	Maintain channel width.	For discharges around 3 m ³ /s the average width of the active channel should be between 11 and 15 m wide. • RHAM monitoring in 2009 measured 13.3 m.
-----------------------	-------------------------	---

11.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	No potential bed material transport analysis or associated detailed bed sediment data collection was undertaken for this site due to budget limitations of the study. This has resulted in no baseline data being available for this site, and thus no specific quantifiable TPCs or EcoSpecs are specified for this site. A qualitative assessment of the active channel bed sediment should indicate a cobble/boulder bed active channel with gravels within the lee areas and margins.
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	This site is within a pool-riffle reach characterised by a cobble bed with a gravel and large sand component. Upstream forestry activities may have increased the sand component which may, in time, cause infilling of the active channel. This would represent an undesirable trend. Monitoring could take place through occasional (5 - 10 year) resurveyed cross-sections at the EWR site.
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 83%.	

11.3 PHYSICO-CHEMICAL VARIABLES

TPCs relating to the RHAM water quality indicators are provided in Section 11.3.1 and EcoSpecs and TPCs for the PES and REC in Section 11.3.2 – 11.3.4.

11.3.1 TPCs relating to RHAM water quality indicators

	RHAM indicators					
	Water odour type and extent	Filamentous algae in water column	Water colour and extent	Turbidity/clarity	Water surface indicator and extent	Algal cover on hard surfaces
PES/baseline (RHAM survey)	None	1	Green, 0.5	1.5	None	4
TPC	Cattle: ≥ 3 Chemical pollution: ≥ 1 Other sources: ≥ 2 Trigger R-DRAM	> 3	Green: ≥ 3 All other colours: ≥ 1 Trigger R-DRAM *	≥ 2 Trigger R-DRAM **	All indicators: ≥ 2 Salt deposits: ≥ 1 Trigger R-DRAM	> 4
Activity at site: Run-off, roads, removal of riparian vegetation: Extent = 2.						

* R-DRAM:

Orange water: pH metric

Milky water: Salt and organic metrics

Green: Nutrient metric

** R-DRAM:

Turbidity indicators

11.3.2 EcoSpecs relating to physico-chemical data: PES and REC

River: Sabie		EWR 1	Monitoring site: X3H001Q01
Water quality metrics		ECOSPEC: PES and REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must range from 6.5 to 8.0.	
	Temperature	No deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 8.0 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.025 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be <10 μ g/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

11.3.3 TPCs relating to physico-chemical data: PES

River: Sabie		EWR 1	Monitoring site: X3H001Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 13 – 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	

	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L.
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.
Physical variables	EC	The 95 th percentile of the data must be 24 – 30 mS/m.
	pH	The 5 th and 95 th percentiles of the data must be <6.7 and >7.8.
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.
	Dissolved oxygen	The 5 th percentile of the data must be 8.2 – 8.0 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.
Nutrients	TIN	The 50 th percentile of the data must be 0.56 – 0.7 mg/L.
	PO ₄ -P	The 50 th percentile of the data must be 0.02 – 0.025 mg/L.
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 µg/L.
	Chl-a periphyton	The 50 th percentile of the data must be 17 – 21 mg/m ² .
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

11.4 DIATOMS

EcoSpecs and TPCs relating to the RHAM water quality indicators are the same as for EWR 1 (Crocodile River) (Section 4.4.1).

11.5 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the RHAM and VEGRAI data are provided Section 11.5.1.

11.5.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
B/C	B	Exotic Invasion (perennial exotics).	Riparian zone.	Exotic species cover between 10 - 15%.	An increase in exotic species covers above 15%.	Exotic species cover between 5 - 10%.	VEGRAI recorded < 10% (marginal zone), 20% (lower zone), 10 - 20% (upper zone). RHAM recorded an absence of perennial exotic species in the marginal zone and an average of 16% on the lower zone.
			Marginal zone.	Riparian woody species cover between 30% and 60%.	An increase in riparian woody species cover above 60% OR a decrease below 30%.	Riparian woody species cover between 30% and 60%.	RHAM average of 30% COVER. VEGRAI range between 20 - 40%.
		Indigenous Riparian Woody Cover.	Lower zone.	Riparian woody species cover between 30% and 60%.	An increase in riparian woody species cover above 60% OR a decrease below 30%.	Riparian woody species cover between 30% and 60%.	RHAM average of 7% cover. VEGRAI range between 40 - 60%.
			Upper zone.	Riparian woody species cover between 30% and 60%.	An increase in riparian woody species cover above 60% OR a decrease below 30%.	Riparian woody species cover between 30% and 60%.	VEGRAI range between 40 - 60%.
		<i>Phragmites</i> (reed) cover.	Marginal zone.	Reed covers between 30% and 40%.	An increase in reed cover above 40%.	Reed covers between 20% and 30%.	RHAM recorded no reeds.
			Lower & Upper zones.	Reed covers between 20% and 30%.	An increase in reed cover above 30%.	Reed covers between 10% and 20%.	RHAM recorded no reeds.

11.6 FISH

EcoSpecs and TPCs are provided for RHAM monitoring and FRAI data in Section 11.6.1. The spatial FROC of EWR 1 is provided in Section 11.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

11.6.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES

Rank	Metric	Indicator spp.	PES					
			EWR SITE		REACH			
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	
3	Species richness.	All indigenous species.	Three of an expected 7 naturally occurring indigenous fish species were sampled during the baseline (EWR-PES) survey.	Less than 3 naturally occurring indigenous fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All indigenous species, esp. CANO, AURA & VNEL.	Baseline FRAI score of 78.3% (B/C) calculated for reach. Any decreased FROC in reach of especially AURA, CANO, VNEL (refer to table 2 ¹ -FROC) <u>OR</u> FRAI scores decreasing below 75% (high C).	
2	Relative abundance.	N/A.	During the baseline (EWR-PES) surveys fish were sampled at 2.8 ind/min.	Relative abundance of less than 1.5 ind/min sampled at the site (during optimal sampling conditions).	N/A.	N/A.		
	Alien fish species.	Any alien/introduced spp.	No alien fish species sampled at site during recent surveys.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien/introduced spp.	Presence of any alien/introduced fish species at sites within reach during any survey.	
1	FD Habitats.	VNEL, CANO	During the baseline survey VNEL was present at site at relative abundance of 2 ind/min electrofishing, while CANO was present at 0.76 ind/min.	VNEL and CANO absent from site during any survey <u>OR</u> present at relative abundance < 1 ind/min for VNEL and < 0.4 ind/min for CANO.	Reduced suitability (abundance & quality) of FD & FS habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).	VNEL	CANO	Any decreased FROC in reach of VNEL & CANO (refer to table 2 - FROC, column F).
	FS habitats.					VNEL	CANO	
	Substrate.					VNEL	CANO	
	Flow dependant spp (flow alteration).	CANO, VNEL (AURA & BBRI if sampled in future at site).				CANO	AURA	Any decreased FROC in reach of CANO & AURA (refer to table 2 - FROC, column F).
Water quality intolerance.	CANO	AURA						
	SD habitats.	AMOS (BANO, BBRI).	AMOS only SD indicator sampled at EWR site during baseline survey, present at relative abundance of 0.01 ind/min electrofishing.	AMOS only SD indicator sampled at site and not a reliable indicator species as they are generally coincidentally sampled (TPCs for BANO & BBRI can be defined in future if they are sampled at site).	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).	BANO	AMOS	Any decreased FROC in reach of BANO & AMOS (refer to table 2 - FROC, column F).
	Water column.	No indicator species available at site or in reach for water column as cover.						

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)
	SS habitats.	(BANO, BBRI & TSPA)	BANO, BBRI & TSPA only SS and overhanging vegetation indicator species expected at site. None of these species were present during baseline (EWR) survey.	TPCs for BANO, BBRI & TSPA can be defined in future if they are sampled at the EWR site.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).	BANO	BBRI	Any decreased FROC in reach of BANO & BBRI (refer to table 2 - FROC, column F).
	Overhanging vegetation.				Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BBRI	TSPA	Any decreased FROC in reach of BBRI & TSPA (refer to table 2 - FROC, column F).
	Undercut banks.	AMOS (BBRI)	AMOS only undercut bank indicator sampled at EWR site during baseline survey, present at relative abundance of 0.01 ind/min electrofishing.	AMOS only SD indicator sampled at site and not a reliable indicator species as they are generally coincidentally sampled. (TPCs for BBRI can be defined in future if they are sampled at site).	Significant change in undercut bank habitats (to be quantified with RHAM).	AMOS	BBRI	Any decreased FROC in reach of AMOS & BBRI (refer to table 2 - FROC, column F).
	Instream vegetation.	(TSPA & BANO)	BANO & TSPA only instream vegetation indicator species expected at site. None of these species were present during baseline (EWR) survey.	TPCs for BANO & TSPA can be defined in future if they are sampled at the EWR site.	Significant change in Instream vegetation habitats (to be quantified with RHAM).	TSPA	BANO	Any decreased FROC in reach of TSPA & BANO (refer to table 2 - FROC, column F).

1 Refer to electronic data (DWA, 2010).

11.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B/C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	4	2	1	2
AURA	<i>Amphilius uranoscopus</i> (Pfeffer, 1889)	4	3	2	3
BANO	<i>Barbus anoplus</i> (Weber, 1897)	4	3	2	3
BBRI	<i>Barbus brevipinnis</i> (Jubb, 1966)	4	3	2	3
CANO	<i>Chiloglanis anoterus</i> (Crass, 1960)	5	5	4	5
TSPA	<i>Tilapia sparrmanii</i> (Smith, 1840)	4	3	2	4
VNEL	<i>Varicorhinus nelspruitensis</i> (Gilchrist & Thompson, 1911)	5	5	4	5

11.7 MACROINVERTEBRATES

11.7.1 Baseline description

The baseline data for the biota is based on an EWR site visit during September 2007 (2 sets of samples) at a flow of 1.6 m³/s. The original SASS5 total score for the site was 170 with an ASPT of 6.3. The reference conditions used to derive the EcoStatus (MIRAI) were based on macroinvertebrate data from the River Health Program 'Rivers Client' for sites X2LUNS-KRUIS, X2CROC-VALYS, X2CROC-DONKE. The reference total SASS5 score for the site was 240 with an ASPT of 7.5. The baseline results are presented in the electronic information that accompanies this Report series (DWA, 2010). The PES and the REC for this site is a B EC.

11.7.2 Indicator taxa

Habitat diversity was high and a number of sensitive flow dependent taxa were collected including Baetidae (> 2 spp); Perlidae, Heptageniidae, and Athericidae.

The habitat preferences for the indicator taxa are as follows:

- Perlidae: Preference for velocities greater than 0.6 m/s, and cobble habitat.
- Heptageniidae: Preference for fast flow over coarse substrate; with high water quality requirements.
- Athericidae: Preference for cobble substrate, typically found in velocities of > 0.3 m/s.
- Baetidae > 2 spp: Preference for high water quality environments.

Sensitive flow-dependent macroinvertebrate taxa expected under reference conditions include Tricorythidae, Hydropsychidae 2 spp, Philopotamidae, and Psephenidae.

Generic minimum values for the various parameters are provided per taxon, below, as a guideline for monitoring. These values may differ slightly from site to site depending on the nature of the coarse substrates and the vegetation.

FDI INDICATOR TAXA GENERIC MINIMUM HYDRAULIC HABITAT REQUIREMENTS:	Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS ¹ %	VFC ² %	VEG ³ %	Emb ⁴ %	Alg ⁵ %
Perlidae	> 0.1	> 0.2	> 0.3	> 0.6	> 10	> 1	> 2	< 10	Isol.
Heptageniidae	> 0.1	> 0.2	> 0.3	> 0.6	> 10	> 0	> 2	< 10	Isol.
Elmidae			> 0.3	> 0.6	> 10	> 0	> 2	< 10	Isol.

1 Flow over coarse substrate
3 Vegetation

2 Very fast over coarse substrate
4 Embedded

5 Algae

11.7.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

ECOSPECS: Habitat	TPCs
Average depth over the top of wetted cobbles/bedrock should exceed 0.1 m. Maximum depth measured should exceed 0.25 m.	Maximum depth less than 0.28 m.
Average and maximum velocities should be > 0.2 and 0.6 m/s respectively.	Average and maximum velocities less than 0.25 and 0.65 m/s.
Small % of FCS, VFCS and inundated vegetation to be present.	No FCS present.
< 10% algal cover on coarse substrates including bedrock.	> 10% algal cover on coarse substrates including bedrock.
< 10% embeddedness of cobbles.	> 10% embeddedness of cobbles.
Marginal vegetation (MV) inundated to a depth of > 0.25 m.	MV inundated to a depth of < 0.2 m.
ECOSPECS: Biota	TPCs
To ensure that the MIRAI score remains within the range of a B category (80% – 89%), using the same reference data used in this study.	A MIRAI score of 80% or less.
Presence of at least three of the following taxa: Perlidae, Heptageniidae, Athericidae, Baetidae > 2 spp.	One or more of the following taxa present as individuals only, or absent: Perlidae, Heptageniidae, Athericidae, Baetidae > 2 spp.
No macroinvertebrate family consistently dominating the fauna defined as C abundance (> 100) over two consecutive surveys.	Any one or more taxa occurring in an abundance of > 100 individuals over two consecutive surveys.

12 RESULTS: ECOSPECS AND TPCs FOR EWR 2: AAN DE VLIET (SABIE RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

12.1 ECOCLASSIFICATION SUMMARY OF EWR 2

EWR 2: Aan de Vliet (Sabie River)				
<p>EIS: HIGH Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.</p> <p>PES: C Forestry and landuse activities, mostly non-flow related.</p> <p>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.</p> <p>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</p>				
Driver Components	PES Category	Trend	REC	AEC _I
HYDROLOGY	C		B/C	D
WATER QUALITY	B		A/B	C
GEOMORPHOLOGY	B	Negative	B	C
Response Components	PES Category	Trend	REC	AEC _I
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

EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 12.2 to 12.6.

12.2 GEOMORPHOLOGY

The REC is the same as the PES. The active channel at the site has shrunk, the riparian zone more densely-wooded and it is likely that the bed material has similarly fined. To maintain the REC, the accumulation of fines within the active channel is the primary focus of the EcoSpecs and TPCs. There was no available baseline RHAM data for this site, so EcoSpecs and TPCs tied to this format of data could not be generated. EcoSpecs and TPCs are provided for GAI monitoring data in Section 12.2.1.

12.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Sand (< 6 mm diameter) should not exceed 20%. <ul style="list-style-type: none"> GAI level IV in 2007 measured 9%. Gravels (< 60 mm diameter) should not be less than 20%. <ul style="list-style-type: none"> GAI level IV in 2007 measured 33%. <p>Sampling protocol: Sediment is to be sampled in the active channel riffle.</p> </p>
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	Changes in flow and in catchment sediment yield have caused the channel to react - the active channel at the site has narrowed and the riparian zone becomes well-wooded. It is likely that the bed material has similarly fined. These all represent an undesirable trend. Monitoring could take place through occasional (5-10 year) resurveyed cross-sections at the EWR site.

Metric	EcoSpec	TPCs
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 85%.	

12.3 PHYSICO-CHEMICAL VARIABLES

There was no available baseline RHAM data for this site. EcoSpecs and TPCs relating for the PES and REC are provided in Section 12.3.1 – 12.3.3.

12.3.1 Physico-chemical data: EcoSpecs – PES

River: Sabie		EWR Site: 2	Monitoring site: X3H006Q01
Water quality metrics		ECOSPEC: PES	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 118 mg/L (A/B category).	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must range from 6.5 to 8.0.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.25 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.025 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 84 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

12.3.2 Physico-chemical data: EcoSpecs – REC

River: Sabie		EWR Site: 2	Monitoring site: X3H006Q01
Water quality metrics		ECOSPEC: REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 118 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must range from 6.5 to 8.0.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.25 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.015 mg/L.	

River: Sabie		EWR Site: 2	Monitoring site: X3H006Q01
Water quality metrics		ECOSPEC: REC	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be <10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 52.5 mg/m ² . **	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** Periphyton (32.97 mg/m²) is actually in a C/D category (C = 12 - 21 and D = 21 - 84 mg/m², DWAF; 2008b), so have defined the upper boundary of a C/D as the EcoSpec for the REC.

12.3.3 TPCs relating to physico-chemical data: PES

River: Sabie		EWR 2	Monitoring site: X3H006Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 13 – 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	
	NaCl	The 95 th percentile of the data must be 95 – 118 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 24 – 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must be < 6.7 and > 7.8.	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.8 – 7.5 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.2 – 0.25 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.02 – 0.025 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 42 – 52 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

12.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 12.4.1.

12.4.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
C	B	Exotic Invasion (perennial exotics).	Riparian zone.	Exotic species cover between 10 - 15%.	An increase in exotic species covers above 15%.	Exotic species cover between 5 - 10%.	VEGRAI recorded 10 - 20% (marginal zone, but mostly annuals), 10 - 20% (lower zone), < 10% (upper zone).
		Indigenous Riparian Woody Cover.	Riparian zone.	Riparian woody species cover between 20% and 70%.	An increase in riparian woody species cover above 70% OR a decrease below 20%.	Riparian woody species cover between 30% and 60%.	VEGRAI range between 20 - 40%.
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Marginal zone.	Non-woody cover between 50 and 60%.	An increase in non-woody cover above 60%.	Non-woody cover between 1 and 5% OR 30 and 40%.	VEGRAI range between 40 - 60%.

12.5 FISH

EcoSpecs and TPCs are provided for the FRAI data in Section 12.5.1. The spatial FROC of EWR 2 is provided in Section 12.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

12.5.1 EcoSpecs and TPCs relating to FRAI data: PES

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)
7	Species richness.	All indigenous species.	14 of the 22 expected indigenous fish species were sampled during the baseline (EWR) survey.	Less than 12 fish species sampled using electrofishing during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All indigenous species.		Baseline (PES) FRAI score of 78.6 (B/C) calculated for reach. Any decreased FROC in reach of especially CANO, VNEL, BEUT & PER (refer to sheet 5-FROC: Table 2 ¹) <u>OR</u> FRAI scores decreasing below 75% (high C).
6	Relative abundance.	N/A.	During the baseline (EWR-PES) surveys fish were sampled at 4.3 ind/min.	Relative abundance of less than 2.5 ind/min sampled at the site (during optimal sampling conditions).	N/A.	N/A.		
13	Alien fish species.	Any alien/introduced spp.	No alien fish species sampled at site during recent surveys.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien/introduced spp.		Presence of any alien/introduced fish species at site during any survey.
5	FD Habitats.	VNEL, BEUT	During the baseline survey VNEL was present at site at relative abundance of 0.43 ind/min electrofishing, while BEUT was present at 0.57 ind/min (electrofishing).	VNEL and BEUT absent from site during any survey OR present at relative abundance < 0.25 ind/min for VNEL and < 0.3 ind/min for BEUT.	Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows) (to be quantified with RHAM).	VNEL	BEUT	Any decreased FROC in reach of VNEL & BEUT (refer to sheet 5-FROC, column F: Table 2).
3	FS habitats.	VNEL, CANO	During the baseline survey VNEL was present at site at relative abundance of 0.43 ind/min while CANO was present at 1.82 ind/min (electrofishing).	VNEL and CANO absent from site during any survey OR present at relative abundance < 0.25 ind/min for VNEL and < 1.2 ind/min for CANO.	Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows) (to be quantified with RHAM).	VNEL	CANO	Any decreased FROC in reach of VNEL & CANO (refer to sheet 5-FROC, column F: Table 2).
4	Substrate.	BPOL, VNEL	During the baseline survey VNEL was present at site at relative abundance of 0.43 ind/min while BPOL was present at 0.15 ind/min (electrofishing).	VNEL absent from site during any survey and BPOL absent during 2 consecutive surveys OR present at relative abundance < 0.25 ind/min for VNEL and < 0.08 ind/min for BPOL.	Reduced suitability (abundance & quality) of substrate habitats (increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, etc.) (to be quantified with RHAM).	BPOL	VNEL	Any decreased FROC in reach of BPOL & VNEL (refer to sheet 5-FROC, column F: Table 2).
1	Flow dependant spp (flow alteration).	OPER, CANO	During the baseline survey OPER was present at site at relative abundance of 0.12 ind/min while	OPER and CANO absent from site during any survey OR present at relative abundance < 0.05 ind/min for		OPER	CANO	Any decreased FROC in reach of OPER & CANO (refer to sheet 5-FROC, column F: Table 2).

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	
			CANO was present at 1.82 ind/min (electrofishing).	OPER and < 1.2 ind/min for CANO.				
2	Water quality intolerance.	BEUT, CANO	During the baseline survey BEUT was present at site at relative abundance of 0.57 ind/min while CANO was present at 1.82 ind/min (electrofishing).	BEUT and CANO absent from site during any survey OR present at relative abundance < 0.3 ind/min for BEUT and < 1.2 ind/min for CANO.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BEUT	CANO	Any decreased FROC in reach of BEUT & CANO (refer to sheet 5-FROC, column F: Table 2).
9	SD habitats.	BMAR, BPOL	During the baseline survey BMAR was present at site at relative abundance of 0.42 ind/min while BPOL was present at 0.15 ind/min (electrofishing).	BMAR absent from site during any survey and BPOL absent during 2 consecutive surveys OR present at relative abundance < 0.25 ind/min for BMAR and < 0.08 ind/min for BPOL.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).	BMAR	BPOL	Any decreased FROC in reach of BMAR & BPOL (refer to sheet 5-FROC, column F: Table 2).
8	Water column.	OPER, BMAR	During the baseline survey BMAR was present at site at relative abundance of 0.42 ind/min while BPOL was present at 0.15 ind/min (electrofishing).	BMAR absent from site during any survey and BPOL absent during 2 consecutive surveys OR present at relative abundance < 0.25 ind/min for BMAR and < 0.08 ind/min for BPOL.	Reduction in suitability of water column (i.e. increased sedimentation of pools).	OPER	BMAR	Any decreased FROC in reach of OPER & BMAR (refer to sheet 5-FROC, column F: Table 2).
11	SS habitats.	MACU, PPHI	MACU & PPHI are the best indicator species of SS at the site (as observed during baseline surveys). During the baseline survey MACU was present at site at relative abundance of 0.05 ind/min while PPHI was present at 0.25 ind/min (electrofishing).	PPHI absent from site during any survey and MACU absent during 2 consecutive surveys OR present PPHI present at relative abundance < 0.15 ind/min.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).	BBRI	BUNI	Any decreased FROC in reach of BUNI & BBRI (refer to sheet 5-FROC, column F: Table 2).
10	Overhanging vegetation.	BEUT, PPHI	During the baseline survey BEUT was present at site at relative abundance of 0.57 ind/min while PPHI was present at 0.25 ind/min (electrofishing).	BEUT and PPHI absent from site during any survey OR present at relative abundance < 0.3 ind/min for BEUT and < 1.5 ind/min for PPHI.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BEUT	BTRI	Any decreased FROC in reach of BEUT & BTRI (refer to sheet 5-FROC, column F: Table 2).
	Undercut banks.	BEUT, PPHI		BEUT and < 1.5 ind/min for PPHI.	Significant change in undercut bank habitats (to be quantified with RHAM).	BEUT	MMAC	Any decreased FROC in reach of BEUT & MMAC (refer to sheet 5-FROC, column F: Table 2).
12	Instream vegetation.	TSPA	The only species with high indicator value for instream vegetation is TSPA. During the baseline survey TSPA was present at site at relative abundance of 0.07 ind/min.	TSPA absent during 2 consecutive surveys or present with relative abundance < 0.03 ind/min.	Significant change in Instream vegetation habitats (to be quantified with RHAM).	TSPA		Any decreased FROC in reach of TSPA (refer to sheet 5-FROC, column F: Table 2).

1 Refer to electronic data (DWA, 2010).

12.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B/C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	4	2	1	2
AURA	<i>Amphilius uranoscopus</i> (Pfeffer, 1889)	4	4	3	4
BARG	<i>Barbus argenteus</i> (Günther, 1868)	3	2	1	2
BBRI	<i>Barbus brevipinnis</i> (Jubb, 1966)	4	1	0	3
BEUT	<i>Barbus eutaenia</i> (Boulenger, 1904)	5	5	4	5
BMAR	<i>Labeobarbus marequensis</i> (Smith, 1841)	5	4	3	4
BPOL	<i>Labeobarbus polylepis</i> (Boulenger, 1907)	5	4	3	4
BTRI	<i>Barbus trimaculatus</i> (Peters, 1852)	5	3	2	5
BUNI	<i>Barbus unitaeniatus</i> (Günther, 1866)	4	2	1	4
CANO	<i>Chiloglanis anoterus</i> (Crass, 1960)	5	5	4	5
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	4	4	3	4
CPAR	<i>Chiloglanis paratus</i> (Crass, 1960)	3	2	1	2
CSWI	<i>Chiloglanis swierstrai</i> (Van der Horst, 1931)	4	4	3	4
LCYL	<i>Labeo cylindricus</i> (Peters, 1852)	4	2	1	3
LMOL	<i>Labeo molybdinus</i> (Du Plessis, 1963)	4	2	1	3
MACU	<i>Micralestes acutidens</i> (Peters, 1852)	4	3	2	3
MMAC	<i>Marcusenius macrolepidotus</i> (Peters, 1852)	4	3	2	3
OPER	<i>Opsaridium peringueyi</i> (Gilchrist & Thompson, 1913)	5	5	4	5
PCAT	<i>Petrocephalus wesselsi</i> (Kramer & Van der Bank, 2000)	4	2	1	2
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	4	3	2	3
TSPA	<i>Tilapia sparrmanii</i> (Smith, 1840)	4	3	2	3
VNEL	<i>Varicorhinus nelspruitensis</i> (Gilchrist & Thompson, 1911)	5	5	4	5

12.5.3 MACROINVERTEBRATES

12.5.4 Baseline description

The baseline data for the biota is based on an EWR site visit during September 2007 at a flow of 1.5 m³/s. The original SASS5 total score for the site was 167 with an ASPT of 7. The reference conditions used to derive the EcoStatus (MIRAI) were based on invertebrate data from one NRHP site, namely: X2 CROC-GOEDE. The total reference condition comprises the cumulative data set from this site and the sample site. The reference total SASS 5 score was 260, with 30 taxa and an ASPT of > 7.5. The baseline, together with those for the reference sites, is presented in the electronic information that accompanies this Report series (DWA, 2010). The PES for this site is a B/C (79.5%), and REC is a B.

12.5.5 Indicator taxa

Three sensitive flow-dependent taxa with a preference for cobble areas were used as indicators for this site: Perlidae which prefer velocities > 0.6 m/s; Elmidae and Heptageniidae, both of which prefer velocities between 0.3 and 0.6 m/s. Perlidae and Heptageniidae are highly sensitive to water quality whereas Elmidae are moderately sensitive to water quality. The hydraulic

parameters associated with the MAINTENANCE DRY flows are presented. These data provide an approximation of the minimum values required at the site during the dry season in order to fulfil the FDI population's preferred hydraulic habitat requirements. They thus serve as a guide in the setting of EcoSpecs, particularly in the event that the EWR and RHAM sites are not in the same locality.

FDI INDICATOR TAXA GENERIC MINIMUM HYDRAULIC HABITAT REQUIREMENTS:			Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	Emb %	Alg %
Perlidae			> 0.1	> 0.2	> 0.2	> 0.6	> 10	> 5	< 10	Isol.
Heptageniidae			> 0.1	> 0.2	> 0.2	> 0.6	> 5	> 0	< 10	Isol.
Elmidae					> 0.2	> 0.6	> 5	> 0	< 10	Isol.
Cat	Flow (m ³ /s)	Season/ Building Block	Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	Emb %	Alg %
B/C	0.864	Dry Maint	0.19	0.26	0.39	1.2	26	13	< 10	isol
B	0.975	Dry Maint.	0.2	0.27	0.43	1.3	26	17	< 10	isol

12.5.6 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

ECOSPECS: HABITAT	TPCs
Average and maximum depth should exceed 0.1 m and 0.2 m respectively.	Average and maximum depth less than 0.15 and 0.25 m respectively.
Average and maximum velocities should exceed 0.2 and 0.6 m/s respectively.	Average and maximum velocities less than 0.25 and 0.65 m/s.
> 10% of FCS to be present and > 5% of VFCS.	< 12% FCS present. < 5% FCS.
< 10% algal cover on cobbles and boulders.	> 10% algal cover on cobbles and boulders.
< 10% embeddedness of cobbles.	> 10% embeddedness of cobbles.
Adequate inundation of marginal and instream vegetation.	Marginal and/or instream vegetation largely exposed.
ECOSPECS	TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 160; ASPT value: > 6.8.	SASS5 scores below 160 and ASPT below 7.
To ensure that the MIRAI score remains within the range of a B/C category (77.4% - 82.01%), using the same reference data used in this study.	A MIRAI score of 80% or less.
Presence of the following taxa at A or greater abundances: Perlidae, Heptageniidae, Elmidae, Baetidae > 2 spp.	One or more of the following taxa present as individuals only, or absent altogether: Perlidae, Heptageniidae, and Elmidae. Less than 2 spp of Baetidae.
To ensure that no group consistently dominates the fauna, defined as C abundance (> 100) over more than two consecutive surveys.	The presence of any taxon occurring in an abundance of > 100 individuals for two consecutive surveys.

13 RESULTS: ECOSPECS AND TPCs FOR EWR 3: KIDNEY (SABIE RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

13.1 ECOCLASSIFICATION SUMMARY OF EWR 3

EWR 3 Kidney (Sabie River)			
<p>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.</p> <p>PES: A/B Forestry, abstraction, Inyaka Dam and landuse activities. (Flow and non-flow related)</p> <p>REC: A/B As the PES is already an A/B, the REC = the PES.</p> <p>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.</p>			
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

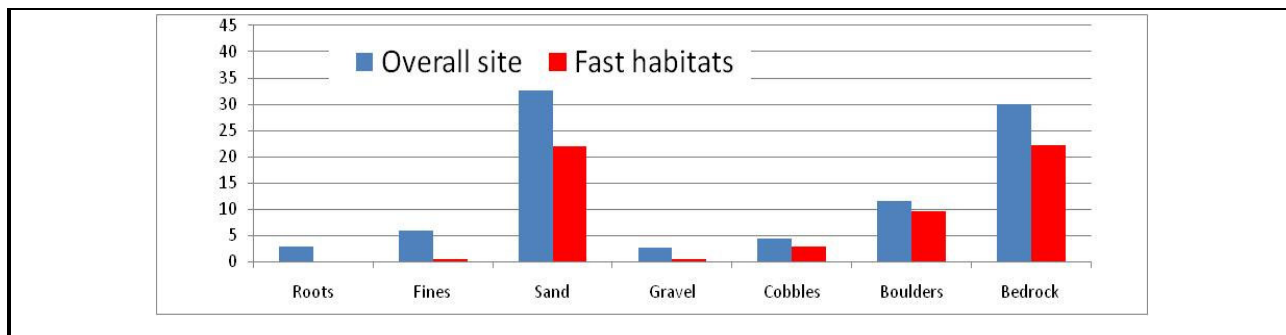
EcoSpecs and TPCs for the PES and REC are provided for the different components in Section 13.2 to 13.7.

13.2 GEOMORPHOLOGY

The REC is the same as the PES. Sedimentation, specifically in the braided and pool-rapid reaches, has resulted in a loss of exposed bedrock and riffles, causing a decrease in the instream habitat diversity as the sites tend towards sandier, shallower shallow systems. Keeping the accumulation of sands in check is the focus of the EcoSpecs and TPCs. EcoSpecs and TPCs are provided for RHAM monitoring data in Section 13.2.1 and GAI monitoring data in Section 13.2.2.

13.2.1 EcoSpecs and TPCs relating to RHAM monitoring data

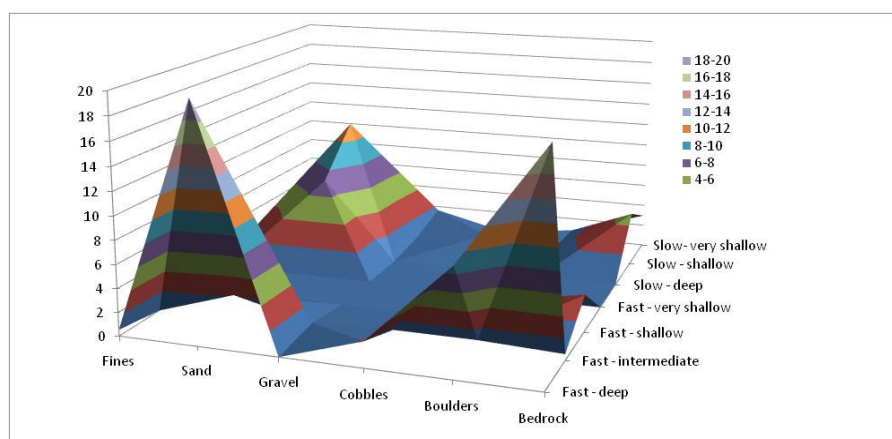
Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Sand (<6 mm) should not exceed 50%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 42%. Bedrock should be more than 20%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 30%. Within all of the fast habitats: Sand should not exceed 30%. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 22%. </p>
The percentage substrate type within the active channel at the RHAM site is provided below.		



Proportion of embedded sediments.	Maintain minimum embeddedness to ensure bed mobility and create habitat for instream biota.	Embedded cobbles should be less than 30% of the site. <ul style="list-style-type: none"> • RHAM monitoring in 2009 measured 14%. Embedded boulders should be less than 30% of the site. <ul style="list-style-type: none"> • RHAM monitoring in 2009 measured 6%.
-----------------------------------	---	---

IN-CHANNEL HABITAT DIVERSITY

Percentage of instream habitat per depth-velocity class and per substrate type is provided below.



ACTIVE CHANNEL GEOMETRY

Active channel width.	Maintain channel width.	For discharges around 1.6 m ³ /s the average width of the active channel should be between 10 and 13 m wide. <ul style="list-style-type: none"> • RHAM monitoring in 2009 measured 11 m.
-----------------------	-------------------------	--

13.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	Overall for the in-channel sediments: Sands (< 6 mm diameter) should not exceed 40%. <ul style="list-style-type: none"> • GAI level IV in 2007 measured 33%. Sampling protocol: Sediment is to be sampled in the active channel riffle.
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	The site should maintain multiple active distributaries through the reach. If less than three parallel distributaries are active during the wet season, or less than two during the dry season, then this would mean a TPC for maintenance of channel form has been exceeded.
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 84%.	

13.3 PHYSICO-CHEMICAL VARIABLES

TPCs relating to the RHAM water quality indicators are provided in Section 13.3.1 and EcoSpecs and TPCs for the PES and REC in Section 13.3.2 – 13.3.4.

13.3.1 TPCs relating to RHAM water quality indicators

	RHAM indicators					
	Water odour type and extent	Filamentous algae in water column	Water colour and extent	Turbidity/clarity	Water surface indicator and extent	Algal cover on hard surfaces
PES/baseline (RHAM survey)	None	0.5	Green, 0.5	0.5	None	4
TPC	Cattle: ≥ 3 Chemical pollution: ≥ 1 Other sources: ≥ 2 Trigger R-DRAM	> 3	Green: ≥ 3 . All other colours: ≥ 1 Trigger R-DRAM*	≥ 2 Trigger R-DRAM**	All indicators: ≥ 2 Salt deposits: ≥ 1 Trigger R-DRAM	> 4
Activity at site: Irrigation return flows: Extent = 1.						

* R-DRAM:

Orange water: pH metric

Milky water: Salt and organic metrics

Green: Nutrient metric

** R-DRAM:

Turbidity indicators

13.3.2 EcoSpecs relating to physico-chemical data: PES and REC

River: Sabie		EWR 3	Monitoring site: X3H013Q01
Water quality metrics		ECOSPEC: PES and REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 30 mS/m.	
	pH	The 5 th percentile of the data must range from 6.5 to 8.0, and the 95 th percentile from 6.5 to 8.8.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.	
	Turbidity	Small to moderate changes to the catchment land-use resulting in minor effects of silting of habitats, largely of a temporary nature, with very intermittent <u>temporary</u> unnaturally high sediment loads and high turbidities.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.25 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.015 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be <10 μ g/L.**	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .**	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** No periphyton or phytoplankton data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

13.3.3 TPCs relating to physico-chemical data: PES

River: Sabie		EWR 3	Monitoring site: X3H013Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 13 – 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	
	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 24 – 30 mS/m.	

River: Sabie		EWR 3	Monitoring site: X3H013Q01
Water quality metrics		TPC	
	pH	The 5 th percentile of the data must be < 6.7 and > 7.8, and the 95 th percentile must be < 6.7 and > 8.6.	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.8 – 7.5 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.2 – 0.25 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.012 – 0.015 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 17 – 21 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

13.4 DIATOMS

EcoSpecs and TPCs relating to the RHAM water quality indicators are the same as for EWR 1 (Crocodile River) (Section 4.4.1).

13.5 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the RHAM and VEGRAI data are provided Section 13.5.1. As both RHAM and VEGRAI data were available, the confidence is high.

13.5.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
A/B	A/B	Exotic Invasion (perennial exotics).	Riparian zone.	Exotic species cover between 1 and 5%.	An increase in exotic species covers above 5%.	Exotic species cover between 1 and 5%.	VEGRAI recorded < 10% (marginal zone, annuals), < 10% (lower zone), < 10% (upper zone). RHAM recorded 5% cover in the marginal zone, 3% cover in the lower zone and 1 % cover in the upper.
		Terrestrialisation .	Marginal zone.	The absence of terrestrial woody species.	A presence of terrestrial woody species.	The absence of terrestrial woody species.	RHAM recorded 1% cover in the marginal zone, 8% cover in the lower zone and 12 % cover in the upper.
			Lower zone.	The absence of terrestrial woody species.	An increase in terrestrial woody species covers above 5%.	The absence of terrestrial woody species.	As above.
			Upper zone.	Terrestrial woody cover between 10 and 20%.	An increase in terrestrial woody species covers above 20%.	Terrestrial woody cover between 10 and 20%.	As above.
		Indigenous Riparian Woody Cover.	Riparian zone.	Indigenous riparian woody cover between 20 and 40%.	A decrease in riparian woody species cover below 10% OR an increase above 40%.	Indigenous riparian woody cover between 20 and 40%.	VEGRAI range from 10 to 40%. RHAM recorded 18% cover in the marginal zone, 10% cover in the lower zone and 14 % cover in the upper.
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Riparian zone.	Maintain grass, sedge and dicotyledonous forb cover between 30% and 90%.	A decrease in sedge, grass and dicotyledonous forb cover below 30% OR above 90%.	Maintain grass, sedge and dicotyledonous forb cover between 30% and 90%.	RHAM recorded an average of 45% cover in the riparian zone.

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
		<i>Phragmites</i> (reed) cover.	Marginal zone.	Reed covers between 20 and 40%.	An increase in reed cover above 80% OR a decrease below 20%.	Reed covers between 20 and 40%.	RHAM recorded 10% cover in the marginal zone, 8% cover in the lower zone and 0% covers in the upper. VEGRAI range between 40 and 60%. The RHAM data show that TPCs have been exceeded, but plot placement has not represented reeds satisfactorily in this section. It is suggested that RHAM plots be shifted for future monitoring.
	Lower zone.		Reed covers between 20 and 40%.	An increase in reed cover above 80% OR a decrease below 20%.	Reed covers between 20 and 40%.	As above.	
	Upper zone.		Reed covers between 1 and 20%.	An increase in reed cover above 30% OR a total loss of reed cover.	Reed covers between 1 and 20%.	As above.	

13.6 FISH

EcoSpecs and TPCs are provided for RHAM monitoring and FRAI data in Section 13.6.1. The spatial FROC of EWR 3 is provided in Section 13.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

13.6.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES

Rank	Metric	Indicator spp.	PES					REC
			EWR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
6	Species richness.	All species.	15 expected indigenous fish species were sampled during the baseline (EWR) survey.	Less than 13 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All species.	Baseline (PES) FRAI score of 85.6 calculated for the reach. Any decreased FROC in reach of especially BMAR, CANO, BEUT, LMOL, OPER, MBRE, PPHI, BVIV and TREN (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 79% (B/C EC.)	N/A PES = REC
5	Relative abundance.	N/A.	During recent surveys fish were sampled at 4.5 ind/min.	Relative abundance of less than 3.5 ind/min sampled at the site (during same season as baseline data) when habitat can be sampled efficiently.	N/A.	N/A.	N/A.	
11	Alien fish species.	Any alien/introduced spp.	No alien fish species sampled at site during recent surveys.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien/introduced spp.	Presence of any alien/introduced fish species in reach during any survey.	
3	FD Habitats.	BMAR & CANO (BEUT)	BMAR and CANO are expected to always be present at the EWR site (conditions similar to baseline conditions). This is based on available data for the site: (192 CANO individuals sampled during EWR survey at 2.02 ind/min), and BMAR 100% present during historical surveys, and sampled at relative abundance of 0.74 ind/min under baseline conditions.	BMAR and CANO present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.5 ind/min for BMAR and < 1.5 ind/min for CANO.	Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).	BMAR BEUT	Any decreased FROC in reach of BMAR and BEUT (refer to sheet 5-FROC, column F: Table 2 ¹).	
4	FS habitats.	BMAR & LMOL	BMAR and LMOL are expected to always be present at the site (conditions similar to baseline conditions). This is based on available data for the site: BMAR and LMOL 100% present during historical surveys, and both species sampled at a relative abundance of 0.7 ind/min under baseline conditions.	BMAR and LMOL present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.5 ind/min for both species.	Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows), (to be quantified with RHAM).	LCYL BMAR	Any decreased FROC in reach of BMAR and LCYL (refer to sheet 5-FROC, column F: Table 2).	
	Substrate.				Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).	LCYL LMOL	Any decreased FROC in reach of LMOL and LCYL (refer to sheet 5-FROC, column F: Table 2).	
1	Flow dependant spp (flow alteration).	OPER & CANO	CANO is expected to always be present at the site (conditions similar to baseline conditions) and OPER sampled 60% of the historical surveys.	OPER present less than 50% of time (not sampled for more than 2 consecutive surveys) and CANO absent during any		OPER CANO	Any decreased FROC in reach of OPER & CANO (refer to sheet 5-FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES					REC
			EWR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
			192 individuals CANO sampled during EWR survey (2.02 ind/min.), and OPER sampled at a relative abundance of 0.14 ind/min under baseline conditions.	survey AND/OR decrease in relative abundance of < 1.5 ind/min. for CANO.				
2	Water quality intolerance.	OPER & BEUT	Both species were sampled during baseline survey: OPER sampled at a relative abundance of 0.14 ind/min (60% of historical surveys), and BEUT sampled at a relative abundance of 0.12 ind/min (40% of historical surveys).	OPER and BEUT present less than 50% of time (not sampled for more than 2 consecutive surveys).	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	OPER	BEUT	Any decreased FROC in reach of OPER & BEUT (refer to sheet 5-FROC, column F: Table 2).
10	SD habitats.	BMAR, TREN & OMOS	OMOS & TREN will be most appropriate indicators of SD habitats at the site. Both species were sampled during historical surveys (80 - 100% of the time) and during the baseline survey, but at low numbers, OMOS being present at 0.04 ind/min electrofishing, and TREN at 0.01 ind/min electrofishing. BMAR have a lower indicator value (0.88), but is more abundant (0.74 ind/min electrofishing) and thus should be used in conjunction with TREN & OMOS.	BMAR absent during any survey (or with relative abundance < 0.5 ind/min.) AND/OR both TREN and OMOS absent during any survey.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).	TREN	OMOS	Any decreased FROC in reach of BMAR, TREN & OMOS (refer to sheet 5-FROC, column F: Table 2).
7	Water column.	BMAR, MBRE & OPER	OPE & MBRE were sampled during baseline survey: OPER sampled at a relative abundance of 0.14 ind/min (60% of historical surveys), and MBRE sampled at a relative abundance of 0.01 ind/min (80% of historical surveys). BMAR have a lower indicator value (0.82), but is more abundant (0.74 ind/min electrofishing) and could be used in conjunction with MBRE & OPER.	Adult BMAR individuals (> 150 mm) absent during any survey AND/OR both MBRE and OPER absent during any survey.	Reduction in suitability of water column (i.e. increased sedimentation of pools).	MBRE	OPER	Any decreased FROC in reach of MBRE & OPER (refer to sheet 5-FROC, column F: Table 2).
8	SS habitats.	BVIV	BVIV was present during baseline EWR survey at relative abundance of 0.17 ind/min electrofishing.	BVIV absent during any survey AND/OR decrease in relative abundance below 0.1 ind/min for BVIV.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).	BVIV	MACU	Any decreased FROC in reach of BVIV & MACU (refer to sheet 5-FROC, column F: Table 2).
	Overhanging	BVIV & PPHI	Both species were sampled during	BVIV absent during any	Significant change in	BVIV	SMER	Any decreased FROC in reach of

Rank	Metric	Indicator spp.	PES					REC	
			EWR SITE			REACH		REACH	
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
	vegetation.		baseline survey: BVIV is the best indicator of overhanging vegetation habitats (Indicator value = 0.98) and is expected to be present at site EWR3 100% of the time at > 0.17 ind/min electrofishing. Alternative overhanging vegetation indicators (SMER, TREN & BUNI) occur in very low numbers, thus PPHI have been selected as additional indicator. PPHI had a relative abundance of 0.25 ind/min during baseline survey and it occurred 60% of surveys conducted at site.	survey AND/OR decrease in relative abundance below 0.1 ind/min for BVIV. PPHI present less than 50% of time (not sampled for more than 2 consecutive surveys).	overhanging vegetation habitats (to be quantified with RHAM).			BVIV & SMER (refer to sheet 5-FROC, column F: Table 2).	
	Undercut banks.	BEUT & PPHI	Both species were sampled during the baseline survey at relatively high numbers. Despite lower numbers in historical sampling surveys, it is expected that both species should be present at site EWR3 100% of the time. During baseline survey BEUT at a relative abundance of 0.12 ind/min, and PPHI at 0.25 ind/min. electrofishing.	Both BEUT & PPHI absent during any survey <u>AND/OR</u> decrease in relative abundance below 0.07 ind/min for BEUT and < 0.15 ind/min for PPHI.	Significant change in undercut bank habitats (to be quantified with RHAM).	MMAC	BEUT	Any decreased FROC in reach of MMAC & BEUT (refer to sheet 5-FROC, column F: Table 2).	
9	Instream vegetation.	TREN & BVIV	TREN & BVIV will be most appropriate indicators of Instream vegetation habitats at the site. Both species were sampled during the baseline survey and 100% of the time during historical surveys. However, TREN was sampled at low numbers (0.01 ind/min electrofishing). BVIV were sampled at 0.17 ind/min electrofishing.	BVIV absent during any survey <u>AND/OR</u> decrease in relative abundance below 0.1 ind/min for BVIV. <u>AND/OR</u> TREN present less than 50% of time (not sampled for more than 2 consecutive surveys).	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	TREN	BVIV	Any decreased FROC in reach of TREN & BVIV (refer to sheet 5-FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010).

13.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	2	1	0	Same as PES
AURA	<i>Amphilius uranoscopus</i> (Pfeffer, 1889)	1	1	0	
BANN	<i>Barbus annectens</i> (Gilchrist & Thompson, 1917)	3	3	2	
BARG	<i>Barbus argenteus</i> (Günther, 1868)	1	0		
BEUT	<i>Barbus eutaenia</i> (Boulenger, 1904)	4	4	3	
BFRI	<i>Barbus afrohamiltoni</i> (Crass, 1960)	1	1	0	
BIMB	<i>Brycinus imberi</i> (Peters, 1852)	1	1	0	
BMAR	<i>Labeobarbus marequensis</i> (Smith, 1841)	5	5	4	
BPAU	<i>Barbus paludinosus</i> (Peters, 1852)	2	2	1	
BRAD	<i>Barbus radiatus</i> (Peters, 1853)	3	3	2	
BTOP	<i>Barbus toppini</i> (Boulenger, 1916)	1	1	0	
BTRI	<i>Barbus trimaculatus</i> (Peters, 1852)	4	4	3	
BUNI	<i>Barbus unitaeniatus</i> (Günther, 1866)	4	4	3	
BVIV	<i>Barbus viviparus</i> (Weber, 1897)	5	5	4	
CANO	<i>Chiloglanis anoterus</i> (Crass, 1960)	4	4	3	
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	4	4	3	
CPAR	<i>Chiloglanis paratus</i> (Crass, 1960)	4	3	2	
CSWI	<i>Chiloglanis swierstrai</i> (Van der Horst, 1931)	4	4	3	
HVIT	<i>Hydrocynus vittatus</i> (Castelnau, 1861)	1	1	0	
LCON	<i>Labeo congoro</i> (Peters, 1852)	2	2	1	
LCYL	<i>Labeo cylindricus</i> (Peters, 1852)	5	5	4	
LMOL	<i>Labeo molybdinus</i> (Du Plessis, 1963)	5	5	4	
LROS	<i>Labeo rosae</i> (Steindachner, 1894) (<i>Labeo altevilli</i>)	4	4	3	
MACU	<i>Micralestes acutidens</i> (Peters, 1852)	5	5	4	
MBRE	<i>Mesobola brevianalis</i> (Boulenger, 1908)	5	5	4	
MMAC	<i>Marcusenius macrolepidotus</i> (Peters, 1852)	4	3	2	
OMOS	<i>Oreochromis mossambicus</i> (Peters, 1852)	5	5	4	
OPER	<i>Opsaridium peringueyi</i> (Gilchrist & Thompson, 1913)	5	4	3	
PCAT	<i>Petrocephalus wesselsi</i> (Kramer & Van der Bank, 2000)	2	1	0	
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	4	4	3	
SINT	<i>Schilbe intermedius</i> (Rüppell, 1832)	4	3	2	
SMER	<i>Serranochromis meridianus</i> (Jubb, 1967)	5	4	3	
SZAM	<i>Synodontis zambezensis</i> (Peters, 1852)	1	1	0	
TREN	<i>Tilapia rendalli</i> (Boulenger, 1896)	5	5	4	
TSPA	<i>Tilapia sparrmanii</i> (Smith, 1840)	2	2	1	

13.6.3 MACROINVERTEBRATES

13.6.4 Baseline description

The baseline data for the biota is based on an EWR site visit during September 2007 at a flow of 0.83 m³/s. The original SASS5 total score for the site was 203 with 32 taxa and an ASPT of 6.3.

The reference total SASS 5 score was established in discussion with DWA:RQS officials C. Thirion and C. Todd (*pers. comm.*). The SASS5 was set at 220, with 32 taxa and an ASPT of > 7.0. The baseline results, together with those for the reference sites, are presented in the electronic information that accompanies this Report series (DWA, 2010). The PES and REC is a B EC.

13.6.5 Indicator taxa

A suite of sensitive flow dependent taxa were collected in Stones-in-current (SIC) and MV habitats at this site. Perlidae and Heptageniidae were used as indicator taxa. Perlid stoneflies prefer velocities of > 0.6 m/s, but will persist at moderate velocities of 0.3 - 0.6 m/s and will even survive lower flows (in low abundances) if water quality is not compromised. Their preferred substrate is cobbles. It is necessary that this habitat is not covered with fines. Heptageniid mayflies prefer velocities of 0.3 - 0.6 m/s and though they prefer cobble habitat, can live on substrates other than this. For both taxa, onset of early summer breeding requires maintenance of high quality water (low in organics and high clarity). The hydraulic parameters associated with the MAINTENANCE DRY flows are presented. These data provide an approximation of the minimum values required at the site during the dry season in order to fulfil the FDI population's preferred hydraulic habitat requirements. They thus serve as a guide in the setting of EcoSpecs. For EWR 3, the EWR and RHAM cross-sections are in the same short stretch of river, so these hydraulic parameters are of particular relevance.

FDI INDICATOR TAXA GENERIC MINIMUM HYDRAULIC HABITAT REQUIREMENTS:			Ave Depth M	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	Emb %	Alg %
Perlidae			> 0.1	> 0.2	> 0.3	> 0.6	> 1		< 10	Isol.
Heptageniidae			> 0.1	> 0.2	> 0.3	> 0.6	> 1		< 10	Isol.
Cat	Flow (m ³ /s)	Season/ Building Block	Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	Emb %	Alg %
B	1.84	Dry Maint	0.31	0.66	0.31	0.66	2		< 10	< 10

As this is a complicated site from a hydraulic perspective (anastomosing channel), these modelled values should be interpreted with caution when monitoring – e.g. the 2% FCS applies across the total width (all branches of the river, not just the channel visible from the right bank).

13.6.6 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

ECOSPECS: HABITAT	TPCs
Average and maximum depth should exceed 0.25 m and 0.5 m respectively.	Average and maximum depth less than 0.25 and 0.5 m respectively.
Average and maximum velocities should exceed 0.3 and 0.6 m/s respectively.	Average and maximum velocities less than 0.3 and 0.6 m/s.
> 2% of FCS to be present.	< 2% FCS present
< 10% algal cover on coarse substrates including bedrock.	> 10% algal cover on coarse substrates including bedrock.
< 10% embeddedness of cobbles.	> 10% embeddedness of cobbles.
Marginal and instream vegetation to be inundated to a depth of > 0.25 m.	Marginal vegetation inundated to a depth of < 0.27 m.
ECOSPECS: BIOTA	TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 190; ASPT value: > 6.	SASS5 scores below 200 and ASPT below 6.2.
To ensure that the MIRAI score remains within the range of a B category (> 82.01%), using the same reference data used in this study.	A MIRAI score of 82.01% or less.

<p>Presence of at least 7 of the following 9 high-scoring taxa: Perlidae, Heptageniidae, Baetidae > 2spp, Helodidae, Athericidae, Philopotamidae, Chlorocyphidae and Peralidae.</p>	<p>Two or more of the following taxa present only as individuals, or absent altogether: Perlidae, Heptageniidae, Helodidae, Athericidae, Chlorocyphidae, Peralidae, and Philopotamidae. Less than 2 spp of Baetidae.</p>
<p>Balanced community structure, i.e. majority of invertebrates at A abundance, certain taxa can be at B abundance (e.g. Simuliidae, Baetidae). No group to consistently dominate the fauna i.e. be present in C abundance (> 100) over more than two consecutive surveys.</p>	<p>The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.</p>

14 RESULTS: ECOSPECS AND TPCs FOR EWR 4: MAC MAC (MAC MAC RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

14.1 ECOCLASSIFICATION SUMMARY OF EWR 4

EWR 4 Mac Mac (Mac Mac River)				
<p>EIS: HIGH Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.</p> <p>PES: B Forestry, exotic vegetation and wastewater input. Impacts are flow and non-flow related.</p> <p>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.</p> <p>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.</p>				
Driver Components	PES Category	Trend	REC	AEC ₁
HYDROLOGY	C		C	C
WATER QUALITY	A/B		A	B/C
GEOMORPHOLOGY	A	Stable	A	B
Response Components	PES Category	Trend	REC	AEC ₁
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

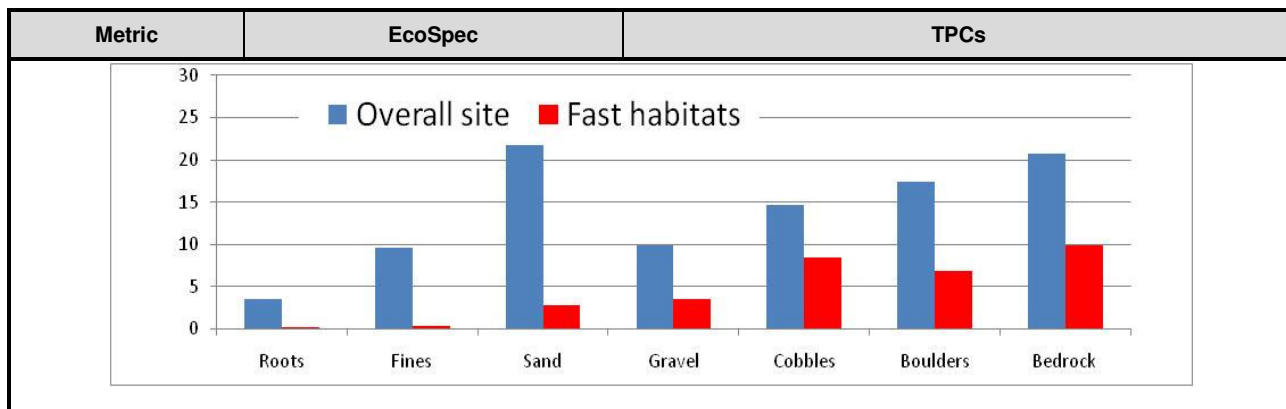
EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 14.2 to 14.6.

14.2 GEOMORPHOLOGY

The REC is the same as the PES. The site is stable and in an A category. Some additional fines from forestry activities may cause a decline in the EC and this is the focus of the EcoSpecs and TPCs. EcoSpecs and TPCs are provided for RHAM monitoring data in Section 14.2.1 and GAI monitoring data in Section 14.2.2.

14.2.1 EcoSpecs and TPCs relating to RHAM monitoring data

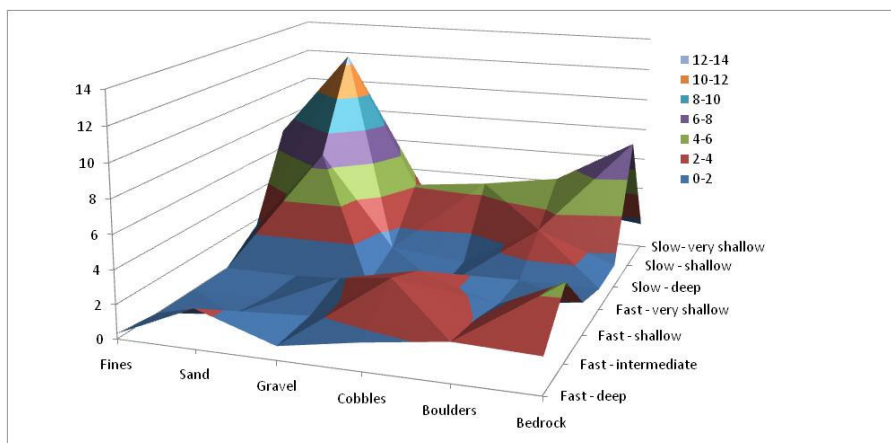
Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Sand percentage should not exceed 30%.</p> <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 24%. <p>Gravels should be more than 15%.</p> <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 10%. <p>Cobbles should not be less than 10%.</p> <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 15%. <p>Within all of the fast habitats: Sand should not exceed 10%.</p> <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 3%.
The percentage substrate type within the active channel at the RHAM site is provided below.		



Proportion of embedded sediments.	Maintain minimum embeddedness to ensure bed mobility and create habitat for instream biota.	Embedded cobbles should be less than 20% of the site. <ul style="list-style-type: none"> • RHAM monitoring in 2009 measured 15%. Embedded boulders should be less than 30% of the site. <ul style="list-style-type: none"> • RHAM monitoring in 2009 measured 14%.
-----------------------------------	---	--

IN-CHANNEL HABITAT DIVERSITY

Percentage of instream habitat per depth-velocity class and per substrate type is provided below.



ACTIVE CHANNEL GEOMETRY

Active channel width.	Maintain channel width.	For discharges around 1 m ³ /s the average width of the active channel should be between 12 and 16 m wide. <ul style="list-style-type: none"> • RHAM monitoring in 2009 measured 14.2 m.
-----------------------	-------------------------	--

14.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>No potential bed material transport analysis or associated sediment distribution data collection were undertaken for this site due to budget limitations of the study. This has resulted in no baseline data being available for this site, and thus no specific quantifiable TPCs or EcoSpecs are specified for this site.</p> <p>A qualitative assessment of the active channel bed sediment should however indicate that the active channel bed is dominated by boulders and cobbles.</p>
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	A qualitative assessment of the site should indicate that the reach is a boulder and cobble covered bed, with extensive bedrock exposure. The site is within a pool-rapid reach, where well-vegetated later bars and terraces.
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 93%.	

14.3 PHYSICO-CHEMICAL VARIABLES

There was no available baseline RHAM data for this site. EcoSpecs and TPCs relating for the PES and REC are provided in Section 14.3.1 – 14.3.3.

14.3.1 EcoSpecs relating to physico-chemical data: PES

River: Mac Mac		EWR 4	Monitoring site: X3H003Q01
Water quality metrics		ECOSPEC: PES	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must range from 6.5 to 8.0.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 8.0 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.015 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 84 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

14.3.2 EcoSpecs relating to physico-chemical data: REC

River: Mac Mac		EWR 4	Monitoring site: X3H003Q01
Water quality metrics		ECOSPEC: REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must range from 6.5 to 8.0.	
	Temperature	Largely natural to small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 8.0 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.25 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.015 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be <10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

14.3.3 TPCs relating to physico-chemical data: PES

River: Mac Mac		EWR 4	Monitoring site: X3H003Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 13 – 16 mg/L	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L	
	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L	
Physical variables	EC	The 95 th percentile of the data must be 24 – 30 mS/m	
	pH	The 5 th and 95 th percentiles of the data must be < 6.7 and > 7.8.	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 8.2 – 8.0 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.56 – 0.7 mg/L	
	PO ₄ -P	The 50 th percentile of the data must be 0.012 – 0.015 mg/L	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 µg/L	
	Chl-a periphyton	The 50 th percentile of the data must be 67 – 84 mg/m ²	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

14.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the RHAM and VEGRAI data are provided Section 14.4.1. As both RHAM and VEGRAI data are available, the confidence is high.

14.4.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
A/B	A/B	Exotic Invasion (perennial exotics).	Riparian zone.	Exotic species cover between 1 and 5%.	An increase in exotic species covers above 5%.	Exotic species cover between 1 and 5%.	RHAM recorded no exotic perennials. VEGRAI recorded small amount < 10%.
		Terrestrialisation	Marginal zone.	The absence of woody kloof species.	A presence of woody kloof species.	The absence of woody kloof species.	Terrestrial species are represented by kloof species at this site. These are expected to naturally have high cover (> 60%) in the upper and lower zones, but expect marked lower cover in the marginal zone.
		Indigenous Riparian Woody Cover.	Marginal zone.	Indigenous riparian woody cover between 20 and 60%.	A decrease in riparian woody species covers below 20%.	Indigenous riparian woody cover between 20 and 60%.	VEGRAI recorded 20 - 40% cover, RHAM recorded 100% cover due to overhang.
			Lower zone.	Indigenous riparian woody cover between 60 and 80%.	A decrease in riparian woody species covers below 60%.	Indigenous riparian woody cover between 60 and 80%.	VEGRAI recorded 60 - 80% cover, RHAM recorded an average of 87%.
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Marginal zone.	Non-woody cover between 30 and 60%.	An increase in non-woody cover above 70%.	Non-woody cover between 30 and 60%.	VEGRAI recorded 40 - 60% cover, RHAM recorded an average of 32%.
		<i>Phragmites</i> (reed) cover.	Riparian zone.	The absence of reeds.	The presence of reeds.	The absence of reeds.	No reeds recorded, nor expected to occur at this site.

14.5 FISH

EcoSpecs and TPCs are provided for RHAM monitoring and FRAI data in Section 14.5.1. The spatial FROC of EWR 4 is provided in Section 14.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

14.5.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	
7	Species richness.	All indigenous species.	5 of the 12 expected indigenous fish species were sampled during the baseline (EWR) survey.	Less than 5 fish species sampled using electrofishing during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All indigenous species.	Baseline (PES) FRAI score of 80.4 (B/C) calculated for reach. Any decreased FROC in reach of especially CANO, VNEL, BEUT & OPER (refer to sheet 5-FROC: Table 2 ¹) OR FRAI scores decreasing below 77.4% (high C).	
6	Relative abundance.	N/A.	During recent surveys fish were sampled at 3.1 ind/min.	Relative abundance of less than 1.6 ind/min sampled at the site (during same season as baseline data).		N/A.		
10	Alien fish species.	Any alien/introduced spp.	No alien fish species sampled at site during recent surveys.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien/introduced spp.	Presence of any alien/introduced fish species at site during any survey.	
3	FD Habitats.	VNEL, BEUT	During the baseline survey VNEL was present at site at relative abundance of 1.58 ind/min electrofishing, while BEUT was present at 0.25 ind/min (electrofishing).	VNEL and BEUT absent from site during any survey OR present at relative abundance < 1 ind/min for VNEL and < 0.1 ind/min for BEUT.	Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows) (to be quantified with RHAM).	VNEL BEUT	Any decreased FROC in reach of VNEL & BEUT (refer to sheet 5-FROC, column F: Table 2).	
2	FS habitats.	VNEL, CANO	During the baseline survey VNEL was present at site at relative abundance of 1.58 ind/min electrofishing, while CANO was present at 0.81 ind/min (electrofishing).	VNEL and CANO absent from site during any survey OR present at relative abundance < 1 ind/min for VNEL and < 0.4 ind/min for CANO.	Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows), Reduced suitability (abundance & quality) of substrate habitats (increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, etc.) (to be quantified with RHAM).	VNEL	CANO	Any decreased FROC in reach of VNEL & CANO (refer to sheet 5-FROC, column F: Table 2).
	Substrate.					VNEL	CANO	
1	Flow dependant spp (flow alteration).	CANO, BEUT (OPER)	During the baseline survey CANO was present at site at relative abundance of 0.81 ind/min electrofishing, while BEUT was present at 0.25 ind/min (electrofishing).	CANO and BEUT absent from site during any survey OR present at relative abundance < 0.4 ind/min for CANO and < 0.1 ind/min for BEUT.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	OPER	CANO	Any decreased FROC in reach of OPER & CANO (refer to sheet 5-FROC, column F: Table 2).
	Water quality intolerance.	BEUT, CANO				BEUT	CANO	Any decreased FROC in reach of BEUT & CANO (refer to sheet 5-FROC, column F: Table 2).
4	SD habitats.	OPER	OPER was only indicator of SD habitats sampled during baseline conditions and it was present in very low abundance (0.02 ind/min).	Due to low abundance of OPER at site, it may not be a valid indicator and will require verification. Preliminary TPC: Absence of OPER for 2 consecutive surveys.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).	CGAR	OPER	Any decreased FROC in reach of CGAR & OPER (refer to sheet 5-FROC, column F: Table 2).
	Water column.	OPER	OPER was only indicator of water column sampled during baseline	Due to low abundance of OPER at site, it may not be a valid indicator	Reduction in suitability of water column (i.e. increased sedimentation of pools).	OPER	BPOL	Any decreased FROC in reach of OPER & BPOL (refer to sheet 5-

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	
			conditions and it was present in very low abundance (0.02 ind/min).	and will require verification. Preliminary TPC: Absence of OPER for 2 consecutive surveys.				FROC, column F: Table 2).
8	SS habitats.	(BBRI, PPHI)	BBRI & PPHI are the best indicators of SS habitats at site, but they were not sampled during baseline EWR survey.	Due to absence of any SS habitat indicators at site during baseline survey, no TPC can be set at present. Should these species be sampled in future, TPCs could be defined.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).	BBRI	PPHI	Any decreased FROC in reach of BBRI & PPHI (refer to sheet 5-FROC, column F: Table 2).
5	Overhanging vegetation.	BEUT	During the baseline survey BEUT was present at 0.25 ind/min (electrofishing).	BEUT absent from site during any survey OR present at relative abundance < 0.1 ind/min.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BEUT	BBRI	Any decreased FROC in reach of BEUT & BBRI (refer to sheet 5-FROC, column F: Table 2).
	Undercut banks.				Significant change in undercut bank habitats (to be quantified with RHAM).	BEUT	AMOS	Any decreased FROC in reach of BEUT & AMOS (refer to sheet 5-FROC, column F: Table 2).
9	Instream vegetation.	(TSPA)	TSPA is the best indicators of instream vegetation habitats at site, but it was not sampled during baseline EWR survey.	Due to absence of an instream vegetation habitat indicator at site during baseline survey, no TPC can be set at present. Should these species be sampled in future, TPCs could be defined.	Significant change in Instream vegetation habitats (to be quantified with RHAM).	TSPA		Any decreased FROC in reach of TSPA (refer to sheet 5-FROC, column F: Table 2).

1 Refer to electronic data (DWA, 2010).

14.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B/C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	4	2	1	2
ANAT	<i>Amphilius natalensis</i> (Boulenger, 1917)	1	1	0	1
AURA	<i>Amphilius uranoscopus</i> (Pfeffer, 1889)	4	4	3	4
BBRI	<i>Barbus brevipinnis</i> (Jubb, 1966)	4	2	1	3
BEUT	<i>Barbus eutaenia</i> (Boulenger, 1904)	5	4	3	4
BPOL	<i>Labeobarbus polylepis</i> (Boulenger, 1907)	1	1	0	1
CANO	<i>Chiloglanis anoterus</i> (Crass, 1960)	5	5	4	5
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	4	4	3	4
OPER	<i>Opsaridium peringueyi</i> (Gilchrist & Thompson, 1913)	5	3	2	4
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	4	3	2	3
TSPA	<i>Tilapia sparrmanii</i> (Smith, 1840)	4	3	2	3
VNEL	<i>Varicorhinus nelspruitensis</i> (Gilchrist & Thompson, 1911)	5	5	4	5

14.6 MACROINVERTEBRATES

14.6.1 Baseline description

The baseline data for the biota is based on an EWR site visit during September 2007 at a flow of 0.51 m³/s. The original SASS5 total score for the site was 225 with 35 taxa and an ASPT of 6.4. The reference total SASS 5 score was established in discussion with DWAF:RQS officials C. Thirion and C. Todd (*pers. comm.*). The reference SASS5 score was set at 270, with 32 taxa and an ASPT of > 7.0. The baseline results, together with those for the reference sites, are presented in the electronic information that accompanies this Report series (DWA, 2010). The PES was an A/B (89.24%), and the REC remained an A/B.

14.6.2 Indicator taxa

Diverse communities of invertebrates were collected in all habitats, with the sensitive (mostly flow dependent) element comprised of Perlidae, Heptageniidae, Dixidae, Philopotamidae, Hydropsychidae, Chlorocyphidae, and Baetidae > 2 spp. Of these only the first two were used as indicators. Perlid stoneflies prefer velocities of > 0.6 m/s, but will persist at moderate velocities of 0.3 - 0.6 m/s and will even survive lower flows (in low abundances) if water quality is not compromised. Their preferred substrate is cobbles. It is necessary that this habitat is not covered with fines. Heptageniid mayflies prefer velocities of 0.3 - 0.6 m/s and though they prefer cobble habitat, can live on substrates other than this. For both taxa, onset of early summer breeding requires maintenance of high quality water (low in organics and high clarity).

The hydraulic parameters associated with the MAINTENANCE DRY flows are presented below. These data provide an approximation of the minimum values required at the site during the dry season in order to fulfil the FDI population's preferred hydraulic habitat requirements. They thus serve as a guide in the setting of EcoSpecs. Where the EWR and RHAM cross sections are in

different stretches of the river, caution must be applied in using these data, and the generic minimum values should serve as a conservative guide.

FDI INDICATOR TAXA GENERIC MINIMUM HYDRAULIC HABITAT REQUIREMENTS:			Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	MV %	Emb %	Alg %
Perlidae			> 0.1	> 0.2	> 0.3	> 0.6	> 3	> 1	> 1	< 10	Isol.
Heptageniidae			> 0.1	> 0.2	> 0.3	> 0.6	> 3	> 1	> 1	< 10	Isol.
Cat	Flow (m ³ /s)	Season/Building Block	Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	MV %		
A/B	0.294	Dry Maint.	0.17	0.42	0.23	0.74	6	2	2		

14.6.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

ECOSPECS: HABITAT	TPCs
Average and maximum depth should exceed 0.15 m and 0.35 m respectively.	Average and maximum depth less than 0.16 and 0.37 m respectively.
Average and maximum velocities should exceed 0.2 and 0.6 m/s respectively.	Average and maximum velocities less than 0.25 and 0.65 m/s.
> 5% of FCS to be present and a small % of VFCS.	< 7% FCS present. No FCS.
Small % of MV to be inundated to a depth of > 0.2 m.	Marginal vegetation inundated < 0.2 m or exposed.
< 10% algal cover on coarse substrates including bedrock.	> 10% algal cover on coarse substrates including bedrock.
< 10% embeddedness of cobbles.	> 10% embeddedness of cobbles.
ECOSPECS: BIOTA	TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 190; ASPT value: > 6.	SASS5 scores below 190 and ASPT below 6.
To ensure that the MIRAI score remains within the range of a B category (> 82.01%), using the same reference data used in this study.	A MIRAI score of 82.01% or less.
Presence of at least 7 of the following 9 high-scoring taxa: Perlidae, Heptageniidae Baetidae > 2spp, Helodidae, Athericidae, Philopotamidae, Chlorocyphidae, and Pyralidae.	Two or more of the following taxa present only as individuals, or absent altogether (for 2 consecutive samples): Perlidae, Heptageniidae, Helodidae, Athericidae, Chlorocyphidae, Pyralidae, and Philopotamidae. Less than 2 spp of Baetidae.
Balanced community structure, i.e. majority of invertebrates at A abundance, certain taxa may occur at B abundance (e.g. Simuliidae). No group to dominate the fauna i.e. be present in C abundance (> 100) over more than two consecutive surveys.	The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.

15 RESULTS: ECOSPECS AND TPCs FOR EWR 5: MARITE (MARITE RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

15.1 ECOCLASSIFICATION SUMMARY OF EWR 5

EWR 5 Marite (Marite River)				
<p>EIS: HIGH Rare, endangered and unique biota. Species richness high and species intolerant to flow and flow related water quality changes present.</p> <p>PES: B/C Increased low flows and landuse activities. Impacts mostly flow related</p> <p>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.</p> <p>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.</p>				
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

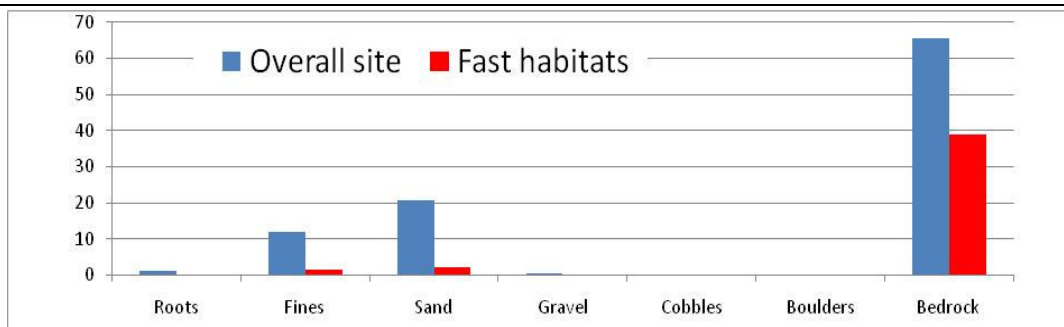
EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 15.2 to 15.6.

15.2 GEOMORPHOLOGY

The REC for EWR 5 is the same as the PES. The active channel is dominated by sand overlying the underlying bedrock, with very little gravel across the EWR cross-section. Accumulation of sands within the active channel is causing a slow decline in the PES and this is the focus of the EcoSpecs and TPCs. EcoSpecs and TPCs are provided for RHAM monitoring data in Section 15.2.1 and GAI monitoring data in Section 15.2.2.

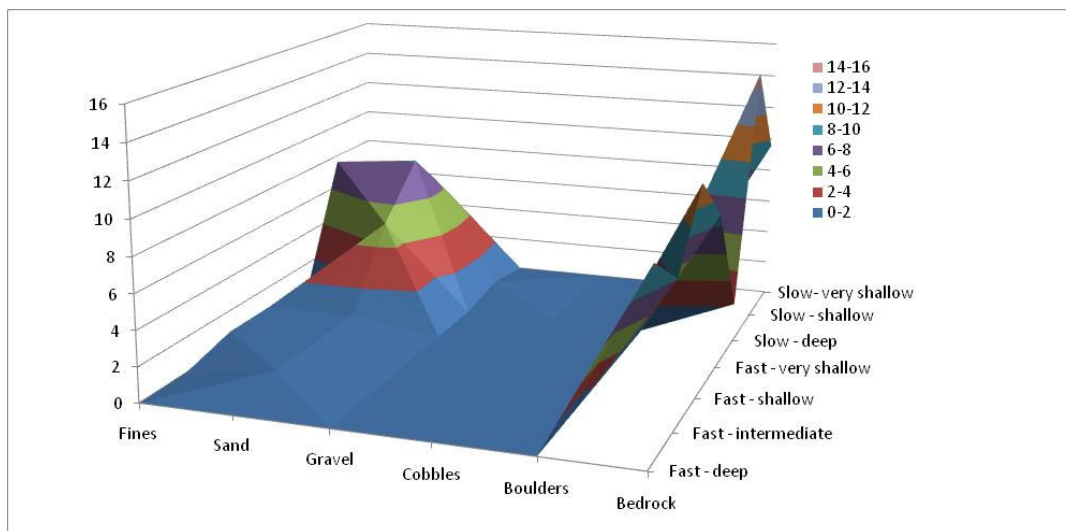
15.2.1 EcoSpecs and TPCs relating to RHAM monitoring data

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Sand percentage should not exceed 30%. • RHAM monitoring in 2009 measured 21%.</p> <p>Within all of the fast habitats: Sand should not exceed 10%. • RHAM monitoring in 2009 measured 2%.</p>
The percentage substrate type within the active channel at the RHAM site is provided below.		



IN-CHANNEL HABITAT DIVERSITY

Percentage of instream habitat per depth-velocity class and per substrate type is provided below.



ACTIVE CHANNEL GEOMETRY

Active channel width.	Maintain channel width.	For discharges around 1 m ³ /s the average width of the active channel should be between 9 and 12 m wide. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 10.4 m.
-----------------------	-------------------------	--

15.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments:</p> <p>Sands (< 6 mm diameter) should not exceed 20%. <ul style="list-style-type: none"> GAI level IV in 2007 measured 11%. <p>Gravels (< 60 mm) should not be less than 20%. <ul style="list-style-type: none"> GAI level IV in 2007 measured 27%. <p>Sampling protocol: Sediment is to be sampled in the active channel riffle.</p> </p></p>
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	The physical habitat diversity within the reach needs to be maintained. Riffles, sandy runs and exposed in-channel boulders as well as deep pools need to be present within the reach.
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 65%.	

15.3 PHYSICO-CHEMICAL VARIABLES

There was no available baseline RHAM data for this site. EcoSpecs and TPCs relating for the PES and REC are provided in Section 15.3.1 – 15.3.2.

15.3.1 EcoSpecs relating to physico-chemical data: PES and REC

River: Marite		EWR 5	Monitoring site: X3H011Q01
Water quality metrics		ECOSPEC: PES and REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must range from 6.5 to 8.0.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.0 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.015 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be <10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 84 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

15.3.2 TPCs relating to RHAM water quality indicators: PES

River: Marite		EWR 5	Monitoring site: X3H011Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 13 – 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	
	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 24 – 30 mS/m.	
	pH	The 5 th and 95 th percentiles of the data must be < 6.7 and > 7.8.	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.2 – 7.0 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.56 – 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.012 – 0.015 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 67 – 84 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

15.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the RHAM and VEGRAI data are provided Section 15.4.1.

15.4.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
B/C	B	Exotic Invasion (perennial exotics).	Riparian zone.	Exotic species cover between 10 - 15%.	An increase in exotic species covers above 15%.	Exotic species cover between 5 - 10%.	VEGRAI and RHAM sites were placed differently, but data show < 10% cover by exotic perennial species on the marginal and upper zones. Lower zone data were < 10% for RHAM site and 10 - 20% for the VEGRAI site.
		Terrestrialisation	Marginal zone.	The absence of terrestrial woody species.	The presence of terrestrial woody species.	The absence of terrestrial woody species.	No terrestrial species recorded in the RHAM.
			Lower zone.	Terrestrial woody cover between 1 and 5%.	An increase in terrestrial woody species cover > 5%.	The absence of terrestrial woody species.	An average of 5% cover was recorded at the RHAM site.
			Upper zone.	Terrestrial woody cover between 15 and 20%.	An increase in terrestrial woody species cover > 20%.	Terrestrial woody cover between 10 and 15%.	An average of 9% cover was recorded at the RHAM site.
		Indigenous Riparian Woody Cover.	Lower & Upper zones.	Indigenous riparian woody cover between 70 and 80%.	A decrease in riparian woody cover below 30% OR an increase above 80%.	Indigenous riparian woody cover between 30 and 70%.	RHAM average of 65% was recorded; VEGRAI range (on a different site) was between 20 and 60%.
		Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	Lower & Upper zones.	Non-woody cover between 40% and 50%.	A decrease in sedge, grass and dicotyledonous forb cover below 40% OR an increase above 90%.	Non-woody cover between 50% and 90%.	RHAM data show 0% on RHB and an average of 44% on LB ¹ . EcoSpecs and TPCs apply to LB only since RB ² consists of solid exposed bedrock unlikely to ever be colonised.
		<i>Phragmites</i> (reed) cover.	Marginal zone.	Reed covers between 20 and 30%.	A decrease in reed cover below 30%.	Reed cover above 30%	RHAM recorded cover of 90% (similarly, EcoSpec, baseline and TPC applies to LB only).
			Lower zone.	Reed covers between 20 and 30%.	An increase in reed cover above 80% or a decrease below 20%.	Reed covers between 30 and 80%.	RHAM recorded an average cover of 27% (similarly, EcoSpec, baseline and TPC applies to LB only).
			Upper zone.	Reed covers below 20%.	An increase in reed cover above 40%.	Reed covers below 40%.	No data to support TPC, RHAM transect should be extended to about 30 m.

1 Left bank

2 Right bank

15.5 FISH

EcoSpecs and TPCs are provided for RHAM monitoring and FRAI data in Section 15.5.1. The spatial FROC of EWR 5 is provided in Section 15.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

15.5.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES

Rank	Metric	Indicator spp	PES					
			EWR SITE		REACH			
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	
7	Species richness.	All indigenous species.	Fifteen of the 23 expected indigenous fish species were sampled during the baseline (EWR) survey.	Less than 11 fish species sampled using electrofishing during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All indigenous species.	Baseline (PES) FRAI score of 77.9 (B/C) calculated for reach. Any decreased FROC in reach of especially CANO, BEUT, OPER & BMAR (refer to sheet 5-FROC: Table 2') <u>OR</u> FRAI scores decreasing below 70% (high C).	
6	Relative abundance.	N/A.	During recent surveys fish were sampled at 4 ind/min.	Relative abundance of less than 3 ind/min sampled at the site (during same season as baseline data).		N/A.		
10	Alien fish species.	Any alien/introduced spp.	No alien fish species sampled at site during recent surveys.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien/introduced spp.	Presence of any alien/introduced fish species in reach during any survey.	
3	FD Habitats.	CANO, BMAR	During the baseline survey CANO was present at site at relative abundance of 1.36 ind/min electrofishing, while BMAR was present at 1 ind/min (electrofishing).	CANO and BMAR absent from site during any survey OR present at relative abundance 1 ind/min for CANO and < 0.6 ind/min for BMAR.	Reduced suitability (abundance & quality) of FD, FS habitats (i.e. decreased flows, increased zero flows), Reduced suitability (abundance & quality) of substrate habitats (increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, etc.) (to be quantified with RHAM).	CANO	BMAR	Any decreased FROC in reach of CANO & BMAR (refer to sheet 5-FROC, column F: Table 2).
	FS habitats.					CANO	BMAR	
	Substrate.					CANO	BMAR	
1	Flow dependant spp (flow alteration).	CANO, AURA	During the baseline survey CANO was present at site at relative abundance of 1.36 ind/min electrofishing, while AURA was present at 0.15 ind/min (electrofishing).	CANO and AURA absent from site during any survey OR present at relative abundance 1 ind/min for CANO and < 0.05 ind/min for AURA.		CANO	OPER	Any decreased FROC in reach of OPER & CANO (refer to sheet 5-FROC, column F: Table 2).
2	Water quality intolerance.	CANO, BEUT	During the baseline survey CANO was present at site at relative abundance of 1.36 ind/min electrofishing, while BEUT was present at 0.39 ind/min (electrofishing).	CANO and BEUT absent from site during any survey OR present at relative abundance < 1 ind/min for CANO and < 0.2 ind/min for BEUT.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	CANO	BEUT	Any decreased FROC in reach of BEUT & CANO (refer to sheet 5-FROC, column F: Table 2).
	SD habitats.	BMAR, CGAR	During the baseline survey CGAR was present at site at relative abundance of 0.1 ind/min electrofishing, while BMAR was present at 1 ind/min (electrofishing).	CGAR and BMAR absent from site during any survey OR present at relative abundance 0.05 ind/min for CGAR and < 0.6 ind/min for BMAR.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).	BMAR	BUNI	Any decreased FROC in reach of BMAR & BUNI (refer to sheet 5-FROC, column F: Table 2).

Rank	Metric	Indicator spp	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)
4	Water column.	BMAR, OPER	BMAR & OPER are the best indicators of water column at site. During the baseline survey OPER was present at site at very low relative abundance of 0.02 ind/min electrofishing, while BMAR was present at 1 ind/min (electrofishing).	BMAR absent from site during any survey OR present at relative abundance < 0.6ind/min for BMAR OR OPER absent for 2 consecutive surveys.	Reduction in suitability of water column (i.e. increased sedimentation of pools).	BMAR	OPER	Any decreased FROC in reach of BMAR & OPER (refer to sheet 5-FROC, column F: Table 2).
8	SS habitats.	PPHI, TSPA	PPHI & TSPA are the best indicators of SS habitats at site. During the baseline survey both were sampled at very low relative abundance of 0.03 ind/min for PPHI and 0.02 ind/min TSPA (electrofishing).	PPHI AND TSPA absent for 2 consecutive surveys.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).	BUNI	PPHI	Any decreased FROC in reach of BUNI & PPHI (refer to sheet 5-FROC, column F: Table 2).
	Overhanging vegetation.				Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BUNI	PPHI	
5	Undercut banks.	MMAC, BEUT	During the baseline survey MMAC was present at site at relative abundance of 0.13 ind/min electrofishing, while BEUT was present at 0.39 ind/min (electrofishing).	MMAC and BEUT absent from site during any survey OR present at relative abundance < 0.05 ind/min for MMAC and < 0.2 ind/min for BEUT.	Significant change in undercut bank habitats (to be quantified with RHAM).	MMAC	BEUT	Any decreased FROC in reach of MMAC & BEUT (refer to sheet 5-FROC, column F: Table 2).
9	Instream vegetation.	TSPA	TSPA is the best indicators of instream vegetation habitats at site. During the baseline survey it was sampled at very low relative abundance of 0.02 ind/min (electrofishing).	TSPA absent for 2 consecutive surveys.	Significant change in Instream vegetation habitats (to be quantified with RHAM).	TSPA		Any decreased FROC in reach of TSPA (refer to sheet 5-FROC, column F: Table 2).

1 Refer to electronic data (DWA, 2010).

15.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B/C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMAR	<i>Anguilla marmorata</i> (Quoy & Gaimard 1824)	2	1	0	1
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	3	2	1	2
ANAT	<i>Amphilius natalensis</i> (Boulenger, 1917)	3	1	0	2
AURA	<i>Amphilius uranoscopus</i> (Pfeffer, 1889)	4	4	3	4
BBRI	<i>Barbus brevipinnis</i> (Jubb, 1966)	1	1	0	1
BEUT	<i>Barbus eutaenia</i> (Boulenger, 1904)	4	4	3	4
BMAR	<i>Labeobarbus marequensis</i> (Smith, 1841)	5	4	3	4
BTRI	<i>Barbus trimaculatus</i> (Peters, 1852)	4	3	2	3
BUNI	<i>Barbus unitaeniatus</i> (Günther, 1866)	4	2	1	3
CANO	<i>Chiloglanis anoterus</i> (Crass, 1960)	5	5	4	5
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	4	4	3	4
CPAR	<i>Chiloglanis paratus</i> (Crass, 1960)	3	2	1	2
CSWI	<i>Chiloglanis swierstrai</i> (Van der Horst, 1931)	2	2	1	2
LCYL	<i>Labeo cylindricus</i> (Peters, 1852)	1	1	0	1
LMOL	<i>Labeo molybdinus</i> (Du Plessis, 1963)	3	3	2	3
MACU	<i>Micralestes acutidens</i> (Peters, 1852)	3	2	1	2
MMAC	<i>Marcusenius macrolepidotus</i> (Peters, 1852)	4	4	3	4
OMOS	<i>Oreochromis mossambicus</i> (Peters, 1852)	3	2	1	2
OPER	<i>Opsaridium peringueyi</i> (Gilchrist & Thompson, 1913)	4	3	2	3
PCAT	<i>Petrocephalus wesselsi</i> (Kramer & Van der Bank, 2000)	3	1	0	1
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	4	4	3	4
TSPA	<i>Tilapia sparrmanii</i> (Smith, 1840)	4	4	3	4
VNEL	<i>Varicorhinus nelspruitensis</i> (Gilchrist & Thompson, 1911)	4	2	1	3

15.6 MACROINVERTEBRATES

15.6.1 Baseline description

The baseline data for the biota is based on an EWR site visit during September 2007 at a flow of 0.51 m³/s. The original SASS5 total score for the site was 231 with 36 taxa and an ASPT of 6.4. The reference total SASS 5 score was established in discussion with DWAF:RQS officials C. Thirion and C. Todd (*pers. comm.*). The reference was set at a SASS5 score of 240, with 34 taxa and an ASPT of > 7.0. The baseline results, together with those for the reference sites, are presented in the electronic information that accompanies this Report series (DWA, 2010). The PES for this site was a B/C (80.5%), and the REC was set as a B.

15.6.2 Indicator taxa

Perlidae, Heptageniidae and Elmidae were selected as indicator taxa for this site. Perlidae prefer cobble areas and velocities > 0.6 m/s. It is necessary that this habitat is not covered with fines. Heptageniidae prefer velocities between 0.3 and 0.6 m/s and can live on substrates other than cobbles. Elmids prefer velocities between 0.3 and 0.6 m/s. Perlidae and Heptageniidae are highly

sensitive to water quality. For both taxa, onset of early summer breeding requires maintenance of high quality water (low in organics and high clarity). The modelled hydraulic parameters associated with the MAINTENANCE DRY flows are not presented for this site, as the EWR and RHAM sites are situated in different stretches of the river, and these data are therefore not valid as a monitoring guideline. Only the generic minimum values for the various parameters are provided per taxon, below, as a guideline for monitoring. Note that these values may differ from site to site depending on the nature of the coarse substrate and the vegetation.

FDI INDICATOR TAXA GENERIC MINIMUM HYDRAULIC HABITAT REQUIREMENTS:	Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	VEG %	Emb %	Alg %
Perlidae	> 0.1	> 0.2	> 0.3	> 0.6	> 5	> 1	> 3	< 10	Isol.
Heptageniidae	> 0.1	> 0.2	> 0.2	> 0.6	> 5	> 0	> 3	< 10	Isol.
Elmidae			> 0.2	> 0.6	> 5	> 0	> 3	< 10	Isol.

15.6.1 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

ECOSPECS: HABITAT	TPCs
Average depth > 0.1 m, maximum depth > 0.2 m.	Maximum depth < 0.25 m.
Average and maximum velocities should be > 0.2 and 0.6 m/s respectively.	Average and maximum velocities less than 0.25 and 0.65 m/s respectively.
> 5% of FCS to be present and a small % of VFCS.	< 5% FCS present.
< 10% algal cover on coarse substrates including bedrock.	> 10% algal cover on coarse substrates including bedrock.
< 10% embeddedness of cobbles.	> 10% embeddedness of cobbles.
Small % of MV to be inundated to a depth of > 0.2 m.	MV exposed or inundated to a depth < 0.2 m.
ECOSPECS: BIOTA	TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: > 225; ASPT value: > 6.2.	SASS5 scores below 230 and ASPT below 6.4.
To ensure that the MIRAI score remains within the range of a B/C category (77.4% - 82.01%), using the same reference data used in this study.	A MIRAI score of 80% or less.
Presence of at least 7 of the following 9 high-scoring taxa: Perlidae, Heptageniidae, Baetidae > 2 spp, Elmidae, Athericidae, Hydropsychidae > 2 spp, and Pyralidae.	Two or more of the following taxa present only as individuals, or absent altogether (for 2 consecutive samples): Perlidae, Heptageniidae, Elmidae, Athericidae, and Pyralidae. Less than 2 spp of Baetidae or Hydropsychidae.
Balanced community structure, i.e. majority of macroinvertebrates at A abundance, certain taxa at B abundance (e.g. Simuliidae, Hydropsychidae, Baetidae, Heptageniidae). No group to dominate the fauna i.e. be present in C abundance (> 100) over more than two consecutive surveys.	The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.

16 RESULTS: ECOSPECS AND TPCs FOR EWR 6: MUTLUMUVI (MUTLUMUVI RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

16.1 ECOCLASSIFICATION SUMMARY OF EWR 6

EWR 6 Mutlumuvi (Mutlumuvi River)				
<p>EIS: HIGH Rare, endangered and unique biota. Taxon species richness high and species intolerant to flow and flow related water quality changes present.</p> <p>PES: C Abstraction, forestry, informal settlements and landuse activities. Impacts flow and non-flow related.</p> <p>REC: B The EIS is high and improvement requires improved system operation which improves the low flow regime.</p> <p>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.</p>				
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

EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 16.2 to 16.7.

16.2 GEOMORPHOLOGY

The REC is the same as the PES. The active channel flows over a bedrock base and is almost free of fines and sands; the only mobile sediment across the EWR site is gravels and cobbles. With catchment degradation and reduced flows the accumulation of sands within the active channel may cause further declines in the PES, but the site is presently considered to be stable. Keeping the accumulation of sands in check and maintaining the instream habitat diversity is the focus of the EcoSpecs and TPCs. There was no available baseline RHAM data for this site, so EcoSpecs and TPCs tied to this format of data could not be generated. EcoSpecs and TPCs are provided for GAI monitoring data in Section 16.2.1.

16.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel mobile sediments (i.e. bedrock excluded): Sands (<6 mm) should not exceed 10%. <ul style="list-style-type: none"> GAI level IV in 2007 measured 0%. Gravels (<60 mm) should be more than 5%. <ul style="list-style-type: none"> GAI level IV in 2007 measured 11%. Cobbles (60 – 250 mm) should not be less than 50%. <ul style="list-style-type: none"> GAI level IV in 2007 measured 78%. </p> <p>Sampling protocol: Sediment is to be sampled in the active channel (bedrock) riffle at the EWR cross-section.</p>
ACTIVE CHANNEL MORPHOLOGY		

Metric	EcoSpec	TPCs
Active channel morphology.	Maintain the channel/reach type.	The site is in a multi-channel, bedrock to mixed anastomosing reach which is strongly bedrock controlled. Whilst the bars have become larger and increasingly stabilised as a result of vegetation, the typically high energy active channels remain almost absent of fine sediment. The multiple bedrock distributaries which are almost free of sands and dunes must be maintained.
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 71%.	

16.3 PHYSICO-CHEMICAL VARIABLES

There was no available baseline RHAM data for this site. EcoSpecs and TPCs relating for the PES and REC are provided in Section 16.3.1 – 16.3.3.

16.3.1 EcoSpecs relating to physico-chemical data: PES

River: Mutlumuvi		EWR 6	Monitoring site: X3H008Q01
Water quality metrics		ECOSPEC: PES	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 42 mS/m (A/B category).	
	pH	The 5 th percentile of the data must range from 6.5 to 8.0, and the 95 th percentile from 6.5 to 8.8.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.0 mg/L.	
	Turbidity	Small to moderate changes to the catchment land-use resulting in minor effects of silting of habitats, largely of a temporary nature, with very intermittent <u>temporary</u> unnaturally high sediment loads and high turbidities.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.125 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 84 mg/m ² .**	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** No periphyton data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

16.3.2 EcoSpecs relating to physico-chemical data: REC

River: Mutlumuvi		EWR: 6	Monitoring site: X3H008Q01
Water quality metrics		ECOSPEC: REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	

River: Mutlumuvi		EWR: 6	Monitoring site: X3H008Q01
Water quality metrics		ECOSPEC: REC	
Physical variables	EC	The 95 th percentile of the data must be ≤ 42 mS/m (A/B category).	
	pH	The 5 th percentile of the data must range from 6.5 to 8.0, and the 95 th percentile from 6.5 to 8.8.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.0 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.025 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be <10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

16.3.3 TPCs relating to physico-chemical data: PES

River: Mutlumuvi		EWR 6	Monitoring site: X3H008Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 13 – 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	
	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 35 – 42 mS/m.	
	pH	The 5 th percentile of the data must be < 6.7 and > 7.8, and the 95 th percentile must be < 6.7 and > 8.6.	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.2 – 7.0 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.56 – 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.1 – 0.125 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 67 – 84 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

16.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 16.4.1.

16.4.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
C	B	Exotic Invasion (perennial exotics).	Riparian zone.	Exotic species cover between 15 - 20%.	An increase in exotic species covers above 20%.	Exotic species cover between 5 - 10%.	VEGRAI recorded < 10% (marginal zone, annuals), 10 - 20% (lower zone), < 10% (upper zone).
		Indigenous Riparian Woody	Marginal zone.	Riparian woody cover between 1 and	An increase in riparian woody cover	Riparian woody cover between 5	VEGRAI recorded < 10% cover.

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
		Cover.		80%.	of more than 70% OR a decrease below 5%.	and 60%.	
	Lower zone.		Riparian woody cover between 5 and 60%.	An increase in riparian woody cover of more than 50% OR a decrease below 10%.	Riparian woody cover between 10 and 50%.	VEGRAI recorded 10 - 20% cover.	
	Upper zone.		Riparian woody cover between 20 and 70%.	A decrease in riparian woody species covers below 20% OR above 70%.	Riparian woody cover between 30 and 60%.	VEGRAI recorded 20 - 40% cover.	
		<i>Phragmites</i> (reed) cover.	Marginal zone.	Reed covers between 10% and 20%.	A decrease in reed cover below 20%.	Reed covers above 30%.	VEGRAI recorded 20 - 30% cover.
	Lower zone.		Reed covers between 10% and 90%.	An increase in reed cover above 80% or a decrease below 20%.	Reed covers between 30% and 80%.	VEGRAI recorded 20 - 40% cover.	
	Upper zone.		Reed covers between 40% and 50%.	An increase in reed cover above 40%.	Reed covers less than 40%.	VEGRAI recorded < 20% cover.	

16.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 16.5.1. The spatial FROC of EWR 6 is provided in Section 16.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

16.5.1 EcoSpecs and TPCs relating to FRAI data: PES

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	
7	Species richness.	All indigenous species.	14 out 29 expected indigenous fish species were sampled during the recent baseline (EWR) survey.	Less than 12 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All species.	Any decreased FROC in reach of indicator species mentioned in this table (refer to sheet 5-FROC ¹) OR FRAI scores decreasing below 65% (C/D EC).	
6	Relative abundance.	N/A.	During recent baseline (EWR) fish were sampled at 5.2 ind/min.	Relative abundance of less than 4.5 ind/min sampled at the site (during same season as baseline data).	N/A.	N/A.	N/A.	
14	Alien fish species.	Any alien/introduced spp.	No alien /introduced fish species sampled at site during recent baseline survey.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien/introduced spp.	Presence of any alien/introduced fish species at site during any survey.	
5	FD Habitats.	CANO, BMAR	During the recent baseline (EWR) survey CANO was present at a relative abundance of 0.50 ind/min and BMAR at 0.55 ind/min.	CANO and BMAR absent during any survey or present at relative abundance of < 0.30 ind/min for CANO and < 0.35 ind/min for BMAR.	Reduced suitability (abundance & quality) of FD & FS habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).	CANO	CPAR	Any decreased FROC in reach of CANO & CPAR (refer to sheet 5-FROC, column G).
3	FS habitats.	CANO, CSWI, BMAR	During the recent baseline (EWR) survey CANO was present at a relative abundance of 0.50 ind/min, CSWI at 0.03 ind/min and BMAR at 0.55 ind/min.	CANO and BMAR absent during any survey or present at relative abundance of < 0.30 ind/min for CANO and < 0.35 ind/min for BMAR and CSWI absent for two consecutive surveys.		CANO	CPAR	
4	Substrate.	CANO, LMOL, BMAR	During the recent baseline (EWR) survey CANO was present at a relative abundance of 0.50 ind/min, LMOL at 0.08 ind/min and BMAR at 0.55 ind/min.	CANO and BMAR absent during any survey or present at relative abundance of < 0.30 ind/min for CANO and < 0.35 ind/min for BMAR and LMOL absent for two consecutive surveys.		CANO	CPAR	
1	Flow dependant spp (flow alteration).	CANO, CSWI, BEUT	CANO & CSWI and BEUT will be most appropriate indicators of flow at the site. During the recent baseline (EWR) survey CANO was present at a relative abundance of 0.50 ind/min, CSWI at 0.03 ind/min and BEUT at 0.43 ind/min.	CANO and BEUT absent during any survey or present at relative abundance of < 0.30 ind/min for CANO and < 0.20 ind/min for BEUT and CSWI absent for two consecutive surveys.		CANO	CSWI		Any decreased FROC in reach of CANO & CSWI (refer to sheet 5-FROC, column G).
2	Water quality intolerance.	CANO, BEUT	CANO and BEUT will be most appropriate indicators of water quality at the site. During the recent baseline (EWR) survey CANO was present at a relative abundance of 0.50 ind/min and BEUT at 0.43 ind/min.	CANO and BEUT absent during any survey OR present at relative abundance of < 0.30 ind/min for CANO and < 0.20 ind/min for BEUT.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	CANO	BEUT	Any decreased FROC in reach of CANO & BEUT (refer to sheet 5-FROC, column G).

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	
12	SD habitats.	OMOS, BMAR	OMOS & BMAR will be most appropriate indicators of SD habitats at the site. During the recent baseline (EWR) survey OMOS was present at a relative abundance of 0.72 ind/min and BMAR at 0.55 ind/min.	OMOS and BMAR absent during any survey or present at relative abundance of < 0.35 ind/min for BMAR and < 0.50 ind/min for OMOS.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).	BUNI	OMOS	Any decreased FROC in reach of BUNI & OMOS (refer to sheet 5-FROC, column G).
9	Water column.	MBRE, BMAR	Species with high indicator value for water column is MBRE & BMAR. During the recent baseline (EWR) survey MBRE was present at a relative abundance of 0.02 ind/min and BMAR at 0.55 ind/min.	BMAR absent during any survey or present at a relative abundance of < 0.35 ind/min and MBRE absent for two consecutive surveys.	Reduction in suitability of water column (i.e. increased sedimentation of pools).	MBRE	BMAR	Any decreased FROC in reach of BMAR & MBRE (refer to sheet 5-FROC, column G).
10	SS habitats.	BVIV, MACU	BVIV & MACU will be most appropriate indicators of SS habitats at the site. During the recent baseline (EWR) survey BVIV was present at a relative abundance of 0.12 ind/min and MACU at 0.03 ind/min.	BVIV absent during any survey or present at a relative abundance of < 0.05 ind/min and MACU absent for two consecutive surveys.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). (To be quantified with RHAM).	BVIV	GGIU	Any decreased FROC in reach of BVIV & GGIU (refer to sheet 5-FROC, column G).
11	Overhanging vegetation.	BVIV, BTRI	BVIV & BTRI will be the most appropriate indicators of overhanging vegetation habitats at the site. During the recent baseline (EWR) survey BVIV was present at a relative abundance of 0.12 ind/min and BTRI at 0.72 ind/min.	BVIV & BTRI absent during any survey or BVIV present with relative abundance < 0.05 ind/min and BTRI < 0.5 ind/min.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BVIV	BUNI	Any decreased FROC in reach of BVIV & BUNI (refer to sheet 5-FROC, column G).
8	Undercut banks.	MMAC, BEUT	MMAC & BEUT will be the most appropriate indicators of undercut banks habitat at the site. During the recent baseline (EWR) survey MMAC was present at a relative abundance of 0.03 ind/min and BEUT at 0.43 ind/min.	BEUT absent during any survey or present at a relative abundance of < 0.20 ind/min and MMAC absent for two consecutive surveys.	Significant change in undercut bank habitats (to be quantified with RHAM).	MMAC	PCAT	Any decreased FROC in reach of MMAC & PCAT (refer to sheet 5-FROC, column G).
13	Instream vegetation.	TREN, BVIV	Species with high indicator value for instream vegetation at this site is TREN & BVIV. During the recent baseline (EWR) survey TREN was present at a relative abundance of 0.07 ind/min and BVIV at 0.12 ind/min.	BVIV absent during any survey or with relative abundance < 0.05 ind/min and TREN absent for two consecutive surveys.	Significant change in Instream vegetation habitats (to be quantified with RHAM).	TREN	BVIV	Any decreased FROC in reach of TREN & BVIV (refer to sheet 5-FROC, column G).

1 Refer to electronic data (DWA, 2010).

16.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	1	1	0	1
BANN	<i>Barbus annectens</i> (Gilchrist & Thompson, 1917)	4	3	2	3
BEUT	<i>Barbus eutaenia</i> (Boulenger, 1904)	4	3	2	4
BFRI	<i>Barbus afrohamiltoni</i> (Crass, 1960)	3	1	0	1
BMAR	<i>Labeobarbus marequensis</i> (Smith, 1841)	5	4	3	5
BPAU	<i>Barbus paludinosus</i> (Peters, 1852)	4	2	1	2
BRAD	<i>Barbus radiatus</i> (Peters, 1853)	4	2	1	2
BTOP	<i>Barbus toppini</i> (Boulenger, 1916)	4	2	1	2
BTRI	<i>Barbus trimaculatus</i> (Peters, 1852)	5	4	3	4
BUNI	<i>Barbus unitaeniatus</i> (Günther, 1866)	5	3	2	3
BVIV	<i>Barbus viviparus</i> (Weber, 1897)	5	4	3	4
CANO	<i>Chiloglanis anoterus</i> (Crass, 1960)	5	4	3	4
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	4	4	3	4
CPAR	<i>Chiloglanis paratus</i> (Crass, 1960)	5	4	3	4
CSWI	<i>Chiloglanis swierstrai</i> (Van der Horst, 1931)	5	3	2	4
GCAL	<i>Glossogobius callidus</i> (Smith, 1937)	3	2	1	2
GGIU	<i>Glossogobius giuris</i> (Hamilton-Buchanan, 1822)	5	3	2	3
LCYL	<i>Labeo cylindricus</i> (Peters, 1852)	5	3	2	4
LMOL	<i>Labeo molybdinus</i> (Du Plessis, 1963)	5	4	3	4
MACU	<i>Micralestes acutidens</i> (Peters, 1852)	5	4	3	4
MBRE	<i>Mesobola brevianalis</i> (Boulenger, 1908)	5	4	3	4
MMAC	<i>Marcusenius macrolepidotus</i> (Peters, 1852)	4	3	2	3
OMOS	<i>Oreochromis mossambicus</i> (Peters, 1852)	5	5	4	5
OPER	<i>Opsaridium peringueyi</i> (Gilchrist & Thompson, 1913)	4	1	0	3
PCAT	<i>Petrocephalus wesselsi</i> (Kramer & Van der Bank, 2000)	4	2	1	2
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	4	4	3	4
SINT	<i>Schilbe intermedius</i> (Rüppell, 1832)	3	2	1	2
SMER	<i>Serranochromis meridianus</i> (Jubb, 1967)	3	2	1	2
TREN	<i>Tilapia rendalli</i> (Boulenger, 1896)	4	4	3	4

16.6 MACROINVERTEBRATES

16.6.1 Baseline description

The baseline data for the biota is based on an EWR site visit during September 2007 at a flow of 0.016 m³/s. The original SASS5 total score for the site was 189 with 32 taxa and an ASPT of 5.9. The reference conditions used to derive the EcoStatus (MIRAI) were based on macroinvertebrate data from the River Health Program 'Rivers Client' for sites X3MUTL-NEWFO, and on discussions with DWAF:RQS officials C. Thirion and C. Todd (*pers. comm.*). The reference SASS5 was set at 270, with 35 taxa and an ASPT of 7.5. The baseline results, together with those for the reference sites, are presented in the electronic information that accompanies this Report series (DWA, 2010). The PES for this site was a B/C (77.7%), and the REC was set as a B.

16.6.2 Indicator taxa

As only a single Perlid was collected at this site, two flow-dependent macroinvertebrate taxa which occurred in A abundances (1 - 10 individuals), Heptageniidae and Hydropsychidae (> 2 spp), were used as indicators for this site. Both prefer cobble substrates and velocities between 0.3 and 0.6 m/s, although they will survive for periods at lower velocity categories and on other substrates. Heptageniidae are highly sensitive and Hydropsychidae are moderately sensitive to water quality.

The hydraulic parameters associated with the MAINTENANCE DRY flows are presented. These data provide an approximation of the minimum values required at the site during the dry season in order to fulfil the FDI population's preferred hydraulic habitat requirements. They thus serve as a guide in the setting of EcoSpecs. Note that at this site, the EWR hydraulic cross-section was through non-critical habitat, whereas biological sampling was done in critical flow habitat. Modelled velocity values are likely to be only approximately half of the actual velocity values (Birkhead, *pers. comm.*). For the purposes of the information provided below, modelled velocity values have thus been doubled (bold).

FDI INDICATOR TAXA GENERIC MINIMUM HYDRAULIC HABITAT REQUIREMENTS:			Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	VEG %	Emb %	Alg %
Heptageniidae			> 0.1	> 0.2	> 0.2	> 0.6	> 7	> 0	> 7	< 10	Isol.
Hydropsychidae						> 0.3	> 3		> 3	< 10	Isol.
RECOMMENDED MAINTENANCE DRY FLOWS HYDRAULICS (with velocities doubled from modelled values, as discussed in text):											
Cat	Flow (m ³ /s)	Season/ Building Block	Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	VEG %	Emb %	Alg %
B/C	0.066	Dry Maint	0.22	0.46	0.02	0.12	0	0	0	< 10	Isol
B	0.163	Dry Maint.	0.25	0.5	0.08	0.28	0	0	0	0	Isol

Note: Velocity ranges are still below the required minima, however the final flow values requested (for fish) and provided, are somewhat higher and will deliver adequate velocities and result in the presence of FCS.

16.6.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

ECOSPECS: HABITAT	TPCs
Average depth > 0.2 m, maximum depth measured > 0.3 m.	Average depth < 0.25 m.
Average and maximum velocities should be > 0.2 and 0.6 m/s respectively.	Average and maximum velocities less than 0.25 and 0.65 m/s
Small % of FCS to be present.	No FCS present.
< 10% algal cover on coarse substrates including bedrock.	> 10% algal cover on coarse substrates including bedrock.
< 10% embeddedness of cobbles.	> 10% embeddedness of cobbles.
ECOSPECS: BIOTA	TPCs
SASS5 scores and ASPT values occur in the following range: SASS5 score: > 180; ASPT value: > 6.	SASS5 scores below 190 and ASPT below 6.
MIRAI score remains within the range of a B/C category (77.4% - 82.01%), using the same reference data used in this study.	A MIRAI score of 80% or less.
Presence of Heptageniidae and Hydropsychidae 2 sp.	Absence of Heptageniidae, and/or less than 2 spp of hydropsychids or individuals only.
Balanced community structure, i.e. majority of macroinvertebrates at A abundance, certain taxa at B abundance (e.g. Simuliidae, Hydropsychidae, Baetidae, and Heptageniidae). No group to dominate the fauna i.e. be present in C abundance (> 100) over more than two consecutive surveys.	The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.

17 RESULTS: ECOSPECS AND TPCs FOR EWR 7: TLULANDZITEKA (TLULANDZITEKA RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

17.1 ECOCLASSIFICATION SUMMARY OF EWR 7

EWR 7 Tlulanziteka (Tlulanziteka 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

EcoSpecs and TPCs for the PES and REC are provided for the different components in Section 17.2 to 17.6.

17.2 GEOMORPHOLOGY

The REC is higher than the PES. Extreme narrowing and stabilisation of the active channel has caused the PES to decline. Historically the reach had a much wider, sandy open channel which is now very narrow, with banks and bars highly stabilised through extensive, dense reed growth. There was no available baseline RHAM data for this site, so EcoSpecs and TPCs tied to this format of data could not be generated. EcoSpecs and TPCs are provided for GAI monitoring data in Section 17.2.1.

17.2.1 TPCs relating to GAI monitoring data: REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	<p>Overall for the in-channel sediments: Sands (<6 mm diameter) must be more than 90%. • GAI level IV in 2007 measured 100%.</p> <p>Sampling protocol: Sediment is to be sampled in the active channel <u>downstream</u> of the bridge (i.e. downstream of the EWR cross-section, this is immediately upstream of the bridge).</p>
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	Historically this reach had a much wider active channel and more open macro-channel (i.e. less vegetation on the macro-channel floor). Currently the banks and bars are highly stabilised by the dense reedbeds.

Metric	EcoSpec	TPCs
		The active channel should widen over time and the density of vegetation on the macro-channel floor reduce with the provision of increased flows and floods; in doing so reducing some of the historical degradation trends.
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should exceed 61%.	

17.3 PHYSICO-CHEMICAL VARIABLES

There was no available baseline RHAM data for this site. EcoSpecs and TPCs relating for the PES and REC are provided in Section 17.3.1 – 17.3.3.

17.3.1 EcoSpecs relating to physico-chemical data: PES

River: Tlulandziteka		EWR 7	Monitoring site: X3H008Q01
Water quality metrics		ECOSPEC: PES	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 42 mS/m (A/B category).	
	pH	The 5 th percentile of the data must range from 6.5 to 8.0, and the 95 th percentile from 6.5 to 8.8.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.0 mg/L.	
	Turbidity	Moderate changes to the catchment land-use resulting in <u>temporary</u> unnaturally high sediment loads and high turbidities.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.125 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be < 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 84 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

17.3.2 EcoSpecs relating to physico-chemical data: REC

River: Tlulandziteka		EWR 7	Monitoring site: X3H008Q01
Water quality metrics		ECOSPEC: REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 42 mS/m (A/B category).	
	pH	The 5 th percentile of the data must range from 6.5 to 8.0, and the 95 th percentile from 6.5 to 8.8.	
	Temperature	Largely natural to small deviation from the natural temperature range.	

River: Tlulandziteka		EWR 7	Monitoring site: X3H008Q01
Water quality metrics		ECOSPEC: REC	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.	
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.025 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be <10 $\mu\text{g/L}$.	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

17.3.3 TPCs relating to physico-chemical data: PES

River: Tlulandziteka		EWR 7	Monitoring site: X3H008Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 13 – 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	
	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 35 – 42 mS/m.	
	pH	The 5 th percentile of the data must be < 6.7 and > 7.8 , and the 95 th percentile must be < 6.7 and > 8.6 .	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.2 – 7.0 mg/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.56 – 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.1 – 0.125 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 $\mu\text{g/L}$.	
	Chl-a periphyton	The 50 th percentile of the data must be 67 – 84 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

17.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 17.4.1.

17.4.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
C	B	Exotic Invasion (perennial exotics).	Riparian zone.	Exotic species cover between 15 - 20%.	An increase in exotic species covers above 20%.	Exotic species cover between 5 - 10%.	VEGRAI recorded data: 10% (marginal zone); 10 - 20% (lower zone); 40 - 60% (upper zone).
		Terrestrialisation.	Lower zone.	Terrestrial woody cover between 5 and 10%.	An increase in terrestrial woody species cover $> 10\%$.	The absence of terrestrial woody species.	Not high, but removal of selected riparian species for wood will facilitate higher values.
			Upper zone.	Terrestrial woody cover between 20 and 30%.	An increase in terrestrial woody species cover $>$	Terrestrial woody cover between 10 and 15%.	As above.

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
					30%.		
		Indigenous Riparian Woody Cover.	Marginal zone.	Riparian woody cover between 1 and 80%.	An increase in riparian woody cover of more than 70% OR a decrease below 5%.	Riparian woody cover between 5 and 60%.	VEGRAI recorded < 10% cover.
	Lower zone.		Riparian woody cover between 5 and 60%.	An increase in riparian woody cover of more than 50% OR a decrease below 10%.	Riparian woody cover between 10 and 50%.	VEGRAI recorded 10 - 20% cover.	
	Upper zone.		Riparian woody cover between 20 and 70%.	A decrease in riparian woody species covers below 20% OR above 70%.	Riparian woody cover between 30 and 60%.	VEGRAI recorded 10 - 20% cover.	
		<i>Phragmites</i> (reed) cover.	Marginal zone.	Reed covers between 10% and 20%.	A decrease in reed cover below 20%.	Reed covers above 30%.	VEGRAI recorded 20 - 40% cover.
	Lower zone.		Reed covers between 10% and 90%.	An increase in reed cover above 80% or a decrease below 20%.	Reed covers between 30% and 80%.	VEGRAI recorded 20 - 40% cover.	
	Upper zone.		Reed covers between 40% and 50%.	An increase in reed cover above 40%.	Reed covers less than 40%.	VEGRAI recorded 10 - 20% cover.	

17.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 17.5.1. The spatial FROC of EWR 7 is provided in Section 17.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

17.5.1 EcoSpecs and TPCs relating to FRAI data: PES

Rank	Metric	Indicator spp.	PES						
			EWR SITE			REACH			
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)		
6	Species richness.	All species.	Five of the 28 expected indigenous fish species were sampled during the baseline (EWR) survey. Sampling conditions were not optimal due to high flows and it can be expected that at least 14 species are present at the site.	Less than 10 fish species sampled during a survey when sampling conditions are optimal and habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All species.	Baseline (PES) FRAI score of 65.4 (C) calculated for reach. Any decreased FROC in reach of indicator species mentioned in this table (refer to sheet 5-FROC ¹) OR FRAI scores decreasing below 62% (category C/D).		
5	Relative abundance.	N/A.	During recent baseline (EWR) survey fish were sampled at 3.5 ind/min. This may be even higher during optimal sampling conditions.	Relative abundance of less than 2 ind/min sampled at the site (during same season as baseline data with optimal sampling conditions).	N/A.	N/A.	N/A.		
8	Alien fish species.	Any alien/introduced spp.	No alien fish species sampled at site during recent surveys.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien/introduced spp.	Presence of any alien/introduced fish species in reach during any survey.		
2	FD habitats.	CANO, BMAR	During recent baseline (EWR) survey CANO was present at site at a relative abundance of 0.15 ind/min and BMAR at a relative abundance of 1.56 ind/min.	CANO and BMAR absent from site during any survey OR present at relative abundance < 0.1 ind/min for CANO and < 1.2 ind/min for BMAR.	Reduced suitability (abundance & quality) of FD & FS habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).	CANO	CPAR	Any decreased FROC in reach of CANO & CPAR (refer to sheet 5-FROC, column G).	
	FS habitats.	CANO, BMAR				CANO	CPAR		
	Substrate.	CANO, BMAR				CANO	CPAR		
1	Flow dependant spp (flow alteration).	CANO, BEUT	CANO & BEUT will be most appropriate indicators of flow at the site. During the recent baseline survey CANO was present at site at a relative abundance of 0.15 ind/min and BEUT at a relative abundance of 1.13 ind/min.	CANO and BEUT absent from site during any survey OR present at relative abundance < 0.1 ind/min for CANO and < 0.9 ind/min for BEUT.		CANO	CSWI	Any decreased FROC in reach of CANO & CSWI (refer to sheet 5-FROC, column G).	
	Water quality intolerance.	CANO, BEUT			Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	CANO	BEUT	Any decreased FROC in reach of CANO & BEUT (refer to sheet 5-FROC, column G).	
7	SD habitats.	OMOS, BMAR	OMOS & BMAR will be most appropriate indicators of SD, SS & water column habitats at the site. During recent baseline (EWR) survey OMOS was present at site at a relative abundance of 0.02 ind/min and BMAR at a relative abundance of 1.56 ind/min.	OMOS and BMAR absent from site during any survey OR BMAR present at relative abundance of < 1.2 ind/min.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).	BUNI	OMOS	Any decreased FROC in reach of BUNI & OMOS (refer to sheet 5-FROC, column G).	
	Water column.	BMAR, OMOS					MBRE	BMAR	Any decreased FROC in reach of MBRE & BMAR (refer to sheet 5-FROC, column G).
	SS habitats.	OMOS, BMAR					BVIV	BUNI	Any decreased FROC in reach of BVIV & BUNI (refer to sheet 5-FROC, column G).

Rank	Metric	Indicator spp.	PES					
			EWR SITE			REACH		
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)
					sedimentation of slow habitats) (to be quantified with RHAM).			
3	Overhanging vegetation.	BTRI, BEUT	BTRI & BEUT will be most appropriate indicators of overhanging vegetation habitats at the site. During recent baseline (EWR) survey BTRI was present at site at a relative abundance of 0.67 ind/min and BEUT at a relative abundance of 1.13 ind/min.	BTRI and BEUT absent from site during any survey OR present at relative abundance < 0.40 ind/min for BTRI and < 0.9 ind/min for BEUT.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BVIV	BUNI	Any decreased FROC in reach of BVIV & BUNI (refer to sheet 5-FROC, column G).
4	Undercut banks.	BEUT	BEUT is the most appropriate indicator of undercut banks at this site. During recent baseline (EWR) survey BEUT was present at site at a relative abundance of 1.13 ind/min	BEUT absent during any survey or present with relative abundance < 0.9 ind/min.	Significant change in undercut bank habitats (to be quantified with RHAM).	MMAC	PCAT	Any decreased FROC in reach of MMAC & PCAT I (refer to sheet 5-FROC, column G).
9	Instream vegetation.	(TREN, BVIV, BPAU & BANO)	No indicator species for instream vegetation were sampled during the recent baseline (EWR) survey and therefore the TPCs and EcoSpecs for this habitat at this site cannot be derived at present. Should any of these species be sampled in future, TPCs should be derived at that stage.		Significant change in Instream vegetation habitats (to be quantified with RHAM).	TREN	BVIV	Any decreased FROC in reach of TREN & BVIV (refer to sheet 5-FROC, column G).

1 Refer to electronic data (DWA, 2010).

17.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	2	1	0	1
BANN	<i>Barbus annectens</i> (Gilchrist & Thompson, 1917)	4	2	1	2
BANO	<i>Barbus anoplus</i> (Weber, 1897)	3	2	1	2
BBRI	<i>Barbus brevipinnis</i> (Jubb, 1966)	3	1	0	2
BEUT	<i>Barbus eutaenia</i> (Boulenger, 1904)	4	3	2	4
BMAR	<i>Labeobarbus marequensis</i> (Smith, 1841)	5	4	3	4
BNEE	<i>Barbus neefi</i> (Greenwood, 1962)	3	2	1	2
BPAU	<i>Barbus paludinosus</i> (Peters, 1852)	4	3	2	3
BRAD	<i>Barbus radiatus</i> (Peters, 1853)	4	3	2	3
BTRI	<i>Barbus trimaculatus</i> (Peters, 1852)	5	4	3	4
BUNI	<i>Barbus unitaeniatus</i> (Günther, 1866)	5	4	3	4
BVIV	<i>Barbus viviparus</i> (Weber, 1897)	5	4	3	5
CANO	<i>Chiloglanis anoterus</i> (Crass, 1960)	5	4	3	5
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	4	4	3	4
CPAR	<i>Chiloglanis paratus</i> (Crass, 1960)	5	3	2	4
CSWI	<i>Chiloglanis swierstrai</i> (Van der Horst, 1931)	5	2	1	4
LCYL	<i>Labeo cylindricus</i> (Peters, 1852)	5	2	1	4
LMOL	<i>Labeo molybdinus</i> (Du Plessis, 1963)	5	3	2	4
MACU	<i>Micralestes acutidens</i> (Peters, 1852)	5	3	2	4
MBRE	<i>Mesobola brevianalis</i> (Boulenger, 1908)	5	3	2	3
MMAC	<i>Marcusenius macrolepidotus</i> (Peters, 1852)	4	2	1	3
OMOS	<i>Oreochromis mossambicus</i> (Peters, 1852)	5	5	4	5
OPER	<i>Opsaridium peringueyi</i> (Gilchrist & Thompson, 1913)	4	2	1	3
PCAT	<i>Petrocephalus wesselsi</i> (Kramer & Van der Bank, 2000)	4	1	0	2
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	4	3	2	4
SINT	<i>Schilbe intermedius</i> (Rüppell, 1832)	3	1	0	2
SMER	<i>Serranochromus meridianus</i> (Jubb, 1967)	3	2	1	2
TREN	<i>Tilapia rendalli</i> (Boulenger, 1896)	4	3	2	4

17.6 MACROINVERTEBRATES

17.6.1 Baseline description

The baseline data for the biota are based on an EWR site visit during September 2007 at a flow of 0.059 m³/s. The original SASS5 total score for the site was 197 with 32 taxa and an ASPT of 6.2. The reference condition was established in discussion with DWAF:RQS officials C. Thirion and C. Todd (*pers. comm.*). The SASS5 was set at 250, with 35 taxa and an ASPT of 7. The baseline results, together with those for the reference sites, are presented in the electronic information that accompanies this Report series (DWA, 2010). The PES for this site was a B/C (78.1%), and the REC was set as a B.

17.6.2 Indicator taxa

The sensitive taxa collected at this site were Heptageniidae, Baetidae (> 2 spp), Perlidae, Chlorocyphidae, Hydropsychidae (> 2 spp), Helodidae, and Athericidae. Of these, perlids, elmids and heptageniids were used as indicator taxa. Perlidae prefer cobble substrates and velocities > 0.6 m/s. Elmidae and Heptageniidae prefer velocities between 0.3 and 0.6 m/s and cobble substrates, although they can also survive at other velocity categories and live on other substrates. Perlidae and Heptageniidae are highly sensitive to water quality whereas Elmidae are moderately sensitive to water quality. The hydraulic parameters associated with the MAINTENANCE DRY flows are presented. These data provide an approximation of the minimum values required at the site during the dry season in order to fulfil the FDI population's preferred hydraulic habitat requirements. They thus serve as a guide in the setting of EcoSpecs, particularly in the event that the EWR and RHAM sites are not in the same locality.

FDI INDICATOR TAXA GENERIC MINIMUM HYDRAULIC HABITAT REQUIREMENTS:			Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	VEG %	Emb %	Alg %
Perlidae			> 0.1	> 0.15	> 0.3	> 0.6	> 10	> 0	Small	< 10	Isol.
Heptageniidae			> 0.1	> 0.15	> 0.3	> 0.6	> 10	> 0	Small	< 10	Isol.
Elmidae					> 0.3	> 0.6	> 10	> 0	Small	< 10	Isol.
RECOMMENDED DRY SEASON MAINTENANCE FLOWS HYDRAULICS											
Cat	Flow (m ³ /s)	Season/Building Block	Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	VEG %	Emb %	Alg %
B/C	0.09	Dry Maint	0.1	0.16	0.39	1.12	32	15	Small	< 5	Isol
B	0.15	Dry Maint.	0.11	0.2	0.47	1.28	28	22	Small	0	0

Note: Marginal vegetation %s were not measured and modelled at this site.

17.6.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

ECOSPECS: HABITAT	TPCs
Average depth >0.1m, Maximum depth > 0.15 m.	Maximum depth < 0.17 m.
Average and maximum velocities > 0.3 and 0.6 m/s respectively.	Average and maximum velocities less than 0.32 and 0.65 m/s respectively.
> 10% FCS and of VFCS.	< 10% FCS and/or VFCS.
< 10% algal cover on coarse substrates and/or MV.	> 10% algal cover on coarse substrates including bedrock.
< 5% embeddedness of cobbles.	Any embeddedness of cobbles.
ECOSPECS: BIOTA	TPCs
SASS5 scores and ASPT values occur in the following range: SASS5 score: > 190; ASPT value: > 6.	SASS5 scores below 195 and ASPT below 6.2.
MIRAI score remains within the range of a B/C category (77.4% - 82.01%), using the same reference data used in this study.	A MIRAI score of 80% or less.
Presence of at least 4 of the following 5 taxa at A (or greater) abundance: Perlidae, Heptageniidae, Chlorocyphidae, Helodidae, Athericidae. At least 2 spp of Hydropsychidae and Baetidae.	Absence (or individuals only) of any 2 of the following taxa over Perlidae, Heptageniidae, Chlorocyphidae, Helodidae, Athericidae. Less than 2 spp of baetids or hydropsychids.
Balanced community structure, i.e. majority of macroinvertebrates at A abundance, certain taxa at B abundance (e.g. Simuliidae, Hydropsychidae, Baetidae, and Heptageniidae). No group to dominate the fauna, i.e. be present in C abundance (> 100) over more than two consecutive surveys.	The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.

18 RESULTS: ECOSPECS AND TPCs FOR EWR 8: LOWER SAND (SAND RIVER)

A summary of the site EcoClassification is provided below (DWA, 2009b).

18.1 ECOCLASSIFICATION SUMMARY OF EWR 8

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

EcoSpecs (PES and REC) and TPCs (PES) are provided for the different components in Section 18.2 to 18.7.

18.2 GEOMORPHOLOGY

The REC is the same as the PES. The river here is a sand-dominated system flowing over underlying bedrock. Within the active channel the accumulation of sand and subsequent smothering of bedrock influence combined with the narrowing of the channel itself have resulted in a decline in the PES and are the focus of the EcoSpecs and TPCs. EcoSpecs and TPCs are provided for RHAM monitoring data in Section 18.2.1 and GAI monitoring data in Section 18.2.2.

18.2.1 EcoSpecs and TPCs relating to RHAM monitoring data

Metric	EcoSpec	TPCs																								
ACTIVE CHANNEL SUBSTRATE CHANGES																										
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	Overall for the in-channel sediments: Sand percentage should not exceed 60%. • RHAM monitoring in 2009 measured 46%.																								
The percentage substrate type within the active channel at the RHAM site is provided below.																										
<table border="1"> <caption>Substrate Type Percentages</caption> <thead> <tr> <th>Substrate Type</th> <th>Overall site (%)</th> <th>Fast habitats (%)</th> </tr> </thead> <tbody> <tr> <td>Roots</td> <td>~2</td> <td>0</td> </tr> <tr> <td>Fines</td> <td>~10</td> <td>0</td> </tr> <tr> <td>Sand</td> <td>~46</td> <td>~12</td> </tr> <tr> <td>Gravel</td> <td>0</td> <td>0</td> </tr> <tr> <td>Cobbles</td> <td>0</td> <td>0</td> </tr> <tr> <td>Boulders</td> <td>0</td> <td>0</td> </tr> <tr> <td>Bedrock</td> <td>~43</td> <td>~8</td> </tr> </tbody> </table>			Substrate Type	Overall site (%)	Fast habitats (%)	Roots	~2	0	Fines	~10	0	Sand	~46	~12	Gravel	0	0	Cobbles	0	0	Boulders	0	0	Bedrock	~43	~8
Substrate Type	Overall site (%)	Fast habitats (%)																								
Roots	~2	0																								
Fines	~10	0																								
Sand	~46	~12																								
Gravel	0	0																								
Cobbles	0	0																								
Boulders	0	0																								
Bedrock	~43	~8																								

IN-CHANNEL HABITAT DIVERSITY		
Percentage of instream habitat per depth-velocity class and per substrate type is provided below.		
ACTIVE CHANNEL GEOMETRY		
Active channel width.	Maintain channel width.	For discharges around 0.5 m ³ /s the average width of the active channel should be between 4 and 7 m wide. <ul style="list-style-type: none"> RHAM monitoring in 2009 measured 5.4 m.

18.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Metric	EcoSpec	TPCs
ACTIVE CHANNEL SUBSTRATE CHANGES		
In-channel sediment (substrate) distribution.	Maintain the bed material size distribution within the active channel in order to maintain the available physical habitats.	The majority of the mobile sediment at the site is sand. There is no TPC linked to this EcoSpec.
ACTIVE CHANNEL MORPHOLOGY		
Active channel morphology.	Maintain the channel/reach type.	The site is located within a mixed anastomosing reach which is characterised by Multiple mixed (sandy with bedrock influence) active channels across the macro-channel floor. The bars are often densely vegetated with reeds. During the wet season, several of these distributary channels should remain activated in order to provide a variety of habitat types for instream biota.
	Maintain at least one active channel.	At least one active flowing channel should be maintained throughout the year at this site.
GAI level IV EC		
GAI level IV PES score.	Maintain or improve the GAI score. PES score from the GAI level IV should equal or exceed 71%.	

18.3 PHYSICO-CHEMICAL VARIABLES

TPCs relating to the RHAM water quality indicators are provided in Section 18.3.1 and EcoSpecs and TPCs for the PES and REC in Section 18.3.2 – 18.3.4.

18.3.1 TPCs relating to RHAM water quality indicators

	RHAM indicators					
	Water odour type and extent	Filamentous algae in water column	Water colour and extent	Turbidity/clarity	Water surface indicator and extent	Algal cover on hard surfaces
PES/baseline (RHAM survey)	None	1	Brown, 2	2 ¹	None	1
TPC	Cattle: ≥ 3 Chemical pollution: ≥ 1 Other sources: ≥ 2 Trigger R-DRAM	> 3	Green: ≥ 3. All other colours: ≥ 1. Trigger R-DRAM*	≥ 2 Trigger R-DRAM**	All indicators: ≥ 2: Salt deposits: ≥ 1: Trigger R-DRAM	> 4
Activity at site: None (conservation area)						

* R-DRAM:

Orange water: pH metric

Milky water: Salt and organic metrics

Green: Nutrient metric

** R-DRAM:

Turbidity indicators

1 The TPC was reached during the RHAM monitoring survey. The recording for *water colour and extent* was incorrectly recorded, as *turbidity/clarity* is scored separately and is not covered under the *water colour* indicator.

18.3.2 EcoSpecs relating to physico-chemical data: PES and REC

River: Sand		EWR 8	Monitoring site: X3H008Q01
Water quality metrics		ECOSPEC: PES and REC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be ≤ 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be ≤ 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be ≤ 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be ≤ 21 mg/L.	
	NaCl	The 95 th percentile of the data must be ≤ 45 mg/L.	
	CaSO ₄	The 95 th percentile of the data must be ≤ 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be ≤ 42 mS/m (A/B category).	
	pH	The 5 th percentile of the data must range from 6.5 to 8.0, and the 95 th percentile from 6.5 to 8.8.	
	Temperature	Small deviation from the natural temperature range.	
	Dissolved oxygen	The 5 th percentile of the data must be ≥ 7.5 mg/L.	
	Turbidity	Small to moderate changes to the catchment land-use resulting in minor effects of silting of habitats, largely of a temporary nature, with very intermittent <u>temporary</u> unnaturally high sediment loads and high turbidities.	
Nutrients	TIN	The 50 th percentile of the data must be ≤ 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be ≤ 0.125 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be <10 µg/L.**	
	Chl-a periphyton	The 50 th percentile of the data must be ≤ 21 mg/m ² .**	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the TWQR as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

** No periphyton or phytoplankton data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

18.3.3 TPCs relating to physico-chemical data: PES

River: Sand		EWR 8	Monitoring site: X3H008Q01
Water quality metrics		TPC	
Inorganic salts*	MgSO ₄	The 95 th percentile of the data must be 13 – 16 mg/L.	
	Na ₂ SO ₄	The 95 th percentile of the data must be 16 – 20 mg/L.	
	MgCl ₂	The 95 th percentile of the data must be 12 – 15 mg/L.	
	CaCl ₂	The 95 th percentile of the data must be 17 – 21 mg/L.	
	NaCl	The 95 th percentile of the data must be 36 – 45 mg/L.	

River: Sand		EWR 8	Monitoring site: X3H008Q01
Water quality metrics		TPC	
	CaSO ₄	The 95 th percentile of the data must be 280 – 351 mg/L.	
Physical variables	EC	The 95 th percentile of the data must be 35 – 42 mS/m.	
	pH	The 5 th percentile of the data must be < 6.7 and > 7.8, and the 95 th percentile must be < 6.7 and > 8.6.	
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
	Dissolved oxygen	The 5 th percentile of the data must be 7.8– 7.5 g/L. Initiate baseline monitoring for this variable if Level II or higher of the DSS.	
Nutrients	TIN	The 50 th percentile of the data must be 0.56 – 0.7 mg/L.	
	PO ₄ -P	The 50 th percentile of the data must be 0.1 – 0.125 mg/L.	
Response variables	Chl-a phytoplankton	The 50 th percentile of the data must be 8 – 10 µg/L.	
	Chl-a periphyton	The 50 th percentile of the data must be 17 – 21 mg/m ² .	
	Toxics	An impact is expected if the 95 th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).	

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

18.4 DIATOMS

EcoSpecs and TPCs relating to the RHAM water quality indicators are the same as for EWR 1 (Crocodile River) (Section 4.4.1).

18.5 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the RHAM and VEGRAI data are provided Section 18.5.1. The confidence is high as both RHAM and VEGRAI data are available.

18.5.1 EcoSpecs and TPCs relating to RHAM and VEGRAI monitoring data: PES

PES	REC	Assessed component	Zone assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Note
B	B	Exotic Invasion (perennial exotics).	Riparian zone.	Exotic species cover between 5 - 10%.	An increase in exotic species covers above 10%.	Exotic species cover between 1-5%.	VEGRAI recorded < 10% exotic cover in all zones; no exotics were recorded in the RHAM assessment.
		Terrestrialisation.	Lower zone.	The absence of terrestrial woody species.	An increase in terrestrial woody species cover > 5%.	The absence of terrestrial woody species.	RHAM site different from VEGRAI, and does not extend into the upper zone. No terrestrial species occurred in plots.
		Phragmites (reed) cover.	Marginal zone.	Reed covers above 30%.	A decrease in reed cover below 30%.	Reed covers above 30%.	RHAM recorded an average of 60% cover.
			Lower zone.	Reed covers between 20% and 80%.	An increase in reed cover above 80% or a decrease below 20%.	Reed covers between 20% and 80%.	RHAM recorded an average of 14% cover; this baseline value falls below the TPC. It is therefore necessary to increase the sampling area of subsequent RHAM assessments and to recheck. VEGRAI recorded a range of 40 - 60% cover which is well above the TPC, but is at a different position on the river.

18.6 FISH

EcoSpecs and TPCs are provided for RHAM monitoring and FRAI data in Section 18.6.1. The spatial FROC of EWR 8 is provided in Section 18.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

18.6.1 EcoSpecs and TPCs relating to RHAM and FRAI data: PES

Metric	Indicator spp.	PES					REC	
		EWR SITE			REACH		REACH	
		ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS	
Species richness.	All indigenous species.	Thirteen of the 30 expected indigenous fish species (for the reach) were sampled during the baseline (EWR) survey at EWR 8.	Less than 10 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features (to be quantified by RHAM).	All indigenous species.	Baseline (PES) FRAI score of 86.8% (B) calculated for reach. Any decreased FROC in reach of especially BMAR, LCYL, LMOL, OPER, CSWI, and BVIV (refer to sheet 5-FROC: Table 2') OR FRAI scores decreasing below 82.5% (B EC).	N/A PES = REC	
Relative abundance.	N/A.	During recent surveys fish were sampled at 13.1 ind/min.	Relative abundance of less than 8.0 ind/min sampled at the site (during same season as baseline data) when habitat can be sampled efficiently.		N/A.			
Alien fish species.	Any alien/introduced spp.	No alien fish species sampled at site during recent surveys.	Presence of any alien/introduced fish species at site during any survey.	N/A.	Any alien/introduced spp.	Presence of any alien/introduced fish species at site during any survey.		
FD Habitats.	BMAR, LCYL & LMOL	BMAR & LCYL will be most appropriate indicators of these metrics at the site. BMAR is expected to always be present at the site at a relative abundance of 0.24 ind/min electrofishing (conditions similar to baseline conditions). Under baseline survey LCYL were absent at site EWR8 while LMOL was monitored at very low numbers (0.02 ind/min.)	BMAR absent during any survey (or with relative abundance < 0.18 ind/min.) AND/OR both LMOL and LCYL absent during any survey.	Reduced suitability (abundance & quality) of the flow dependant species in FD, FS and substrate habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).	BMAR	LCYL		Any decreased FROC in reach of BMAR, LCYL, LMOL, CSWI and OPER (refer to sheet 5-FROC, column F: Table 2).
FS habitats.					LCYL	BMAR		
Substrate.					LCYL	LMOL		
Flow dependant spp (flow alteration).					CSWI	OPER			Any decreased FROC in reach of CSWI and OPER (refer to sheet 5-FROC, column F: Table 2).
Water quality intolerance.	LCYL & LMOL	Under baseline survey LCYL were absent at site EWR 8 while LMOL was monitored at very low numbers (0.02 ind/min.)	Both LMOL and LCYL absent during any survey.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	CANO	OPER		Any decreased FROC in reach of CANO and OPER (refer to sheet 5-FROC, column F: Table 2).
SD habitats.	TREN & OMOS	TREN & OMOS will be most appropriate indicators of SD habitats and expected to always be present at the site. Under baseline conditions TREN was monitored at a relative abundance of 0.17 ind/min, while OMOS was monitored at 3.69 ind/min.	TREN and OMOS absent during any survey AND/OR TREN present with relative abundance < 0.10 ind/min and OMOS < 2.0 ind/min.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).	TREN	OMOS		Any decreased FROC in reach of TREN and OMOS (refer to sheet 5-FROC, column F: Table 2).
Water column.	BMAR & OMOS	BMAR & OMOS will be most appropriate indicators of Water column	BMAR and OMOS absent during any survey AND/OR	Reduction in suitability of water column (i.e. increased	BMAR	OMOS		Any decreased FROC in reach of BMAR and OMOS (refer to

Metric	Indicator spp.	PES					REC
		EWR SITE			REACH		REACH
		ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
		habitats and expected to always be present at the site. Under baseline conditions BMAR was sampled at a relative abundance of 0.24 ind/min electrofishing and OMOS was monitored at a relative abundance of 3.69 ind/min.	BMAR present with relative abundance < 0.18 ind/min and OMOS < 2.0 ind/min.	sedimentation of pools).			sheet 5-FROC, column F: Table 2).
SS habitats.	TREN & BVIV	TREN & BVIV will be most appropriate indicators of SS, overhanging vegetation and instream vegetation habitats and expected to always be present at the site. Under baseline conditions TREN was monitored at a relative abundance of 0.17 ind/min, and BVIV was monitored at a relative abundance of 4.05 ind/min,.	TREN & BVIV absent during any survey AND/OR TREN present with relative abundance < 0.10 ind/min and BVIV < 2.0 ind/min.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).	BVIV	TREN	Any decreased FROC in reach of TREN and BVIV (refer to sheet 5-FROC, column F: Table 2).
Overhanging vegetation.				Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BVIV	TREN	
Instream vegetation.				Significant change in overhanging vegetation habitats (to be quantified with RHAM).	TREN	BVIV	
Undercut banks.	PPHI	PPHI is the best indicators of undercut banks and should be present at site EWR 8 100% of the time at a relative abundance > 3.81 ind/min.	PPHI absent during any survey or present with relative abundance < 0.2 ind/min.	Significant change in undercut bank habitats (to be quantified with RHAM).	MMAC	PPHI	Any decreased FROC in reach of MMAC and PPHI (refer to sheet 5-FROC, column F: Table 2).

1 Refer to electronic data (DWA, 2010).

18.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
AMAR	<i>Anguilla marmorata</i> (Quoy & Gaimard 1824)	1	1	0	Same as PES
AMOS	<i>Anguilla mossambica</i> (Peters 1852)	1	1	0	
BANN	<i>Barbus annectens</i> (Gilchrist & Thompson, 1917)	4	3	2	
BFRI	<i>Barbus afrohamiltoni</i> (Crass, 1960)	3	3	2	
BIMB	<i>Brycinus imberi</i> (Peters, 1852)	4	3	2	
BMAR	<i>Labeobarbus marequensis</i> (Smith, 1841)	5	5	4	
BRAD	<i>Barbus radiatus</i> (Peters, 1853)	3	3	2	
BTOP	<i>Barbus toppini</i> (Boulenger, 1916)	3	3	2	
BTRI	<i>Barbus trimaculatus</i> (Peters, 1852)	5	5	4	
BUNI	<i>Barbus unitaeniatus</i> (Günther, 1866)	3	3	2	
BVIV	<i>Barbus viviparus</i> (Weber, 1897)	5	5	4	
CANO	<i>Chiloglanis anoterus</i> (Crass, 1960)	2	1	0	
CGAR	<i>Clarias gariepinus</i> (Burchell, 1822)	4	4	3	
CPAR	<i>Chiloglanis paratus</i> (Crass, 1960)	4	2	1	
CSWI	<i>Chiloglanis swierstrai</i> (Van der Horst, 1931)	4	2	1	
GCAL	<i>Glossogobius callidus</i> (Smith, 1937)	2	2	1	
GGIU	<i>Glossogobius giuris</i> (Hamilton-Buchanan, 1822)	3	2	1	
LCYL	<i>Labeo cylindricus</i> (Peters, 1852)	5	4	3	
LMOL	<i>Labeo molybdinus</i> (Du Plessis, 1963)	5	4	3	
LROS	<i>Labeo rosae</i> (Steindachner, 1894) (<i>Labeo alteviliis</i>)	3	3	2	
MACU	<i>Micralestes acutidens</i> (Peters, 1852)	4	4	3	
MBRE	<i>Mesobola brevianalis</i> (Boulenger, 1908)	3	3	2	
MMAC	<i>Marcusenius macrolepidotus</i> (Peters, 1852)	4	3	2	
OMOS	<i>Oreochromis mossambicus</i> (Peters, 1852)	5	5	4	
OPER	<i>Opsaridium peringueyi</i> (Gilchrist & Thompson, 1913)	2	1	0	
PCAT	<i>Petrocephalus wesselsi</i> (Kramer & Van der Bank, 2000)	2	1	0	
PPHI	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	4	4	3	
SINT	<i>Schilbe intermedius</i> (Rüppell, 1832)	3	3	2	
SMER	<i>Serranochromis meridianus</i> (Jubb, 1967)	3	3	2	
TREN	<i>Tilapia rendalli</i> (Boulenger, 1896)	5	5	4	
HVIT	<i>Hydrocynus vittatus</i> (Castelnau, 1861)	1	1	0	

18.7 MACROINVERTEBRATES

18.7.1 Baseline description

The baseline data for the biota are based on an EWR site visit during September 2007 at a flow of 0.0001 m³/s. The original SASS5 total score for the site was 105 with 20 taxa and an ASPT of 5.3. The reference conditions used to derive the EcoStatus (MIRAI) were based on macroinvertebrate data from the River Health Program 'Rivers Client' for XSAND-SKUKU, and in discussion with DWAF:RQS officials C. Thirion and C. Todd (*pers. comm.*). The SASS5 was set at 250, with 35 taxa and an ASPT of 7. The baseline results, together with those for the reference sites, are

presented in the electronic information that accompanies this Report series (DWA, 2010). The PES for this site was a C (68.8%), and the REC was set as a B.

18.7.2 Indicator taxa

The only flow-dependent family occurring commonly at the site at the time of sampling was Heptageniidae, which prefer cobble substrates, velocities between 0.3 and 0.6 m/s, and very good quality water. The balance of the fauna was typical of a temporary sand-dominated system with a marginal vegetation component. Marginal vegetation taxa included atyid shrimps, dytiscids and hydrophilids. The modelled hydraulic parameters associated with the MAINTENANCE DRY flows are not presented for this site, as the EWR and RHAM sites are situated in different stretches of the river, and these data are therefore not valid as a monitoring guideline. Only the generic minimum values for the various parameters are provided per taxon, below, as a guideline for monitoring. Note that these values may differ from site to site depending on the nature of the coarse substrate and the vegetation.

FDI INDICATOR TAXA GENERIC MINIMUM HYDRAULIC HABITAT REQUIREMENTS:	Ave Depth m	Max Depth m	Ave vel. m/s	Max vel. m/s	FCS %	VFCS %	VEG % NM	Emb %	Alg %
Heptageniidae	> 0.1	> 0.15	> 0.3	≥ 0.6	N/A	N/A	> 15	N/A	Isol.

18.7.3 EcoSpecs and TPCs relating to RHAM and MIRAI monitoring data: REC

The TPCs and EcoSpecs are provided for habitat and biota at REC conditions.

ECOSPECS: HABITAT	TPCs
Maximum depth > 0.15 m.	Maximum depth < 0.17 m.
Average and maximum velocities should be > 0.3 and > 0.6 m/s respectively.	Average and maximum velocities less than 0.32 and 0.65 m/s respectively.
> 15% inundated marginal vegetation to be present.	< 17% inundated marginal vegetation.
< 10% algal cover on bedrock and/or MV.	> 10% algal cover on bedrock or MV.
ECOSPECS: BIOTA	TPCs
SASS5 scores and ASPT values occur in the following range: SASS5 score: > 100; ASPT value: > 5.	SASS5 scores below 105 and ASPT below 5.3.
MIRAI score remains within the range of a C category (62.01% - 77.04%), using the same reference data used in this study.	A MIRAI score of 66% or less.
Presence of Heptageniidae and Atyidae.	Absence (or individuals only) of Heptageniidae and Atyidae
Balanced community structure, i.e. majority of invertebrates at A abundance, certain taxa at B abundance (e.g. Simuliidae). No group to dominate the fauna i.e. be present in C abundance (> 100) over more than two consecutive surveys.	The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.

19 RECOMMENDATIONS

To date formal implementation of the monitoring step of the Reserve has not taken place (CJ Kleynhans, C Thirion, *pers. comm*). Furthermore, there has been minimal (only informally on the Palmiet River and on a private dam in the Western Cape) implementation (with reference to the supply of the flows and management of other drivers to achieve the required EC) of the Ecological Reserve. This is of major concern as all EWRs, EcoSpecs; TPCs etc. are hypotheses until tested. With increased development and pressure on the water resources in this country there are no structures in place to monitor the further deterioration of our rivers. All methods related to monitoring and the identification of EcoSpecs and TPCs therefore require testing and refinement.

The Crocodile River system has high demands imposed on it by the irrigation sector, international requirements (IncoMaputo Water Use Agreement) as well as industrial and domestic sectors. The Sabie-Sand River system supplies the bulk of the irrigation requirements in this sub-catchment as well as international water requirements. These river systems are also of national importance with respect to the Kruger National Park (KNP) and monitoring is of vital importance.

No specific Ecological Reserve Monitoring has been initiated in the Crocodile and Sabie Sand River systems. The results generated from the Instream Flow Requirement undertaken in 1996 at comprehensive level in the Sabie-Sand sub-catchment, is now outdated as no monitoring was initiated after this assessment. A single national River Health Programme survey was undertaken approximately 14 years ago. Some provincial monitoring has taken place since. The survey results undertaken during the previous Reserve study on the Crocodile River (Godfrey, 2002) during 2002 now serves as historical data and cannot be used as part of the baseline. EWR 3 on the Crocodile River has been surveyed extensively as it has been part of various pilot studies and testing of procedures.

Immediate monitoring is necessary as the surveys undertaken during the Reserve study represent the baseline against which change is measured. These surveys were undertaken during 2007 and it can already (pending changes in the catchments), not be applicable. The longer monitoring is delayed, the bigger the chance is that the baseline surveys will have to be repeated because of outdated data.

The RHAM was developed during 2007 – 2009. A RHAM survey was undertaken during 2009 and this data is available as part of the electronic information and data of this study (RDM Report 26/8/3/10/14/016) (DWA, 2010) and from D:RQS (Dr CJ Kleynhans). The D:RQS is currently analysing the data to further streamline the monitoring techniques and process to determine EcoSpecs and TPCs. As a low intensity method aimed to minimise the dependence on specialist resources, it is important that the methods are included in the monitoring.

For the RHAM to be successfully used in future to set EcoSpecs and TPCs, the RHAM MUST take place at the same time as the EWR survey during which the hydraulic cross-section is surveyed and or a hydraulic calibration obtained. This will provide a link between the hydraulic predictive data and the more extensive habitat coverage provided by the RHAM.

It is **VERY IMPORTANT** to note that the R-DRAM was specifically designed for use within EWRM at a Level 3 assessment and that it is still under development. Under no circumstances should this rapid assessment method be applied to any higher level of assessment within the DSS framework

of the EWRM or any other riverine related monitoring programme. At higher levels of assessment, procedures as outlined in Taylor *et al.* (2007) should be followed at all times.

The R-DRAM is still under development and by no means finalized. This rapid assessment method needs to undergo comprehensive field testing and further refinement and users of this method are instructed to proceed with caution. It is recommended that an additional sample is preserved as outlined in Taylor *et al.* (2007) during sampling to ensure higher confidence results to support the outcome of the R-DRAM when needed.

In summary, all methods related to monitoring and the identification of EcoSpecs and TPCs require testing and refinement.

20 REFERENCES

Burton, J. and Gerritsen, J. 2003. A Stream Condition Index for Virginia Non-Coastal Streams USEPA Office of Science and Technology, Office of Water, Washington, DC.

Cormier, S.M. and Suter, G.W. 2008. A framework for fully integrating environmental assessment. *Environmental Management* 42:543–556.

Department of Water Affairs and Forestry, South Africa (DWA). 1996. *South African Water Quality Guidelines. Volume 7: Aquatic Ecosystems*. Department of Water Affairs and Forestry, Pretoria, South Africa.

Department of Water Affairs and Forestry, South Africa (DWA). 1999. Resource directed measures for the protection of water resources. Volume 3: River ecosystems, version 1.0.

Department of Water Affairs and Forestry, South Africa (DWA). 2006. Kromme/Seekoei Catchments Reserve Determination Study – Technical Component. Monitoring Report: Rivers. Prepared by Coastal & Environmental Services. Report no. RDM/ K90/ 00/CON/0905.

Department of Water Affairs and Forestry, South Africa (DWA). 2008a. Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. Sabie and Crocodile Systems: Resource Unit Delineation: Prepared by Water for Africa, authored by Louw, MD. Report no. 26/8/3/10/12/006.

Department of Water Affairs and Forestry, South Africa (DWA). 2008b. Methods for determining the Water Quality component of the Ecological Reserve. Prepared by Scherman Consulting.

Department of Water Affairs, South Africa (DWA). 2009a. Operationalise the Reserve: Main Report. Prepared by Water for Africa. Compiled by D Louw and S Louw. RDM Report no. RDM/NAT/05/CON/0907.

Department of Water Affairs, South Africa (DWA). 2009b. 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: Prepared by Water for Africa, edited by Louw, MD and Koekemoer, S. Report no 26/8/3/10/12/009.

Department of Water Affairs and Forestry (DWA). 2009c. Rapid Diatom Reserve Assessment Method for Ecological Water Resource Monitoring. Supporting document for the Rapid Habitat Assessment Method (RHAM) Manual Report number: RDM/Nat/00/CON/0707. Report produced by Water for Africa. Authored by S Koekemoer and JC Taylor.

Department of Water Affairs, South Africa. 2010. Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. Sabie-Sand and Crocodile Systems: Electronic information and data. Prepared by Rivers for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/010.

Elzinga, C.L., Salzer, D.W., and Willoughby, J.W. 1998. "Measuring and monitoring plant populations". BLM Technical Reference 1730-1, BLM/RS/ST-98/005+1730.

Godfrey, L. (Ed), 2002. Ecological Reserve Determination for the Crocodile River Catchment, Incomati System, Mpumalanga. Technical Report for the Department of Water Affairs and Forestry, by the Division of Water Environment and Forestry Technology, CSIR, Pretoria. Report No. ENV-P-C 2001. iii + 70 pp.

Kershner, J.L., Bischoff, C.M., Horan, D.L. 1997. Population, habitat, and genetic characteristics of Colorado River cutthroat trout in wilderness and non-wilderness stream sections in the Uinta Mountains of Utah and Wyoming. *North American Journal of Fisheries Management* 17, 1134-1143.

Kleynhans, C.J. and Louw, M.D. 2007. Module A: EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT329-08.

Kleynhans, C.J., Thirion, C., Moolman, J and Gaulana, L. 2007. A Level II River EcoRegion classification System for South Africa, Lesotho and Swaziland. Report No. N/000/00/REQ0XXX. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

Kleynhans, C.J., Louw, M.D., Birkhead, A.L., Thirion, C., Deacon, A., Angliss, M., Maseti, P., Rodgers, S and Weston, B. 2009. On the way to implementation: Ecological reserve Monitoring. International Conference on Implementing Environmental Water Allocations (IEWA), Port Elizabeth – South Africa 23-26 February 2009.

Lecoite, C., Coste, M. and Prygiel, J. 1993. "Omnidia": Software for taxonomy, calculation of diatom indices and inventories management. *Hydrobiol.* **2691/270**: 509-513.

NATIONAL WATER ACT (NWA). 1998. Act No 36 of 1998. Republic of South Africa Government Gazette, Vol 398, No 19182, Government Printer, Pretoria, South Africa. pp. 200.

Parsons, M., Mc Loughlin, C. A., Rountree, M. W. & Rogers, K. H. 2006. The biotic and abiotic legacy of a large infrequent flood disturbance in the Sabie River, South Africa. *River Research and Applications*, 22:187-201.

Rogers, K.H. and Bestbier, R. 1997. "Development of a protocol for the definition of the desired state of riverine systems in South Africa". Department of Environmental Affairs and Tourism, Pretoria.

Rountree, M.W. and Rogers, K.H. 2004. Channel pattern changes in the mixed bedrock/alluvial Sabie river, South Africa: response to and recovery from large infrequent floods. In D.G. de Jalon and P. Vizcaino (ed.s) *Proceedings of the Fifth International Symposium on Ecohydraulics*, IAHR, Spain, p318-324.

Rountree, M. W., Heritage, G. L. and Rogers, K. H. 2001. In-channel metamorphosis of a mixed bedrock/alluvial river system: Implications for Instream Flow Requirements, In M.C. Acreman (Ed) *Hydro-Ecology: linking hydrology and ecology*. IAHS, p113-125.

Taylor, JC, Harding, W.R. and Archibald, C.G.M. 2007. *A Methods Manual for the Collection, Preparation and Analysis of Diatom Samples*. Version 1.0. WRC Report No. 281/07. Water Research Commission, Pretoria.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (USEPA). 1998. *Lake and Reservoir Bioassessment and Biocriteria*, Technical Guidance Document Nr. EPA-841-B-98-007. <http://www.epa.gov/owow/monitoring/tech/lakes.html>

Van Dam, H., Mertens, A. and Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *J. of Aquat. Ecol.* **28**:117-133.
