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: MAIN REPORT

MARCH 2010

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DWAF Project No: WP 9133
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Reports as part of this project:

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

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: Main Report: Prepared by Water for Africa, compiled by D Louw and S Koekemoer. Report no. 26/8/3/10/12/015.

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The specialists from the Project Team involved in the 2005 study were:

- *Ms Delana Louw (Water for Africa);*
- *Mr Greg Huggins (Water for Africa);*
- *Mr Toriso Tlou (Water for Africa);*

The specialists from DWAF: RQS and Mpumalanga Parks Board involved in the 2005 study were:

- *Dr CJ Kleynhans*
- *Ms Christa Thirion*
- *Dr Johan Engelbrecht*
- *Mr Francios Roux*

CHAPTER 6: WETLAND TYPING AND ECOCLASSIFICATION

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CHAPTER 8: ECOCLASSIFICATION (LEVEL 4) OF EWR SITES

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CHAPTER 13: IDENTIFICATION OF ECOSPECS

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Dr Scherman, Patsy (Physico-chemical variables)
Ms Thirion, Christa (Macroinvertebrates)
Dr Uys, Mandy (Macroinvertebrates)

CHAPTER 14: ESTIMATION AND EXTRAPOLATION OF EWRS AT SELECTED HYDRONODES

The Desktop Reserve model adjustments for hydronodes in the Sabie, Crocodile and Mokolo River catchments were performed by D Birkhead, D Louw, J Mackenzie, A Desai and M Uys.

Dr CJ Kleynhans developed and ran the models to determine the biophysical similarity of sites and predict the indicator fish guilds.

Stephen Mallory and Delana Louw developed the methods to present the results based on the yield modelling.

EXECUTIVE SUMMARY

BACKGROUND

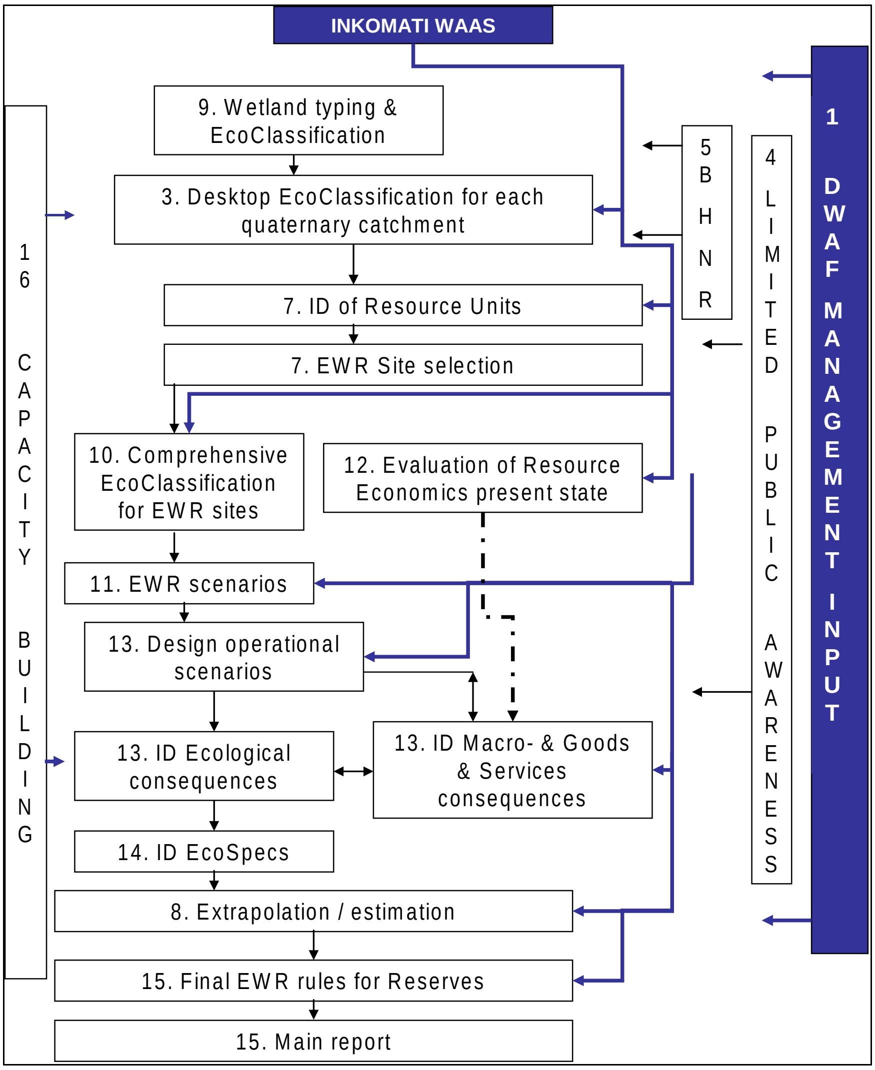
The CD:RDM identified the Inkomati Water Management Area (WMA) as requiring a comprehensive Reserve assessment in light of the initiation of the Compulsory Licensing Process in the WMA and the proposed construction of the Montrose and Mountain View Dams. These studies require higher levels of confidence 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 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 Reserve requirements for the Komati River system (the remaining major river system in WMA 5) was determined and approved in 2003, the results of which are at a high confidence and are still relevant for use and implementation by the DWA. As such it was deemed unnecessary to include this system in the study area. The focus of this study therefore is only on the Crocodile (X2) and Sabie-Sand (X3) catchments.

PROJECT PLAN

The project plan designed around the 8 step Reserve process is illustrated in the flow diagram below.



The numbers in the flow diagram refers to the study tasks. Various reports have been produced for these tasks and these reports, with specific emphasis on the results, are summarised in this main report.

An extensive training programme was also followed as part of the study.

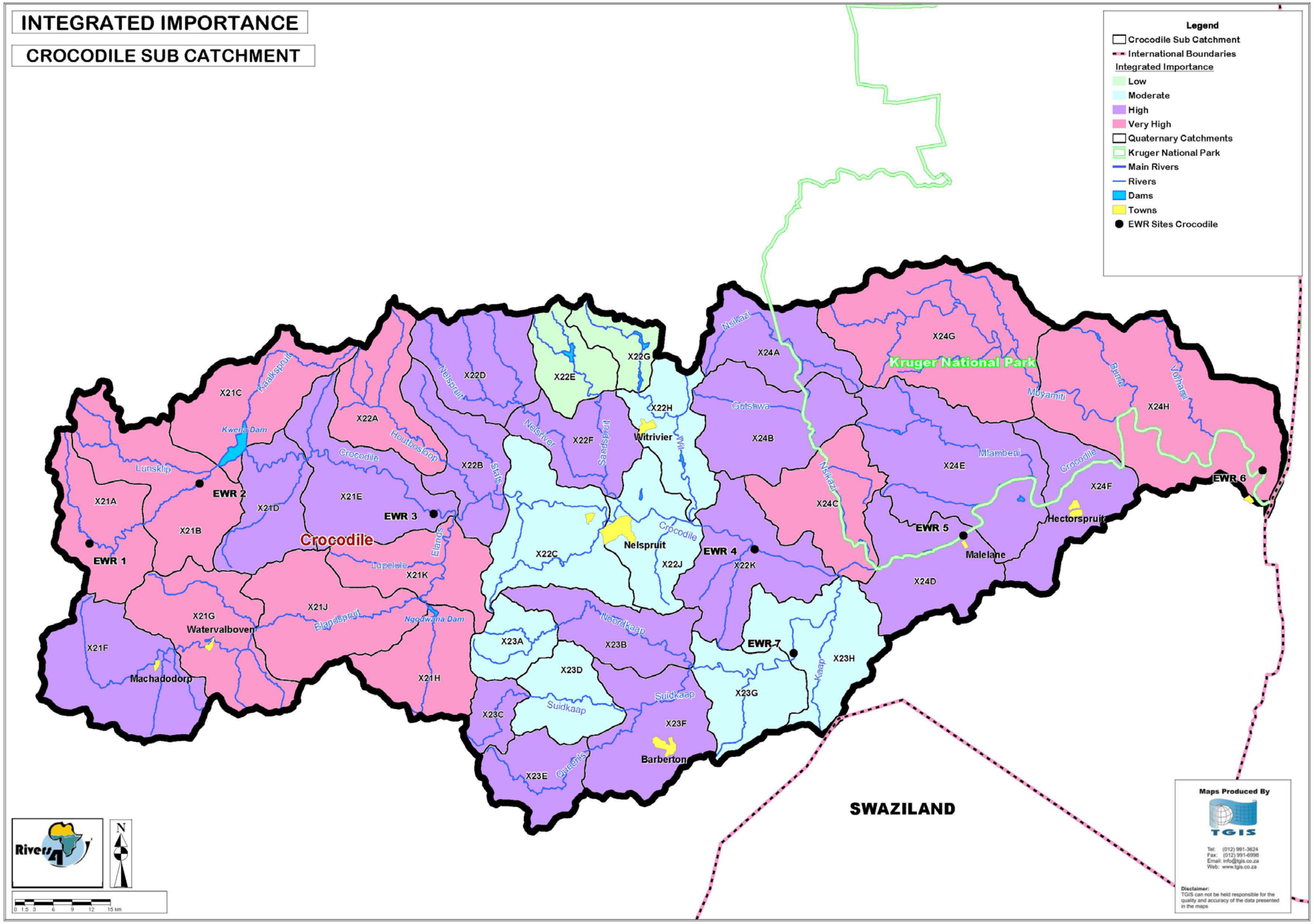
DESKTOP ECOCLASSIFICATION: CATCHMENT SCALE

Rivers

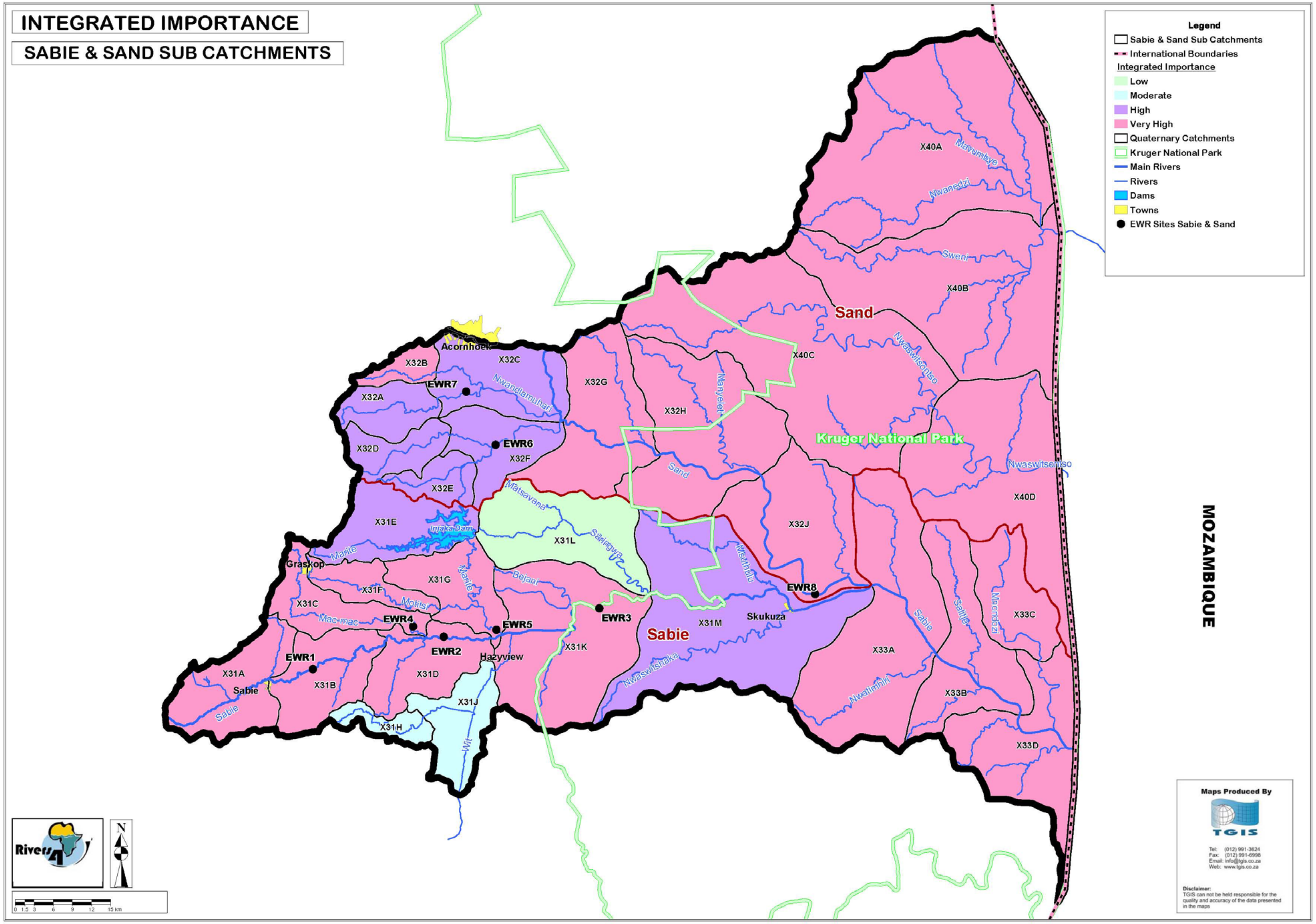
This task provides EcoClassification information at a scoping or desktop level, as well as a more detailed assessment. The purpose of EcoClassification is to gain insight into the causes and sources of the deviation of the PES from the reference condition. This provides the information needed to derive the desirable and attainable future ecological objectives for the river. The present state of the river is described in terms of Ecological Categories (A to F).

A combination of EIS, SCI, and PES provide an indication of overall / integrated importance with the emphasis on the restoration potential. The restoration potential refers to the probability of achieving the rehabilitation of the river to an improved state. The results are provided in the integrated importance map.

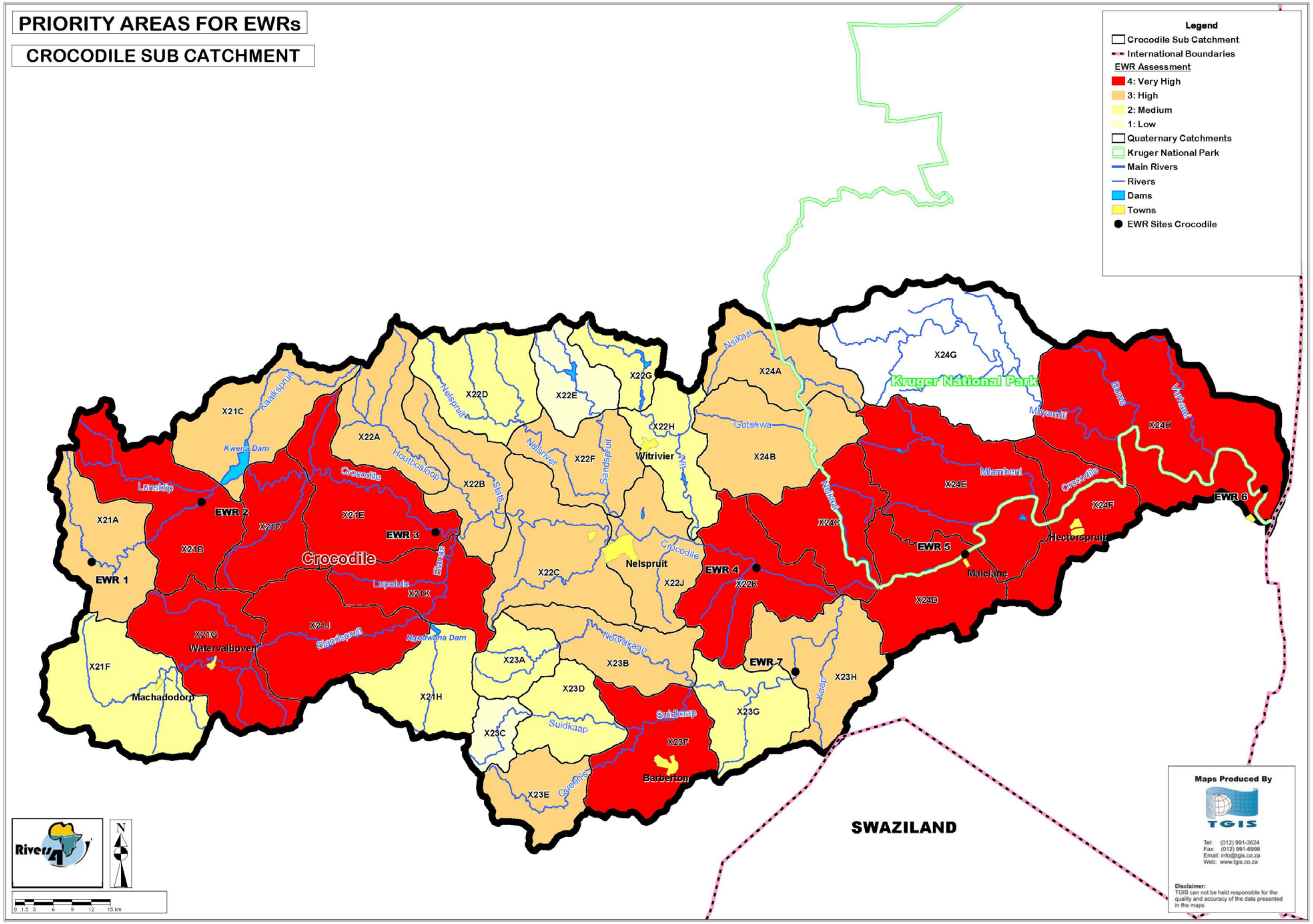
The integrated importace was compared to an assessment of Water Resource Use importance to identify quaternary catchments which are so called 'hotspots'. A biodiversity/ecological hotspot is a *biogeographic region which is a significant reservoir of biodiversity which is threatened with destruction ([http://en.wikipedia. org/wiki/Biodiversity_hotspot](http://en.wikipedia.org/wiki/Biodiversity_hotspot)). In the context used in the Desktop EcoClassification, the hotspot represents a quaternary catchment with a high Integrated Importance which could be under threat due to its importance for water resource use. These hotspots indicate areas where Reserve assessments should ideally result in high confidence recommendations. This then guides the initial estimate of the level of the assessments required, and indicates areas where detailed investigations would be required if development was being considered.*



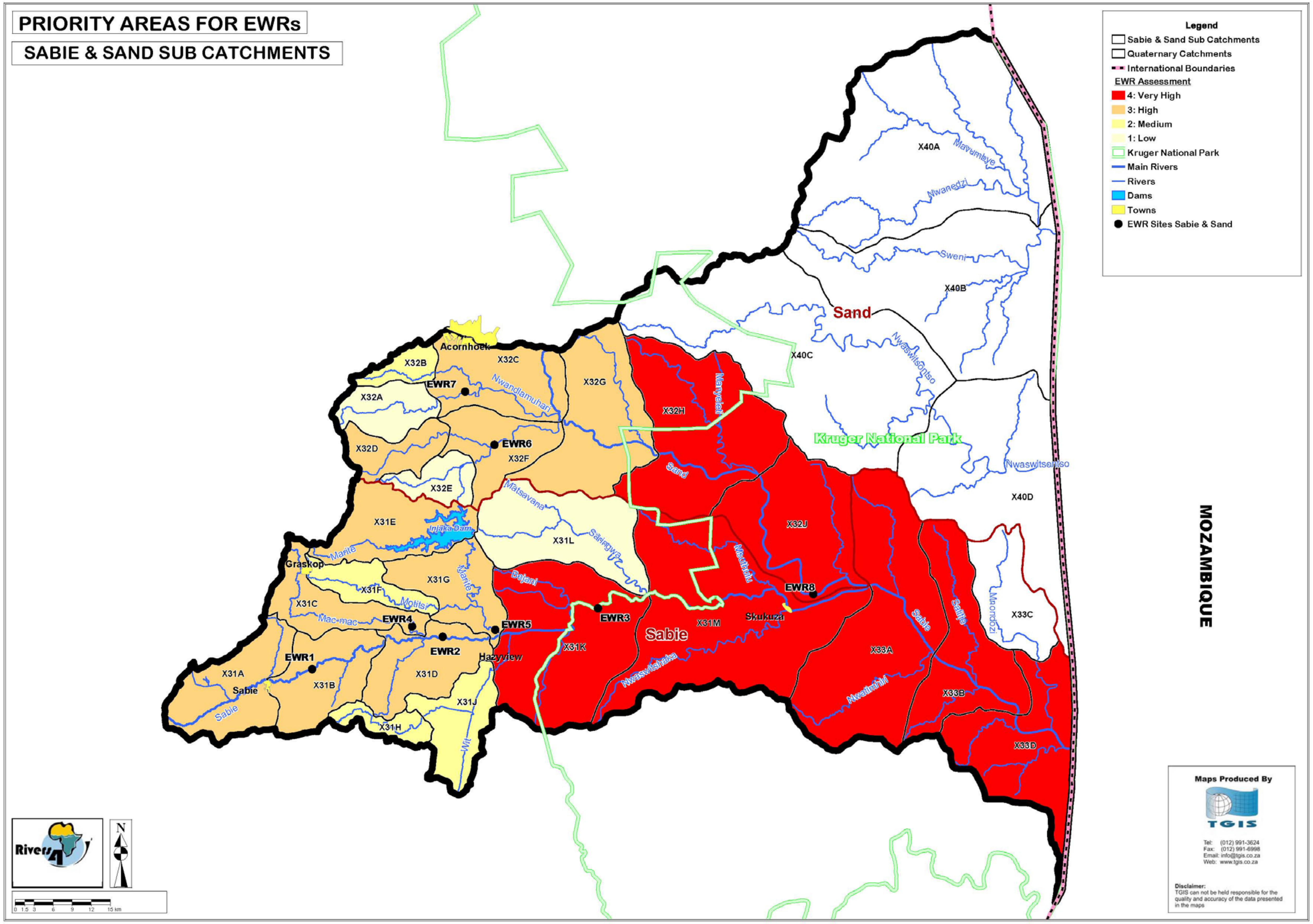
Crocodile Sub-catchment: Map illustrating areas of high Integrated Importance



Sabie & Sand Sub-catchment: Map illustrating areas of high Integrated Importance



Crocodile Sub-catchment: Sections in rivers which are important for Reserve assessment (Hotspots) (derived from overlaying Integrated Importance and Water Resource Use)



Sabie & Sand Sub-catchment: Sections in rivers which are important for Reserve assessment (Hotspots) (derived from overlaying Integrated Importance and Water Resource Use)

Wetlands

The purpose of this study was to identify the major wetland types within the catchment and conduct a predominantly desktop level EcoClassification assessment of wetlands within the Mokolo catchment.

In this catchment the Vegetation Types and Level I and II EcoRegion boundaries were primarily used to delineate the Wetland Resource Units. Six main Wetland Resource Units (WRUs) were delineated, namely the:

- *WRU 1: Highveld Grassland WRU.*
- *WRU 2: Escarpment Grasslands WRU.*
- *WRU 3: Bushveld WRU, which can be subdivided into the Sour and Mountain Bushveld zones.*
- *WRU 4: Granite Lowveld WRU.*
- *WRU 5: Basalt Lowveld WRU; and*
- *WRU 6: Lebombo WRU.*

A summary of the WRU within the Inkomati WMA and associated wetlands are provided in the table below

Summary of WRU and associated wetlands

WRU	Quatenaries	Description	Impacts	PES, EIS
1	*Portions of catchments X11 and X12.*	*High density of large wetlands. Very large pans (rare). The vegetation type is regarded as "Endangered". Assumed that the wetland - dependent species within this vegetation type are similarly threatened.*	*Widespread agriculture (water quality impacts; trampling/grazing, erosion; encroachment into & channelization). Water quality impacts from mining. Limited impacts from invasive alien plants and the effects of dams drowning some wetlands and reducing water availability.*	*Moderate - estimates range from a C to C/D EC. High EIS*
2	*Portions of catchments X11, X12, X21, X23 and X14.*	*High density of very large wetlands. Ddiversity of types moderate. Vegetation types are "Vulnerable" - assumed that the wetland-dependent species are therefore similarly not critically threatened.*	*Trout farming - dams drowning wetlands & reducing water availability, water quality impacts and canalisation. Agricultural areas - runoff; trampling/grazing & erosion; encroachment & channelization. Afforestation, invasive alien vegetation, mining.*	*Most Moderate EIS scores. X21A, X21B, X21C and X21F: High EIS scores. In these quats diversity of wetland types is higher (number of large pans - rare). Density of wetlands high. X21A adjacent to the RAMSAR-listed Verloren Vlei. PES relatively High - estimates range from a B/C to C EC.*
3	*X22 and portions of catchments X21, X31, X23 & X24.*	*Moderate (Mountain Bushveld) to low (Sour Bushveld) density. Wetlands moderate to small. Density & diversity is low , density slightly higher in the Sour Bushveld area. Veg type endangered . Veg types in the Mountain Bushveld unit - "Least Threatended" - accounts for the slight differences in average EIS scores.*	*Extensive afforestation - reduced interflow, reducing water availability for wetlands. Forestry has encroached. Edge effects of forestry & roads disturb wetlands. Result in degradation. Irrigation farming, peri-urban areas of the former homelands and invasive alien vegetation have also caused some wetland degradation.*	*PES of the wetlands is relatively low - Range from a C to D EC. Quaternary catchments within the Sour Bushveld WRU have Moderate EIS scores, whilst those in the Mountain Bushveld WRU tend to have Low EIS scores.*
4	*Portions of catchments X31, X32, X40, X33,*	*Wetlands small or cryptic. Density & diversity very low – few wetlands. Those that do occur are not rare or*	*Afforestation, agriculture and peri-urban areas. Forestry and the extensive agricultural areas have reduced the area*	*Low EIS scores. A wide range of PES: D to A ECs - indicative of the diverse conditions. Entire catchments*

WRU	Quaternaries	Description	Impacts	PES, EIS
	X24, X14 and X13.	high diversity relative. The vegetation types are listed as "Vulnerable". Large areas of this section of the catchment are protected within significant conservation areas.	of wetlands and the water available. Both landuse activities have encroached in places on the wetlands; whilst per-urban areas have caused erosion (though increased runoff, grazing pressures and confinement of the drainage lines associated with infrastructure development).	are impacted by urbanisation of former homeland areas, Lower quats within KNP and private conservation areas. Little change from reference conditions in these areas; albeit that very few wetlands are found here.
5	Portions of catchments X40, X33, X24 and X13.	Wetlands confined to valley bottom positions. Density and diversity is very low. Few that do occur are not rare types or occur in high diversity relative to one another. The vegetation types are listed as "Least Threatened".	Most of the quaternaries are located within the Kruger National Park, and no significant impacts at a regional (catchment) scale are likely to have occurred.	Low EIS scores. PES very high – in A & B ECs. Notable exceptions are the quaternaries X13J, X13K and X13L which have been heavily impacted by urban and peri-urban areas of the former homelands, as well as by extensive irrigation farming.
6	Portions of catchments X40, X33 and X24.	No wetlands of any regional importance are expected due to steep slopes, shallow soils, low rainfall and high evaporation demands. Diversity would be very low, and density/occurrence extremely low.		

. BASIC HUMAN NEEDS RESERVE

In order to calculate the BHNR the following steps were undertaken:

- *The population size of the communities/areas dependant on run of river was calculated at quaternary catchment level. The point of departure had been the 2001 National Census at "sub-place name level".*
- *Communities likely to be reliant on run of river were identified within the catchment. In order to do this, available mapping was consulted. Mapping was checked for its currency and the necessary interviews at a district or local municipal planning level were undertaken to verify the assumptions as to areas/communities dependant on run of river.*
- *Having calculated the qualifying population per quaternary catchment the next step in determining the BHNR was to project the population to a target date. For the purposes of this exercise the population was projected to a sensible target year. The population was projected using generic growth rates applicable to the kinds of municipalities in the resource area or analysis of all settlement types within the study area and the application of different rates based on settlement type, economic forecasts and from historic trends. For the purposes of the Crocodile East catchments a 0% growth rate was used. Virtually all of the population deemed to be reliant on run of river lives in the rural parts of the catchment. Trends indicate that the growth rate in rural area is negative. As a precautionary measure the population is deemed not to decline but to remain stable.*
- *Using the population figures a BHNR for the qualifying population can be estimated per quaternary catchment. The results calculated at 25 l per person per day are set out.*
- *Figures are expressed as m^3 per day consumption.*

Cumulative BHNR per EWR site in the Incomati WMA

EWR site	Quaternary Catchment	BHNR as m^3 per day	BHNR as MCM	Cumulative BHNR per day m^3	Cumulative BHNR as MCM
CROCODILE SUB-CATCHMENT					

EWR 1	*X21A*	*6.98*	*0.00255*	*6.975*	*0.00255*
EWR 2	*X21B*	*9.35*	*0.00341*	*16.325*	*0.00596*
EWR 3	*X21E*	*16.90*	*0.00617*	*48.825*	*0.01782*
EWR4	*X22K*	*0.00*	*0.00000*	*172.425*	*0.06294*
EWR 7	*X23H*	*25.18*	*0.00919*	*78.575*	*0.02868*
EWR5	*X24D*	*13.98*	*0.00510*	*264.975*	*0.09672*
EWR6	*X24H*	*15.25*	*0.00557*	*303.325*	*0.11071*
SABIE-SAND SUB-CATCHMENT					
EWR 1	*X31B*	*0.00*	*0.00000*	*0*	*0.00000*
EWR 4	*X31C*	*5.03*	*0.00183*	*5.025*	*0.00183*
EWR 2	*X31D*	*22.10*	*0.00807*		
EWR 5	*X31G*	*198.85*	*0.07258*	*280.025*	*0.10221*
EWR 3	*X31K*	*496.90*	*0.18137*	*889.925*	*0.32482*
EWR 7	*X32C*	*223.35*	*0.08152*	*451.9*	*0.16494*
EWR 6	*X32F*	*308.10*	*0.11246*	*514.35*	*0.18774*
EWR 8	*X32J*	*0.60*	*0.00022*	*1086.5*	*0.39657*

GROUNDWATER COMPONENT OF THE RESERVE

Based on the groundwater flow balance assessment, the quaternary catchments were classified based on the ratio of outflow/inflow, before groundwater evapo-transpiration losses or actual base flow takes place.

There are 5 catchments where further development of groundwater resources should be approached with caution (Figure 5-1).

- *Status D = 3 (3.23 %);*
- *Status E = 2 (2.15 %);*

There are 88 quaternary catchments in which the groundwater resource status range from A to C. Additional development of groundwater resources is still possible in these catchments (Figure 5-1):

- *Status A = 49 (52.7 %)*
- *Status B = 30 (32.3 %)*
- *Status C = 9 (9.68 %);*

According to the Groundwater Yield Model and interpretations from the results obtained, the regional groundwater balance calculations of the Inkomati WMA indicate that overall there is a surplus of groundwater in the WMA due to inflow (1 333 319 818 m^3/a) exceeding outflow (114 934 413 m^3/a). The total volume of groundwater recharge is in the order of 1326 Mm^3/a

MANAGEMENT RESOURCE UNITS AND EWR SITES

Resource Units (RUs) are required as it would not be appropriate to set the same numerical Reserve for the headwaters of a river as for the lowland reaches. The breakdown of a catchment into RUs for the purpose of determining the Reserve for rivers is therefore done primarily on a biophysical basis within the catchment and called Natural Resource Units (NRUs). Management requirements (DWAF, 1999, volume 3) also play a role in the delineation. Furthermore, the type of disturbance/impact on river plays a role to select homogenous river reaches from a biophysical basis under present circumstances. These are called Management Resource Units (MRUs).

The results of the delineation are summarized in the table below and illustrated in the map.

Description of MRUs

MRU	Delineation	Quat
CROCODILE RIVER		
MRU Croc A	Origin of river to upper reaches of Kwena Dam.	X21A, X21B
MRU Croc B	Kwena Dam Wall to the Elands River confluence.	X21D, X21E
MRU Croc C	Elands River confluence to Nelspruit.	X22B, X22C, X22J, X22K
MRU Croc D	Nelspruit to border of KNP.	X22J, X22K, X24C
RUA Croc D.1	Gorge.	X22K, X24C
MRU Croc E	KNP border to Komati confluence.	X24D, X24E, X24G, X24H
KAAP RIVER		
MRU Kaap A	Confluence of the Noord and Suid Kaap to confluence with the Crocodile.	X23G, X32H, X23B
RAU Kaap A.1	Start and end of Upper Foothills.	X23H, X23G
MRU	Delineation	Quat
SABIE RIVER		
MRU Sabie A	Origin of the river to the Marite confluence.	X31A, X31B, X31D
RAU Sabie A.1	Source of river to end of the Mountain Stream.	X31A
RAU Sabie A.2	Mac-Mac confluence to Marite confluence.	X31D
MRU Sabie B	Marite confluence (start of EcoRegion 3.07) to KNP entrance.	X31M, X31K
MRU Sabie B.1	Point where river forms the border of the KNP to the Kruger Gate.	X31M, X31K
MRU Sabie C	Kruger Gate to border of KNP with Mozambique.	X31M, X33A, X33B, X33D
RAU Sabie C.1	Kruger Gate to Sand confluence.	X31M
SAND & MUTLUMUVI		
MRU Sand A	Origin of river to confluence with Mutlumuvi.	X32A, X32C
MRU Mutlumuvi A	Origin of river to confluence with Sand.	X32D, X32F
MRU Sand B	Confluence with the Mutlumuvi to the confluence with the Sabie.	X32G, X32H, X32J
RAU Sand B.1	Border of the Sabie Sand to the confluence with the Sabie.	X32G, X32H, X32J

The selection of EWR sites is guided by a number of considerations. The key considerations are:

- The suitability of the sites for accurate hydraulic modelling throughout the range of possible flows, especially low flows.
- Accessibility of the sites.
- An area or site that could be critical for ecosystem functioning. These are often represented by riffle units, where low flow conditions or the cessation of flow constitutes a break in the functioning of the river, and consequently, the biota dependant on this habitat and/or perennial flow are adversely affected. Pools are not considered critical habitats in perennial system since they are still able to function or at least maintain life during periods of no flow.

Details regarding the sites selected are provided in the table below and the map.

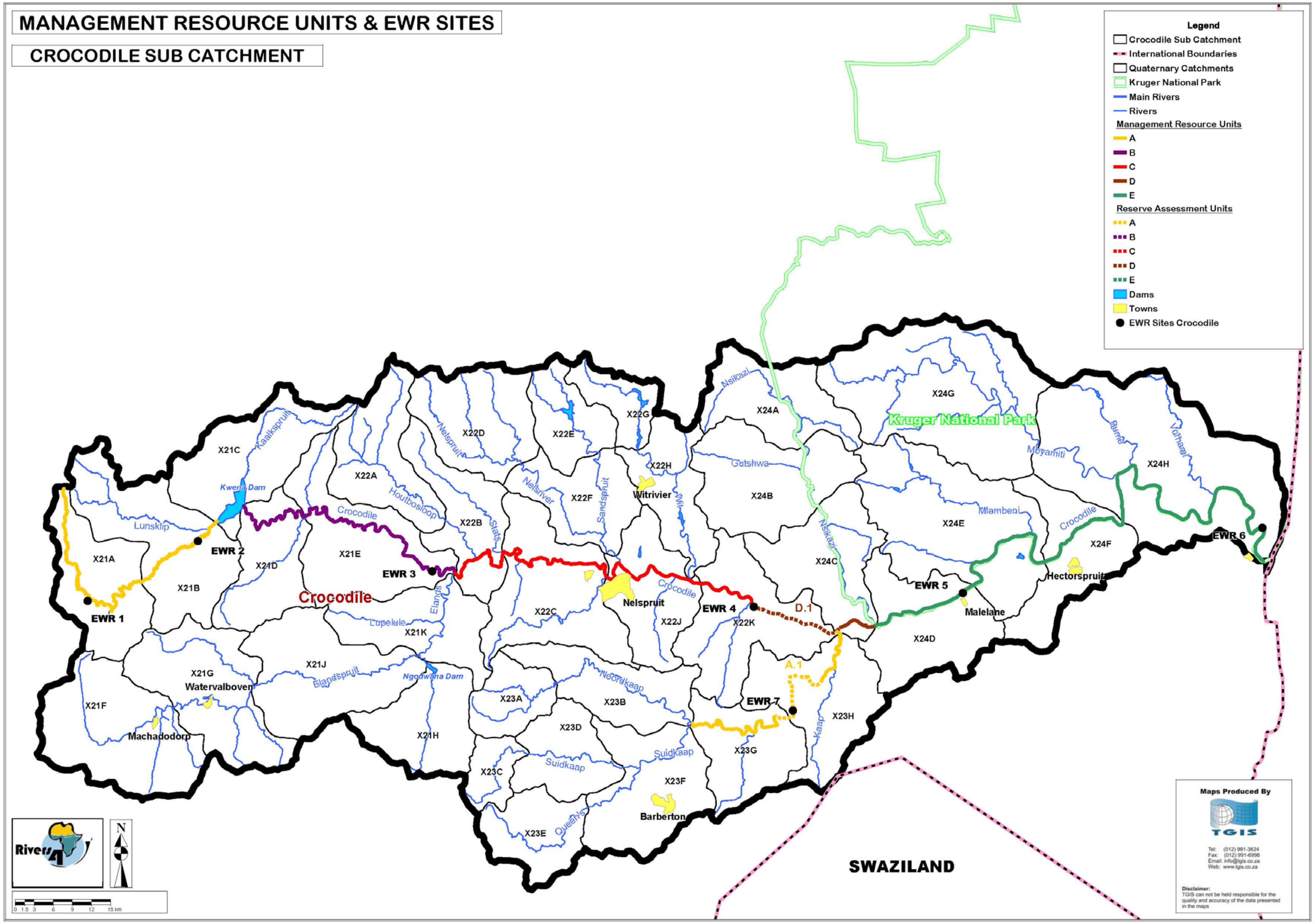
Locality and characteristics of the EWR sites.

Site information	EWR sites	Illustration
Crocodile		
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	*EWR 1 Valyspruit Crocodile EWR 1 X2Croc-Valys -25.49412, 30.14427 S25 29.647, E30 08.656 9.02 Upper Foothills 1852 MRU Croc A X21A Valyspruit -*	
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	*EWR 2 Goedenhoop Crocodile EWR 2 X2CROC-UKWEN -25.40925, 30.31592 S25 24.555, E30 18.955 9.04 Upper Foothills 1207 MRU Croc A X21B Goedenhoop -*	
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	*EWR 3 Poplar Creek Crocodile EWR 3 X2CROC-DKWEN -25.45211, 30.68108 S25 27.127, E30 40.865 10.02 Lower Foothills 834 MRU Croc B X21E Mooifontein X2H013*	
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	*EWR 4 KaNyamazane Crocodile EWR 4 X2CROC-DNELS -25.50243, 31.18198 S25 30.146,E31 10.919 4.04 Lower Foothills 472 MRU Croc D X22K State ground X2H032*	

Site information	EWR sites	Illustration
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 5 Malelane* *Crocodile* *EWR 5* *X2CROC-MALEL* *-25.48287,31.50773* *S25 28.972,E31 30.464* *3.07* *Lower Foothills* *286* *MRU Croc E* *X24D* *KNP* *S2H046*	
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 6 Nkongoma* *Crocodile* *EWR 6* *X2CROC-NKONG* *-25.39050,31.97444* *S25 23.430, E31 58.467* *12.01* *Lower Foothills* *135* *MRU Croc E* *X24H* *KNP* *X2H016*	
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 7 Honeybird* *Kaap* *EWR 7* *X2Kaap-Honey* *-25.64947, 31.24286* *S25 38.968, E31 14.572* *4.04* *Upper Foothills* *470* *MRU Kaap A* *X23H* *Lovedale* *-*	
Sabie-Sand		
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 1 Upper Sabie* *Sabie* *-* *-* *-25.0737, 30.84874* *S25 04.424, E30 50.924* *4.04* *Upper Foothills* *862* *MRU Sabie A* *X31B* *-* *-*	

Site information	EWR sites	Illustration
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *MRU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 2 Aan de Vliet* *Sabie* *-* *X3Sabie-Brand* *-25.0279, 31.05166* *S25 01.675, E31 03.099* *4.04* *Lower Foothills* *463* *MRU Sabie A, RAU A.2* *X31D* *Evert 5* *X3H023*	
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 3 Kidney* *Sabie* *IFR 3* *X3Sabie-Sekur* *-24.9876, 31.29287* *S24 59.256,E31 17.572* *3.07* *Lower Foothills* *369* *MRU Sabie B.1* *X31K* *KNP* *X3H021*	
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 4 Mac Mac* *Mac Mac* *-* *-* *-25.0133, 31.00405* *S25 00.800, E31 00.243* *4.04* *Upper Foothills* *582* *MRU Mac A* *X31C* *Richmond 573* *-*	
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 5, Marite* *Marite* *IFR 1* *X3Mari-Sandf* *-25.018, 31.13328* *S25 01.077, E31 07.997* *4.04* *Upper Foothills* *457* *MRU Mar A* *X31G* *291/33* *-*	

Site information	EWR sites	Illustration
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	EWR 6 Mutlumuvi Mutlumuvi IFR 6 X3Mutl-Thula -24.7559, 31.13205 S24 45.352, E31 07.923 3.05 Upper Foothills 503 MRU Mut A X32F New Forest 234 -	
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	EWR 7 Tlulandziteka Tlulandziteka (Sand) - - -24.6805, 31.08647 S24 40.829, E31 05.188 3.07 Lower Foothills 543 MRU Sand A X32C - -	
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	EWR 8 Lower Sand Sand IFR 8 X3Sand-Skuku -24.9674, 31.62734 S24 58.045, E31 37.641 3.07 Lower Foothills 250 MRU Sand B, RAU B.1 X32J KNP -	


MANAGEMENT RESOURCE UNITS & EWR SITES
CROCODILE SUB CATCHMENT
Legend
Crocodile Sub Catchment
International Boundaries
Quaternary Catchments
Kruger National Park
Main Rivers
Rivers
Management Resource Units
A
B
C
D
E
Reserve Assessment Units
A
B
C
D
E
Dams
Towns
EWR Sites Crocodile
X21A
X21B
X21C
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X21E
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EWR 1
EWR 2
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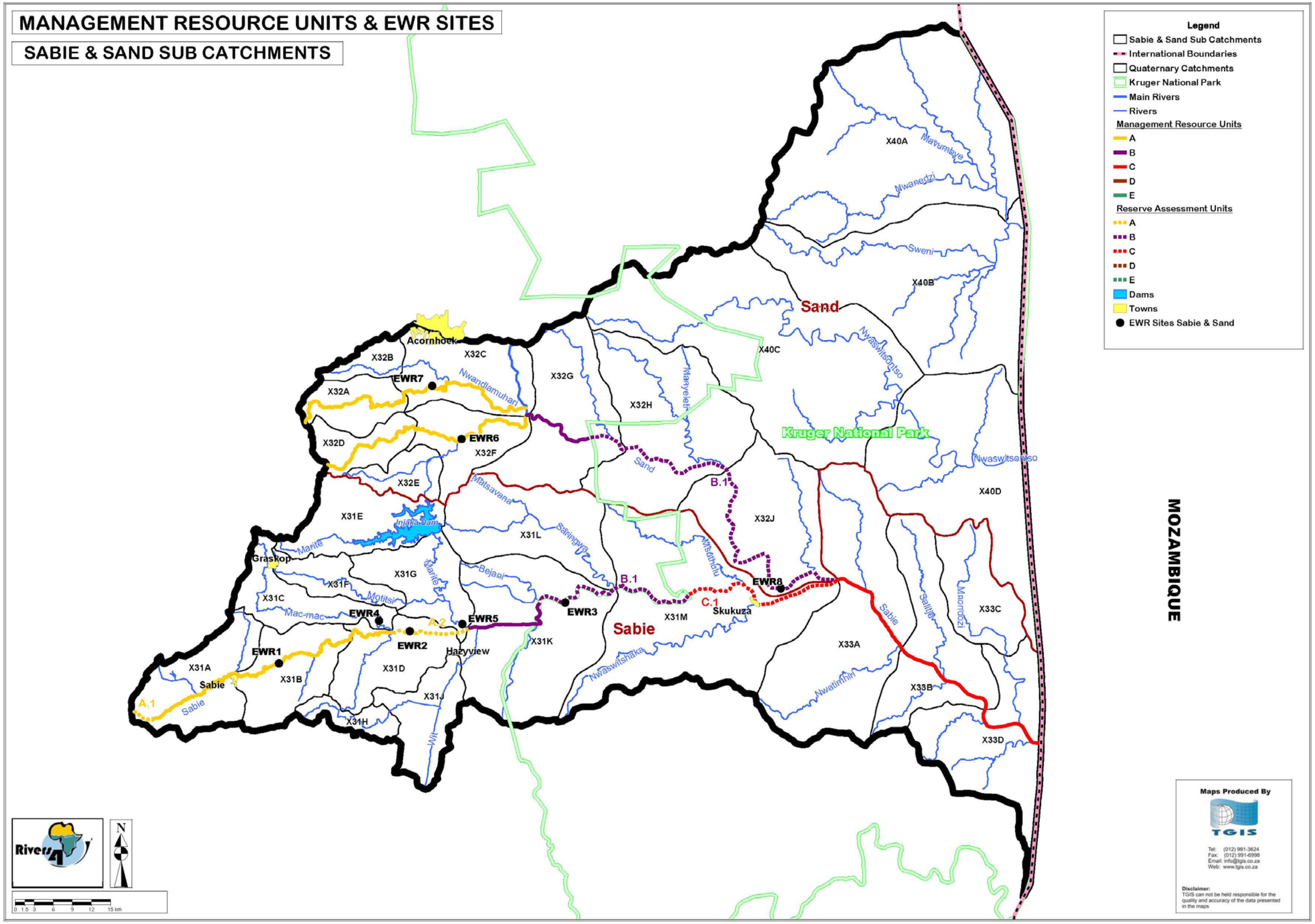
D.1
A.1
Crocodile
Kwena Dam
Ngodwana Dam
Nelspruit
Witrivier
Machadodorp
Watervalboven
Barberton
Malelane
Hectorspruit
Kruger National Park
SWAZILAND
Maps Produced By
TGIS
Rivers


MANAGEMENT RESOURCE UNITS & EWR SITES
SABIE & SAND SUB CATCHMENTS
Legend
Sabie & Sand Sub Catchments
International Boundaries
Quaternary Catchments
Kruger National Park
Main Rivers
Rivers
Management Resource Units
A
B
C
D
E
Reserve Assessment Units
A
B
C
D
E
Dams
Towns
EWR Sites Sabie & Sand
MOZAMBIQUE
Kruger National Park
Sand
Sabie
X40A
X40B
X40C
X40D
X32A
X32B
X32C
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X31A
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X31L
X31M
X33A
X33B
X33C
X33D
EWR1
EWR2
EWR3
EWR4
EWR5
EWR6
EWR7
EWR8
A.1
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B.1
C.1
Acornhoek
Graskop
Sabie
Hazyview
Skukuza
Injaka Dam
Mavumbye
Nwanedzi
Sweni
Nwaswitsontso
Manyeleti
Nwandlamuhari
Matsavana
Saringwa
Mutlumuvi
Marite
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Motitsi
Mac-mac
Nwaswitshaka
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ECOCLASSIFICATION (LEVEL 4) OF EWR SITES

The procedure for the EcoClassification of the rivers and Physico-chemical input was according to the revised methods for rivers as outlined in Louw and Hughes (2002), and the EcoClassification manual version 2 (Kleynhans and Louw, 2007). The approach consists broadly of the following steps:

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

The EcoClassification results are summarised in the table below

EcoClassification results for the EWR sites

EWR 1 Valeyspruit (Crocodile River)

EIS: Moderate
Highest scoring metric were diversity of sensitive habitat types present e.g. wetlands (including floodplains containing various oxbows).
PES: A/B
Minor impacts, mainly due to farming, exotic vegetation species and trout. Impacts are mostly non-flow related
REC: A/B
Maintain the PES as only moderate EIS.
AEC down: B/C
Scenario includes decreased low flows due to e.g. increased golf estates, trout farms and increased abstractions for Dullstroom. Growth of Dullstroom will also result in increased sewage. Increased grazing causing trampling and destabilisation of banks.

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

EWR 2 Goedehoop (Crocodile River)

EIS: High
Rare and endangered fish spp. which are sensitive to flow and quality changes. High species diversity.
PES: B
Impacts as for EWR 1 with increased agricultural activities and decreased flows. However, impacts mostly still non-flow related.
REC: B
Although the EIS is high, the PES is already a B and as the impacts are mostly non-flow related, it would not be realistic to improve the PES through flow related interventions.
AEC down: C
See EWR 1. Possible zero flow situations and additional impacts on moderate events.

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

EWR 3 Poplar Creek (Crocodile River)

EIS: High
Rare and endangered fish, vegetation and bird spp, some of which are sensitive to flow and quality changes.
PES: B/C
Major problems related to upstream Kwena Dam and its operation, e.g. migration, sedimentation, changed flow regime. The changed flow regime consists of higher than natural flows in the dry season and much lower low flows in the wet season.
REC: B
The EIS is high; therefore the REC is an improvement of the PES. This can be achieved by improving the flow regime (low flows) and removal of exotic vegetation species.
AEC down: C/D
Lower flows than natural in both the dry and wet season. Associated increase in temperature and oxygen.

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

EWR 4 KaNyamazane (Crocodile River)

EIS: High
Rare and endangered species that are sensitive to flow and quality changes are present. There is also a high species taxon richness and a diversity of habitat types
PES: C
Combination of flow and non-flow related impacts. Changes mostly related to changes in flow regime due to upstream Kwena Dam and the operation of upstream system. Abstractions, return flows, landuse mismanagement, water quality issues, and sedimentation.
REC: B
The EIS is HIGH, therefore the REC is an improvement of the PES. Improvements to flow regime will be required. Only successful if combined with removal of exotic vegetation and if there are some improvement in grazing and browsing.
AEC down: C/D
Montrose Dam with decreased floods. Pools will fill in, bars will appear, riffles will be clogged and covered with sediment, reed growth will increase, the marginal zone will expand and vegetation will encroach.

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

EWR 5 Malelane (Crocodile River)

EIS: Very High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on LB.
PES: C
Change in low flows, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.
REC: B
The EIS is VERY HIGH, therefore the REC is an improvement of the PES. Changes mostly focussing on improving the low flow regime and some land use management.
AEC down: D
Decreased low flows and periods of zero flows in some stretches of the river which will result in increased algal growth, temperature and nutrient problems, loss of deeper channel sections, increased reed and vegetation growth.

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

EWR 6 Nkongoma (Crocodile River)

EIS: Very High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on left bank.
PES: C
Change in low flows, even zero flows present, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.
REC: B
The EIS is VERY HIGH, therefore the REC is an improvement of the PES. Changes mostly focussing on improving the low flow regime and some land use management.
AEC down: D
Decreased low flows and periods of zero flows in some stretches of the river which will result in increased algal growth, temperature and nutrient problems, loss of deeper channel sections, increased reed and vegetation growth.

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

EWR 7 Kaap (Kaap River)

EIS: High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and habitat types sensitive to flow and quality changes.
PES: C
Changes are flow and non-flow related. Low to zero flows present due to upstream abstractions. Land-use activities related to agriculture and mining. Extensive exotic

vegetation present.
REC B:
The EIS is high, therefore the REC is an improvement of the PES.
No zero flows, increased low flows, more moderate floods. This must happen in conjunction with exotic vegetation removal.
AEC D:
Mountain View Dam will be present which will result in much lower flows than present and decreased floods. The channel will be narrower, some riffles will be sandier and smaller in general which will result in more reeds and a narrower marginal zone.

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

EWR 1: Upper Sabie (Sabie River)

EIS: High
Rare and endangered fish and vegetation species. Fish species present that are intolerant to flow and flow related water quality changes. .
PES: B/C
Impacts due to forestry, exotic vegetation species, and abstraction. Impacts largely non-flow related.
REC: B
The EIS is high, therefore the REC is an improvement of the PES. Inactivity of picnic site and removal of aliens is required. Improved fish EC dependent on improved vegetation cover.
AEC down: C/D
Decreased low flows resulting in increased sediment with increased nutrients, turbidity, temperature, additional toxics. Increased vegetation exotics and reeds on bars.

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

EWR 2: Aan de Vliet (Sabie River)

EIS: High
Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.
PES: C
Forestry and landuse activities, mostly non-flow related.
REC: B
Changes in flow are not required to improve the state.
Remove exotic vegetation and cease mowing in the riparian zone. Reduce recreational disturbances. The nutrient status must also be improved.
AEC down: C/D
Increased abstraction could lead to increased return flows that will cause problems due to pesticides, nutrient loading etc. Mismanagement of land use in terms of forestry and agriculture

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

EWR 3 Kidney (Sabie River)

EIS: Very High
Rare and endangered species, taxon richness and species intolerant to flow and flow related water quality changes. Refuge area for biota and an important migration corridor for birds and fish. Within KNP.
PES: A/B
Forestry, abstraction, Inyaka Dam and landuse activities. (Flow and non-flow related)
REC: A/B
As the PES is already an A/B, the REC = the PES.
AEC Down: B/C
Increased abstractions, no Reserve implementation, less floods. Increased nutrients, changes in temperature, oxygen etc. Riffles lost due to sedimentation, channel shallower and sandier. Vegetation exotics will increase.
More reeds will be present in sandier areas.

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

EWR 4 Mac Mac (Mac Mac River)

EIS: High
Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.
PES: B
Forestry, exotic vegetation and wastewater input. Impacts are flow and non-flow related.
REC: A/B
The EIS at EWR 4 is high and the REC is therefore to improve the PES by improving the fish. Improved water quality required.
AEC down: C
Decreased low flows due to e.g. a weir or small dam in the upper catchment. This will result in embedded cobbles. Nutrients and temperature will increase. Increased exotic vegetation in the riparian zone.

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

EWR 5 Marite (Marite River)

EIS: High.
Rare, endangered and unique biota. Species richness high and species intolerant to flow and flow related water quality changes present.
PES: B/C
Increased low flows and landuse activities. Impacts mostly flow related
REC: B
The EIS is high; therefore the REC is an improvement of the PES. More natural distribution of flows required. Reduce grazing and trampling, remove exotic vegetation.
AEC down: C/D
No flow releases for the EWR, less dilution and less floods due to e.g. direct abstraction from the dam. More nutrients and toxics present. Sandier river, some riffles and bedrock areas in the reach will be lost, vegetation encroachment on bars and banks and embedded cobbles. Increased aliens, removal, grazing, and trampling.

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

EWR 6 Mutlumuvi (Mutlumuvi River)

EIS: High
Rare, endangered and unique biota. Taxon species richness high and species intolerant to flow and flow related water quality changes present.
PES: C
Abstraction, forestry, informal settlements and landuse activities. Impacts flow and non-flow related.
REC: B
The EIS is high and improvement requires improved system operation which improves the low flow regime.
AEC down: C/D
Decreased low flows and longer periods of zero flows. Increased algal growth. Less moderate floods will cause some impact on sedimentation. The reedbeds will become less dense and Matumi will disappear.

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

EWR 7 Tlulandziteka (Tlulandziteka River)

EIS: Moderate
Rare and endangered species, high taxon richness, species intolerant to flow and flow related water quality changes.
PES: C
Forestry, abstraction, flow modification and poor landuse management. Impacts flow and non-flow related.
REC: C
Due to the moderate EIS, the REC = the PES.
AEC Up: B
Improved flows through fixing of canals, rehabilitation of forestry areas and improved management of canal system and landuse. Remove exotic vegetation, minimise agricultural disturbance and remove unused orchards.
AEC Down: D
Increased use of the dam with less spills, i.e. less floods. More abstraction and forestry. Nutrients, temperature, oxygen, and turbidity levels will change. Increase in bed height, more subsurface flows and sediment with resulting decrease in riffles and shallower pools. More reeds, alien vegetation and more removal.

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

EWR 8 Lower Sand (Sand River)

EIS: High *Rare and endangered species, high taxon richness and species intolerant to flow and flow related water quality changes. Situated in KNP* **PES: B** *Abstraction, dams, weirs, poor landuse management. Impacts are flow and non-flow related.* **REC: B** *Although the EIS is High, the PES is already in a B therefore the REC = PES. Improve the macroinvertebrate EC by increasing low flows.* **AEC down: C** *More decreased low flows and longer periods of no flow.*	

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

EWR SCENARIOS

This task consists of determining the EWR for different ecological river states, i.e. different Ecological Categories. The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O'Keeffe et al., 2002), a modification of the Building Block Methodology (BBM) (King and Louw, 1998) was used to determine the low (base) flow EWRs. The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM. These results generated will then form the basis against which the ecological consequences of operational flow scenarios will be tested during a further task in this study.

The results are summarised in the table below for the different EWR sites as a percentage of the natural Mean Annual Runoff (nMAR).

EWR scenario results as a percentage of the nMAR

EWR site	nMAR	PMAR	%PMAR of nMAR	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
	MCM	MCM	MCM		MCM	(%nMAR)	MCM	(%nMAR)	MCM	(%nMAR)	MCM	(% nMAR)
Crocodile												
EWR 1	15.19	14.90	98%	A/B PES, REC	3.76	24.78	1.54	10.13	0.993	6.14	4.75	30.9
				B/C AEC	2.56	16.84	1.54	10.13	0.993	6.14	3.7	24.4
EWR 2	47.11	44.80	95%	B PES, REC	23.53	49.94	9.23	19.58	3.50	7.43	27	57
				C AEC	11.39	24.18	9.22	19.58	3.03	6.44	17.43	37
EWR 3	169.9	1515.2	892%	B/C PES	74.76	44	30.75	18.1	16.7	9.8	93.78	55.2
				B REC		A time series of requirements could not be generated as improvement of the PES required flows higher than the reference time series (present day), during the wet season.						
EWR 4	754.1	528.3	70%	B PES, REC	216.4	28.7	74.66	9.9	46.8	6.2	260.16	34.5
				C/D AEC	99.54	13.2	74.66	9.9	38.7	5.1	160.62	21.3
EWR 5	1006.2	637.9	63%	C PES	214.3	21.3	121.8	12.1	53.3	5.3	301.87	30
				B REC	349.2	34.7	121.8	12.1	74.5	7.4	404.50	40.2
				D AEC	121.8	12.1	121.8	12.1	29.2	2.9	214.33	21.3

EWR 6	1063.1	525.2	49%	C PES	147.8	13.9	112.7	10.6	78.7	7.4	264.72	24.9
				B REC	323.2	30.4	112.7	10.6	140.3	13.2	466.71	43.9
				D AEC	123	11.6	47.84	4.5	48.9	4.6	152.03	14.3
EWR 7	169	86.6	51%	C PES	25.2	14.9	11.16	6.6	10.82	6.4	38.87	23
				B REC	50	29.6	11.16	6.6	12.51	7.4	62.20	36.8
				D AEC	10.14	6	11.16	6.6	8.96	5.3	27.72	16.4
Sabie Sand												
EWR 1	140.18	109	78%	B/C PES	46.54	33.2	17	12.1	7.43	5.3	52.99	37.8
				B REC	61.82	44.1	17	12.1	8.55	6.1	64.90	46.3
				C/D AEC	29.02	20.7	17	12.1	6.31	4.5	43.46	31
EWR 2	262.1	199.5	76%	B/C PES	51.90	19.8	29.1	11.1	11.5	4.4	73.39	28
				B REC	81.52	31.1	29.1	11.1	13.1	5	93.57	35.7
				C/D AEC	32.76	12.5	29.1	11.1	9.44	3.6	57.93	22.1
EWR 3	495.86	322.1	65%	A/B PES/REC	155.2	31.3	48.1	9.7	31.7	6.4	183.5	37
				B/C AEC	101.2	20.4	48.1	9.7	26.8	5.4	134.4	27.1
EWR 4	65.78	51.8	79%	A/B PES/REC	20.59	31.3	6.38	9.7	4.21	6.4	24.34	37
				B/C AEC	13.42	20.4	6.38	9.7	3.55	5.4	17.83	27.1
EWR 5	157.09	89.7	57%	B/C PES	32.67	20.8	12.6	8	10.2	6.5	44.30	28.2
				B REC	47.44	30.2	12.6	8	11.2	7.1	57.02	36.3
				C/D AEC	15.39	9.8	12.6	8	8.48	5.4	31.10	19.8
EWR 6	44.99	29.9	66%	C PES	9.99	22.2	4.63	10.3	2.83	6.3	14.58	32.4
				B AEC	**14.49**	**32.2**	**6.03**	**13.4**	**2.83**	**6.3**	**17.37**	**38.6**
				C/D AEC	6.21	13.8	4.63	10.3	2.56	5.7	11.56	25.7
EWR 7	28.88	17.3	60%	C PES	5.11	17.7	2.05	7.1	3.18	11	9.15	31.7
				B REC	**7.65**	**26.5**	**3.23**	**11.2**	**3.81**	**13.2**	**11.38**	**39.4**
				D AEC	2.71	9.4	2.05	7.1	2.95	10.2	7.77	26.9
EWR 8	133.61	88.5	66%	**B PES/REC**	**22.85**	**17.1**	**4.54**	**3.4**	**9.75**	**7.3**	**33.80**	**25.3**
				C AEC	12.69	9.5	4.54	3.4	8.82	6.6	24.58	18.4

The confidence in the low and high flow Ecological Reserve requirements for each EWR site is provided in the table below. A score of 1 – 1.9 indicates a low confidence (red), 2 – 3.9 a moderate confidence (yellow) and 4 -5, high confidence (green) in the results.

EWR sites	Low flow confidence	High flow confidence	Recommendations
Crocodile			
EWR 1	4	3.5	EWRM
EWR 2	4	3	EWRM
EWR 3	2	3	EWRM
EWR 4	1	4	The hydraulics for EWR 4 should be updated with sufficient low flow calibrations to improve the low flow confidence. EWRM.
EWR 5	3.5	3.3	This site did not provide sufficient cues for EWR assessment, neither for hydraulic analysis. As EWR 6 is the critical site, this site should be seen as supplementary. EWRM
EWR 6	4	4	EWRM

EWR sites	Low flow confidence	High flow confidence	Recommendations
EWR 7	*3*	*2.5*	*EWRM*
Sabie Sand			
EWR 1	*3.5*	*3*	*EWRM.*
EWR 2	*3.5*	*3*	*EWRM.*
EWR 3	*3.5*	*4*	*EWRM.*
EWR 4	*4*	*2.3*	*EWRM.*
EWR 5	*3.5*	*3*	*EWRM.*
EWR 6	*3.5*	*3*	*Hydrological monitoring.* *EWRM.*
EWR 7	*2.5*	*2.3*	*Hydrological monitoring.* *EWRM.*
EWR 8	*2*	*3*	*Additional low flow hydraulic information for calibration purposes.* *Hydrological monitoring.* *EWRM.*

CONSEQUENCES OF OPERATIONAL SCENARIOS AND SELECTION OF EWR TO BE SIGNED OFF

During this part of an Ecological Reserve study, aspects other than ecology are also considered for the evaluation of various operational flow scenarios and/or future development scenarios. The purpose of this is to provide the decision-maker with sufficient information to make informed decisions regarding the implications of the flow scenario and the Ecological Category which will be signed off as the Ecological Reserve. This will in future form part of the Classification System.

Operational scenarios are any flow scenarios other than the present which could be implemented in future.

For the Crocodile River, a combination of operating rules, restrictions, and/or curtailments were applied to agriculture. A range of plausible operational scenarios were modelled (Sc 2 to 6) and the scenario flow at each EWR site provided for the determination of ecological consequences. Additional scenarios, Sc C3.1 and C3.2 were evaluated. These scenarios were adjustments of Sc C3 and C6 as the increased yield in Kwena Dam, due to the restrictions and/or curtailments on agriculture, were used to supply the Reserve.

Operational scenarios on the Sabie River focussed on increased agriculture. The Sand scenarios were based on the assumption that the four abstraction weirs in the upper Sand River would be rehabilitated, thus improving the flow downstream

Socio-economic consequences

Crocodile: On the assumption that the assurance or supply of water will not change, and that neither will the crop types change, all the scenarios showed negative changes from the baseline as follows:

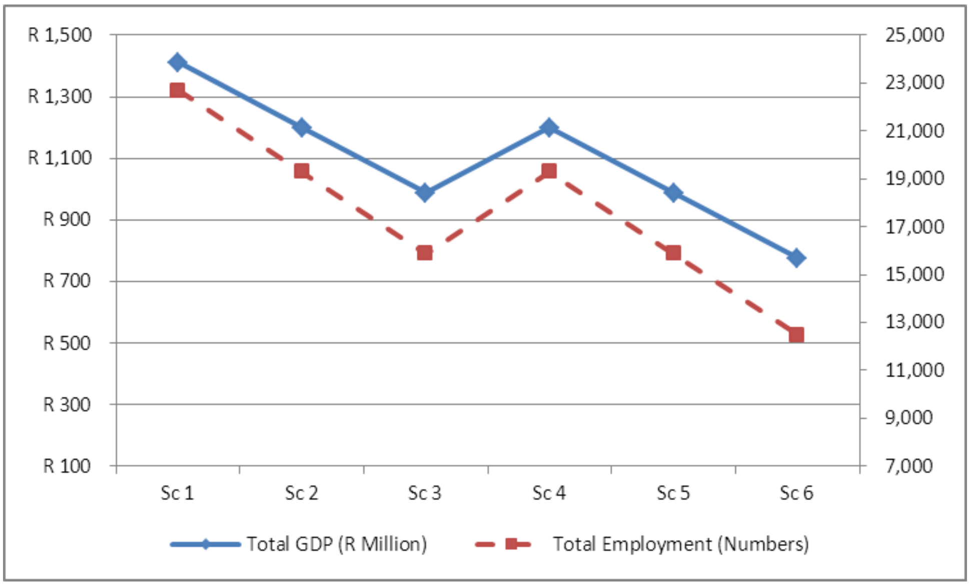
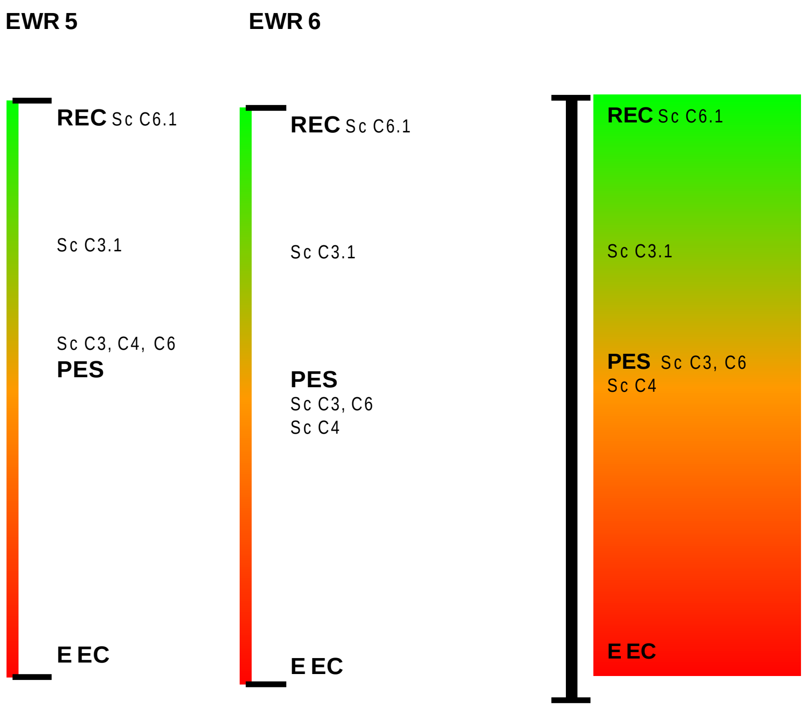


Figure: Economic consequences in terms of GDP and Total employment compared to the baseline (Sc 1)

*.**Ecological consequences***

The purpose of this task is to predict the driver and biota responses to each operational scenario and derive the Ecological Category (EC) for the EWR site and Management Resource Unit (MRU).

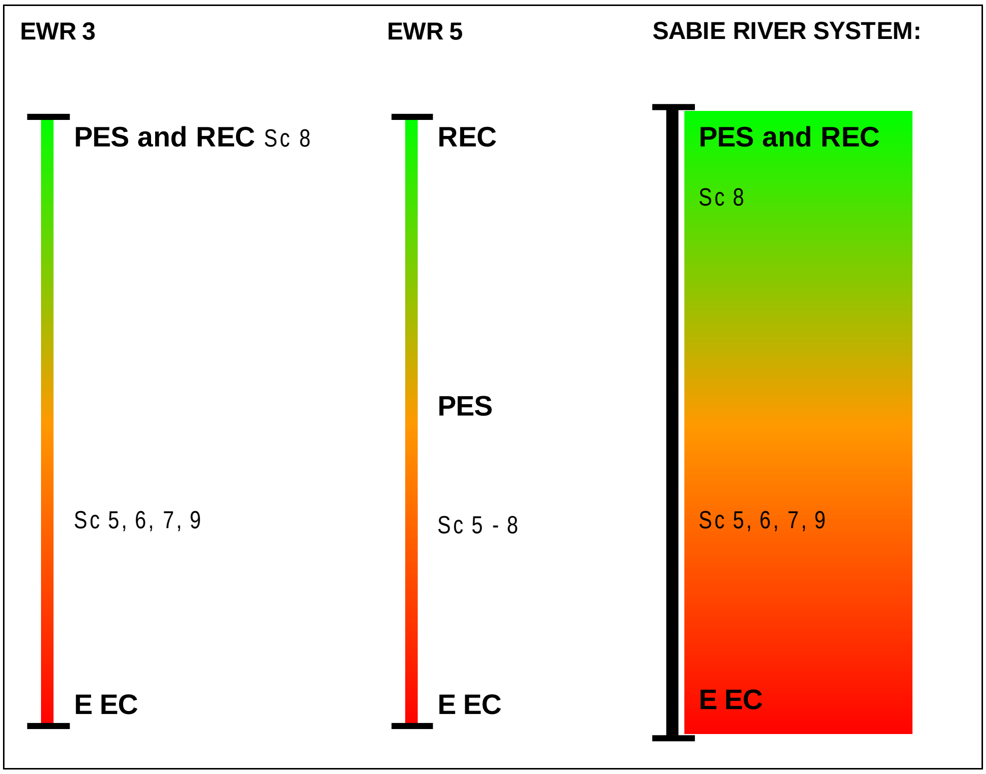
The results provided are ranked and illustrated on a scale from good (REC) to 'bad' (an E EC) where in this case the PES has been placed in the middle (figure below). This provides an indication of the DEGREE to which the scenarios do not meet the REC and takes into consideration the more detailed assessment on which the summaries are based. The figure below provides the ranking of operational scenarios per EWR site as well as a summarised ranking for the Crocodile system as a whole in terms of a traffic diagram.



Ranking of operational scenarios per EWR site and a summary ranging for the Crocodile as a whole.

Within a system context none of the scenarios met the REC at any of the EWR sites. The PES was maintained under Sc C3 and C6. Scenario C4 met the PES EcoStatus; the fish component however deteriorated to an unacceptable level and therefore the overall PES requirement was not met and was ranked below the PES in the above figure.

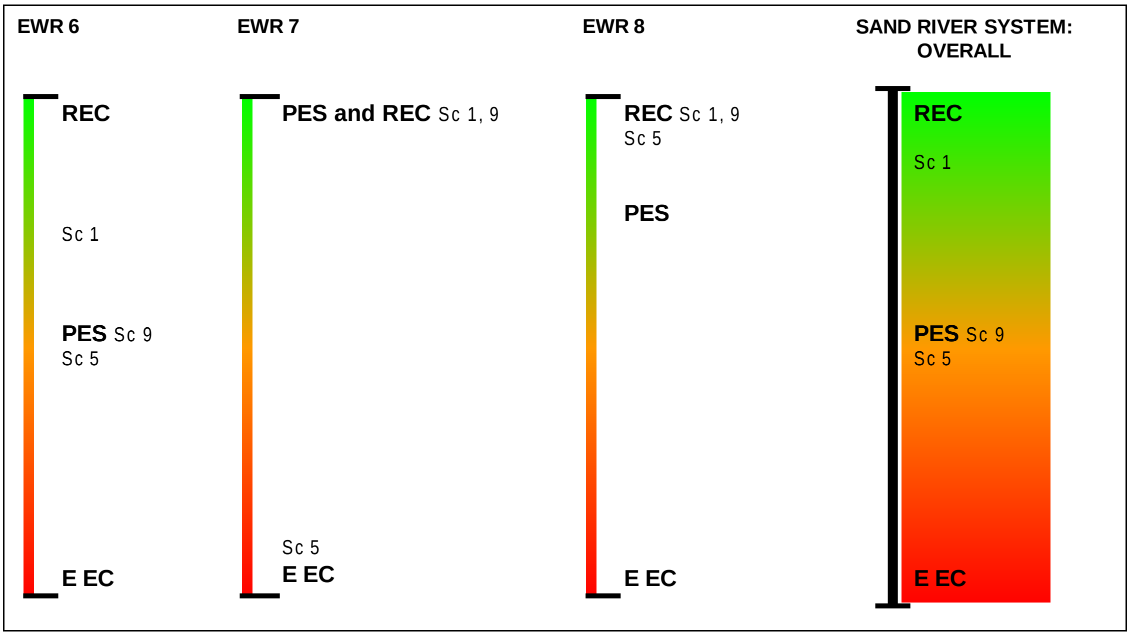
The figure below provides the ranking of operational scenarios per EWR site as well as a summarised ranking for the Sabie system as a whole in terms of a traffic diagram.



Ranking of operational scenarios per EWR site and a summary ranging for the Sabie as a whole

Scenario 8 met the PES/REC at EWR 3 in KNP but not at EWR 5 (Marite). Therefore it was significantly better than the other scenarios which were lower than the PES at both sites. EWR 3 was the key site in the system.

The figure below provides the ranking of operational scenarios per EWR site as well as a summarised ranking for the Sabie system as a whole in terms of a traffic diagram.



Ranking of operational scenarios per EWR site and a summary ranging for the Sand as a whole

Scenario 1 was an improvement of the PES at EWR 6 and met the REC at EWR 7 and 8. It was a better scenario than Sc 9 which only met the PES at EWR 6 and did not improve it as was the case with Sc 1. Scenario 5 was the worst scenario as it did not meet the PES/REC at EWR 7.

Goods and Services consequences

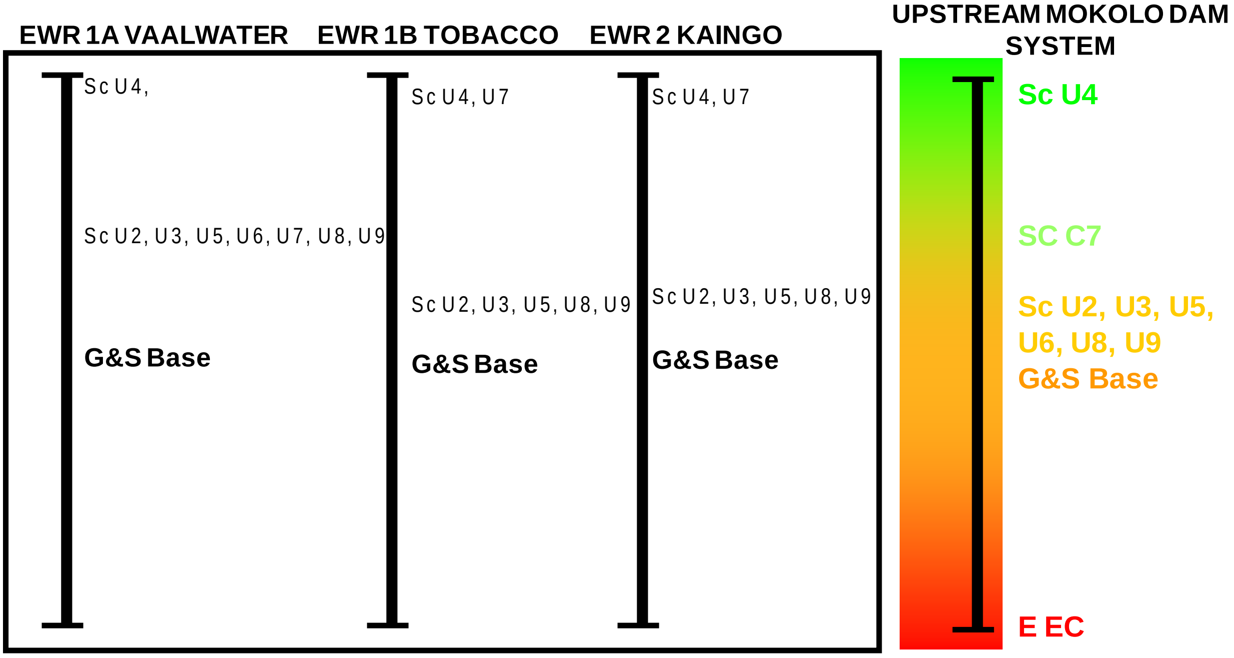
From detailed work at the EWR sites the potential impacts of scenarios on the G&S were estimated by the specialists.

The Table below represents a summary of consequences of the operational scenarios on the G&S by economic zone. Those in green are positive and relates to the scenario providing increased resources for the utilization of goods and services; negative (shaded red) relates to a decrease in resources. Those scenarios shaded in yellow are neutral and indicates either (a) no change in resources and will be the same as present or (b) some G&S will be positively affected and some will be negatively affected but overall there is no driving indicator that would suggest either a positive or a negative overall outcome.

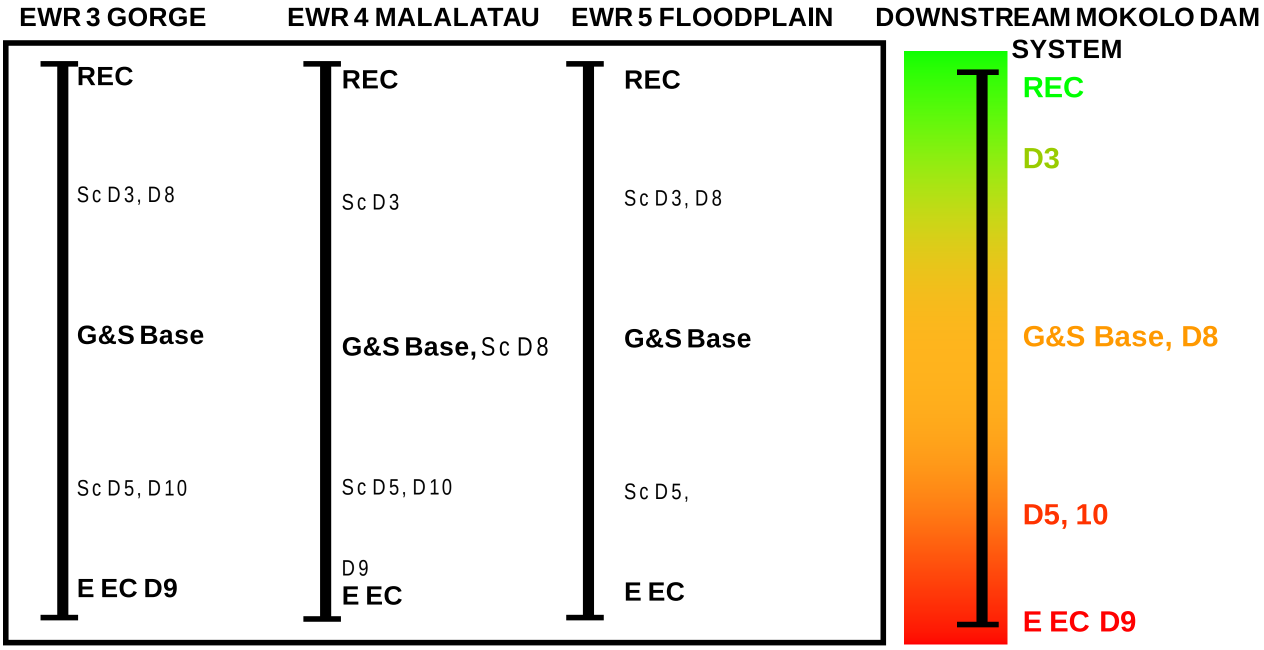
Summary of predicted impact of scenarios on G&S in the Crocodile and Sabie-Sand River catchment

Economic Zone	EWR Site	Scenarios							
Crocodile sub-catchment									
Upper Crocodile	*EWR 1, 2*	*None*							
Elands		*None*							
Lower Kwena	*EWR 3*	*3*	*7*	*10*	*12*				
Middle Crocodile	*EWR 4*	*7*	*9*	*10*	*11*	*12*			
Kaap	*EWR 7*	*8*	*9*						
White River		*None*							
Lower Crocodile	*EWR 5, 6*	*3*	*4*	*6*	*7*	*8*	*9*	*10*	*12*
Sabie-Sand sub-catchment									
Sabie	*EWR 1, 2, 4*	*None*							
Maritsane/Inyaka	*EWR 3, 5*	*5*							

Economic Zone	EWR Site	Scenarios							
Sand	*EWR 6 - 8*	*1*	*5*	*9*					



Summary of the G&S consequences upstream of Mokolo Dam



Summary of the G&S consequences upstream of Mokolo Dam

CONCLUSIONS AND RECOMMENDATIONS

The consequences of all the scenarios on the ecological state, G&S and socio-economics are compared and a recommendation made; first by the direct project team, then by a wider internal DWA meeting and finally, if necessary by a presentation to DWA management and stakeholders.

The consequences are summarised using traffic diagrams with green implying good and red implying bad. A numberless scale is also provided to indicate how much better or worse certain scenarios are from the baseline.

The EWR Rule and EWR Tables that will be recommended as the final Ecological Reserve are provided in Appendix A.

Crocodile River: Reserve recommendation

The scenarios that were finally considered were only those that implied restrictions and curtailments of irrigation. (Sc C2 to C6). Sc C3.1 and C6.1 is a modification of Sc C3 and C6 as it uses the increased yield in Kwena Dam resulting from the agricultural restrictions and curtailments to supply the Reserve.

Figure 13-1 illustrates the ecological, Goods and Services and socio-economic consequences. All the EWR sites considered (EWR 3 to 7) was of High importance and the REC consisted of an improvement of the PES. The figure illustrates that there are no scenario that will meet the REC apart from Sc C6.1.

Sc C3.1 was the ecological recommendation as the prediction is that it will improve the PES, however not to the REC level. It is however possible that with non-flow related measurements and with monitoring to verify, the REC could be achieved. This scenario also improved the Goods and Services and but however had a negative socio-economic input (in terms of a los of GDP and job losses). The decision was made that at this stage, the present hydrology must be signed off which will maintain the PES.

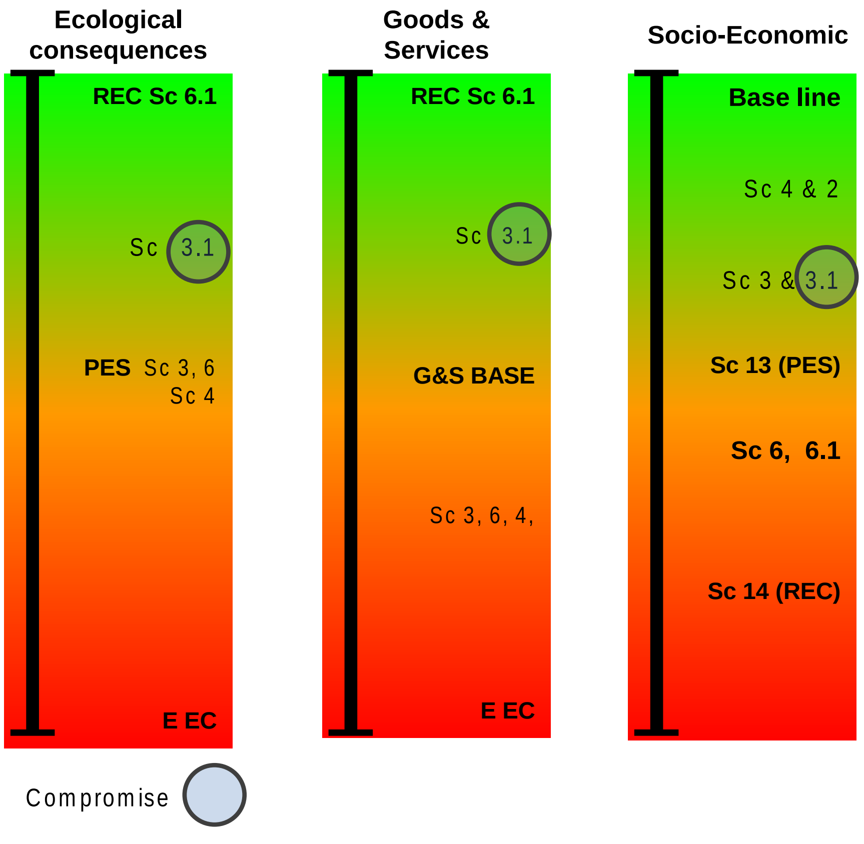


Figure 0.1 Consequences of various operational scenarios in the Crocodile River

Sabie River: Reserve recommendation

Socio-economic scenarios were not evaluated for the Sabie River as all the scenarios were an improvement of the present agriculture. Goods and Services followed the ecological consequences trend and the decision regarding the Reserve recommendation was based on the ecological consequences.

The REC of all the EWR sites apart from EWR 5 (Marite River) can be achieved with the present day flows. Achieving the Marite River REC will require a different operation of Inyaka dam which would result in economic consequences and the REC in the lower EWR sites will not be achieved.

The recommendation was therefor made to sign off the REC at EWR 1, 2, 3, 4 and the PES at EWR 5.

Sand River: Reserve recommendation

Socio-economic scenarios were not evaluated for the Sand River as all the scenarios will result in an improvement of water supply to agriculture. Goods and Services followed the ecological consequences trend and the decision regarding the Reserve recommendation was based on the ecological consequences.

The scenarios were based on the assumption that the four abstraction weirs in the upper Sand River would be rehabilitated, thus improving the flow downstream. Of the various scenarios evaluated, only Sc 1 (the so-called Sellick-rule) will achieve the REC at the key site, EWR 8 in the lower Sabie. This scenario will improve the PES (and REC which was set to maintain the PES) at EWR 7 (upper Sand River). It will also improve the PES towards the REC at EWR 6 and hopefully, with some non-flow related measures (specifically removal of alien vegetation) combined with flow related improvements, the REC will be met.

The recommendation was therefore made that the Sellick Rule should be implemented as the advantages would be much wider than just to ensure the Ecological Reserve. The Ecological Categories that must be signed off is:

- *EWR 6 – REC. It must be acknowledged that without some crucial catchment management improvements, the increased flows on their own will not achieve the REC but could likely achieve an improvement of the PES.*
- *EWR 7 – REC (=PES). Scenario 1 will achieve the AEC up, however the main motivation for applying Scenario 1 is to meet the REC at EWR 8.*
- *EWR 8 – REC.*

ESTIMATION AND EXTRAPOLATION OF EWRS AT VARIOUS HYDRONODES

A comprehensive Reserve study assesses EWRs at EWR sites that are usually situated on the main rivers and large tributaries. For the purpose of, amongst others, Compulsory Licensing and general licensing, Reserves have to be set at many points (hydronodes) in the catchment.

The objective of this task is to provide an estimate which will be of higher confidence than the Desktop Reserve Model at every hydronode in the study area.

Extrapolation consists of

- *determining which sites are sufficiently similar to the comprehensive EWR sites in terms of biophysical similarity as well as indicator guilds used for setting EWRs; and*

- *Deriving the EWRs for these sites using the comprehensive EWR results at the EWR sites.*

Estimation consists of a process to estimate the EWRs at each hydronode for the Recommended Ecological Category (REC) (using the information generated as part of the Desktop EcoClassification (Kleynhans & Louw, 2007)). This estimation will entail the prediction of indicator species at various hydronodes, and the determination of the EWRs at these hydronodes using a higher confidence method than the Desktop Ecological Reserve Model.

EWR estimates were supplied at approximately 76 hydronodes as .rul and .tab tables.

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TERMINOLOGY AND ACRONYMS

AEC	*Alternative Ecological Category*
BBM	*Building Block Methodology*
BEC	*Baseline Ecological Category*
BHNR	*Basic Human Needs Reserve*
BTP	*Bosbokrand Transfer Pipeline*
CD: RDM	*Chief Directorate: Resource Directed Measures*
COMBUD	*Computer Based Budgets*
DAM	*Desktop Adjustment Method*
D:RQS	*Directorate: Resource Quality Services*
DRIFT	*Downstream Response to Imposed Flow Transformation*
DS	*Down Stream*
DSS	*Decision Support System*
DWA	*Department of Water Affairs (Name change 2009)*
DWAF	*Department of Water Affairs and Forestry*
EC	*Ecological Category*
EcoSpecs	*Ecological Specifications*
EIS	*Ecological Importance and Sensitivity*
ERM	*Ecological Resource Monitoring*
EWRM	*Ecological Water Resource Monitoring*
EWR	*Ecological Water Requirements*
EZ	*Economic Zone*
FDI	*Flow dependent macroinvertebrate*
FDCD	*Flow Dependant Cobble Dwelling*
FDT	*Flow Duration Table*
FFHA	*Fish Flow Habitat Assessment*
FRAI	*Fish Response Assessment Index*
FROC	*Fish Frequency of Occurrence*
FV	*Future value*
G&S	*Goods and Services*
GAI	*Geomorphological Driver Assessment Index*
GDP	*Gross Domestic Product*
GGP	*Gross Geographic Product*
GIS	*Geographic Information System*
GRA	*Groundwater Resource Assessment*
GRDM	*Groundwater resource directed measures*
GW	*Ground Water*
GYMR	*Groundwater yield model for the reserve*
HFSR	*Habitat Flow Stressor Response*
HGM	*Hydro-Geomorphic Unit*
IFR	*Instream Flow Requirements*
KNP	*Kruger National Park*
LB	*Left Bank*
LR	*Large rheophilic fish*
LSR	*Large semi-rheophilic fish*
MAR	*Mean Annual Runoff*
PMAR	*Present Mean Annual Runoff*
VMAR	*Virgin Mean Annual Runoff*
MCM	*Million Cubic Metres*
MIRAI	*Macroinvertebrate Assessment Index*
MRU	*Management Resource Unit*

MVI	*Marginal vegetation macroinvertebrate*
NRU	*Natural Resource Unit*
NWA	*National Water Act*
PAI	*Physico Chemical Driver Assessment Index*
PD	*Present Day*
PES	*Present Ecological State*
PSP	*Professional Service Provider*
Quat	*Quaternary catchment*
RAU	*Resource Assessment Unit*
RB	*Right Bank*
REC	*Recommended Ecological Category*
RHP	*River Health Programme*
REC	*Recommended Ecological Category*
RQO	*Resource Quality Objectives*
RU	*Resource Unit*
SAM	*Social Accounting Matrix*
Sc	*Scenario*
SCI	*Socio Cultural Importance*
SR	*Small rheophilic fish*
ToR	*Terms of Reference*
TPC	*Threshold of Potential Concern*
US	*Upstream*
VBA	*Visual Basic Applications*
VEGRAI	*Riparian Vegetation Response Assessment Index*
WIM	*Water Impact Model*
WMA	*Water Management Area*
WSUQ	*Water Quality Sub Unit*
WRU	*Wetland Resource Unit*
WULA	*Water User Licence Application*

1 INTRODUCTION

The National Water Act (NWA, Act No. 36 of 1998, Section 3) requires that the Reserve be determined for water resources, i.e. the quantity, quality and reliability of water needed to sustain both human use and aquatic ecosystems, so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems. It is therefore imperative that the Reserve be determined and requirements met before other economic activities can be satisfied. As the Department of Water Affairs (DWA) is the trustee of the nation's water resources, it is their responsibility to ensure the adequate protection and effective management of these resources. The Chief Directorate: Resources Directed Measures (CD:RDM) is the directorate within the DWA tasked with the responsibility of ensuring that Reserve assessments take place before licensing can proceed.

The 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 DWA to make informed decisions regarding the authorisation of future water use and the magnitude of the impacts of the present and proposed developments.

1.1 STUDY AREA

1.1.1 Description of Study area

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

The Reserve requirements for the Komati River system (the remaining major river system in WMA 5) was determined and approved in 2003, the results of which are at a high confidence and are still relevant for use and implementation by the DWA. As such it was deemed unnecessary to include this system in the study area. The focus of this study therefore is only on the Crocodile (X2) and Sabie-Sand (X3) catchments (Figure 1-1).

1.1.2 Economic Characteristics

The gross geographic product (GGP) of the Inkomati WMA was R6,7 billion in 1997. The most important magisterial districts in terms of contribution to GGP in this WMA are Barberton, White River, Nsikazi, Pilgrims Rest and others. The most important sectors in terms of contribution to the GGP are manufacturing, agriculture government, trade and other.

The largest part of the Inkomati WMA falls within the Lowveld, which has a warm sub-tropical climate which is suitable for growing many frost-sensitive crops and tropical fruit, such as bananas, avocados and mangoes. Sugarcane which is an irrigated crop is grown in the eastern parts mainly the lower Crocodile and Komati River valleys. The Malelane and Komati Sugar Mills are located here.

The higher mountainous areas are suitable for forestry and large plantations of pine and eucalyptus supply the wood, pulp and paper industries. SAPPI Ngodwana, one of the largest paper mills in the country is located in the Crocodile River catchment approximately 40 km west of Nelspruit. A large number of manufacturing activities are situated in and around Nelspruit and industrial development is expanding rapidly. Development opportunities have been identified especially in the steel, chemicals, food, wood products, paper and pulp. An international airport just outside of Nelspruit improves access to international markets and tourism

A very important feature of the Inkomati WMA is the Kruger National Park, which also extends into the Olifants and Levuvhu/Letaba WMAs. This forms a large part of the tourism industry. The scenic areas around Sabie, Graskop, Pilgrim's Rest and the Blyde River Canyon also draw large numbers of tourists throughout the year. Trout fishing is another well-supported tourist activity in the area, in places such as Dullstroom and areas around Belfast (which falls partly in the Olifants WMA), Waterval Boven and Machadodorp.

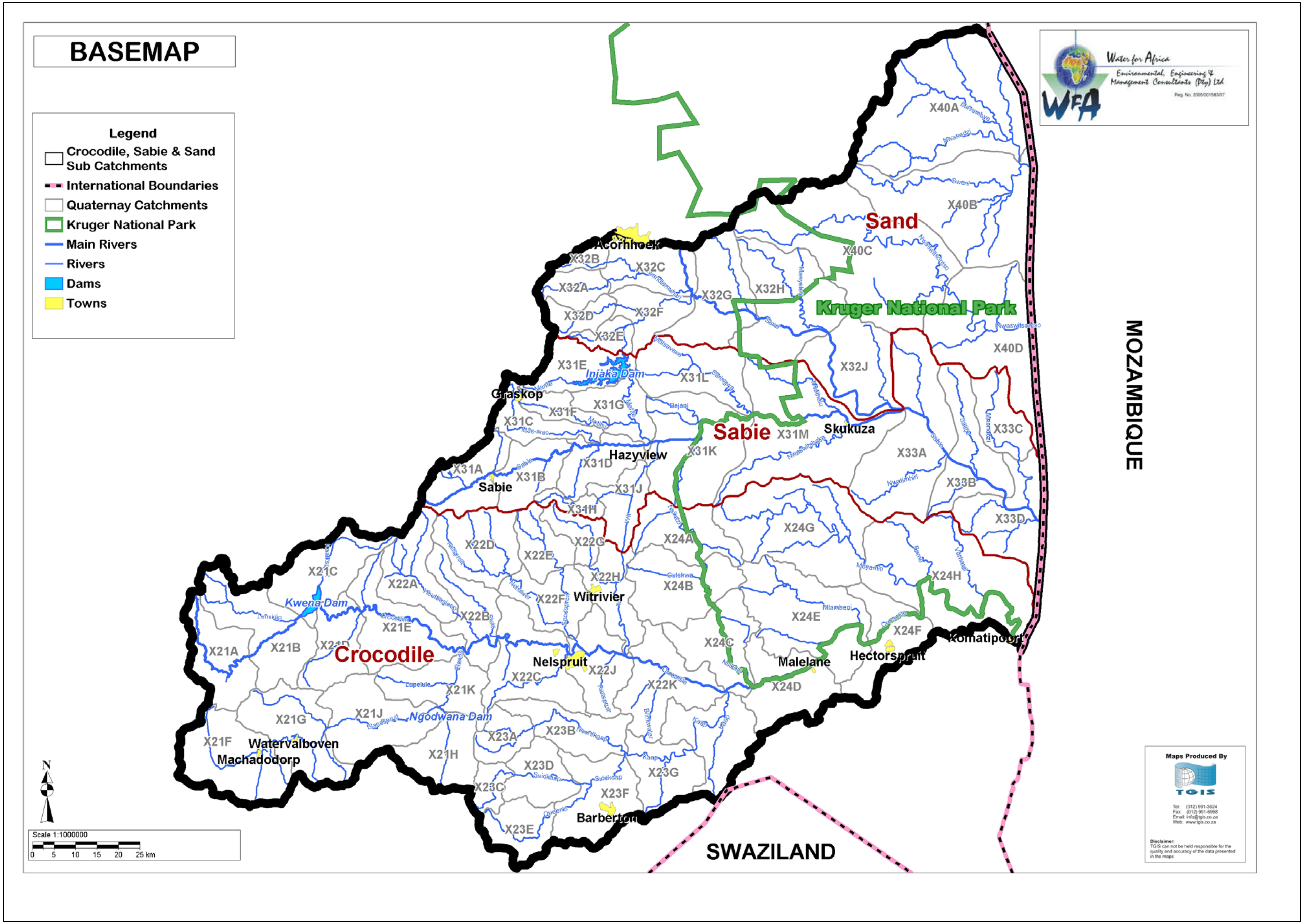

Figure 1.1 Layout and location of the Inkomati WMA

1.2 WATER REQUIREMENTS IN THE CATCHMENT

The Inkomati WMA mainly consists of urban and semi-urban populations. A large number of rural settlements exist in the Mhala, Mapulanneng, Nsikazi, Nkomati and Mswati regions. Major urban centres in the WMA are Nelspruit, White River, Komatipoort, Carolina, Badplaas, Barberton, Sabie, Bushbuckridge, Kanyamazane and Matsulu.

Future growth in population is expected to be moderate and to be concentrated in the urban areas, with a decline in some rural areas.

1.2.1 Existing water related infastructure

Several major dams exist in the Inkomati WMA. The Komati River system is highly regulated by dams with the Crocodile and Sabie River systems less so.

Crocodile River System

- *The Kwena Dam in the Upper reaches of the Crocodile River which augments water supplies to users along the Crocodile River.*
- *Two new dams are proposed on the Crocodile River system, namely the Montrose Dam at the confluence of the Crocodile and Elands Rivers and the Mountain View Dam on the Kaap River (tributary of the Crocodile River).*

Sabie River System

- *Inyaka Dam on the Marite River a tributary of the Sabie River was constructed mainly to supply the domestic and ecological water requirements on the lower Sabie River and the domestic water requirements in the Sand River sub-catchment by means of the Bosbokrand Transfer Pipeline (BTP) which will transfer up to 25million m^3/annum to the Sand River sub-catchment for this purpose.*

There are a number of important canal systems that transfer water to irrigators in the Crocodile and Sabie River Catchments.

1.2.2 Water Quality

- ***Crocodile sub-catchment***

The water quality in the Crocodile sub-area is generally good although some deterioration of the quality in the lower Kaap River (often high levels of arsenic) and lower Crocodile River is observed. This is due to return flows from upstream users including irrigation, urban areas and old gold mining activities. Irrigation return seepage is noticeable during periods of low flow.

The potential water quality problems emanating from the SAPPI paper mill at Ngodwana is probably the most serious water quality problem in the catchment. Effluent has been disposed of through irrigation for a number of years but the soil has become saturated with salts (especially chlorine) and these leach out into the Elands River and then enter the Crocodile River.

- ***Sabie-Sand sub-catchment***

The surface water quality in the Sabie River sub-catchment is good with no immediate threats. Following completion of the Inyaka Dam there is considerable assimilative capacity available to *maintain the water quality in the Sabie River in its current good state. Water entering the Kruger National Park is a major concern if appropriate sanitation upstream of the Park is not implemented.*

The surface water quality in the Sand River sub-catchment is not as good as in the Sabie River sub-catchment due to over-abstraction which reduces the natural assimilative capacity of the river. Occasional elevated levels of nutrients in the Sand River are noted, with informal housing developments a suspected cause. The large number of rural settlements which rely on pit latrines is cause for concern as far as ground-water pollution goes but to date there have been no reported incidences of groundwater pollution.

2 PROJECT PLAN AND APPROACH

Author: MD Louw (Rivers for Africa)

2.1 INTRODUCTION

The approach to the Reserve study was within context of the eight-step Reserve procedure (Louw and Hughes, 2002). The eight step procedure is provided in Figure 2-1.

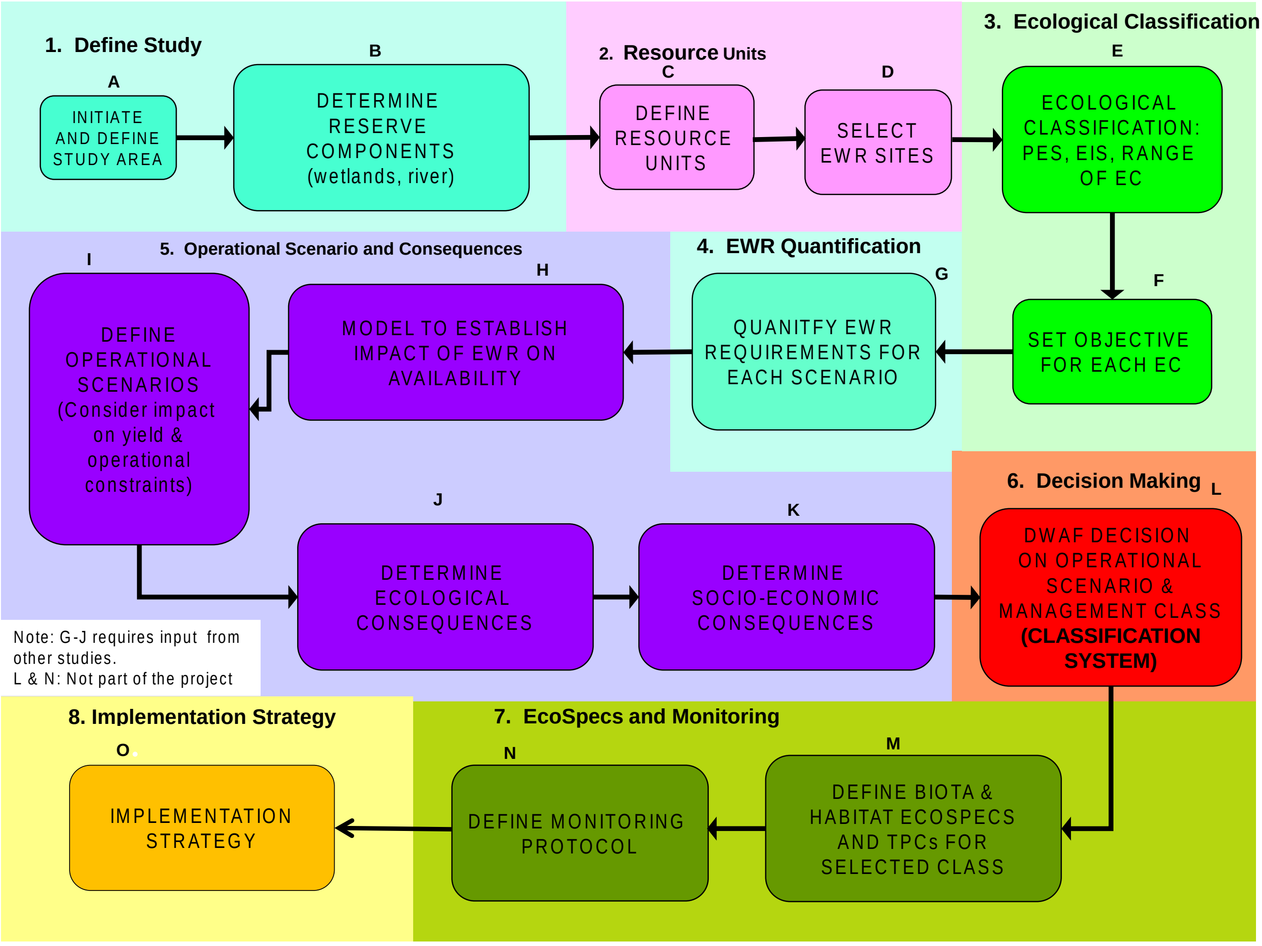

Figure 2.1 Diagram illustrating the process to be followed for the Inkomati WMA Reserve study (Adapted from DWAF, 2006)

2.2 AIMS, OBJECTIVES AND OUTCOMES OF THE STUDY

The overall aim of the project as described in the Terms of Reference (ToR) was to provide EcoClassification results and Reserves for WMA 5 as well as a detailed capacity building programme. The detailed aims, objectives and proposed outcomes of the study were as follows:

- *Provide technical and project management.*
- *Provide the typing, importance and habitat integrity for wetlands and make recommendations regarding Reserve assessments.*
- *Groundwater: Assess groundwater input to base flows at an intermediate level and make recommendations for Reserve assessments at a higher level of confidence if necessary.*
- *Provide Level 4 EcoStatus assessment for the Resource Units (RUs) represented by comprehensive EWR sites as part of the EcoClassification process.*
- *Identify a range of Ecological Categories (ECs) for which water requirements must be set.*

- *Determine EWRs for each of these ECs or, where relevant, test existing EWRs for adequacy and purposes of monitoring.*
- *Determine the impact of EWRs on the allocatable yield and, based on the impacts, devise additional scenarios to optimize the allocatable yield.*
- *Determine the ecological and resource-economic consequences of each of these additional scenarios.*
- *Provide the Ecological Specifications (EcoSpecs), as input to the Resource Quality Objectives (RQOs), associated with the Management Class provided to the PSP, if available.*
- *Provide extrapolated results for each hydrological node in the Sabie and Crocodile catchment.*
- *Provide an implementation strategy for the Reserve.*
- *Train selected specialist trainees in specific tasks relating to Reserve determinations.*

The output of the study is Ecological Water Requirement (EWR) Rules for every site and for a range of Ecological Categories, as well as the EcoSpecs.

2.3 PROJECT PLAN

The project plan generally used by Rivers for Africa for Reserve studies was modified for the Inkomati Reserve Study and consisted of a range of tasks and sub-tasks listed in Table 2.1. These task numbers are linked to those in Figure 2-2.

The results of these tasks are described within this main report and the corresponding chapters are provided in the Table 2.1.

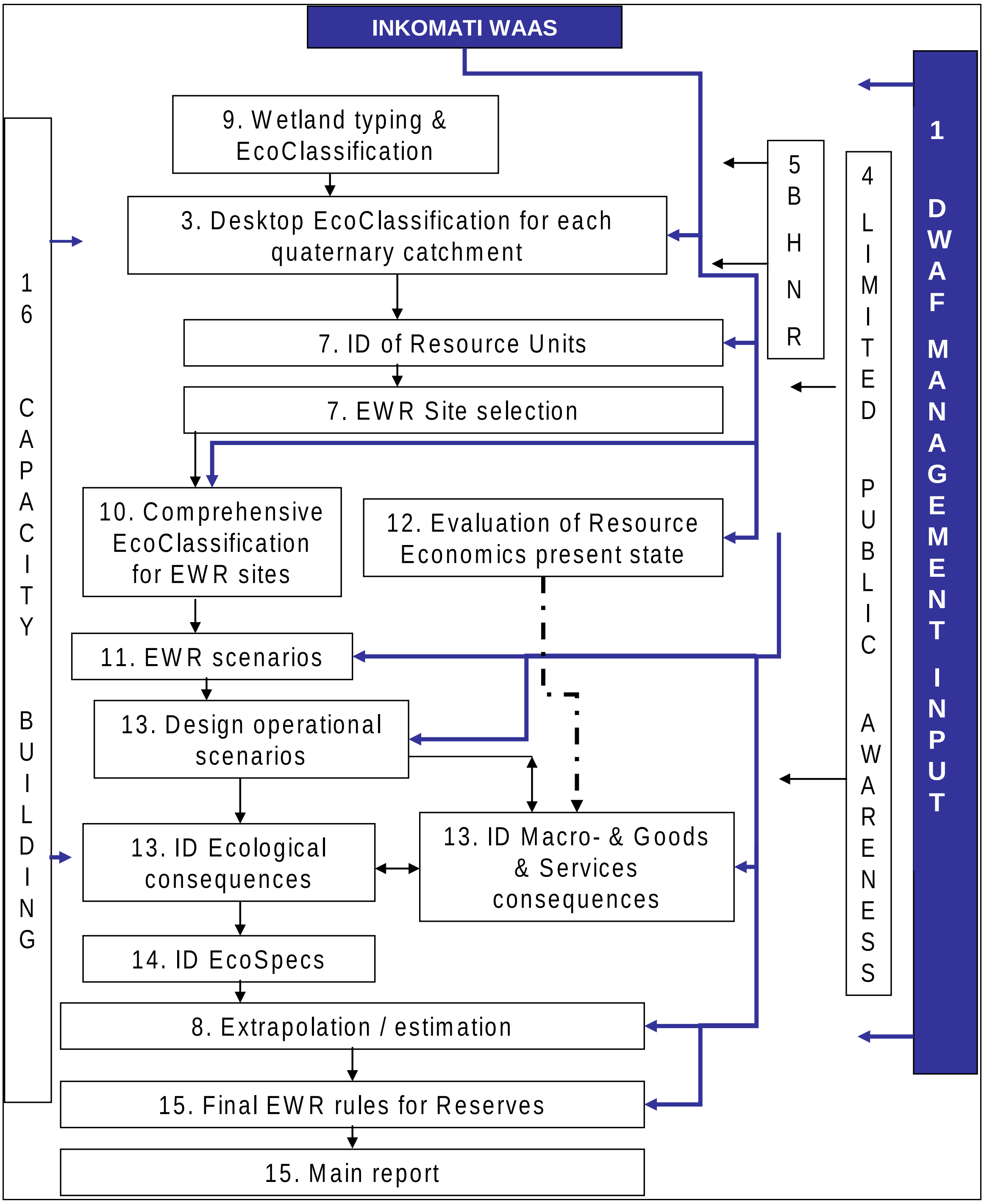

Figure 2.2 Project Plan for the Inkomati Reserve study

Table 2.1 List of tasks within the Project Plan

TASKS AND SUBTASKS	Corresponding chapters in main report
TASK 1 - PROJECT MANAGEMENT	
1.1 Project Management	
1.2 Technical management	
1.3 PMT Meetings	
1.4 Financial management	
PHASE I: STUDY INITIATION AND DESIGN	
TASK 2 - PROJECT PLANNING AND PROCESS INTEGRATION	**Chapter 2**
2.1 Design of project plan and available current data collection	

2.2 Mobilisation of study team	
PHASE II: STUDY IMPLEMENTATION	
TASK 3 - DESKTOP ECOCLASSIFICATION	**Chapter 3**
3.1 Socio-cultural importance at quaternary level *3.2 Populating SCI model* *3.3 Include in DFID Recommendations*	
TASK 4 - LIMITED PUBLIC AWARENESS ASSESSMENT	
TASK 5 - BASIC HUMAN NEEDS RESERVE	**Chapter 4**
TASK 6 – GROUNDWATER COMPONENT	**Chapter 5**
6.1 Study description *6.2 Delineation of resource units* *6.3 Resource Classification* *6.4 Quantification of the groundwater contribution to the Ecological Reserve* *6.5 Setting of quality and quantity groundwater Resource Quality Objectives*	
TASK 7 – RESOURCE UNITS	**Chapter 7**
7.1 Geomorphological zones *7.2 EcoRegions* *7.3 System operation* *7.4 Water quality subunits* *7.5 Land cover* *7.6 Groundwater sub-units* *7.7 Identification of Resource Units* *7.8 Sabie EWR site selection and dry season survey* *7.9 RU Report*	
TASK 8 – EXTRAPOLATION/ESTIMATION	**Chapter 15**
8.1 Predict the indicator species at each hydrological node *8.2 Indicate the reach that each hydrological node and the EWR sites represent* *8.3 Predict flow requirements for each hydrological node* *8.4 Report*	
TASK 9 – WETLAND TYPING AND ECOCLASSIFICATION	**Chapter 6**
9.1 Identify and map the wetlands *9.2 Classification of wetland types (HGM classification system)* *9.3 Reference conditions* *9.4 General Current Ecological Condition* *9.5 Ecological Importance and Sensitivity* *9.6 Prioritization of possible sites for pilot testing of Rapid Reserve methods* *9.7 Report writing*	
TASK 10 – RIVER ECOCLASSIFICATION	**Chapter 8**
10.1 Crocodile River survey & hydraulic calibration *10.2 Data and model preparation* *10.3 Diatom assessment* *10.4 EcoStatus assessment* *10.5 Specialist meeting* *10.6 Reporting*	
TASK 11: EWR SCENARIO ASSESSMENT	**Chapter 9**
11.1 Hydraulic calibration *11.2 EcoHydraulic modelling* *11.3 Sediment Transport modelling* *11.4 EcoHydrology analysis* *11.5 Data Collation and Preparation* *11.6 EWR scenario determination* *11.7 Reporting*	
TASK 12 SOCIO ECONOMIC PRESENT STATE EVALUATION	**Chapter 12**

Task 12.1 Identification of the sectors *Task 12.2 Determination of economic zones and current water allocation* *Task 12.3 Determination of the valuation technique* *Task 12.4 Economic value of water*	
TASK 13 – DETERMINING OPERATIONAL SCENARIOS AND CONSEQUENCES	**Chapter 10-12**
13.1 Yield modelling *13.2 Concentration modelling* *13.3 Determining ecological consequences* *13.4 Socio economics & Ecosystem services consequences* *13.5 Reporting*	
TASK 14 – IDENTIFICATION OF ECOSPECS AND MONITORING PROGRAMME	**Chapter 14**
14.1 Component assessments *14.2 Reporting*	
PHASE III: STUDY TERMINATION	
TASK 15- STUDY TERMINATION	**Chapter 13 & 16**
15.1 Preparation of final Reserve results *15.2 Capacity building analysis and audit* *15.3 Compilation of main report* *15.4 Preparation of Reserve templates*	
TASK 16 CAPACITY BUILDING: TRAINING PROGRAMME	**Chapter 17**

2.4 VARIATION ORDERS

One variation order (VO) was approved during the course of the study. The VO is outlined below:

2.4.1 Re-assessment of EWR 6

EWR 6, the most downstream site in the Crocodile River and situated just upstream of the Komati River confluence, is the key site for EWR. Changes in the hydrology emanating from the Water Availability Assessment Study (WAAS) identified after the EWR scenario assessment task required that EWR 6 had to be re-assessed. The re-assessment of the site entailed the following:

- *Obtaining a low flow calibration for EWR 6*
- *Refining the hydraulic information*
- *Re-assessing the site EWR 6 EWR requirements*
- *Determine the ecological consequences at EWR 6*

2.4.2 Determination of a monitoring programme with emphasis on EcoSpecs

During the course of the study, Ecological Water Resource Monitoring (of which Ecological Reserve Monitoring forms part of) was further developed and refined. In order to include the newest developments, additional budget was required to include a habitat assessment. This habitat assessment required a baseline consisting of measuring numerous cross-sections at the EWR sites. This work was based on the newly developed Rapid Habitat Assessment Method (RHAM) and would be used to analyse the results from which Thresholds of Probable Concern could be derived and used within a Monitoring Decision Support System.

3 DESKTOP ECOCLASSIFICATION

Department of Water Affairs and Forestry (DWAF), 2008. Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. Sabie and Crocodile Systems: Desktop EcoClassification report. Report produced by Water for Africa. Authored by Louw D & Huggins G P. Report no: 26/8/3/10/12/002.

3.1 APPROACH

The objective of the EWR study is to provide information at two levels of detail, i.e. at scoping or desktop level, as well as a more detailed assessment. This task presents the results of the Desktop assessment of the EcoClassification process for each quaternary and sub-quaternary catchment. The term used for Ecological Classification "EcoClassification" (Kleynhans et al., 2005) refers to the determination and categorisation of the Present Ecological State (PES) - or health or integrity - of various biophysical attributes of rivers, compared with the natural or close to natural reference condition. The purpose of EcoClassification is to gain insight into the causes and sources of the deviation of the PES from the reference condition. This provides the information needed to derive the desirable and attainable future ecological objectives for the river. The present state of the river is described in terms of Ecological Categories (A to F). The EcoClassification process also includes an assessment of Ecological Importance and Sensitivity (EIS), and Socio-Cultural Importance (SCI). These are described in terms of Low to Very High (EIS) and Minimal to Very High (SCI). All assessments include a confidence rating that may range from 1 (low confidence) to 5 (high confidence).

This PES and EIS assessment were undertaken during a previous study (Louw and Singh, 2006). During this study the SCI and analysis of hotspots were assessed using the 2006 results.

3.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The ecological importance of a river is an expression of its contribution to the maintenance of biological diversity and ecological functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience) (Resh et al., 1988; Milner, 1994).

The EIS model is used, irrespective of the level of assessment. Only the intensity of data collection varies according to the level of assessment. Based on Louw and Singh (2006), of the 36 quaternary catchments assessed in the Crocodile River sub-catchment, two quaternary catchments had a very high EIS rating (Z21A and X24H, Crocodile River), while 21 quaternary catchments were rated as having a high EIS.

Twenty nine quaternary catchments were assessed in the Sabie-Sand sub-catchment of which six quaternaries had a very high EIS rating (X31C (Mac Mac River); X31K, X31M, X32H, X33A, B, D (Sabie River) and 11 quaternaries were rated as having a high EIS. The results are summarised in Table 3.1 and in Figure 3-1.

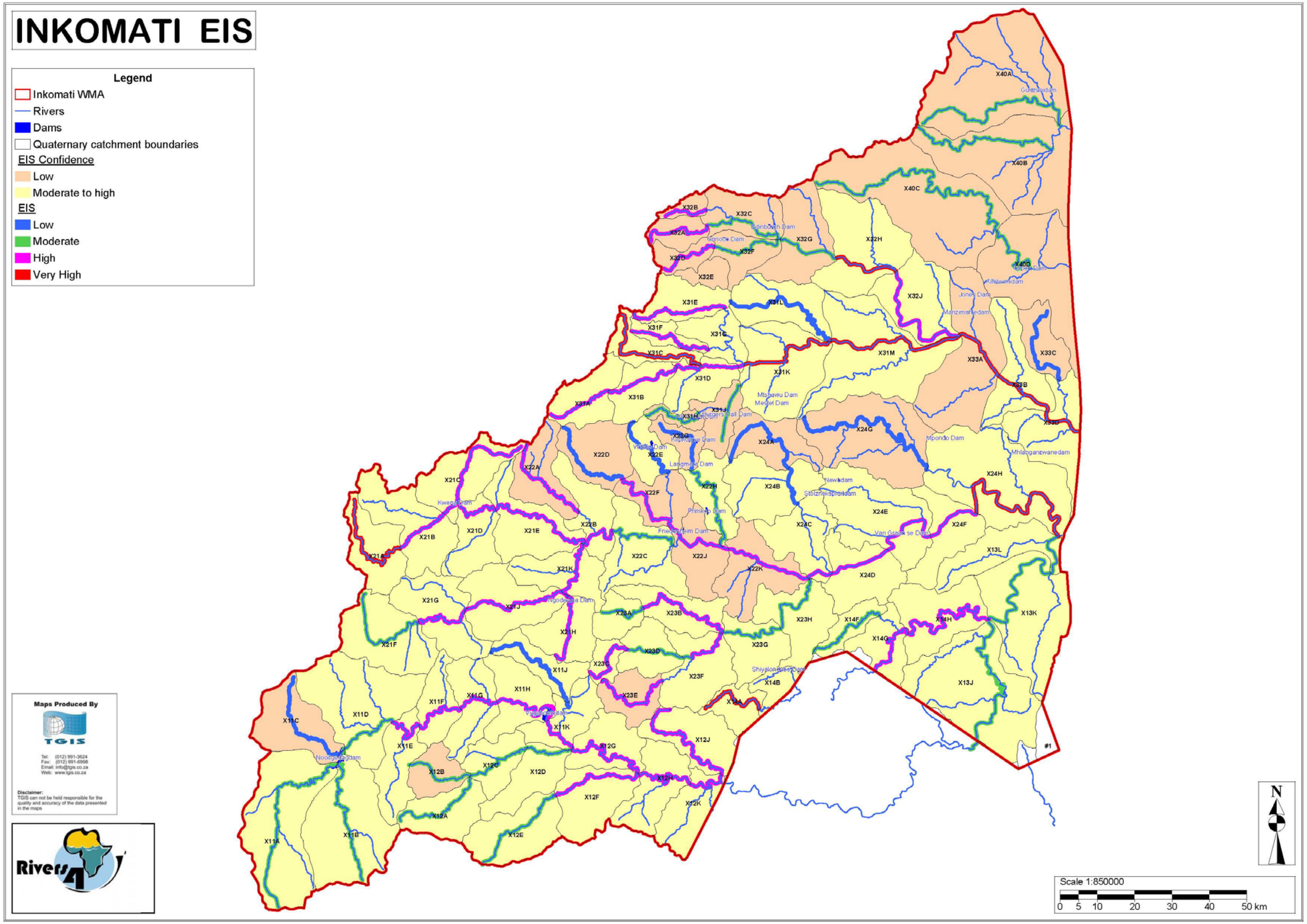

Figure 3.1 Crocodile and Sabie-Sand River sub-catchments: EIS per quaternary and sub quaternary catchment with associated confidence

3.3 SOCIO-CULTURAL IMPORTANCE

The SCI was determined from:

- *A site visit that covered points along the river;*
- *Extrapolation to sites not visited by reference to available literature, as well as to existing mapping.*

The SCI was generated by scoring each quaternary, based on the following features:

- *Ritual Use (e.g., ceremonial purposes, spiritual/religious activities).*
- *Aesthetic Value.*
- *Resource Dependence (referring to the goods and services delivered by the river system and people's dependence on these components).*
- *Recreational Use.*
- *Historical/Cultural Value (e.g. Fugitives Drift on the Buffalo River or components of the Mzimvubu River that have played a central role in Xhosa cultural history).*

Scores were then modified to reflect the adjudged importance of each component relative to the other.

The SCI examination of the Sabie and Crocodile systems revealed that there were certain quaternary catchments that scored in the "high" and "very high" importance category. To some extent this was a geographical accident in that quaternaries that covered both the Kruger Park area as well as some of the former homeland areas were included. As such, these areas score high in both the aesthetic recreation value (Kruger Park) and the ritual andresource use components(subsistence areas). Despite the geographical coincidence it was evident that many of the quaternary areas and associated resource components were highly important in terms of the SCI and as such arguments for improving or at least maintaining the PES were probably well founded.

A SCI map illustrating the SCI rating and confidence is provided in Figure 3-2 and 3-3 for the Crocodile sub-system and Sabie-Sand sub-system respectively.

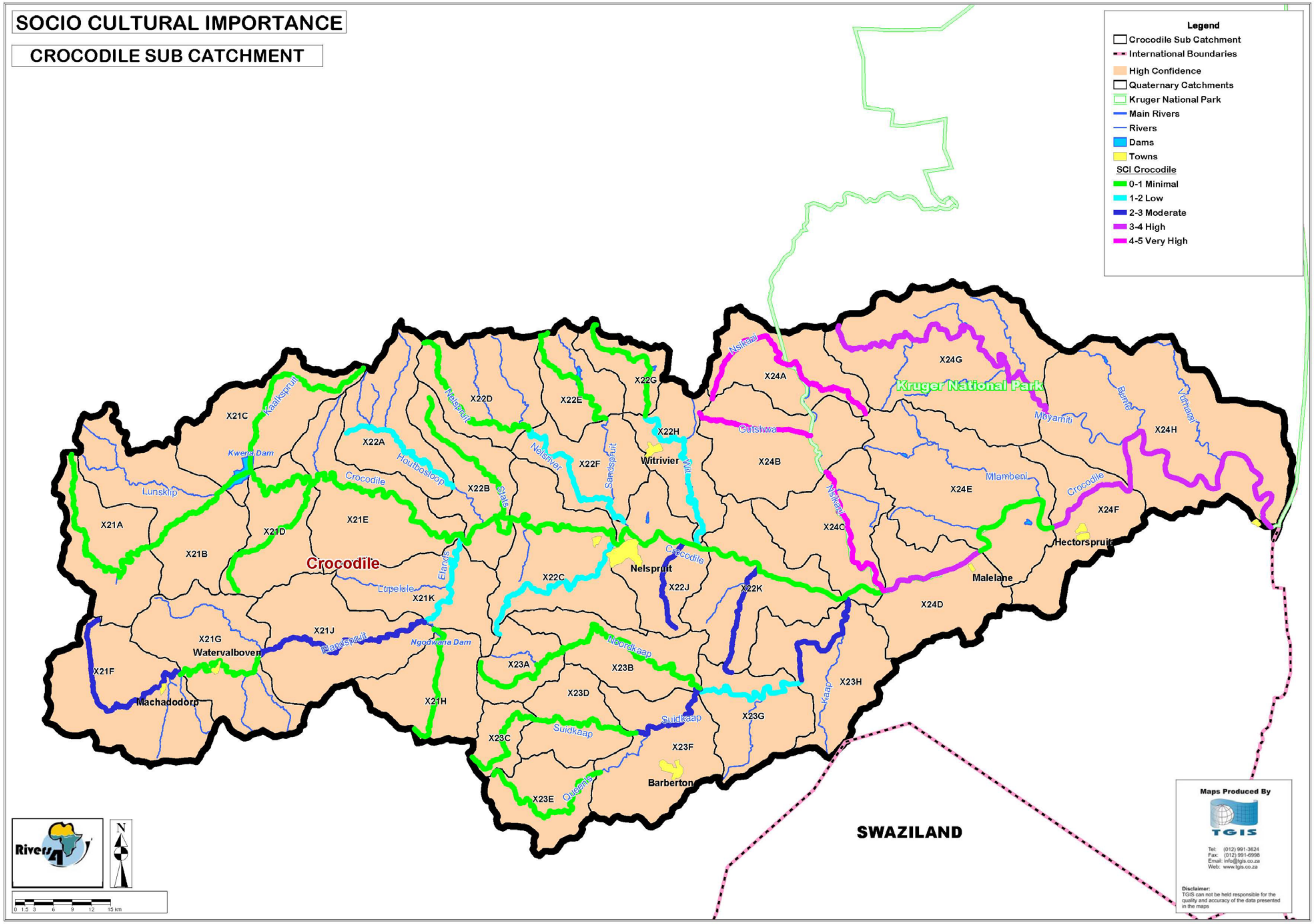

Figure 3.2 Crocodile sub-catchment: SCI map illustrating SCI rating and confidence

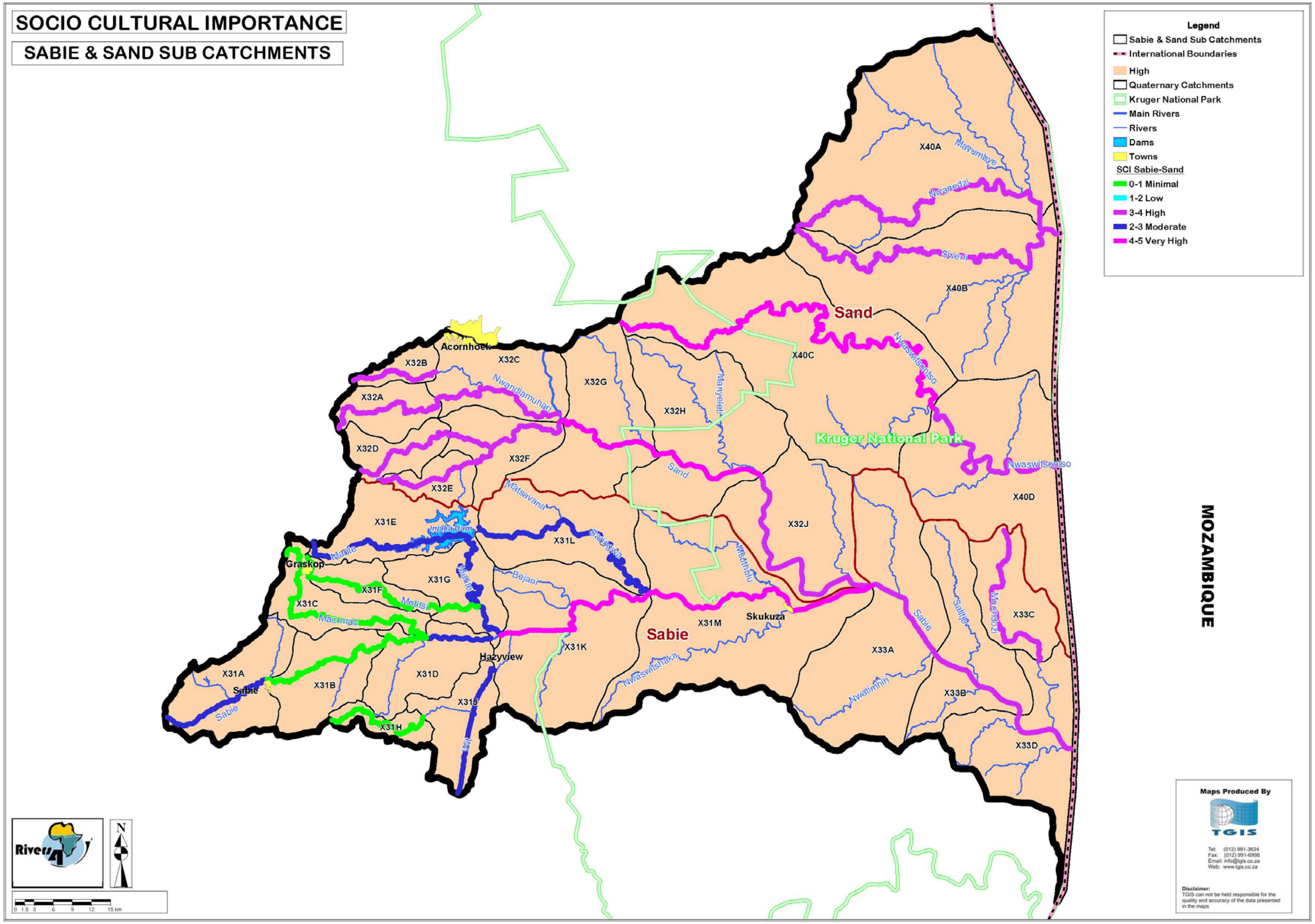

Figure 3.3 Sabie Sand sub-catchment: SCI map illustrating SCI rating and confidence

3.4 PRESENT ECOLOGICAL STATE

The PES of the river is expressed in terms of various components, i.e., drivers (physico-chemical variables, geomorphology, hydrology) and biological responses (fish, riparian vegetation and macroinvertebrates), as well as an integrated state, the EcoStatus.

Based on Louw and Singh (2006) the PES of most of the rivers evaluated in the Crocodile River sub-catchment fell within categories B to C/D, with only four rivers falling within category D (XX22E-Sand River, X24A,B-Nsikaze River and X22J-Crocodile River).

During the 2006 study the PES of most of the rivers evaluated in the Sabie-Sand sub-catchment fell within categories B to C, with only one river falling within a C/D category (X31J-Noord Sand River).

The PES of the following rivers was within categories A - A/B and B:

- *Crocodile River sub-catchment:*
  - *X21A Crocodile River (B)*
  - *X21B Crocodile River (B)*
  - *X21F-G,J-K Elands River (B)*
  - *X22A Houtbosloop (B)*
  - *X22D Nels River (B)*
  - *X24G Mbyaniti River (A/B)*
- *Sabie-Sand River sub-catchment:*
  - *X31A-B,D,G Sabie River (B)*
  - *X31C Mac Mac River (A/B)*
  - *X31F Motitsi River (B)*
  - *X32B Klein Sand (B)*
  - *X32H,JSand River (B)*
  - *X33A-B,D Sabie River (A//B)*
  - *X33C Mlondolozi (A)*
  - *X40A Sweni (A)*
  - *X40B Nwanetsi (A)*
  - *X40C-D Nwasitsontso (A)*

The reason for these rivers still being in a good condition is related to the low accessibility to most of them (which result in some protection), or they are situated in protected areas. The results are summarised in Table 3.1 and in Figure 3-4.

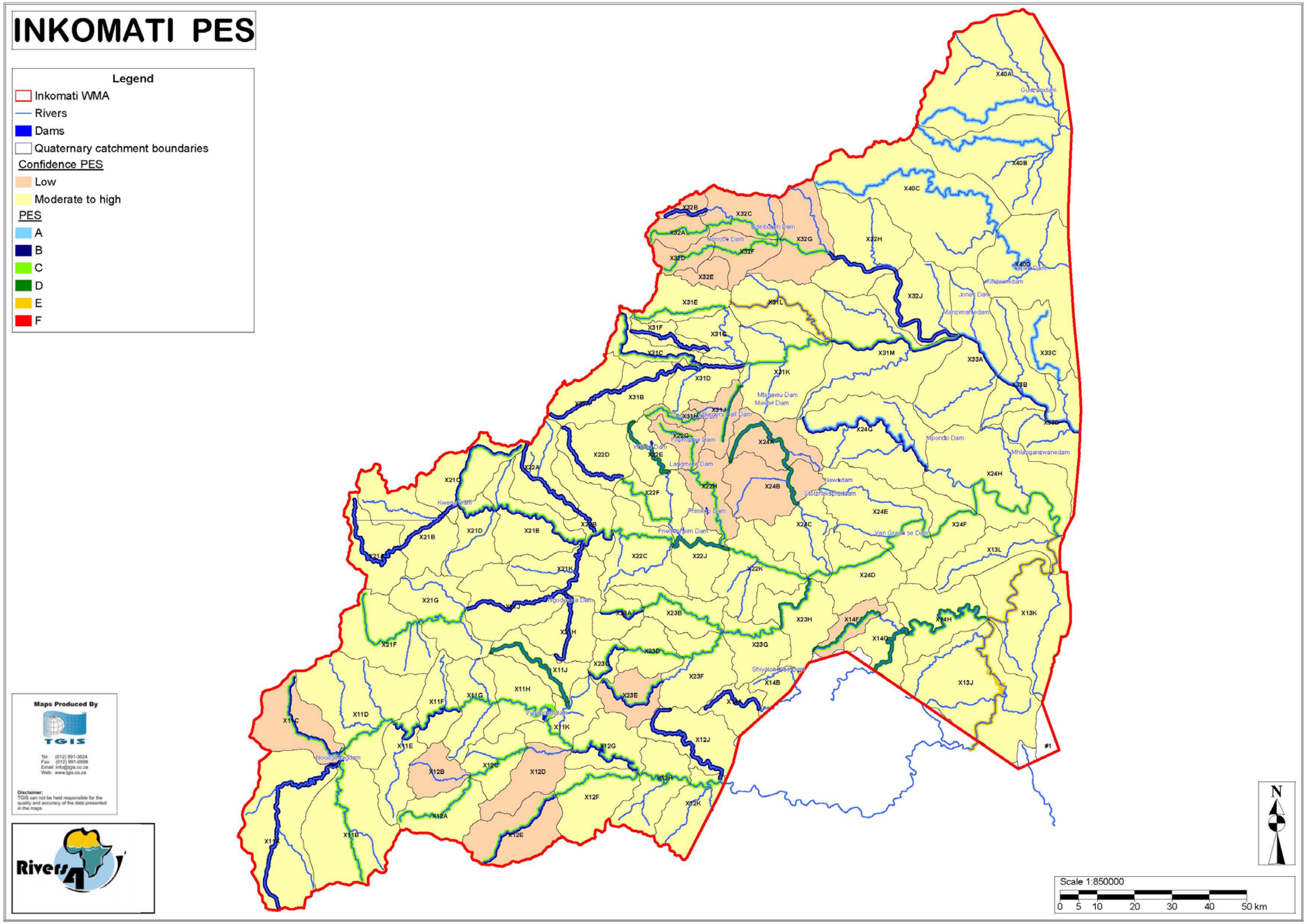

Figure 3.4 Crocodile and Sabie-Sand River sub-catchments: PES Map illustrating PES categories and confidence

3.5 INTEGRATED IMPORTANCE CONSIDERING EIS, PES AND SCI

A combination of EIS, SCI, and PES provide an indication of overall / integrated importance with the emphasis on the restoration potential. The restoration potential refers to the probability of achieving the rehabilitation of the river to an improved state. For example, if a river has very high overall importance, but is in bad condition, the restoration potential is often low.

However, rivers in good condition are scarce, and therefore important in their own right. A river that is in very good condition, but of low EIS, and/or SCI; might still be important from an ecological perspective, as it could be one of a limited number of that type of river that is still in good condition.

According to the matrix below (Figure 3-5), an Integrated Importance value is estimated from 1 (low importance to 4 high importance).

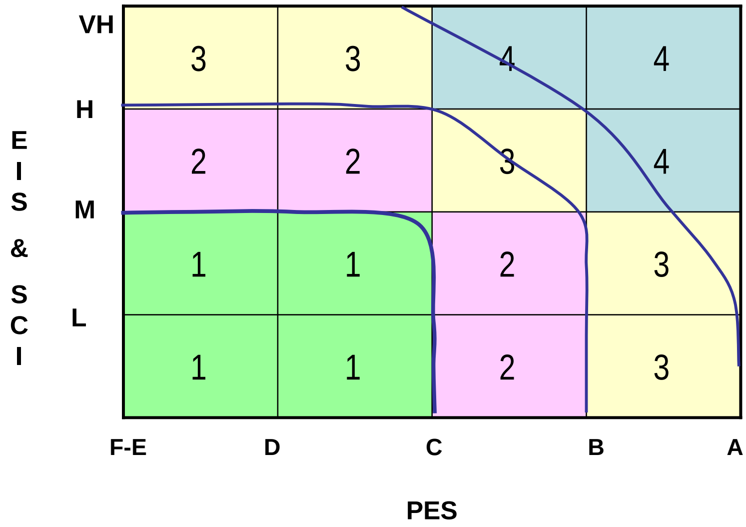

Figure 3.5 Matrix used to determine an Integrated Importance value on a scale of 0 – 4 (modified from Louw and Huggins, 2007)

The results of the evaluation are listed in Table 3.1 and illustrated in Figures 3-6 and 3-7. Note that the highest score between EIS and SCI is used to compare to the PES. The additional information provided in the figures are the rivers where a specific EIS have rated a 4. These are illustrated as lines on the rivers.

Table 3.1 Integrated importance of the river reaches assessed

(Orange rows indicate the quaternary catchments where the importance rating changed due to the SCI results being incorporated in the 2006 assessment results)

Quaternary Catchment	River	EIS	SCI	PES	Importance Rating (0 – 4)
CROCODILE SUB-CATCHMENT					
X21A	*Crocodile*	*VERY HIGH*	*MINIMAL*	*B*	*4*
X21B	*Crocodile*	*HIGH*	*MINIMAL*	*B*	*4*
X21C	*Alexanderspruit*	*HIGH*	*MINIMAL*	*B/C*	*4*
X21D	*Crocodile*	*HIGH*	*MINIMAL*	*B/C*	*3*
X21E	*Crocodile*	*HIGH*	*MINIMAL*	*B/C*	*3*
X21F	*Elands*	*MODERATE*	*MODERATE*	*B*	*3*

Quaternary Catchment	River	EIS	SCI	PES	Importance Rating (0 – 4)
X21G	Elands	HIGH	MINIMAL	B	4
X21H	Ngodwana	HIGH	MINIMAL	B	4
X21J	Elands	HIGH	MODERATE	B	4
X21K	Elands	HIGH	LOW	B	4
X22A	Houtbosloop	HIGH	LOW	B	4
X22B	Crocodile	HIGH	MINIMAL	B/C	3
X22C	Crocodile	MODERATE	LOW	C	2
X22D	Nels River	MODERATE	MINIMAL	B	3
X22E	Sand	LOW/MARGINAL	MINIMAL	D	1
X22F	Nels River	HIGH	LOW	C	3
X22G	Wit River	LOW/MARGINAL	MINIMAL	C	1
X22H	Nels River	MODERATE	LOW	C	2
X22J	Crocodile	HIGH	MODERATE	D	2
X22K	Crocodile	HIGH	MODERATE	C	3
X23A	Noord Kaap	MODERATE	MINIMAL	B/C	2
X23B	Noord Kaap	HIGH	MINIMAL	C	3
X23C	Queens	HIGH	MINIMAL	B/C	3
X23D	Queens	MODERATE	MINIMAL	C	2
X23E	Suid Kaap	HIGH	MINIMAL	B/C	3
X23F	Suid Kaap	HIGH	MODERATE	C	3
X23G	Kaap	MODERATE	LOW	C	2
X23H	Kaap	MODERATE	MODERATE	C/D	2
X24A	Nsikaze	LOW/MARGINAL	VERY HIGH	D	3
X24B	Nsikaze	LOW/MARGINAL	VERY HIGH	D	3
X24C	Crocodile	HIGH	VERY HIGH	C	4
X24D	Crocodile	HIGH	HIGH	C	3
X24E	Crocodile: Malelane to Hectorspruit	HIGH	HIGH	C	3
X24F	Crocodile	HIGH	HIGH	C	3
X24G	Mbyaniti	LOW/MARGINAL	HIGH	A/B	4
X24H	Crocodile	VERY HIGH	HIGH	C	4
SABIE-SAND SUB-CATCHMENT					
X31A	Sabie	HIGH	MODERATE	B	4
X31B	Sabie	HIGH	MINIMAL	B	4
X31C	Mac Mac	VERY HIGH	MINIMAL	A/B	4
X31D	Sabie	HIGH	MODERATE	B	4
X31E	Marite	HIGH	MODERATE	C	3
X31F	Motitsi	HIGH	MINIMAL	B	4
X31G	Sabie	HIGH	MODERATE	B	4
X31H	Whitewaters	MODERATE	MINIMAL	C	2
X31J	Noord Sand	MODERATE	MODERATE	C/D	2
X31K	Sabie	VERY HIGH	VERY HIGH	C	4
X31L	Saringwa	LOW/MARGINAL	MODERATE	E	1
X31M	Sabie	VERY HIGH	VERY HIGH	B/C	3
X32A	Groot Sand	HIGH	HIGH	C	3
X32B	Klein Sand	HIGH	HIGH	B	4
X32C	Sand	MODERATE	HIGH	C	3
X32D	Mutlumuvi	HIGH	HIGH	C	3
X32E	Nwarehle	HIGH	HIGH	C	3

Quaternary Catchment	River	EIS	SCI	PES	Importance Rating (0 – 4)
X32F	*Mutlumuvi*	*MODERATE*	*HIGH*	*C*	*3*
X32G	*Sand*	*MODERATE*	*VERY HIGH*	*C*	*4*
X32H	*Sand*	*VERY HIGH*	*VERY HIGH*	*B*	*4*
X32J	*Sand*	*HIGH*	*HIGH*	*B*	*4*
X33A	*Sabie*	*VERY HIGH*	*HIGH*	*A/B*	*4*
X33B	*Sabie*	*VERY HIGH*	*HIGH*	*A/B*	*4*
X33C	*Mlondolozi*	*LOW/MARGINAL*	*HIGH*	*A*	*4*
X33D	*Sabie*	*VERY HIGH*	*HIGH*	*A/B*	*4*
X40A	*Sweni*	*MODERATE*	*HIGH*	*A*	*4*
X40B	*Nwanetsi*	*MODERATE*	*HIGH*	*A*	*4*
X40C	*Nwasitsontso*	*MODERATE*	*VERY HIGH*	*A*	*4*
X40D	*Nwasitsontso*	*MODERATE*	*HIGH*	*A*	*4*

Orange cells indicated changes to 2006 study results due to the inclusion of SCI results.

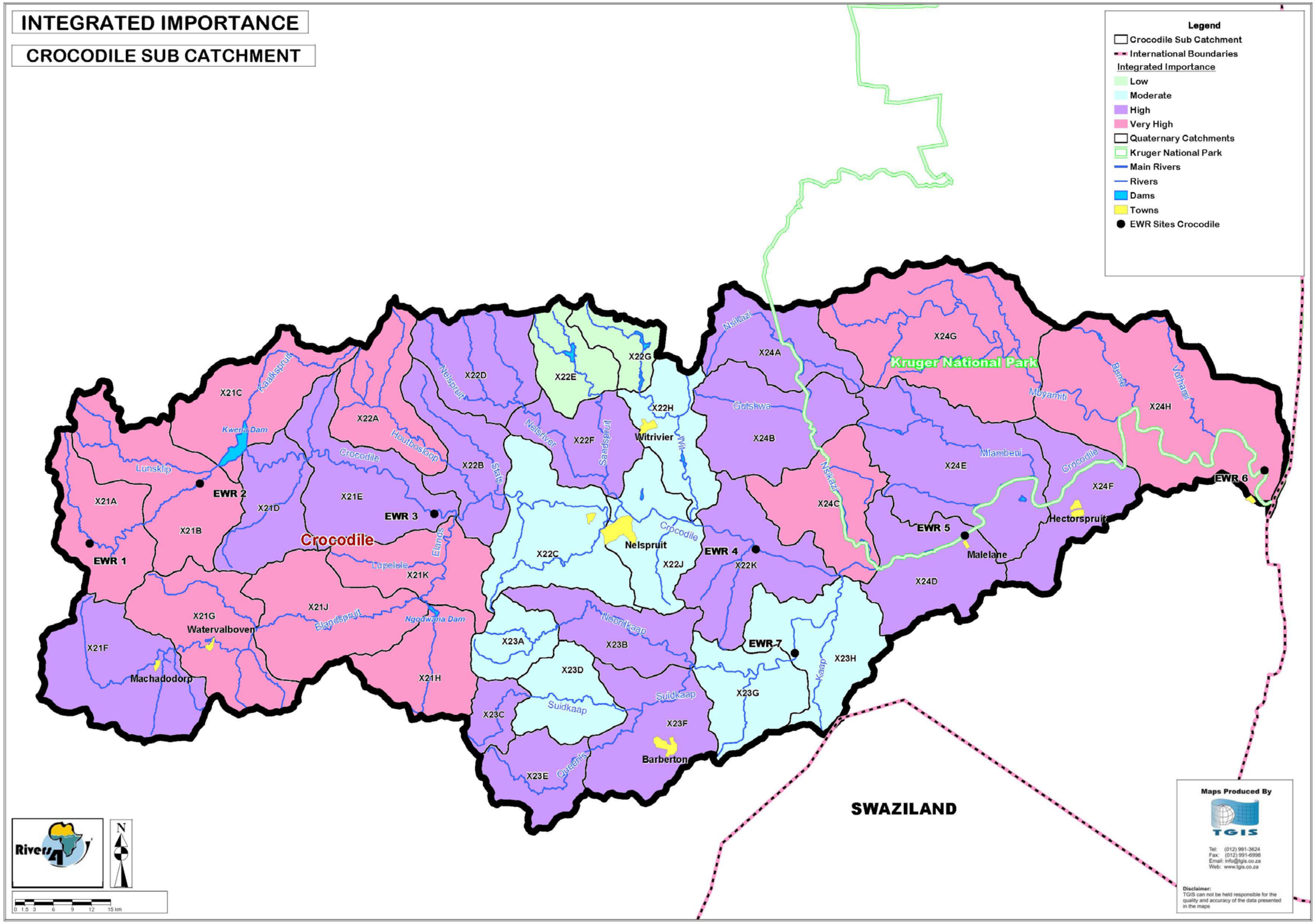

Figure 3.6 Crocodile sub-catchment: Map illustrating areas of high Integrated Importance

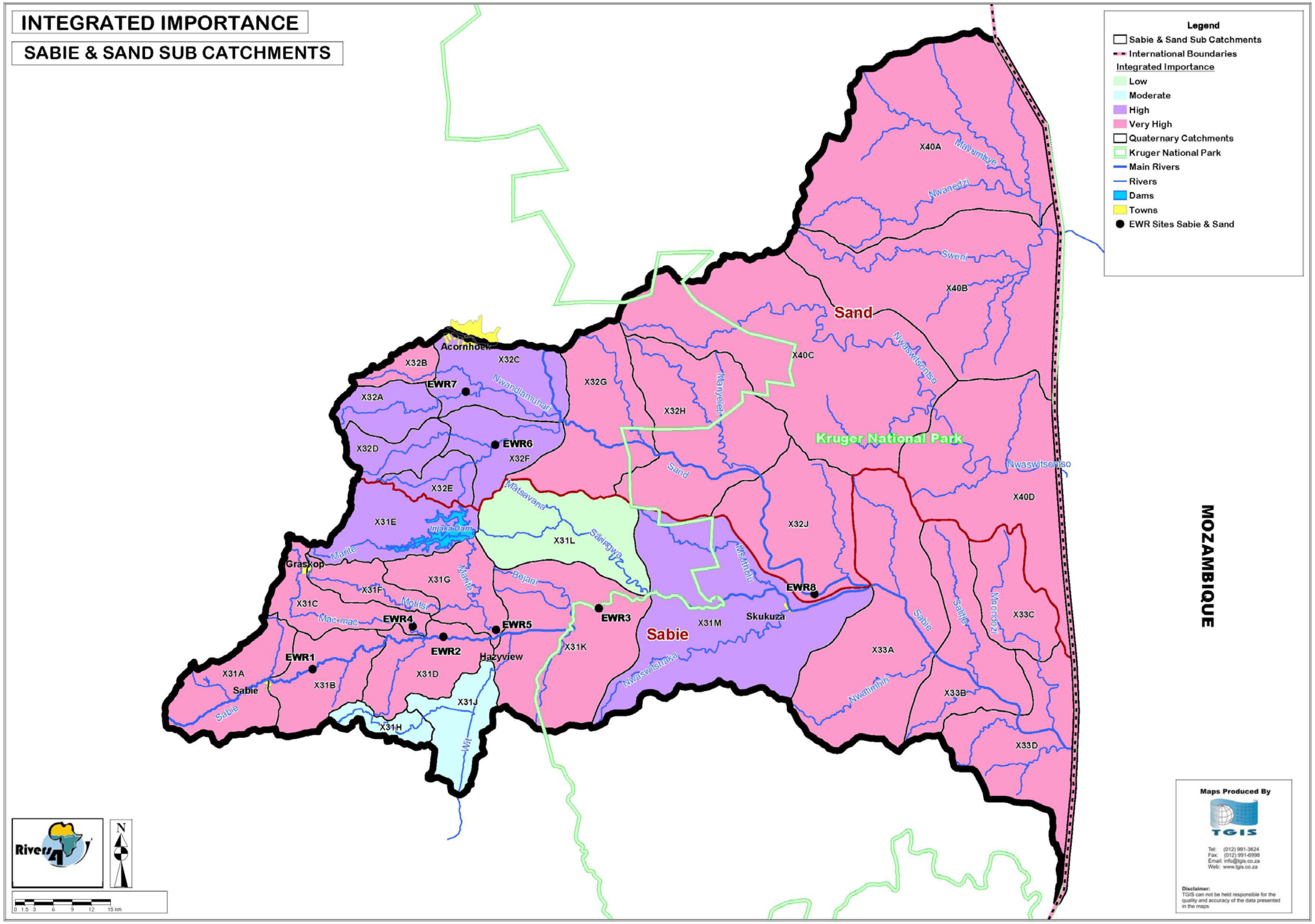

Figure 3.7 Sabie-Sand sub-catchment: Map illustrating areas of high Integrated Importance

Nearly the whole Crocodile sub-catchment was rated as a high to very high integrated importance. The upper reaches of the Noord and Suid Kaap River as well as the Kaap River in quaternary catchment X23G and H was rated as moderate integrated importance along with quaternaries occurring in the areas of White River and Nelspruit.

In the Sabie-Sand sub-catchment areas of very high integrated importance dominate. Only three quaternary catchments were rated as moderate and includes X31H, J, and L.

3.6 PRIORITY AREAS FOR EWR ASSESSMENT

A matrix (Figure 3-8) is again used to assess the rating of priority areas. The X-axis is based on the Integrated Importance value derived from the first matrix (Figure 3-5, Table 3.1 and results illustrated in Figure 3.6 and 3-7). The Y-axis depicts an estimate of water resource use (DWAF, 2007), with a 0 being of no importance and 4 being of very high importance. This matrix was used to identify quaternary catchments which are so called 'hotspots'. A biodiversity/ecological hotspot is a biogeographic region which is a significant reservoir of biodiversity which is threatened with destruction (http://en.wikipedia.org/wiki/Biodiversity_hotspot). In the context used in the Desktop EcoClassification, the hotspot represents a quaternary catchment with a high Integrated Importance which could be under threat due to its importance for water resource use. These hotspots indicate areas where Reserve assessments should ideally result in high confidence recommendations. This then guides the initial estimate of the level of the assessments required, and indicates areas where detailed investigations would be required if development was being considered. It must be noted that a detailed Reserve assessment does not necessarily provide high confidence results. This is usually due to constraints such as lack of available data (hydrology, biota etc.).

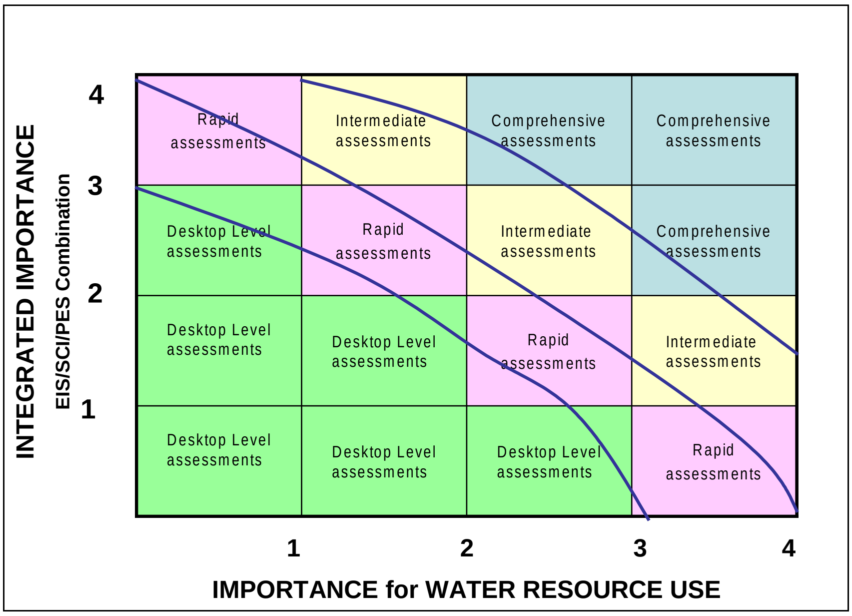

Figure 3.8 Matrix indicating the level of EWR assessments required ((modified from Louw and Huggins, 2007)

3.6.1 Importance of Water Resource Use

The priority rating method consists of assigning a qualitative score to a river reach for four variables or factors that represent the status of the instream flow. The scores of the four variables are combined to determine (qualitatively) an overall score which represents the importance of the *river reach in terms of the water resource use and guides decision making with regard to what level of assessment is needed (DWAF, 2007).*

3.6.2 Determine level of EWR

The matrix was used to compare the Integrated Importance with the Water Resource Use Importance (Louw and Huggins, 2007) and the results are provided in Table 3.2 and Figure 3-9 and 3-10.

Table 3.2 Quaternary catchments of high Integrated Importance and/or high Water Resource Use Importance

Quaternary Catchment	River	Integrated Importance Rating (0 – 4)	Water Resource Use Rating (WRU)	Recommendations PRIORITY RATING	Reasons for Evaluation
CROCODILE SUB-CATCHMENT					
X21A	Crocodile	4	1-2	3	Very High integrated importance
X21B	Crocodile	4	2-3	4	Very High integrated importance
X21C	Alexanderspruit	4	2-3	3	Very High integrated importance
X21D	Crocodile	3	3-4	4	High integrated importance and High WRU
X21E	Crocodile	3	3-4	4	High integrated importance and High WRU
X21F	Elands	3	1	2	High integrated importance but Low WRU
X21G	Elands	4	2-3	4	Very High integrated importance
X21H	Ngodwana	4	1	2	Very High integrated importance but Low WRU
X21J	Elands	4	2-3	4	Very High integrated importance
X21K	Elands	4	2-3	4	Very High integrated importance
X22A	Houtbosloop	4	1-2	3	Very High integrated importance but Low WRU
X22B	Crocodile	3	2-3	3	High integrated importance and High WRU
X22C	Crocodile	2	4	3	Very High WRU
X22D	Nels River	3	1-2	2	High integrated importance but Low WRU
X22E	Sand	1	1-2	1	Low integrated importance and WRU
X22F	Nels River	3	2	3	High integrated importance
X22G	Wit River	1	4	2	Very High WRU but Low integrated importance
X22H	Nels River	2	1-2	2	Moderate integrated importance and WRU
X22J	Crocodile	2	4	3	Very High WRU and Moderate integrated importance
X22K	Crocodile	3	4	4	High integrated importance and High WRU
X23A	Noord Kaap	2	1-2	2	Moderate integrated importance and WRU
X23B	Noord Kaap	3	1-2	3	High integrated importance and Low WRU
X23C	Queens	3	0-1	1	High integrated importance and Low WRU
X23D	Queens	2	1-2	2	Moderate integrated importance and WRU
X23E	Suid Kaap	3	1-2	3	High integrated importance and WRU
X23F	Suid Kaap	3	3-4	4	High integrated importance and High WRU
X23G	Kaap	2	1-2	2	Moderate integrated importance and WRU
X23H	Kaap	2	1-2	2	Moderate integrated importance and WRU
X24A	Nsikaze	3	1-2	3	High integration importance and Low to Moderate WRU
X24B	Nsikaze	3	1-2	3	High integration importance and Low to Moderate WRU
X24C	Crocodile	4	4	4	Very High integrated importance and Very High WRU

Quaternary Catchment	River	Integrated Importance Rating (0 – 4)	Water Resource Use Rating (WRU)	Recommendations PRIORITY RATING	Reasons for Evaluation
X24D	Crocodile	3	4	4	High integrated importance and Very High WRU
X24E	Crocodile: Malelane to Hectorspruit	3	4	4	High integrated importance and High WRU
X24F	Crocodile	3	4	4	High integrated importance and High WRU
X24G	Mbyaniti	4	0	0	In the KNP so does not require priority rating for EWR assessment
X24H	Crocodile	4	4	4	Very High integrated importance and Very High WRU
SABIE-SAND SUB-CATCHMENT					
X31A	Sabie	4	1	3	Very High integrated importance and Low WRU
X31B	Sabie	4	1	3	Very High integrated importance and Low WRU
X31C	Mac Mac	4	1	3	Very High integrated importance and Low WRU
X31D	Sabie	4	1-2	3	Very High integrated importance and Low WRU
X31E	Marite	3	1-2	3	High integration importance and Low to Moderate WRU
X31F	Motitsi	4	1	2	Very High integrated importance and Low WRU
X31G	Sabie	4	1-2	3	Very High integrated importance and Low WRU
X31H	Whitewaters	2	1-2	2	Moderate integrated importance and WRU
X31J	Noord Sand	2	1-2	2	Moderate integrated importance and WRU
X31K	Sabie	4	2-3	4	Very High integrated importance and Moderate to High WRU
X31L	Saringwa	1	1-2	1	Low Integrated importance and WRU
X31M	Sabie	3	3-4	4	High integrated importance and High WRU
X32A	Groot Sand	3	0-1	1	High integrated importance but Low WRU
X32B	Klein Sand	4	0-1	2	Very High integrated importance but Low WRU
X32C	Sand	3	1-2	3	High integration importance and Low to Moderate WRU
X32D	Mutlumuvi	3	1-2	3	High integrated importance but Low WRU
X32E	Nwarehle	3	1	1	High integrated importance but Low WRU
X32F	Mutlumuvi	3	3-4	3	High integrated importance and High WRU
X32G	Sand	4	2	3	Very high Integrated importance and Moderate WRU
X32H	Sand	4	2-3	4	Very High integrated importance but Moderate WRU
X32J	Sand	4	2-3	4	Very High integrated importance but Moderate WRU
X33A	Sabie	4	2-3	4	Very High integrated importance but Moderate WRU
X33B	Sabie	4	2-3	4	Very High integrated importance but Moderate WRU
X33C	Mlondolozi	4	0	0	In the KNP so does not require priority rating for EWR assessment
X33D	Sabie	4	2-3	4	Very High integrated importance but Moderate WRU
X40A	Sweni	4	0	0	In the KNP so does not require priority rating for EWR assessment
X40B	Nwanetsi	4	0	0	In the KNP so does not require priority rating for EWR assessment
X40C	Nwasitsontso	4	0	0	In the KNP so does not require priority rating for EWR assessment
X40D	Nwasitsontso	4	0	0	In the KNP so does not require priority rating for EWR assessment

These areas are illustrated spatially on a map (Figure 3-9 and 3-10). These dark and light red quaternaries represent the main river reaches where considerable care should be taken when considering development and which would require intermediate or comprehensive EWR assessment.

This assessment guided the selection of EWR sites (See Chapter 7). It will be attempted to place most of the EWR sites within the 'Very High' and 'High' areas. The selection of EWR sites is also dependant on other factors such as the suitability of potential sites for EWR assessments and areas with a high demand for licenses.

In the Crocodile sub-catchment (Figure 3-9) the 'hotspots' (red areas) are located in:

- *The KNP due to the Very High EIS and SCI as well as the role the river plays to provide international requirements and other users.*
- *The area downstream of Kwena Dam and the Elands River due to the High and Very high EIS as well as its Water Resource Use importance.*

In the Sabie-Sand sub-catchment (Figure 3-10) the hotspots (red areas) are located in:

- *The KNP and conservation areas due to the Very High EIS and SCI.*
- *The Sabie River outside the KNP due to the high EIS.*

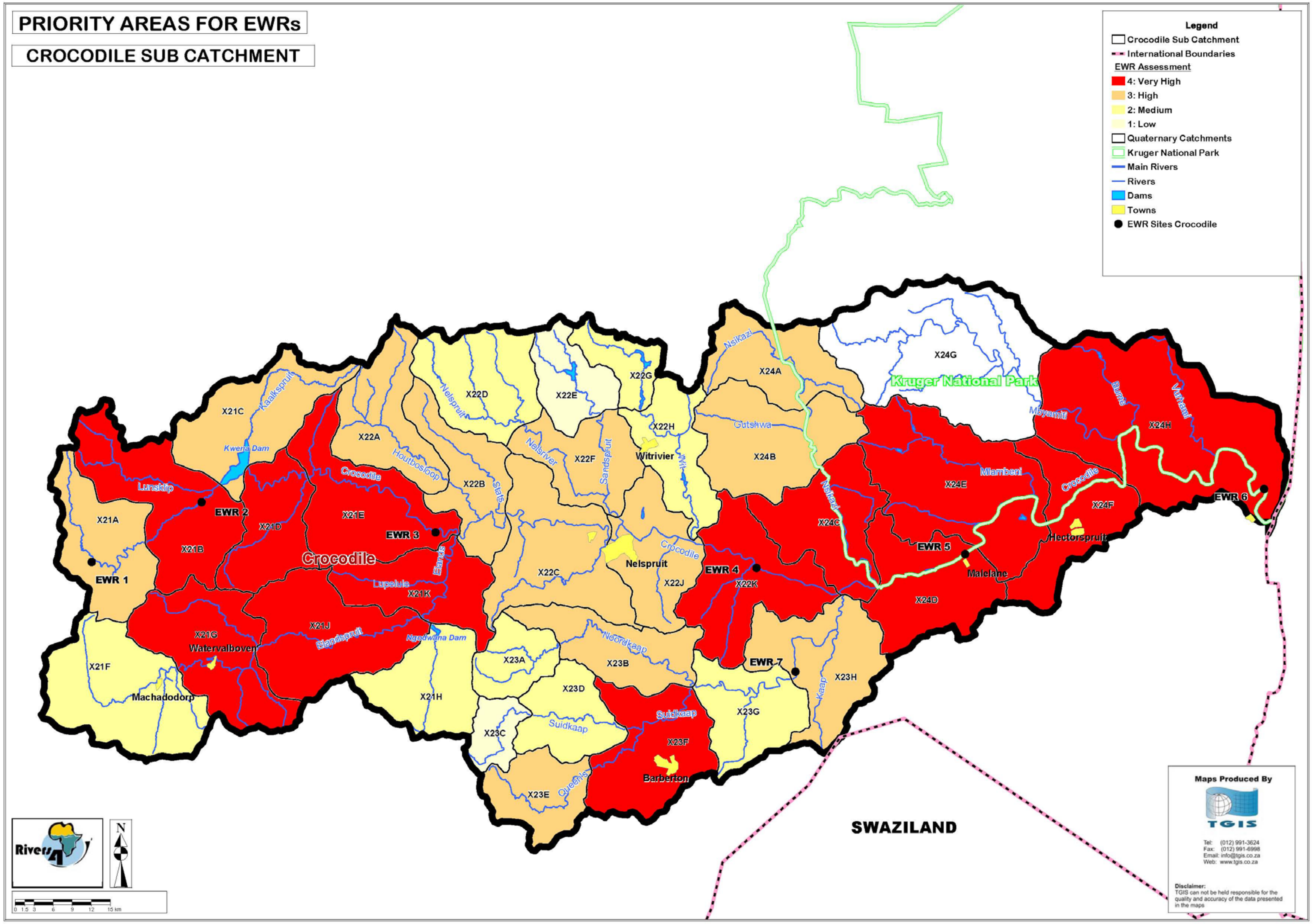

Figure 3.9 Crocodile sub-catchment: Sections in rivers which are important for Reserve assessment (Hotspots) (derived from overlaying Integrated Importance and Water Resource Use)

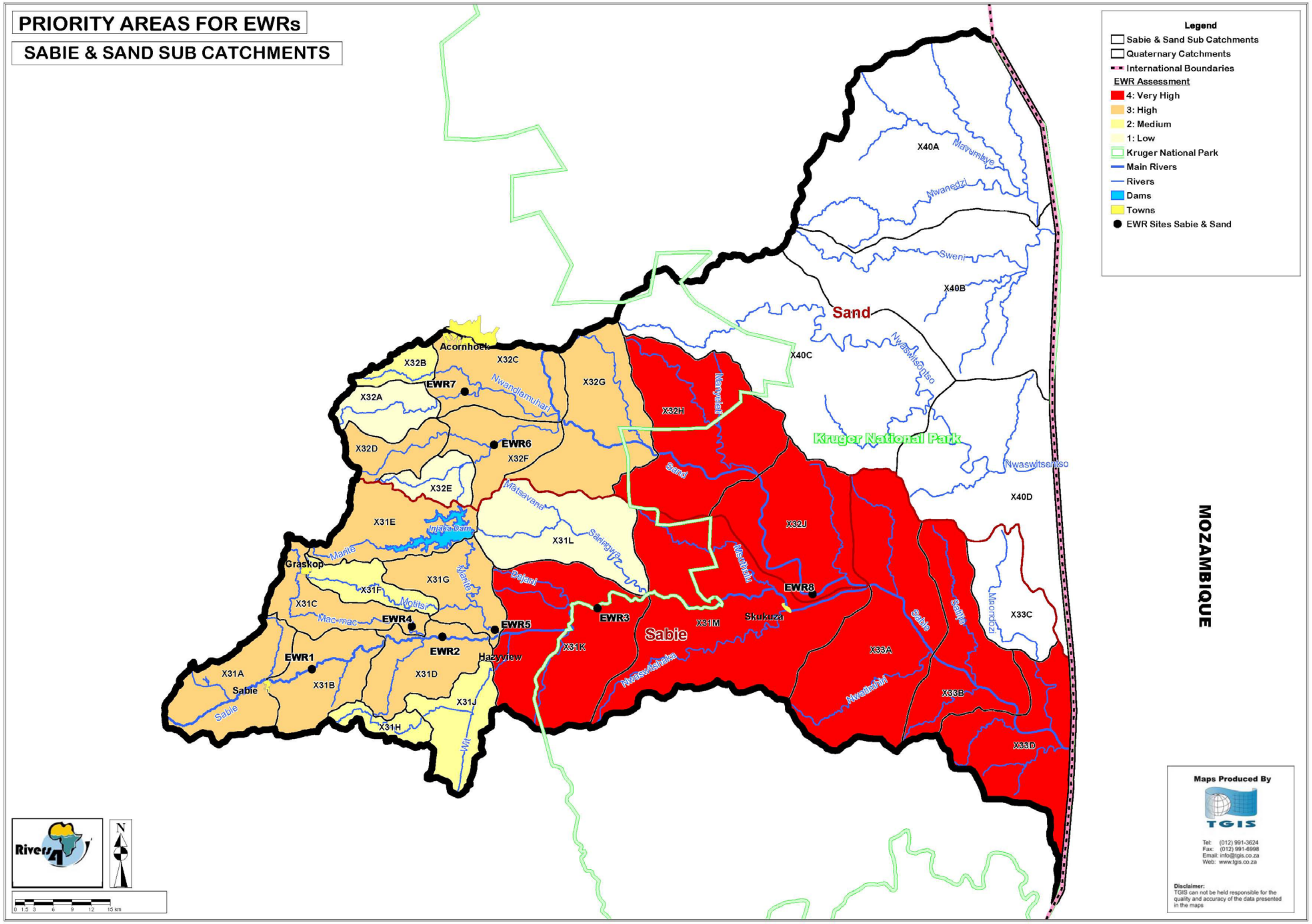

Figure 3.10 Sabie-Sand sub-catchment: Sections in rivers which are important for Reserve assessment (Hotspots) (derived from overlaying Integrated Importance and Water Resource Use)

4 BASIC HUMAN NEEDS RESERVE

Author: G Huggins (Nomad Consulting)

4.1 WHAT IS THE BASIC HUMAN NEEDS RESERVE?

*The concept of a Basic Human Needs Reserve (BHNR) is deeply entrenched within the National Water Act (Act No 36 of 1998). In Chapter 1 (Interpretation and Fundamental Principles) the Act states that "Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the **basic human needs** of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act."*

Further, in defining the Reserve the National Water Act states that:

"Reserve" means the quantity and quality of water required -

(a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be

(i) relying upon;
(ii) taking water from; or
(iii) being supplied from, the relevant water resource; and

In Part 3 of the National Water Act, that dealing with the Reserve, the following definition occurs:

The basic human needs reserve provides for the essential needs of individuals served by the water resource in question and includes water for drinking, for food preparation and for personal hygiene.

4.2 HOW MUCH WATER IS NEEDED FOR BASIC HUMAN NEEDS?

Although the National Water Act gives the reader cues as to the importance of the BHNR and what it encompasses, there is no quantity of water set, which would be deemed to be adequate to satisfy these basic human needs. The Water Services Act (Act No. 108 of 1997) is no more insightful in determining the amount of water deemed to be satisfactory for basic human needs. Rather the Water Services Act sets out a definition not far removed from that of the National Water Act. The Water Services Act states that:

"basic water supply" means the prescribed minimum standard of water supply services necessary for the reliable supply of a sufficient quantity and quality of water to households, including informal households, to support life and personal hygiene.

The amount of water required for basic human needs is a question that encourages vigorous debate. Without repeating the debate it is probably sufficient to say that the minimum amount of water required to meet basic needs varies depending upon what is included as "basic needs". The figures generally vary from 20 to 50 litres per person per day.

In South Africa the RDP target of 25 litres per person per day has generally been accepted as the standard quantum for the purposes of the BHNR. This is slightly at odds with the "Free Basic

Water" recommended amount of 6 000 litres per household per month.[1] *Given average household sizes in South Africa, the amount of 6 000 litres per month is closer to 40 litres per person per day than to 25.*

4.3 THE BHNR FOR THE CROCODILE EAST, AND SABIE-SAND SUB-CATCHMENTS

According to 2001 population figures for the Crocodile and Sabie-Sand sub-catchment area just 20% of the population is classified as urban, while 80% of the population is rural. The central band of this area, running from Cottondale/Acornhoek in the north, trough Hazyview, Whiteriver, and Nelspruit to Baberton in the south, is the most densely populated. Population density in the rural parts of the water management area is sparse. The population of the Sabie River catchment is expected to increase from about 338 000 in 1985 to about 691 000 in 2010. About 80 000 people outside the catchment boundaries were also dependent on water from the Sabie River catchment in 1985; this number is expected to increase to about 166 000 in 2010 (Chunnet, Fourie and Partners, 1990). The most notable urban settlements within the Croc East, Sabie and Sand sub-catchments are Barberton, Nelspruit, Sabie and Waterval Boven.

The following steps were undertaken In order to calculate the BHNR:

- *The population size of the communities/areas dependant on run of river was calculated at quaternary catchment level. The point of departure had been the 2001 National Census at "sub-place name level".*
- *Communities likely to be reliant on run of river were identified within the catchment. In order to do this, available mapping was consulted. Mapping was checked for its currency and the necessary interviews at a district or local municipal planning level were undertaken to verify the assumptions as to areas/communities dependant on run of river.*
- *Having calculated the qualifying population per quaternary catchment the next step in determining the BHNR was to project the population to a target date. For the purposes of this exercise the population was projected to a sensible target year. The population was projected using generic growth rates applicable to the kinds of municipalities in the resource area or analysis of all settlement types within the study area and the application of different rates based on settlement type, economic forecasts and from historic trends. For the purposes of the Crocodile East catchments a 0% growth rate was used. Virtually all of the population deemed to be reliant on run of river lives in the rural parts of the catchment. Trends indicate that the growth rate in rural area is negative. As a precautionary measure the population is deemed not to decline but to remain stable.*
- *Using the population figures a BHNR for the qualifying population can be estimated per quaternary catchment. The results calculated at 25 l per person per day are set out.*
- *Figures are expressed as m^3 per day consumption.*

The results are provided in Table 4.1 and Table 4.2 for the Crocodile and Sabie-Sand River catchments respectively. The cumulative BHNR per EWR site in the Incomati WMA is provided in Table 4.3.

[1] *For the provenance of the recommended 6 000 litres see http://www.dwaf.gov.za/Documents/ FBW/QAbrochureAug2002.pdf.*

Table 4.1 Water required for the BHNR per quaternary expressed in m^3 per day – Crocodile sub-catchment

Quaternary Catchment	Total Population	Population Dependant on Run of River	Litres required per person per day	BHNR as total litres per day	BHNR as m^3 per day	BHNR as MCM
X21A	1723	279	25	6975	6.975	0.00255
X21B	1496	374	25	9350	9.35	0.00341
X21C	1020	321	25	8025	8.025	0.00293
X21D	1166	303	25	7575	7.575	0.00276
X21E	3734	676	25	16900	16.9	0.00617
X21F	6913	0	25	0	0	0.00000
X21G	6861	0	25	0	0	0.00000
X21H	2343	444	25	11100	11.1	0.00405
X21J	1386	243	25	6075	6.075	0.00222
X21K	4244	871	25	21775	21.775	0.00795
X22A	2228	499	25	12475	12.475	0.00455
X22B	2695	0	25	0	0	0.00000
X22C	10571	1281	25	32025	32.025	0.01169
X22D	3095	384	25	9600	9.6	0.00350
X22E	1584	0	25	0	0	0.00000
X22F	3238	724	25	18100	18.1	0.00661
X22G	1993	498	25	12450	12.45	0.00454
X22H	14616	0	25	0	0	0.00000
X22J	24576	0	25	0	0	0.00000
X22K	44410	0	25	0	0	0.00000
X23A	1421	353	25	8825	8.825	0.00322
X23B	2782	691	25	17275	17.275	0.00631
X23C	847	210	25	5250	5.25	0.00192
X23D	1790	443	25	11075	11.075	0.00404
X23E	1773	439	25	10975	10.975	0.00401
X23F	27129	0	25	0	0	0.00000
X23H	4034	1007	25	25175	25.175	0.00919
X24A	59058	0	25	0	0	0.00000
X24B	51921	0	25	0	0	0.00000
X24C	42186	0	25	0	0	0.00000
X24D	3500	559	25	13975	13.975	0.00510
X24E	2764	343	25	8575	8.575	0.00313
X24F	2664	579	25	14475	14.475	0.00528
X24G	7	2	25	50	0.05	0.00002
X24H	3488	610	25	15250	15.25	0.00557
Total	**345256**	**12133**		**303325**	**303.325**	**0.11071**

Table 4.2 Water required for the BHNR per quaternary expressed in m^3 per day – Sabie-Sand sub-catchment

Quaternary Catchment	Total Population	Population Dependant on Run of River	Litres required per person per day	BHNR as total litres per day	BHNR as m^3 per day	BHNR as MCM
X31A	8983	0	25	0	0	0.00000
X31B	3044	0	25	0	0	0.00000
X31C	2018	201	25	5025	5.025	0.00183
X31D	3807	884	25	22100	22.1	0.00807
X31E	14442	3128	25	78200	78.2	0.02854
X31F	1590	119	25	2975	2.975	0.00109
X31G	32038	7954	25	198850	198.85	0.07258
X31H	940	0	25	0	0	0.00000
X31J	30937	3435	25	85875	85.875	0.03134
X31K	95730	19876	25	496900	496.9	0.18137

Quaternary Catchment	Total Population	Population Dependant on Run of River	Litres required per person per day	BHNR as total litres per day	BHNR as m^3 per day	BHNR as MCM
X31L	41607	8250	25	206250	206.25	0.07528
X31M	25014	6146	25	153650	153.65	0.05608
X32A	25375	6339	25	158475	158.475	0.05784
X32B	11334	2803	25	70075	70.075	0.02558
X32C	48890	8934	25	223350	223.35	0.08152
X32D	25042	6261	25	156525	156.525	0.05713
X32E	42088	1989	25	49725	49.725	0.01815
X32F	44078	12324	25	308100	308.1	0.11246
X32G	36430	4786	25	119650	119.65	0.04367
X32J	277	24	25	600	0.6	0.00022
X33A	6	0	25	0	0	0.00000
X33B	123	0	25	0	0	0.00000
X33C	2	0	25	0	0	0.00000
X33D	3	0	25	0	0	0.00000
X40A	207	0	25	0	0	0.00000
X40B	7	0	25	0	0	0.00000
X40C	7711	1917	25	47925	47.925	0.01749
X40D	5	0	25	0	0	0.00000
Total	**501728**	**95370**		**2384250**	**2384.25**	**0.87025**

Table 4.3 Cumulative BHNR per EWR site in the Incomati WMA

EWR site	Quaternary Catchment	BHNR as m^3 per day	BHNR as MCM	Cumulative BHNR per day m^3	Cumulative BHNR as MCM
CROCODILE SUB-CATCHMENT					
EWR 1	X21A	6.98	0.00255	6.975	0.00255
EWR 2	X21B	9.35	0.00341	16.325	0.00596
EWR 3	X21E	16.90	0.00617	48.825	0.01782
EWR4	X22K	0.00	0.00000	172.425	0.06294
EWR 7	X23H	25.18	0.00919	78.575	0.02868
EWR5	X24D	13.98	0.00510	264.975	0.09672
EWR6	X24H	15.25	0.00557	303.325	0.11071
SABIE-SAND SUB-CATCHMENT					
EWR 1	X31B	0.00	0.00000	0	0.00000
EWR 4	X31C	5.03	0.00183	5.025	0.00183
EWR 2	X31D	22.10	0.00807		
EWR 5	X31G	198.85	0.07258	280.025	0.10221
EWR 3	X31K	496.90	0.18137	889.925	0.32482
EWR 7	X32C	223.35	0.08152	451.9	0.16494
EWR 6	X32F	308.10	0.11246	514.35	0.18774
EWR 8	X32J	0.60	0.00022	1086.5	0.39657

5 GROUND WATER

Department of Water Affairs (DWA), 2010. Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. Sabie and Crocodile Systems: Groundwater Report. Report produced by Rivers for Africa. Authored by JJP Vivier, C. J. De W. Raath & JR Bulasigobo. Report no: 26/8/3/10/12/005.

5.1 BACKGROUND

The main groundwater unit is the Inkomati WMA No 5. The primary drainage region X includes the following main river systems: Nwanedzi, Sabi, Crocodile (east) and Komati Rivers.

The input data was generated with Geographical Information Systems (GIS) from the National Groundwater Database (NGDB), WR90 datasets, GRA II, WARMS, GRDM and South African Groundwater Decision Tool (SAGDT) data.

From west to east the Inkomati WMA is underlain by the following geological lithologies:

- *Ecca group shale and sandstone of the Karoo sequence with intruded dolerite dykes and sheets.*
- *Magaliesburg, Silverton, Daspoort and Timeball Hill formation quartzite, shale, diamictite and iron formation of the Pretoria group.*
- *Malmani dolomite of the Chuniespoort group, Transvaal sequence.*
- *Nelspruit Suite granite, granodiorite, tonalite, gneiss and migmatite of Swazian age.*
- *Moodies, Figtree and Onverwacht group sandstone, shale, conglomerate, lava and pyroclastic rocks of the Barberton sequence.*
- *Karoo formation sandstone, siltstone, mudstone and shale intruded by dolerite.*
- *Letaba formation basalt and north south trending dolerite dykes of the Lebombo Group.*
- *Jozini formation rhyolite, granophyre, syenite, tuff, breccia and minor sedimentary rocks of the Lebombo Group.*

A comparison of the geology and the borehole distribution indicated that the boreholes were not concentrated along the dolomite as is normally expected. The dolomite had high yielding boreholes in the vicinity of the Sudwala caves and the Inkomati Cu-Ni mine. The dolomite aquifer in general is high yielding and because of its high recharge potential is also vulnerable to contamination (Ages 2007).

The high abstracting boreholes in the granite and granite gneiss in response to the demand from agriculture were most probably sited in fault and fracture zones with a high yielding potential. Boreholes drilled in the weathered granite would have lower yields than the boreholes in the fault and fracture zones.

As was evident that many of the boreholes were clustered around the rivers and those drilled in the river alluvium were expected to be abstracting some of the river water indirectly due to their proximity to the rivers. The sandstone aquifers were potentially high yielding aquifers and are vulnerable to over exploitation and pollution.

5.2 THE GROUNDWATER COMPONENT OF THE RESERVE

The determination of the groundwater component of the Reserve entails the calculation of the groundwater contribution to base flow and thus the Ecological Water Requirements (EWR) as well *as the portion of groundwater which must be allocated for Basic Human Need Reserve (BHNR). The latter is relatively simple to determine as population data is readily available. The determination of the EWR is the forte of surface water scientists and hydrologists. Estimates are determined on a quaternary catchment scale. The detailed EWR is determined for an EWR site which is representative of a river reach which is similar in terms of operation and physical characteristics.*

The determination of the groundwater component of the Reserve for an aquifer unit or management unit is required before licensing of groundwater use can occur.

5.2.1 Groundwater sources and sinks in the GYMR model

Inflow to the aquifer occurs from recharge due to rainfall and dam seepages. Unnatural sinks excluding evapo-transpiration and the groundwater base flow (groundwater outflow components) are shown in the scenario summary tables. The total outflow before losses was calculated at 114.9 Mm^3/a:

- *The recharge totals 1326 Mm^3/a at a 95% level of assurance as determined from the rainfall distribution. The highest recharge of 39.1 Mm^3/a occurred in X31A and the lowest recharge of 1.3 Mm^3/a in X33C. The total contribution from dam seepage across the WMA was 7.04 Mm^3/a.*
- *Borehole abstraction of 8.9 Mm^3/a, (representing 0.7 % of recharge). The average abstraction rate was 0.25 L/s/borehole. Most of the groundwater use is in X32D where 693792 m^3/a was used.*
- *Livestock water use of 6.7 Mm^3/a. It was assumed that a farm uses 0.25 L/s for 24 hours per day.*
- *BHN community water allocation of 18.94 Mm^3/a (representing 1.4 % of recharge), for a total of 1984466 people in the regional catchment. The water was allocated at 60 L person/day in catchments with less than 10 000 people and 25 L/person/day if more than 10 000 people. X24B had the most people at 210100 with an allocation of 1.9 Mm^3/a.*
- *A total of 70440 ha are under farm irrigation, which represents 2.4% of the catchment area. The model was very sensitive to this parameter and it was assumed that 10% was from groundwater resources, which amounted to 70.4 Mm^3/a (5.3 % of recharge) allocated to farm irrigation.*
- *Forestry covers a total of 389200 ha, which is 13.5% of the catchment area. The potential forestry groundwater use was assumed to be relevant for 1% of the forestry surface area and amounted to 3.9 Mm^3/a, which represents 0.3% of recharge.*
- *Riparian vegetation covers 9430 ha, which is 0.3 % of the total surface area with a potential water use of 94300 m^3/a. The riparian vegetation water use was estimated at 1000 mm/a.*
- *The areas covered by wetlands were measured from the DWA GIS shape files and were not very accurate. The potential wetland water use was 3 975 m^3/a. It was assumed that the wetland water use is 1000 mm/a.*
- *Spring flow was one of the lowest users of groundwater at 551 880 m^3/a from 9 springs, which represented 0.04 % of recharge. Eight springs are mentioned in the NGDB and one is mentioned in the WARMS data. The spring in catchment X12D (Badplaas) flow at a volume of 9 ℓ/s, the spring in X22C at 5 ℓ/s and an assumption of 0.5 ℓ /s was made for the rest of the springs since no data was available.*

The biggest potential sink next to irrigation is groundwater flow losses (evapo-transpiration), which accounted for 2.7 % (35.58 Mm^3/a) of the recharge. Borehole abstraction and basic human need allocation totalled almost 2.1% of the recharge.

5.2.2 Groundwater contribution to the Reserve and management classifications of the scenarios

Two scenarios were evaluated based on the GYMR approach:

1. *Scenario 1: GYMR – Present Day: GYMR quantification approach with recharge at 95% assurance level and accounting for GW losses and sinks (EWR was assumed to 40% of base flow).*
2. *Scenario 2: GYMR - Pristine: GYMR quantification approach with recharge at 95% assurance level and accounting for GW losses - pristine scenario (EWR was assumed to 40% of base flow).*

The results and classifications for both scenarios are described below.

1. Scenario 1: GYMR – Present Day

- *The recharge for both the GYMR scenarios was the same at 133 Mm^3/a determined for a 95% level of assurance.*
- *According to the current GRDM classification the overall status for the WMA was B (vulnerability status is low or slightly stressed). The highest classification E was for X13K and X13L (high vulnerability status or highly stressed) where the recharge were relatively low at 4% and where the highest potential water uses was due to irrigation. There were several low or A classifications as well as several B classifications which was mainly due to low irrigation volumes.*

2. Scenario 2: GYMR – Pristine

- *The overall classification was low (A). This was due to the fact that during pristine conditions, it was assumed that there were no losses due to irrigation, borehole abstraction, alien vegetation and forestry.*

5.3 GROUNDWATER BALANCE RESULTS AND DISCUSSION

Based on the groundwater flow balance assessment, the quaternary catchments were classified based on the ratio of outflow/inflow, before groundwater evapo-transpiration losses or actual base flow takes place.

From the assessment, the groundwater component in the Inkomati River WMA is mostly status B.

There are 5 catchments with classification further development of groundwater resources should be approached with caution (Figure 5-1).

- *Status D = 3 (3.23 %);*
- *Status E = 2 (2.15 %);*

There are 88 quaternary catchments in which the groundwater resource status range from A to C. Additional development of groundwater resources is still possible in these catchments (Figure 5-1):

- *Status A = 49 (52.7 %)*
- *Status B = 30 (32.3 %)*

- *Status C = 9 (9.68 %);*

According to the Groundwater Yield Model and interpretations from the results obtained, the regional groundwater balance calculations of the Inkomati WMA indicate that overall there is a surplus of groundwater in the WMA due to inflow (1 333 319 818 m^3/a) exceeding outflow (114 934 413 m^3/a). The total volume of groundwater recharge is in the order of 1326 Mm^3/a.

5.4 DOLOMITE RESOURCE UNIT

A separate groundwater component of the Reserve was calculated for the dolomite in the Inkomati WMA. The dolomite covers a north south strip from catchment X31C in the north to X12B in the south. All the catchments underlain by dolomite have an A status (Figure 5-1).

If the dolomite water balance is done as a separate unit on its own all the dolomite sub-catchments have an A status except for dolomite in X11J which have an B status due to a combination of potential mine usage, forestry, livestock, spring flow and evapo-transpiration on a much smaller surface area than the total catchment surface area.

The total inflow for the dolomite is 101 Mm^3/a at a 95% level of assurance as determined from the rainfall distribution, the total outflow before losses were calculated at 2.58 Mm^3/a.

If 40% of the groundwater component of base flow (39.01 Mm^3/a) is allocated for the EWR the groundwater allocation left for exploitation is 58.52 Mm^3/a. According to the current GRDM classification, the overall status for the dolomite is A (not vulnerable).

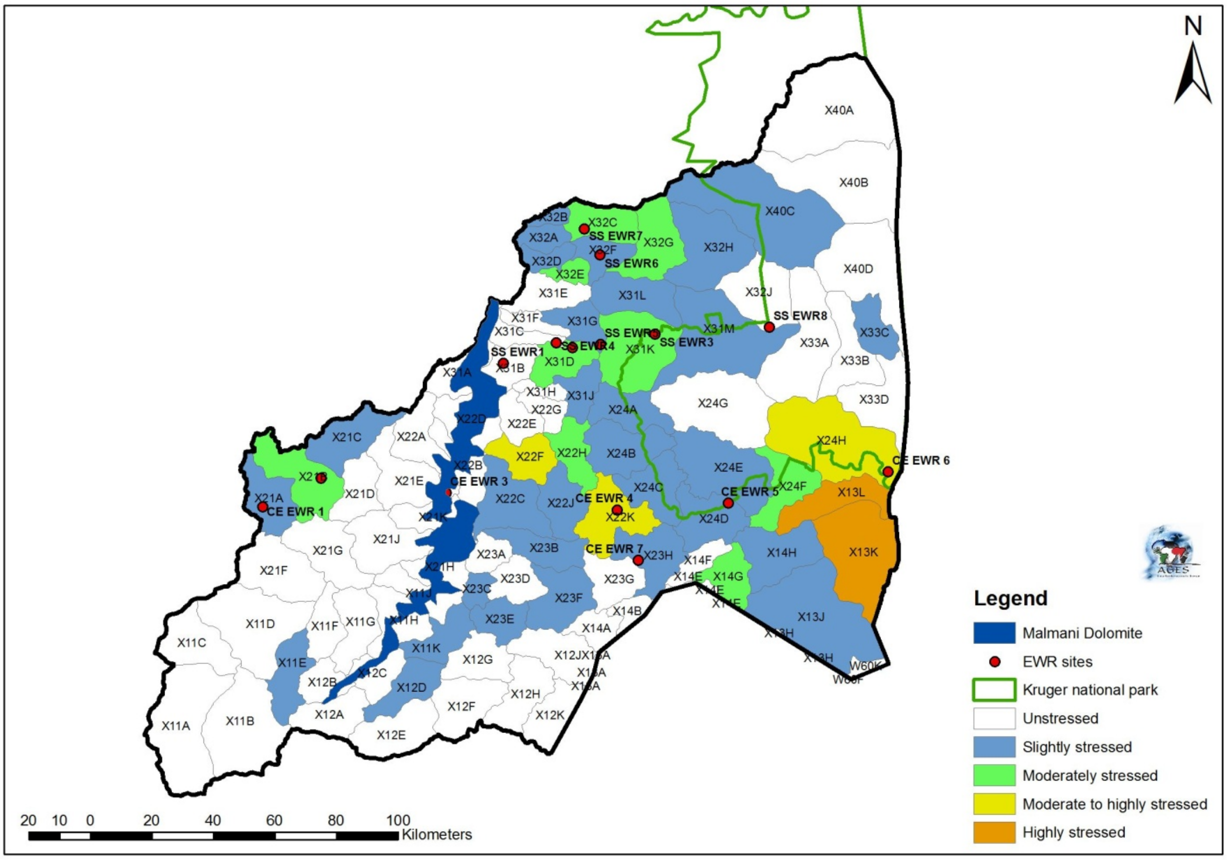

Figure 5.1 Groundwater status of the Inkomati WMA

5.5 RECOMMENDATIONS

The following recommendations are made:

- *Groundwater contribution to the Reserve determinations should be done by qualified geohydrological specialists with modelling experience in conjunction with surface water hydrological modellers. The base flow values that are generated by surface water modellers should e.g. not be lower than the values determined by geohydrological modellers as the hydrologic cycle should be taken into account in a holistic system balance approach. The same assurance levels and scenario definitions should be used. This would require additional training in modelling for the purposes of the reserve determination.*
- *It is recommended that geohydrological modelling specialists be screened trained and certified to conduct reserve determinations as it should be based on modelling capabilities.*
- *Scenario 1 of the GYMR method should be used as the management option for the quaternary catchments.*
- *The development of groundwater in catchments X13K, X13L, X22F, X22K and X24H should not be done without prior investigation and authorization.*
- *Groundwater development in all the catchments not mentioned under point 4 is possible since these catchments are not vulnerable to future groundwater development.*
- *Additional field studies will have to be done to collect data regarding recharge values to be used to update existing model.*
- *Additional groundwater field studies should be done to verify the dependence of wetlands on groundwater. The surface water supported wetlands should be distinguished from the groundwater supported wetlands.*
- *Additional field studies will have to be done to map the actual areas covered by alien vegetation if such studies have not been undertaken in the past. The alien vegetation areas should be delineated and a programme be put in place to prevent the water loss.*
- *The irrigation and forestry areas supported by groundwater should be verified.*
- *A detailed groundwater component of the Reserve determination study must be undertaken for the Inkomati WMA where the all the surface water data (transient data) can be incorporated in the study and where detailed field verification regarding pumping tests, water quality, basic human need can be done.*
- *Information regarding mining and mine groundwater use must be updated.*
- *A proper groundwater surface water integration must be done.*
- *Base flow need to be qualified with surface water flows.*
- *A comprehensive reserve determination study must be done on catchments with a C, D and E status.*

6 WETLAND TYPING AND ECOCLASSIFICATION

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. Wetland Report. Authored by Fluvius Environmental Consultants for Water for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/008.

The purpose of this study was to identify the major wetland types within the catchment and conduct a primarily desktop assessment of wetlands within the Inkomati catchment. If any high priority wetlands (in terms of broad conservation importance, social importance and/or threats from proposed developments) were identified during the study, these were to be highlighted for further studies.

6.1 METHODS

The wetland classification system developed by Rountree and Batchelor (in prep) was used to classify the wetlands in this study. This system is a modification of a hierarchical system for the classification of South African wetlands (developed by Ewart-Smith et al, 2003) and uses the underlying contemporary hydrological processes and formative geomorphological setting as the basis of classification of hydrogeomorphic (HGM) wetland types. The common HGM wetland types were identified and described across the study area. The HGM wetland typology is based on the underlying hydrological processes that create and maintain the wetlands. The likely sensitivities to particular types of activities (such as abstraction or increased runoff), and thus recommendations for future management, were then determined from this information, albeit at low confidence,

Since there are too many wetlands to evaluate in detail on an individual basis, a desktop level quaternary-scale catchment assessment of the wetlands across the entire study area was undertaken. A desktop scoring system for quaternary catchment scale wetland PES and EIS determination was developed and refined during this study. This tool was used to determine the average PES and EIS categories (at a low confidence) of wetlands within each quaternary catchment.

The wetlands in the study area were also grouped into Wetland Resource Units. These are broad groupings of similar types of wetlands that tend to be correlated with underlying dominant geology, EcoRegions and vegetation distribution. The identification of these Wetland Resource Units, and the identification and description of the common wetland types and sensitivities are provided to aid management of the wetlands within the study area.

6.2 RESULTS

Results from the desktop Wetland PES and EIS assessments (at the quaternary catchment scale), and comparison with the available desktop river PES and EIS data are provided below. The PES and EIS scores reflect the expected AVERAGE scores of all wetlands within the quaternary catchment. PES is generally good to moderate whilst EIS scores range from Low to Moderate to High (Figure 6.2 and 6.3). The wetlands in the extreme west (headwaters) have the highest EIS scores (See circled area in the Figure 6-1). The results are provided in Table 6.1.

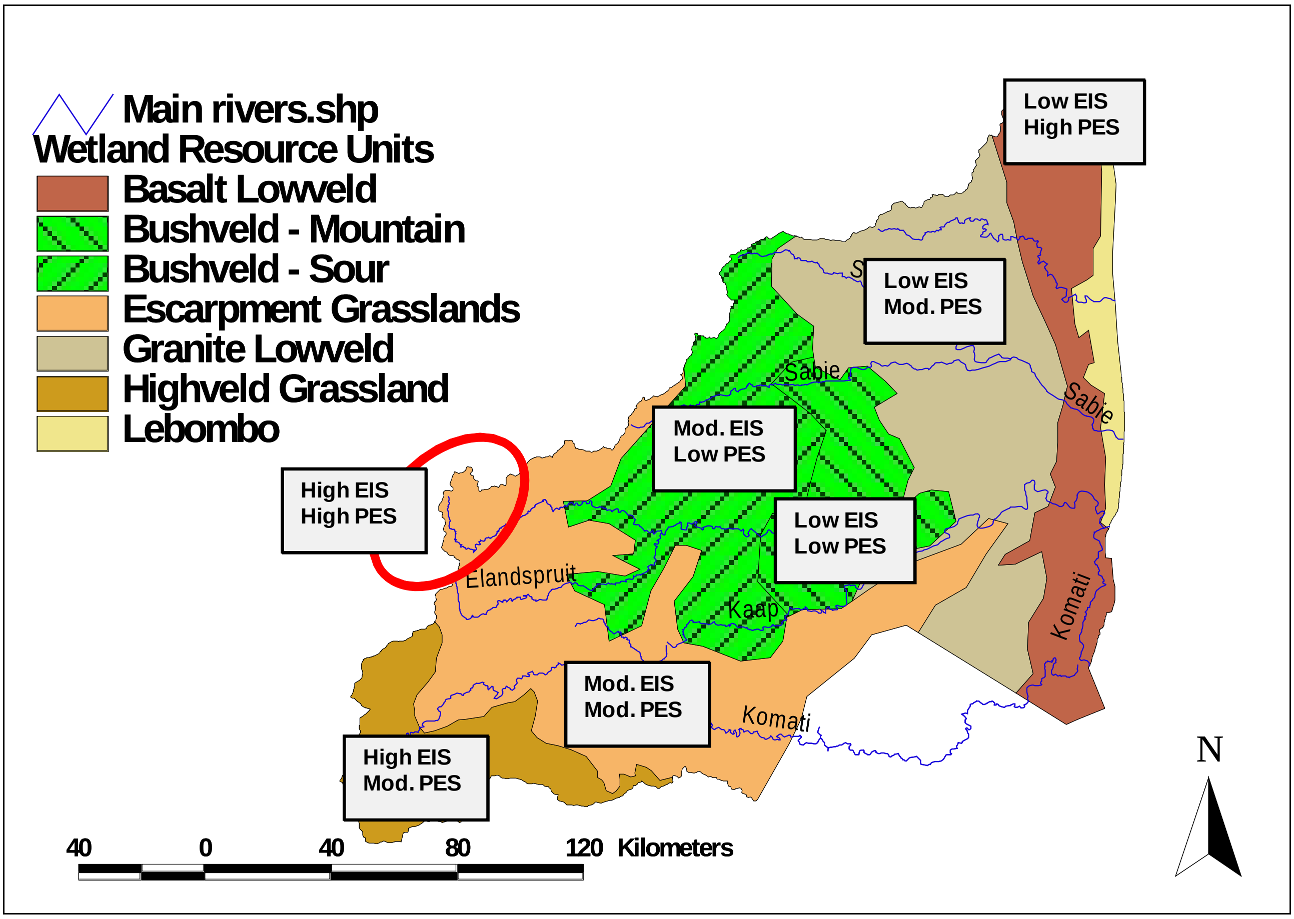

Figure 6.1 Summary of the PES and EIS attributes across the catchment

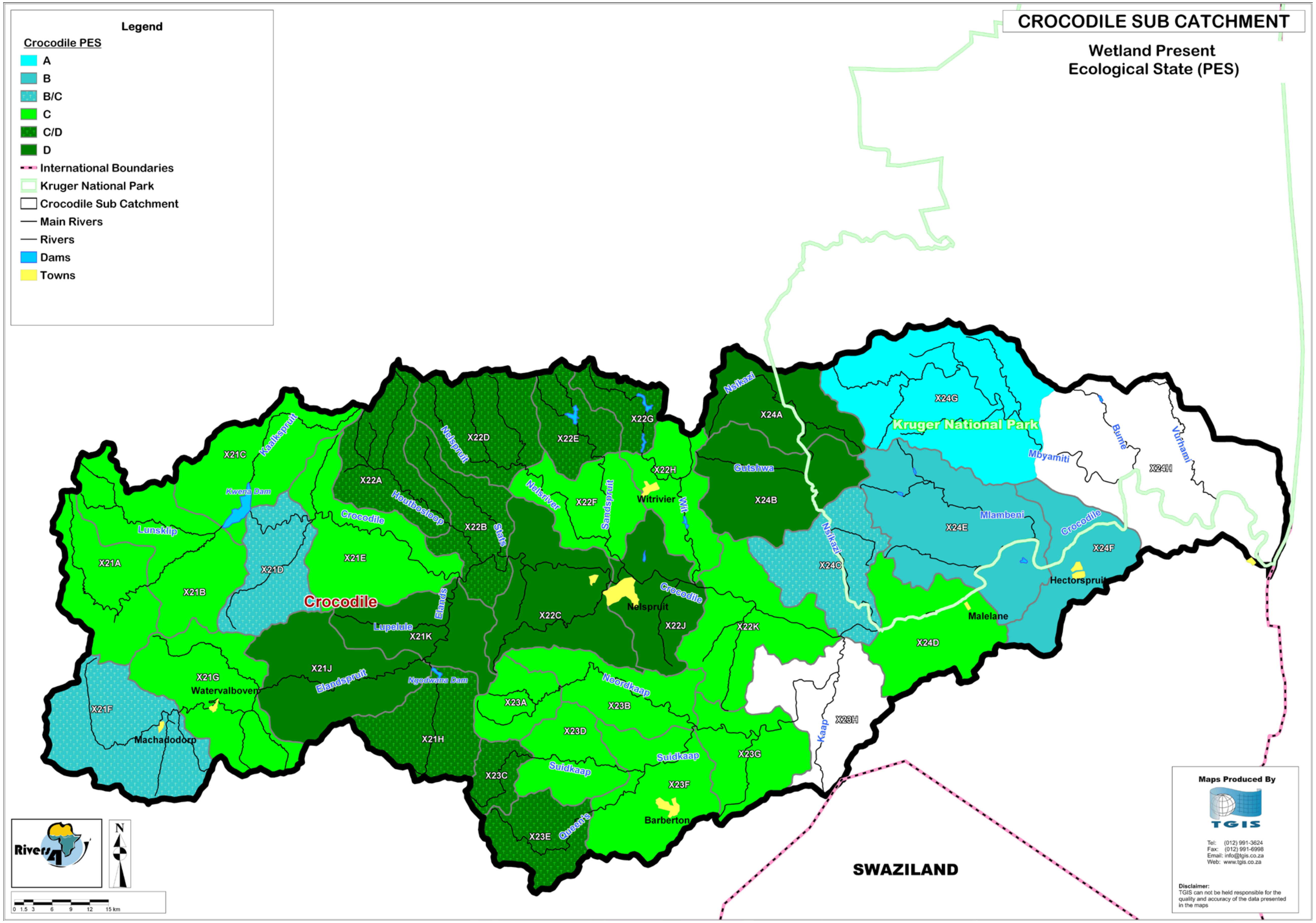

Figure 6.2 Crocodile Sub catchment Wetland PES of quaternary catchments

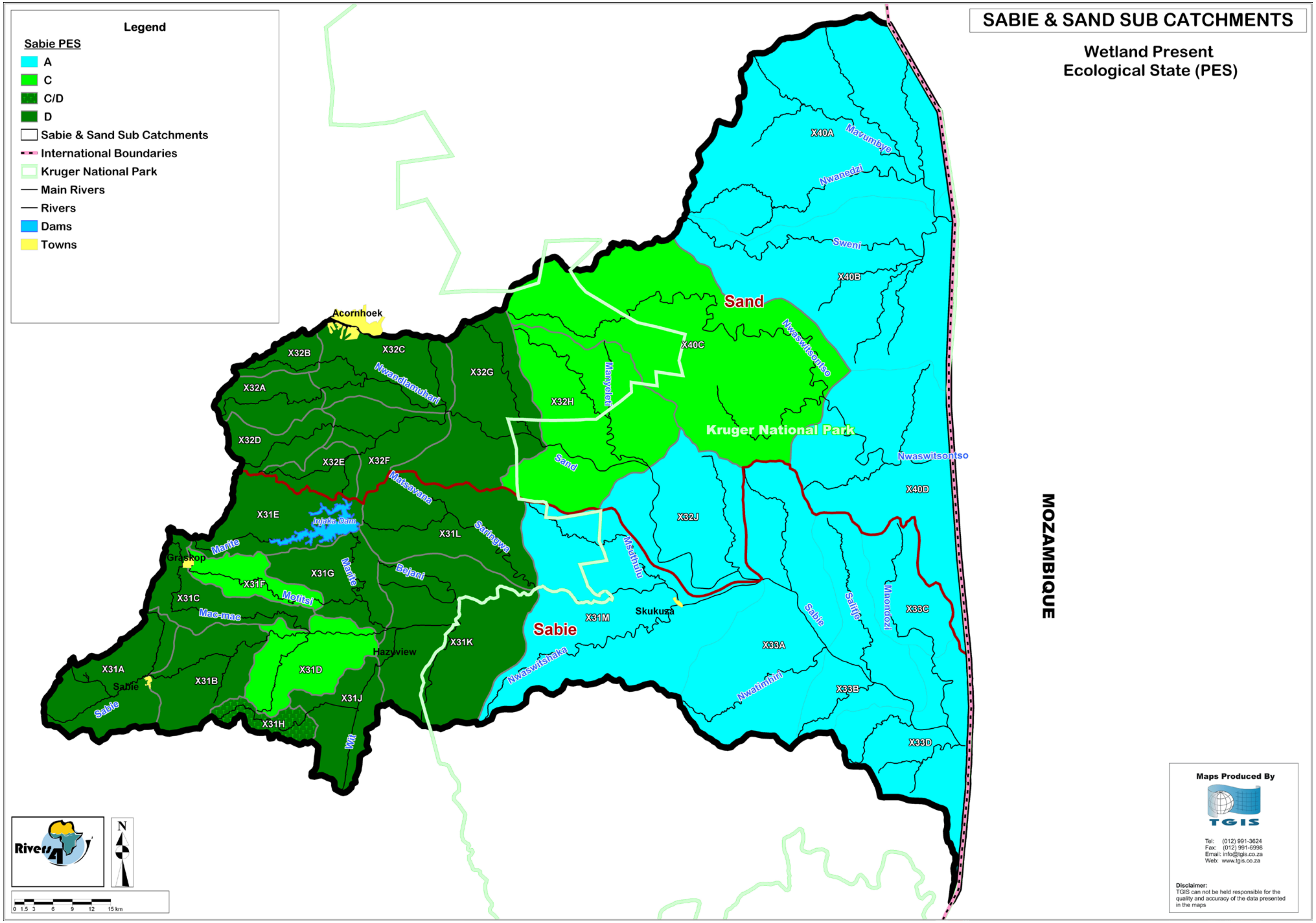

Figure 6.3 Sabie & Sand Sub catchment Wetland PES of quaternary catchments

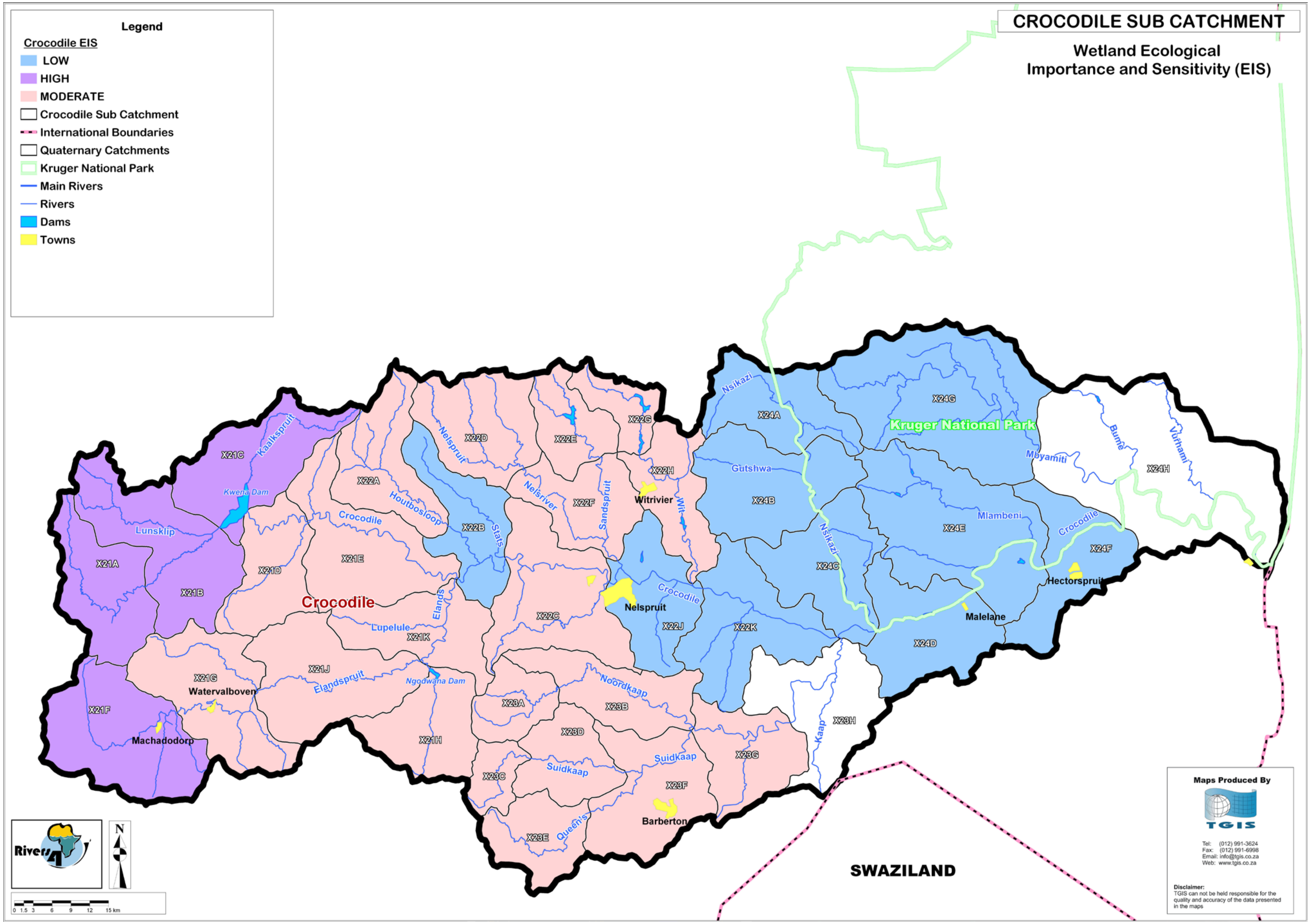

Figure 6.4 Crocodile sub catchment Wetland EIS of quaternary catchments

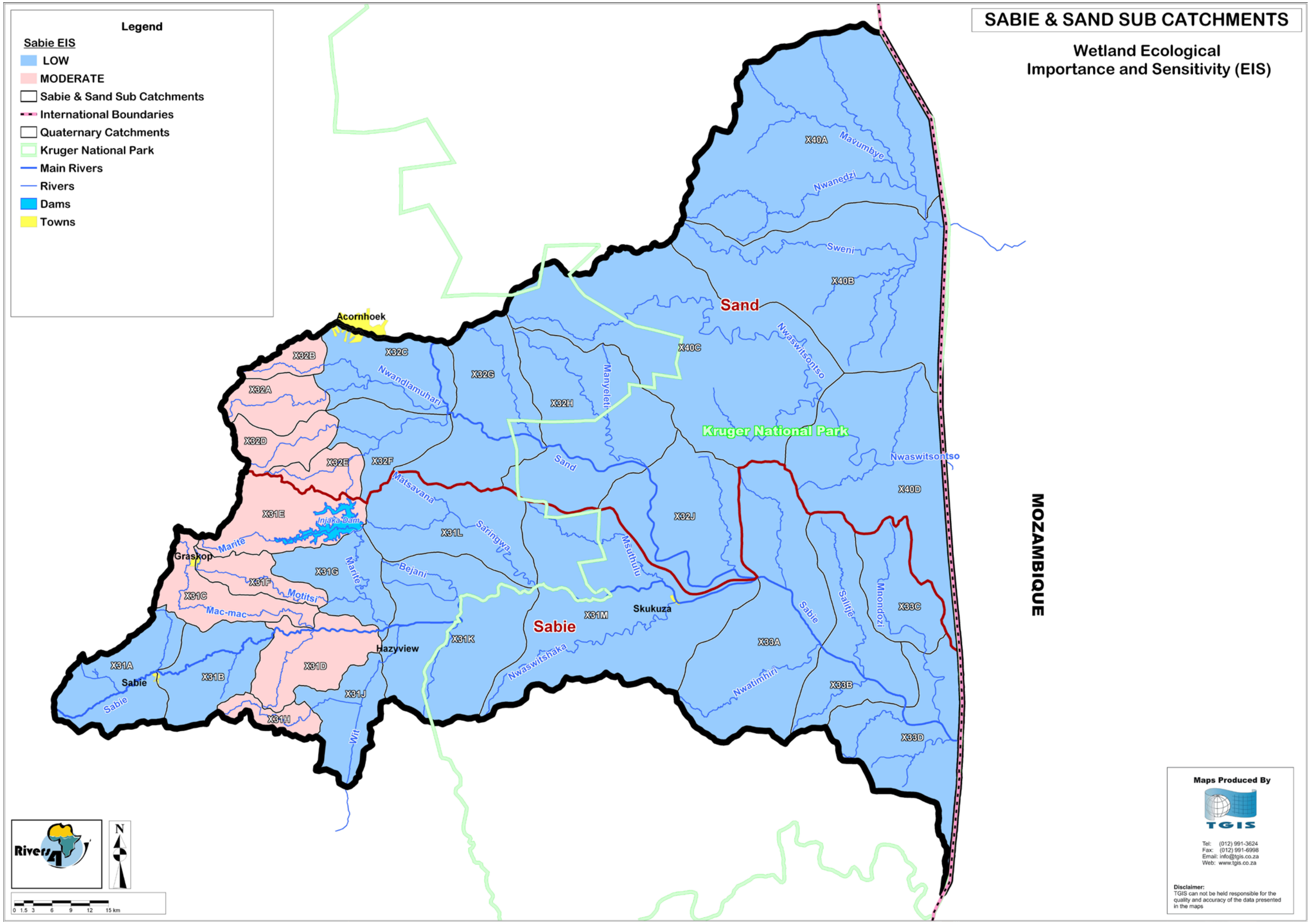

Figure 6.5 Sabie & Sand sub catchment Wetland EIS of quaternary catchments

Table 6.1 Estimated EIS and PES (average) for the wetlands within the quaternary catchments of the Inkomati WMA

Quat	Desktop EIS	Desktop PES
X21A	**HIGH**	*C*
X21B	**HIGH**	*C*
X21C	**HIGH**	*C*
X21D	*MODERATE*	**B/C**
X21E	*MODERATE*	*C*
X21F	**HIGH**	**B/C**
X21G	*MODERATE*	*C*
X21H	*MODERATE*	*C/D*
X21J	*MODERATE*	*D*
X21K	*MODERATE*	*D*
X22A	*MODERATE*	*C/D*
X22B	*LOW*	*C/D*
X22C	*MODERATE*	*D*
X22D	*MODERATE*	*C/D*
X22E	*MODERATE*	*C/D*
X22F	*MODERATE*	*C*
X22G	*MODERATE*	*C/D*
X22H	*MODERATE*	*C*
X22J	*LOW*	*D*
X22K	*LOW*	*C*
X23A	*MODERATE*	*C*
X23B	*MODERATE*	*C*
X23C	*MODERATE*	*C/D*
X23D	*MODERATE*	*C*
X23E	*MODERATE*	*C/D*
X23F	*MODERATE*	*C*
X23G	*MODERATE*	*C*
X23H	*LOW*	*C*
X24A	*LOW*	*D*
X24B	*LOW*	*D*
X24C	*LOW*	**B/C**
X24D	*LOW*	*C*
X24E	*LOW*	**B**
X24F	*LOW*	**B**
X24G	*LOW*	*A*
X31A	*LOW*	*D*
X31B	*LOW*	*D*
X31C	*MODERATE*	*D*
X31D	*MODERATE*	*C*
X31E	*MODERATE*	*D*
X31F	*MODERATE*	*C*
X31G	*LOW*	*D*
X31H	*MODERATE*	*C/D*
X31J	*LOW*	*D*
X31K	*LOW*	*D*
X31L	*LOW*	*D*
X31M	*LOW*	**A**
X32A	*MODERATE*	*D*
X32B	*MODERATE*	*D*
X32C	*LOW*	*D*
X32D	*MODERATE*	*D*
X32E	*MODERATE*	*D*
X32F	*LOW*	*D*
X32G	*LOW*	*D*
X32H	*LOW*	*C*
X32J	*LOW*	**A**
X33A	*LOW*	**A**

Quat	Desktop EIS	Desktop PES
X33B	LOW	A
X33C	LOW	A
X33D	LOW	A
X40A	LOW	A
X40B	LOW	A
X40C	LOW	C
X40D	LOW	A

6.3 WETLAND RESOURCE UNITS

In this catchment the Vegetation Types and Level I and II EcoRegion boundaries were primarily used to delineate the Wetland Resource Units. Six main Wetland Resource Units (WRUs) (Figure 6-2) were delineated, namely the:

- *WRU 1: Highveld Grassland WRU.*
- *WRU 2: Escarpment Grasslands WRU.*
- *WRU 3: Bushveld WRU, which can be subdivided into the Sour and Mountain Bushveld zones.*
- *WRU 4: Granite Lowveld WRU.*
- *WRU 5: Basalt Lowveld WRU; and*
- *WRU 6: Lebombo WRU.*

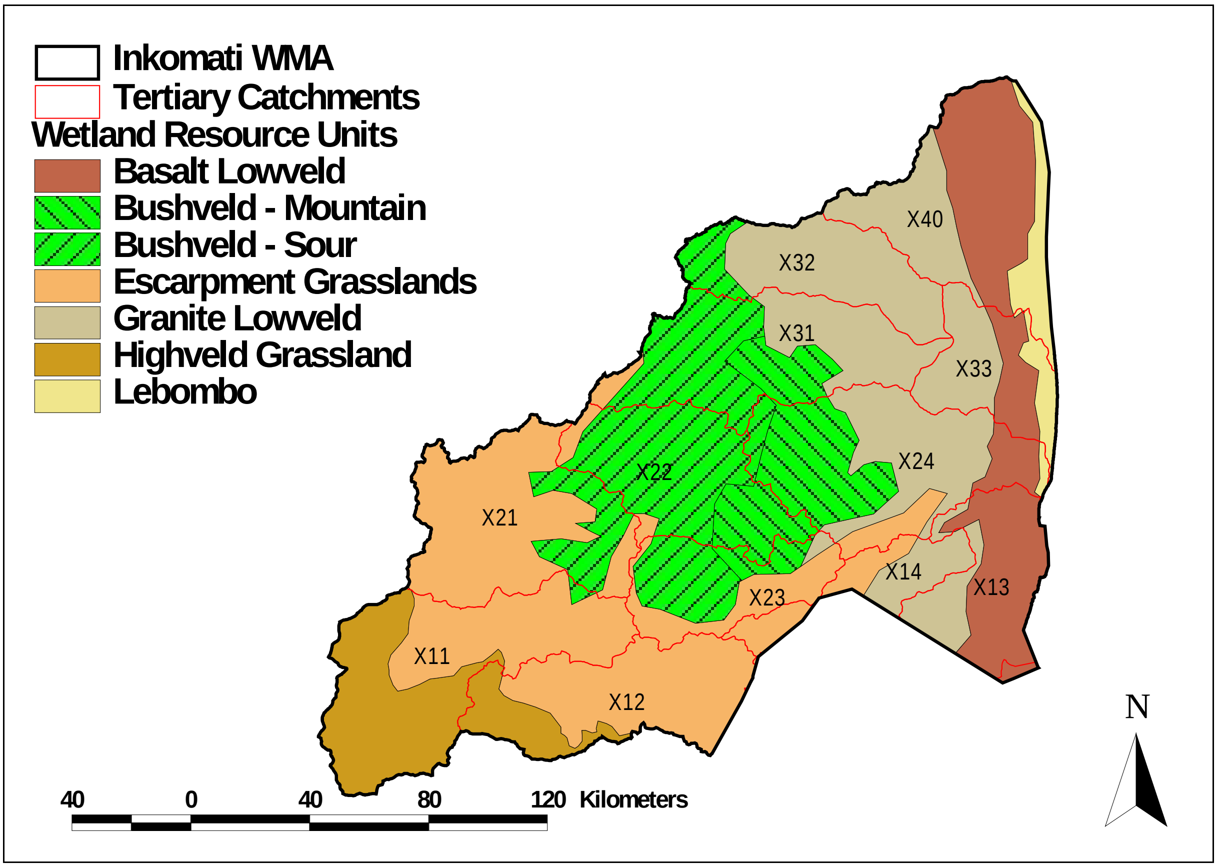

Figure 6.6 Distribution of quaternary catchments in relation to the Wetland Resource Units

A summary of the WRU within the Inkomati WMA and associated wetlands are provided in Table 6.2.

Table 6.2 Summary of WRU and associated wetlands

WRU	Quatenaries	Description	Impacts	PES, EIS
1	*Portions of catchments X11 and X12.*	*High density of large wetlands. Very large pans (rare). The vegetation type is regarded as "Endangered". Assumed that the wetland - dependent species within this vegetation type are similarly threatened.*	*Widespread agriculture (water quality impacts; trampling/grazing, erosion; encroachment into & channelization). Water quality impacts from mining. Limited impacts from invasive alien plants and the effects of dams drowning some wetlands and reducing water availability.*	*Moderate - estimates range from a C to C/D EC. High EIS*
2	*Portions of catchments X11, X12, X21, X23 and X14.*	*High density of very large wetlands. Ddiversity of types moderate. Vegetation types are "Vulnerable" - assumed that the wetland-dependent species are therefore similarly not critically threatened.*	*Trout farming - dams drowning wetlands & reducing water availability, water quality impacts and canalisation. Agricultural areas - runoff; trampling/grazing & erosion; encroachment & channelization. Afforestation, invasive alien vegetation, mining.*	*Most Moderate EIS scores. X21A, X21B, X21C and X21F: High EIS scores. In these quats diversity of wetland types is higher (number of large pans - rare). Density of wetlands high. X21A adjacent to the RAMSAR-listed Verloren Vlei. PES relatively High - estimates range from a B/C to C EC.*
3	*X22 and portions of catchments X21, X31, X23 & X24.*	*Moderate (Mountain Bushveld) to low (Sour Bushveld) density. Wetlands moderate to small. Density & diversity is low , density slightly higher in the Sour Bushveld area. Veg type endangered . Veg types in the Mountain Bushveld unit - "Least Threatended" - accounts for the slight differences in average EIS scores.*	*Extensive afforestation - reduced interflow, reducing water availability for wetlands. Forestry has encroached. Edge effects of forestry & roads disturb wetlands. Result in degradation. Irrigation farming, peri-urban areas of the former homelands and invasive alien vegetation have also caused some wetland degradation.*	*PES of the wetlands is relatively low - Range from a C to D EC. Quaternary catchments within the Sour Bushveld WRU have Moderate EIS scores, whilst those in the Mountain Bushveld WRU tend to have Low EIS scores.*
4	*Portions of catchments X31, X32, X40, X33, X24, X14 and X13.*	*Wetlands small or cryptic. Density & diversity very low – few wetlands. Those that do occur are not rare or high diversity relative. The vegetation types are listed as "Vulnerable". Large areas of this section of the catchment are protected within significant conservation areas.*	*Afforestation, agriculture and peri-urban areas. Forestry and the extensive agricultural areas have reduced the area of wetlands and the water available. Both landuse activities have encroached in places on the wetlands; whilst per-urban areas have caused erosion (though increased runoff, grazing pressures and confinement of the drainage lines associated with infrastructure development).*	*Low EIS scores. A wide range of PES: D to A ECs - indicative of the diverse conditions. Entire catchments are impacted by urbanisation of former homeland areas, Lower quats within KNP and private conservation areas. Little change from reference conditions in these areas; albeit that very few wetlands are found here.*
5	*Portions of catchments X40, X33, X24 and X13.*	*Wetlands confined to valley bottom positions. Density and diversity is very low. Few that do occur are not rare types or occur in high diversity relative to one another. The vegetation types are listed as "Least Threatened".*	*Most of the quaternaries are located within the Kruger National Park, and no significant impacts at a regional (catchment) scale are likely to have occurred.*	*Low EIS scores. PES very high – in A & B ECs. Notable exceptions are the quaternaries X13J, X13K and X13L which have been heavily impacted by urban and peri-urban areas of the former homelands, as well as by extensive irrigation farming.*
6	*Portions of catchments X40, X33 and X24.*	*No wetlands of any regional importance are expected due to steep slopes, shallow soils, low rainfall and high evaporation demands. Diversity would be very low, and density/occurrence extremely low.*		

6.4 PRIORITY WETLANDS IN THE INKOMATI CATCHMENT

Two areas of priority wetlands were identified in this study based on extremely high EIS scores (Table 6.1) derived from the desktop assessment:

- *The wetlands around Dullstroom (quaternary catchments X21A, X21B, X21C and X21F) all have High EIS scores and relatively high PES scores. These catchments are part of the Escarpment WRU (Figure 4-3) and are located close to the RAMSAR Verloeren Vallei wetland complex. Quaternary catchment X21A has an EIS bordering on Very High (Table 6.1).*
- *Wetlands of the Highveld WRU (X11A, X11B, X11C, X12A, X12B and X12E) generally have High EIS and Moderate PES scores. Of particular importance are the wetlands near the Chrissiesmeer Lake system – a dense grouping of pans in the headwaters of the Inkomati, Vaal and Usutu Rivers provides unique wetland habitats for birds and other fauna, and has a strong recreational and conservation value. This quaternary catchment (X11A) has an EIS bordering on Very High (Table 6.1).*

Early reviews of the state of wetland ecosystems in South Africa have highlighted these same areas for priority planning and research (Noble and Hemens, 1978).

*It has recently been reported that prospecting rights for coal are again being applied for[2] in the area of pans surrounding Chrissiesmeer. **A Comprehensive assessment of the high conservation priority Chrissiesmeer wetland complex should be undertaken to ensure that strategic, proactive management of these wetlands is enabled**, and thus avoid the rather piecemeal approach to wetland management and impacts from coal mining as exists in the upper Olifants Catchment. Chrissiesmeer is unique in southern Africa in terms of the size and concentration of pans and associated wetlands, and has been proposed as a RAMSAR site. The hydrological characteristics of, and connectivity between, the pans should be thoroughly investigated in order than impacts of future developments can be more accurately predicted and mitigated if necessary. Some small mines already exist in the area, and given the global demand for coal and requirement for job creation and foreign exchange earnings through coal exports provided by mines, it is likely that future expanded mining will need to be evaluated in this region.*

Thus whilst the wetlands around Dullstroom/Verloeren Vallei have both High EIS and High PES scores, the Highveld WRU wetlands are likely to be under greater threat and thus should be prioritised despite their generally lower PES scores.

Previous reviews of wetlands in this area of the country have also highlighted the temporary pans along the Sabie River; cited as providing important refuge for the Serranochromis meridianus fish (Noble and Hemens, 1978). Since these pans are maintained by large flood events that are beyond reasonable management intervention, it is not recommended that these areas are prioritised for research or studies to aid management of wetland resources in this WMA.

6.5 RECOMMENDATIONS FOR MANAGEMENT

The first step in the protection of wetlands and the regulation of their use is to determine if wetlands exist at proposed development sites, and if so, what the potential is that the proposed

[2] http://www.fin24.com/articles/default/display_article.aspx?ArticleId=1518-25_2577498, accessed 29th March 2010.

activity will impact upon the wetland/s and how it will do so. For this reason, wetlands should be identified and mapped according to the DWA (DWAF, 2005 and DWAF, 2008) guidelines on wetland delineation. If a wetland is located at the site, and the development footprint is within 500 m of the wetland, or the nature of the impact is such that a Water User Licence is required, then the developer should be advised to proceed with the WULA application in conjunction with the standard EIA study.

General management actions for the protection of wetlands within the Inkomati WMA are outlined below.

6.5.1 Road crossings

Road crossings through wetlands can cause erosion and drainage of wetlands. Where diffuse flows are concentrated into one or two culverts, an incised channel develops downstream of the road and this lowers the local water table, drying out the wetland and enhancing further erosion by the continued concentration of flows. If the headcuts from the erosion pass under the road crossing, the eroding channel can propagate upstream and further reduce wetland condition and integrity. Simple drop inlet structures as part of the bridge or road crossing design can prevent upstream erosion, whilst flow dissipaters; numerous culverts and sensitive sitting of road crossings can reduce downstream erosion.

Wetlands which are eroded - where flows are concentrated into channels and floodplains desiccate - have reduced functioning and cannot attenuate floods or ameliorate water quality problems as well as intact wetlands.

To minimise the impacts of road crossings, the following recommendations are provided:

- *No road crossings through unchannelled valley bottom wetlands; since these are specifically sensitive to flow concentrations and erosion.*
- *Wherever possible, road crossings could coincide with the local key points across the wetland.*
- *Drop inlets should be built as part of the bridge design where culverts are proposed on small wetlands and streams;*
- *Numerous culverts and flow dissipators should be constructed where feasible and necessary to prevent risk of erosion on downstream wetlands.*

6.5.2 Forestry

Adequate buffers between forestry areas, roads and/or infrastructure must be maintained, since this can allow the wetlands within them to persist with fair ecological integrity.

To minimise the impacts of afforestation, the following recommendations are provided:

- *Delineate the temporary wet hydrological zone of wetlands (following the DWAF, 2005 guidelines) and move all afforestation and agricultural activity at least 20 meters from this edge.*
- *This buffer zone should be managed for indigenous vegetation to reduce edge effects and allow for some water table recovery.*
- *Roads cannot be included as part of the buffer since these enhance the disturbance/edge effects.*
- *Invasive exotic vegetation must be controlled within the wetland and buffer zones.*

6.5.3 Agriculture

Agriculture impacts directly on wetlands through encroachment of fields into wetlands, canalisation/drainage of wetlands to increase useable land and through grazing and trampling effects of livestock. Runoff from fields can also create secondary water quality impacts on the receiving wetlands.

To mitigate these impacts:

- *Appropriate buffers should be placed around wetlands, and the buffer vegetation managed correctly. Buffers of natural vegetation should also be left in place along the major rivers of the WMA.*
- *SusFarms, Farming for the Future and other lower input approaches to farming can create win-win situations for the farmer and water resources, since the former reduces costs through reduced inputs, and the receiving waters have lower doses of nutrients to process.*

6.5.4 Mining

Coal mining is likely to expand within the WMA; specifically in the Highveld WRU. Each mining should be evaluated on its individual merits, but it is highly recommended that a strategic approach to wetland management be adopted if the footprint of mining is to expand within the catchment. This would enable trade-off and reasonable, effective mitigation options to be identified upfront and avoid the current piecemeal approach being applied in the now critically modified Upper Olifants River catchment.

In lieu of the prospecting rights for coal application in the area of pans surrounding Chrissiesmeer, and it is highly recommended that a Comprehensive assessment of the high conservation priority Chrissiesmeer wetland complex be undertaken to ensure that strategic, proactive management of these wetlands is enabled.

In general, some of the objectives which could be considered for mining might be:

- *No net loss of wetlands, or no net loss of the functions of wetlands (incorporating aspects of off-site mitigation, wetland engineering and recognition of the ecosystem goods and services that need to be replaced or reinstated if wetlands are impacted).*
- *Maintenance or restoration of as much of the pre-mining hydrological (diffuse surface, channelled and soil interflow) flows as possible.*
- *Where river diversions are required, the same HGM wetland must be created – i.e. diffuse lows across unchannelled valley bottoms should not be replaced with a canal.*
- *Clean water should be diverted and reinstated in the landscape in a similar way so that similar landscape hydrological processes can be achieved.*

6.6 GENERAL MANAGEMENT AND REHABILITATION ACTIONS

- *Eradicate all exotic invader vegetation species and, where feasible, rehabilitate important palustrine wetlands.*
- *Comply with the recommended grazing carrying capacity for that area, to prevent over-grazing in wetlands.*
- *Establish a fire management plan to benefit the integrity of wetlands.*

7 RESOURCE UNITS

Department of Water Affairs and Forestry, South Africa. 2008. 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.

7.1 DELINEATION APPROACH

Resource Units (RUs) are required as it would not be appropriate to set the same numerical Reserve for the headwaters of a river as for the lowland reaches. The breakdown of a catchment into RUs for the purpose of determining the Reserve for rivers is therefore done primarily on a biophysical basis within the catchment and called Natural Resource Units (NRUs). Management requirements (DWAF, 1999, volume 3) also play a role in the delineation. Furthermore, the type of disturbance/impact on river plays a role to select homogenous river reaches from a biophysical basis under present circumstances. These are called Management Resource Units (MRUs). MRUs can be further delineated in even smaller assessment units called Reserve Assessment Units (RAUs). It is preferred that a EWR site is selected within each MRU, and if a RAU occurs within the MRU, the EWR should, if possible, be selected within the RAU.

The following is considered for selection of MRUs:
- *EcoRegions (Level II).*
- *Geomorphic zones.*
- *Land cover.*
- *Presence of dams and other operational aspects.*
- *Water quality.*
- *Groundwater.*
- *Local knowledge.*

7.2 CROCODILE SUB-CATCHMENT

7.2.1 Delineation results

The focus of this study was on the Crocodile (East) River and the Kaap River, a major tributary of the Crocodile River. The rivers were divided into Management Resource Units (MRUs) based on the criteria illustrated in Figure 7-1 and Figure 7-2. The description of the MRUs and the rationale for selection is provided in Table 7.1 and 7.2.

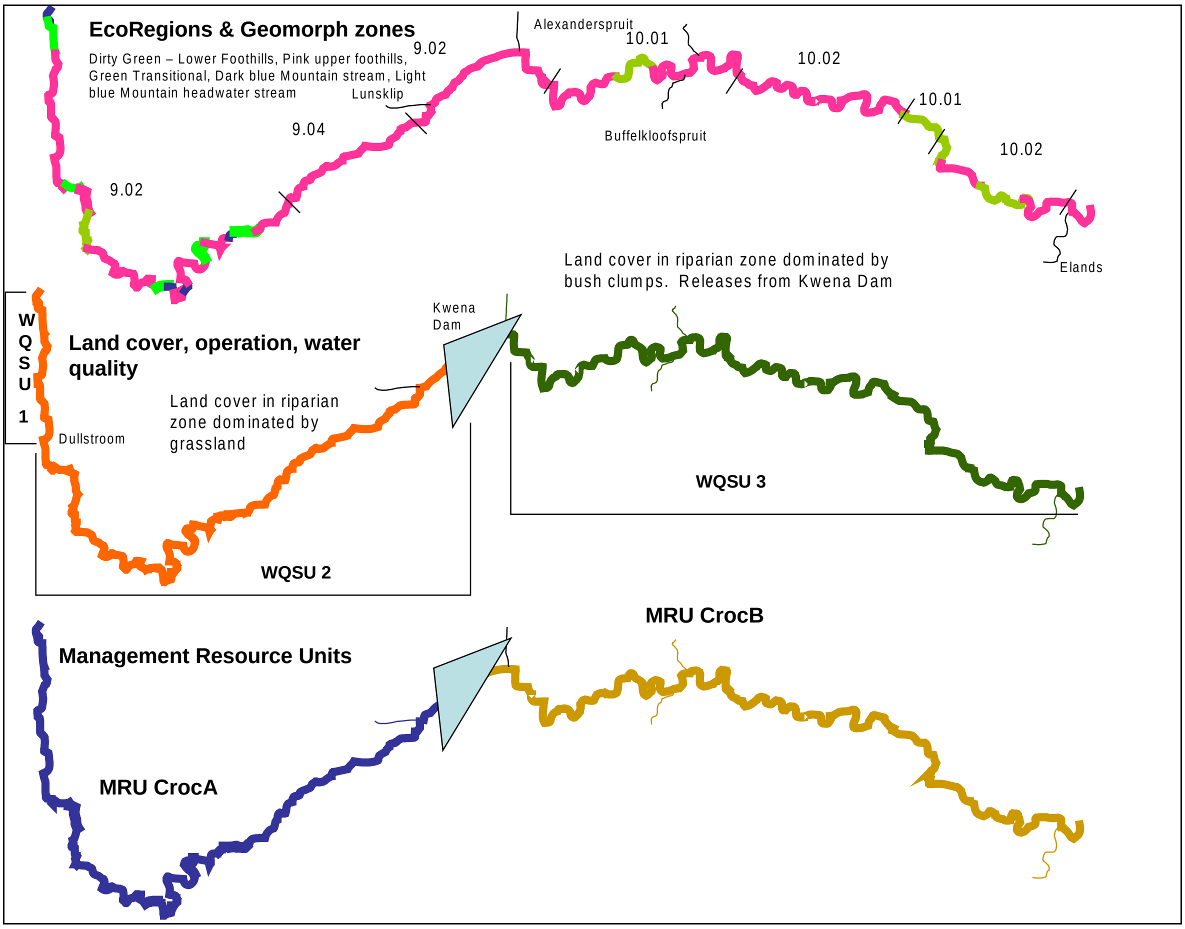

Figure 7.1 Crocodile (East) River Management Resource Units

Table 7.1 Description and rationale of the Crocodile River MRUs

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Croc A	*9.02 (70%) 9.04 (30%)*	*Mountain Stream (1%) Transitional (6%) Upper Foothills (90%) Lower Foothills (3%)*	*Dominated by grassland*	*The river is dominated by EcoRegion 9.02 and Upper Foothills. Has similar land cover and land use and includes WQSU (1 and 2). Kwena Dam is the operational break in the MRU. The MRU = primary NRU A, B and C.*	*Origin of river to upper reaches of Kwena Dam. 30.1074;-25.3380. 30.3443;-25.3821*	*X21A X21B*
MRU Croc B	*10.02 (15%) 4.04 (5%) 3.07 (80%)*	*Lower foothills (20%) Upper foothills (80%)*	*Riparian zone dominated by bush clumps. Operation to Elands River dominated by releases (unseasonal) from Kwena Dam.*	*The river is dominated by EcoRegion 3.07, and Upper Foothills. The releases from Kwena Dam forms a change from the natural hydrology and an EWR site in this reach will represent the reach. Water quality is homogenous. The Elands River (largest tributary) forms a hydrological break as it introduces a more natural diversity of flow at times. The MRU = primary NRU C and E = WQSU3.*	*Kwena Dam Wall to the Elands River confluence. 30.3862; -25.3590. 30.7156; -25.4527*	*X21D X21E*
MRU Croc C	*4.04 (100%)*	*Upper Foothills (2%) Lower Foothills (98%)*	*Riparian indigenous bush with exotics and irrigation.*	*Consists of EcoRegion 4.04 and Lower Foothills. Land cover and use similar to Nelspruit and adjacent KaNyamazane. A logical break due to water quality impacts. (WQSU 4). The MRU = primary NRU F =*	*Elands River confluence to Blinkwater confluence. 30.7156;-25.4527 31.18018; -25.4996*	*X22B X22C X22J X22K*

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
				WQSU 4.		
MRU Croc D	*3.07 (100%)*	*Upper Foothills (47%) Lower Foothills (47%) Transitional (6%)*	*Riparian indigenous bush with exotics.*	*Breaks are indicated by change in land use and a distinctive gorge. The lower border indicates the change of sugarcane on the RB and Kruger Park on the LB.*	*Blinkwater confluence to border of KNP. 31.18018; -25.4996 31.3714; -5.5278*	*X22K X24C*
RAU Croc D.1	*3.06 (100%)*	*Upper Foothills (90%) Lower Foothills (9%) Transitional (1%)*	*Gorge with a railway and tar roads flanking it with indigenous riparian bush with exotics.*	*This section of river is protected by flanking mountains. Ecological indicators more intact. The steeper gradient makes this section more sensitive to decreased flows and an EWR site within this section was recommended.*	*Gorge 31.2026; -25.5090 31.3164; -25.5328*	*X22K X24C*
MRU Croc E	*3.06 (15%) 3.07 (70%) 12.01 (15%)*	*Lower Foothills (100%)*	*Natural bush (KNP) on LB and irrigation/lodges on RB.*	*RU consists of Lower Foothills and the same land cover and use and water quality. The logical breaks are therefore from the point where the KNP borders the Crocodile River to the Komati River confluence.*	*KNP border to Komati confluence. 31.3714; -25.5278 31.9359; -25.3390*	*X24D X24E X24F X24H*

Shaded blocks indicate MRUs where EWR sites were recommended.

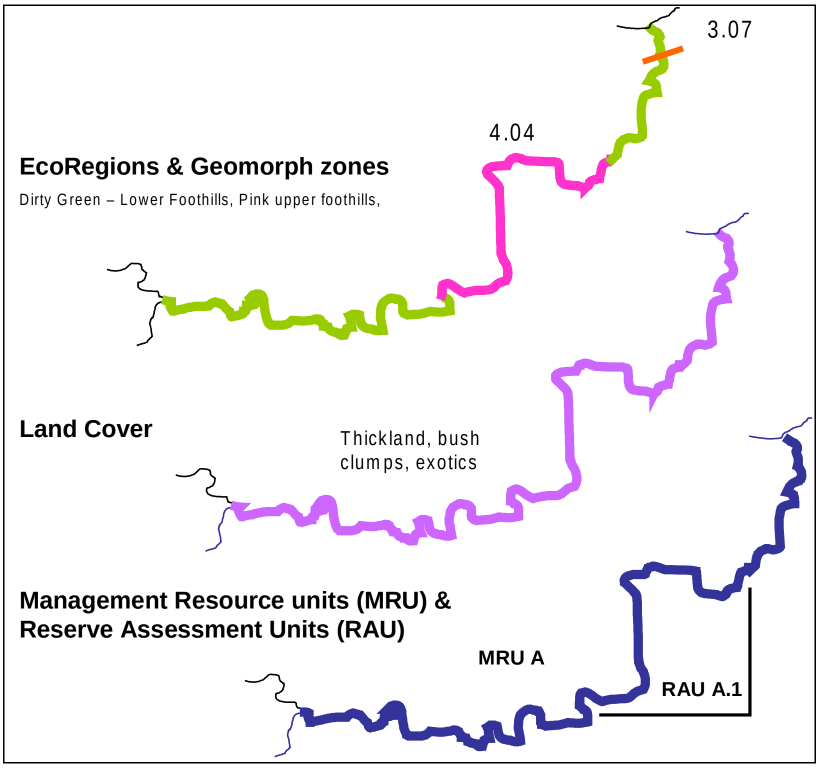

Figure 7.2 Kaap River Management Resource Units

Table 7.2 Description and rationale of the Kaap River MRUs

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Kaap A	*4.04 (98%) 3.07 (2%)*	*Upper Foothills (30%) Lower Foothills (70%)*	*Thickets, bush clumps, exotics bush.*	*The river is dominated by EcoRegion 4.04 and Lower Foothills. Has similar land cover and land use. The NRU = MRU A = WQSU 7*	*Confluence of the Noord and Suid Kaap to confluence with the Crocodile. 31.0838; -25.6659 31.3120; -25.5371*	*X23G X23H*
RAU Kaap A.1	*4.04 (100%)*	*Upper Foothills (100%)*	*Gorge*	*This area forms an inaccessible gorge as indicated by the different geomorphic zone. This section could be a different (higher) PES than the rest of the unit and it would therefore be preferable to select an EWR site within this RAU (depending on access). An EWR set here will cater for the rest of the MRU.*	*Start and end of Upper Foothills. 31.2126;-25.6609 31.2920;-25.6003*	*X23H X23G*

The results of the delineation of the Crocodile River and Kaap River are summarized in Table 7.3 and illustrated in Figure 7.3.

Table 7.3 Description of MRUs in the Crocodile sub-catchment

MRU	Delineation	Quat
CROCODILE RIVER		
MRU Croc A	*Origin of river to upper reaches of Kwena Dam.*	*X21A, X21B*
MRU Croc B	*Kwena Dam Wall to the Elands River confluence.*	*X21D, X21E*
MRU Croc C	*Elands River confluence to Nelspruit.*	*X22B, X22C, X22J, X22K*
MRU Croc D	*Nelspruit to border of KNP.*	*X22J, X22K, X24C*
RUA Croc D.1	*Gorge.*	*X22K, X24C*
MRU Croc E	*KNP border to Komati confluence.*	*X24D, X24E, X24G, X24H*
KAAP RIVER		
MRU Kaap A	*Confluence of the Noord and Suid Kaap to confluence with the Crocodile.*	*X23G, X32H, X23B*
RAU Kaap A.1	*Start and end of Upper Foothills.*	*X23H, X23G*

7.2.2 EWR sites

The selection of EWR sites was guided by a number of considerations. The key considerations were:

- *The suitability of the sites for accurate hydraulic modelling throughout the range of possible flows, especially low flows.*
- *Accessibility of the sites.*
- *An area or site that could be critical for ecosystem functioning. These are often represented by riffle units, where low flow conditions or the cessation of flow constitutes a break in the functioning of the river, and consequently, the biota dependant on this habitat and/or perennial flow are adversely affected. Pools were not considered critical habitats in perennial systems since they are still able to function or at least maintain life during periods of no flow.*

7.2.3 Locality and description of sites

Seven EWR sites were selected in the Crocodile sub-catchment (Figure 7.3, Table 7.3 and Table 7.4). Recommendations regarding the number and locality of EWR sites were made as part of the MRU delineation and are provided in Table 7.4.

Table 7.4 Management Resource Units and EWR sites: Crocodile sub-catchment

MRUs	Recommendation (see Table 7.1 and 7.2)	EWR site
Crocodile River		
MRU A	*One EWR site.*	*EWR1 - Valeyspruit* *EWR2 - Goedenhoop* *Two EWR sites originally selected. Both served a purpose as the one was upstream in the more Grassveld wetland type area whereas the downstream one was situated immediately upstream of the dam, i.e. it represented all upstream impacts.*
MRU B	*One EWR site.*	*EWR3 – Poplar Creek* *The releases from Kwena Dam formed a change from the natural hydrology and one EWR site represented the reach.*
MRU C	*One EWR site.*	*No EWR site was situated in this Resource Unit. During a 1999 study and the 2002 study (Godfrey, 2002), no site suitable for EWR assessment, especially from a hydraulic viewpoint, could be found.*
MRU D	*The steeper gradient made the RAU more sensitive to decreased flows and an EWR site within this section was recommended.*	*EWR 4: KaNyamazane* *Site was situated at the start of RAU D1. No site further downstream in the RAU was available.*
MRU E	*One EWR site.*	*EWR 5 – Malelane* *EWR 6 – Nkongoma* *Two sites were originally selected. Due to the increasing impacts between the sites, both sites plays an important role in the management of the system*
Kaap River		
MRU A	*One EWR site in the RAU as it could be a higher PES than the rest of the RU due to the presence of indicators for EWR assessment*	*EWR 7 – Kaap* *Site was situated at the entrance of the gorge in the RAU.*

Details regarding the sites selected are provided in the Table 7.5, summarized in Table 7.6 and illustrated in the Figure 7.3.

Table 7.5 Locality and characteristics of the Crocodile sub-catchment EWR sites

Site information	EWR sites	Illustration
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 1 Valeyspruit* *Crocodile* *EWR 1* *X2Croc-Valys* *-25.49412, 30.14427* *S25 29.647, E30 08.656* *9.02* *Upper Foothills* *1852* *MRU Croc A* *X21A* *Valeyspruit* *-*	

Site information	EWR sites	Illustration
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 2 Goedenhoop* *Crocodile* *EWR 2* *X2CROC-UKWEN* *-25.40925, 30.31592* *S25 24.555, E30 18.955* *9.04* *Upper Foothills* *1207* *MRU Croc A* *X21B* *Goedenhoop* *-*	
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 3 Poplar Creek* *Crocodile* *EWR 3* *X2CROC-DKWEN* *-25.45211, 30.68108* *S25 27.127, E30 40.865* *10.02* *Lower Foothills* *834* *MRU Croc B* *X21E* *Mooifontein* *X2H013*	
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 4 KaNyamazane* *Crocodile* *EWR 4* *X2CROC-DNELS* *-25.50243, 31.18198* *S25 30.146, E31 10.919* *4.04* *Lower Foothills* *472* *MRU Croc D* *X22K* *State ground* *X2H032*	
EWR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *Decimal Minutes* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	*EWR 5 Malelane* *Crocodile* *EWR 5* *X2CROC-MALEL* *-25.48287, 31.50773* *S25 28.972, E31 30.464* *3.07* *Lower Foothills* *286* *MRU Croc E* *X24D* *KNP* *S2H046*	

<table>
<tr><th>Site information</th><th>EWR sites</th><th>Illustration</th></tr>
<tr><td>EWR nr & name
River
Previous IFR site
National RHP site
Decimal Degrees
Decimal Minutes
EcoRegion (Level II)
Geomorphic Zone
Altitude (m)
RU
Quaternary
Farm name
Hydrological gauge</td><td>EWR 6 Nkongoma
Crocodile
EWR 6
X2CROC-NKONG
-25.39050, 31.97444
S25 23.430, E31 58.467
12.01
Lower Foothills
135
MRU Croc E
X24H
KNP
X2H016</td><td></td></tr>
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River
Previous IFR site
National RHP site
Decimal Degrees
Decimal Minutes
EcoRegion (Level II)
Geomorphic Zone
Altitude (m)
RU
Quaternary
Farm name
Hydrological gauge</td><td>EWR 7 Honeybird
Kaap
EWR 7
X2Kaap-Honey
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S25 38.968, E31 14.572
4.04
Upper Foothills
470
MRU Kaap A
X23H
Lovedale
-</td><td></td></tr>
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Table 7.6 Summary of EWR sites in the Crocodile sub-catchment

EWR site number	EWR site name	River	Decimal Min S	Decimal Min E	EcoRegion (Level II)	Geomorphic Zone	Altitude (m)	RU	Quat	Gauge
EWR 1	*Valeyspruit*	*Crocodile*	*S25 29.647*	*E30 08.656*	*9.02*	*Upper Foothills*	*1852*	*MRU Croc A*	*X21A*	
EWR 2	*Goedenhoop*	*Crocodile*	*S25 24.555*	*E30 18.955*	*9.04*	*Upper Foothills*	*1207*	*MRU Croc A*	*X21B*	
EWR 3	*Poplar Creek*	*Crocodile*	*S25 27.127*	*E30 40.865*	*10.02*	*Lower Foothills*	*834*	*MRU Croc B*	*X21E*	*X2H013*
EWR 4	*KaNyamazane*	*Crocodile*	*S25 30.146*	*E31 10.919*	*4.04*	*Lower Foothills*	*472*	*MRU Croc D RUA Croc D.1*	*X22K*	*X2H032*
EWR 5	*Malelane*	*Crocodile*	*S25 28.972*	*E31 30.464*	*3.07*	*Lower Foothills*	*286*	*MRU Croc E*	*X24D*	*S2H046*
EWR 6	*Nkongoma*	*Crocodile*	*S25 23.430*	*E31 58.467*	*12.01*	*Lower Foothills*	*135*	*MRU Croc E*	*X24H*	*X2H016*
EWR 7	*Honeybird*	*Kaap*	*S25 38.968*	*E31 14.572*	*4.04*	*Upper Foothills*	*470*	*MRU Kaap A*	*X23H*	

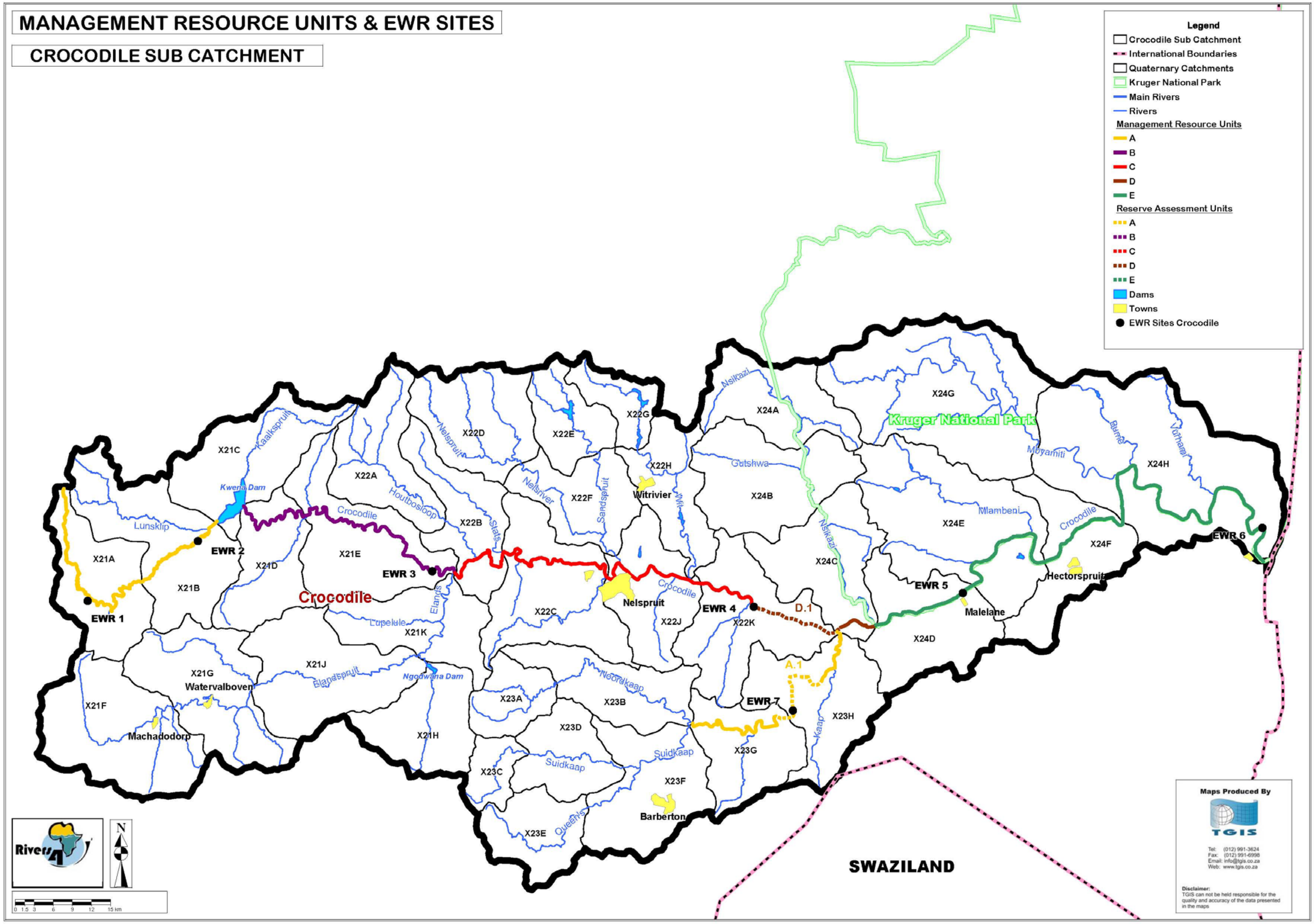


Figure 7.3 MRUs and EWR sites of the Crocodile sub-catchment

7.2.4 Site suitability

The site suitability of each site was assessed and is provided in Table 7.6 and 7.7. The following scoring system was used to determine relative site suitability (Colour coding as used in Table 7.6 and 7.7):

0: Not suitable
0.1-1 Very low suitability
1.1-2.0: Low suitability
2.1-3.0: Moderate suitability
3.1-4.0: High suitability
4.1-5.0: Very high suitability

Table 7.6 illustrates the site suitability from a biophysical point of view. Any comments regarding outliers are also provided. From a biophysical point of view, the sites were mostly highly suitable for EWR determination. EWR 1 (Valeyspruit) was of moderate suitability due to the limited fish guilds present while EWR 7 was bedrock dominated and impacted.

Table 7.7 Biophysical Site suitability for the Crocodile River system

EWR sites	Geomorph	Riparian veg	Fish	Inverts	Average	Median	Max	Min	Comments
EWR 1	3.8	3.9	2.5	3.4	3.4	**3.4**	3.9	2.5	Fish is lower suitability as only semi rheophilics are naturally present. This provides difficulties for setting flow requirements for fish during the dry season. This does not mean that there are better sites available.
EWR 2	3.5	4.1	4.0	3.8	3.9	**3.9**	4.1	3.5	Not easy to relate geomorphological cues to cross-section.
EWR 3	3.8	4.2	4.5	3.6	4.0	**4.0**	4.5	3.6	Lack of diverse hydraulic habitat for invertebrates.
EWR 4	3.6	4.2	4.0	4.0	4.0	**4.0**	4.2	3.6	Disturbed banks problematic for geomorphological assessment.
EWR 5	3.4	4.2	3.5	4.1	3.8	**3.8**	4.3	3.4	No clear terraces present - problematic for geomorph assessment.
EWR 6	3.3	4.0	4.0	3.7	3.8	**3.8**	4.0	3.3	No clear terraces present - problematic for geomorph assessment.
EWR 7	3.0	3.6	4.5	4.3	3.9	**3.9**	4.5	3	Impacts worse at site than rest of RU, bridge has impact, presence of bedrock - problematic for geomorph assessment.

Hydraulic suitability is however crucial as this converts the biophysical requirements to flow. For the purposes of determining flow requirements, the low flows and high flows are evaluated separately. Geomorphology and vegetation usually are the most crucial components for high flows and fish and invertebrate for low flows (Table 7.6). The suitability of the sites are therefore evaluated for both low and high flows and compared to the corresponding suitability for low and high flow hydraulics.

The rationale is that the lowest rating of either the biophysical or hydraulic components represents the overall suitability for either low or high flows. The reasoning is that even if a site has all the indicators for ecological flow assessment the overall suitability cannot be high if the hydraulic suitability is low as that will affect the final confidence in the flow assessment. And vice versa, if the suitability is high for hydraulics but low for the biophysical component, then the overall confidence will still be low as high suitability in hydraulics does not guarantee a high confidence answer if the indicators at the sites (indicating the biophysical suitability) is not present to interpret flow requirements. The low flow suitability was high apart from at EWR 4, 6 and 7 (due to lack of hydraulic suitability). The suitability for high flow determination was high at all sites apart from EWR 7 (due to lack of hydraulic suitability; Table 7.7). It must be noted that the hydraulic suitability *is much higher than normal. This is because the sites were selected previously, and good calibrations have already been obtained (Table 7.7).*

Table 7.8 Integrated site suitability for the Crocodile River system

EWR SITES	Biophysical		Hydraulics		Suitability		Comment
	Low flows	High flows	Low flows	High flows	Low flows	High flows	
EWR 1	*4*	*3*	*4*	*5*	*4*	*4*	*Highly suitable from both low and high flow perspective and both biophysical and hydraulic perspective.*
EWR 2	*4*	*4*	*4*	*4*	*4*	*4*	*Highly suitable from both low and high flow perspective and both biophysical and hydraulic perspective.*
EWR 3	*4*	*4*	*3*	*4*	*4*	*4*	*Highly suitable from both low and high flow perspective and both biophysical and hydraulic perspective.*
EWR 4	*4*	*4*	*3*	*3*	*3*	*4*	*Highly suitable for high flows, slightly less suitable for low flows due to the complicated hydraulics. A low flow cross-section might have to be added to address the complications associated with the very steep rapid selected during the previous studies.*
EWR 5	*4*	*4*	*4*	*5*	*4*	*4*	*Highly suitable from both low and high flow perspective and both biophysical and hydraulic perspective.*
EWR 6	*4*	*4*	*2*	*4*	*3*	*4*	*Highly suitable for high flows, slightly less suitable for low flows due to the complicated hydraulics.*
EWR 7	*3*	*4*	*2*	*2*	*3*	*3*	*Moderate suitability for both low and high flows. Low suitability for hydraulics due to rapidly varied flow conditions and large scale roughness due to bedrock influence in this gorge.*

0: Not suitable *0.1 – 1: Very low suitability* *1.1 - 2.0: Low suitability*
2.1 - 3.0: Moderate suitability *3.1 - 4.0: High suitability* *4.1 - 5.0: Very high suitability*

7.3 SABIE-SAND SUB-CATCHMENT

7.3.1 Delineation results

The focus was on the Sabie River (including the Mac Mac and Marite River tributaries) and the Sand River (including the Mutlumuvi tributary and Tlulandziteka River). The Sabie and Sand rivers were divided into MRUs based on the criteria illustrated in Figure 7-4 and Figure 7-5. The description of the MRUs and the rationale for selection is provided in Table 7.9 and 7.10.

Table 7.9 Description and rationale of the Sabie River MRUs

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Sabie A	*10.01 (15%) 4.04 (75%)*	*Mountain Headwater Stream and Mountain Stream (15%) Transitional (10%) Lower foothills (5%) Upper foothills (70%)*	*Dominated by forestry.*	*Dominated by Upper foothills with a small section of mountain headwater mixed with Mountain stream. Approximately 75% of the unit falls into EcoRegion 4.04. Land cover is mostly forestry with some natural areas in the upper catchment. Sabie town is situated in the upper reaches.*	*Origin of the river to the Marite confluence. 30.6224; -25.1420 31.1456; -25.1521 NRU A is combined with NRU as NRU A is too short to warrant its own RU.*	*X31A X31B X31D*
RAU Sabie A.1	*10.01 (100%)*	*Mountain Headwater Stream (50%) and Mountain Stream (50%)*	*Land cover dominated by natural fynbos.*	*This area is likely in excellent condition as minimal impacts apart from forestry. This section therefore in a different EcoStatus than the RU and, as it is a small river in this section, will require a different EWR. Recommendation: As there is unlikely to be any demand on this section, no EWR site and EcoClassification*	*Source of river to end of the Mountain Stream. 30.6224; -25.1420 30.6535; -25.1521 RAU Sabie A.1 = NRU Sabie A*	*X31A*

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
				recommended.		
RAU Sabie A.2	*4.04 (100%)*	*Upper Foothills (20%) Lower Foothills (80%)*	*Land cover dominated by forestry.*	*Critical area DS of Mac-Mac due to dilution effect to ameliorate Sabie impacts. EcoStatus could be in a higher category than the river DS of Sabie Town. EWR site will cater for the rest of the RU. Recommendation: If a site meeting to EWR site criteria can be found, it is recommended that it be situated between the Mac Mac and the Marite. The EcoClassification must be undertaken for this section.*	*Mac-Mac confluence to Marite confluence. 31.0258; -25.0295 31.1456; -25.0230 RAU Sabie A.2 = NRU Sabie B.2*	*X31D*
MRU Sabie B	*3.07 (100%)*	*Lower Foothills (95%) Upper Foothills (5%)*	*Dominated by irrigation. About 70% includes the KNP on the right bank.*	*RU represents a smaller section than the 3.07 EcoRegion and the Lower Foothills zone due to the change of land use at the KNP entrance. From this point the Sabie falls wholly within the KNP.*	*Marite confluence (start of 3.07 EcoRegion) to KNP entrance. 31.1456; -25.1521 31.4860;-24.9817*	*X31K X31M*
RAU Sabie B.1	*3.07 (100%)*	*Lower Foothills (100%)*	*The KNP on the RB with irrigation and recreational areas on LB.*	*Better condition than rest of the MRU as the river borders the KNP and is mostly enclosed in the KNP. Recommendation: EWR site in this MRU be situated within the RAU.*	*Point where river forms border of KNP to Kruger gate. 31.24485; -25.0187 31.4860;-24.9817*	*X31K X31M*
MRU Sabie C	*3.07 (60%) 3.06 (20%) 12.01 (20%)*	*Lower Foothills (100%)*	*All relatively natural as in the KNP.*	*Logical RU due to homogeneity of landuse and similar geomorphic zone.*	*Kruger Gate to border of KNP with Mozambique. 31,250; -25.0178 32,0307; 25,1815*	*X33A X33B X33D X31M*
RAU Sabie C.1	*3.07 (100%)*	*Lower Foothills (100%)*	*All relatively natural as in the KNP.*	*The inflow from the Sand brings about subtle changes as more alluvial than the Sabie. Prior to the 2000 floods, the Sabie upstream of the confluence was much rockier and therefore provided more critical habitat. Recommendation: The critical habitat is still present, and, the EWR site should be situated in the RAU.*	*Kruger Gate to Sand confluence. 31,250; -25.0178 31,7136; -24,9552 RAU Sabie C.1 = NRUC.2*	*X31M*

Shaded blocks indicate MRUs where EWR sites were recommended.

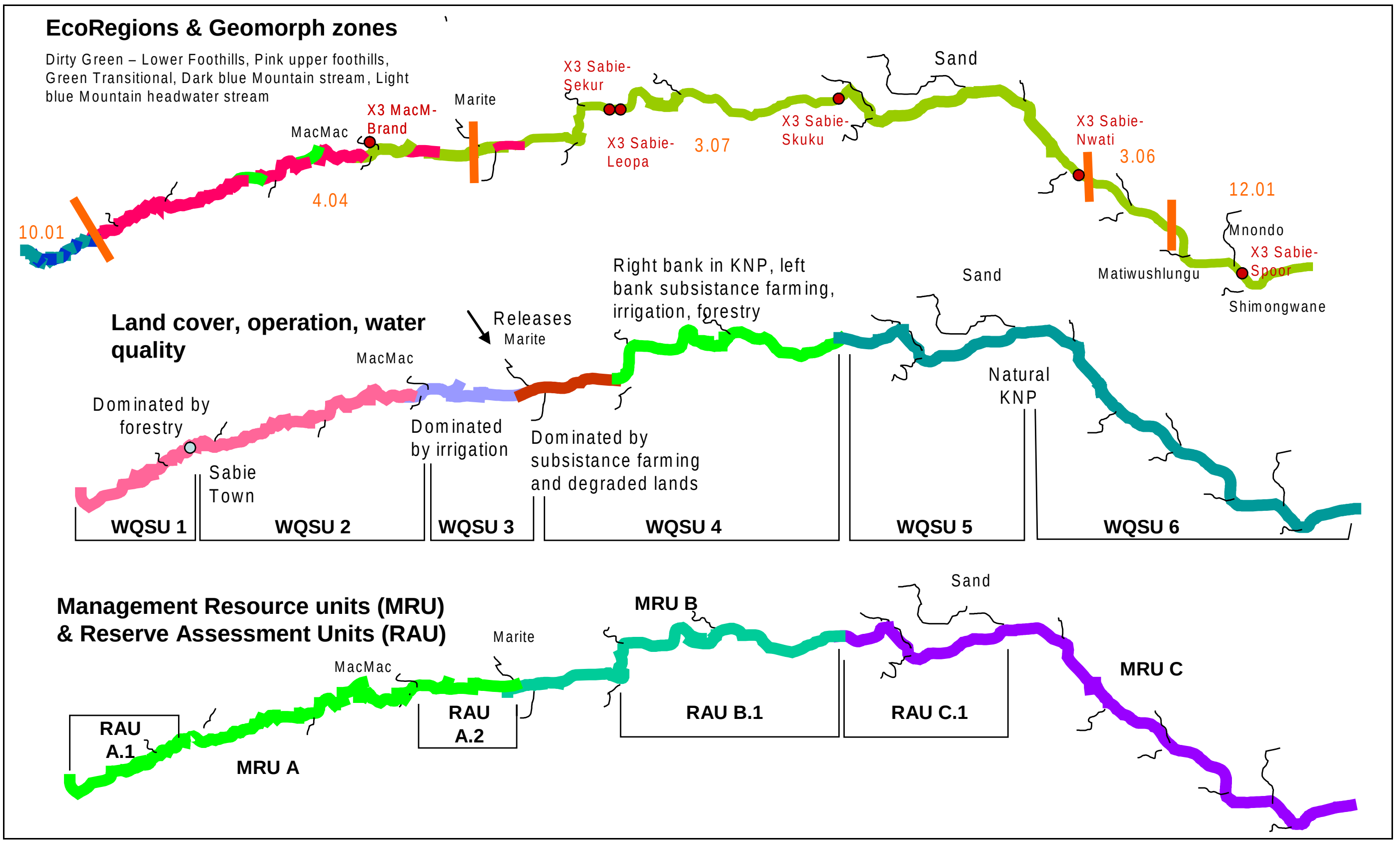


Figure 7.4 Sabie River Management Resource Units

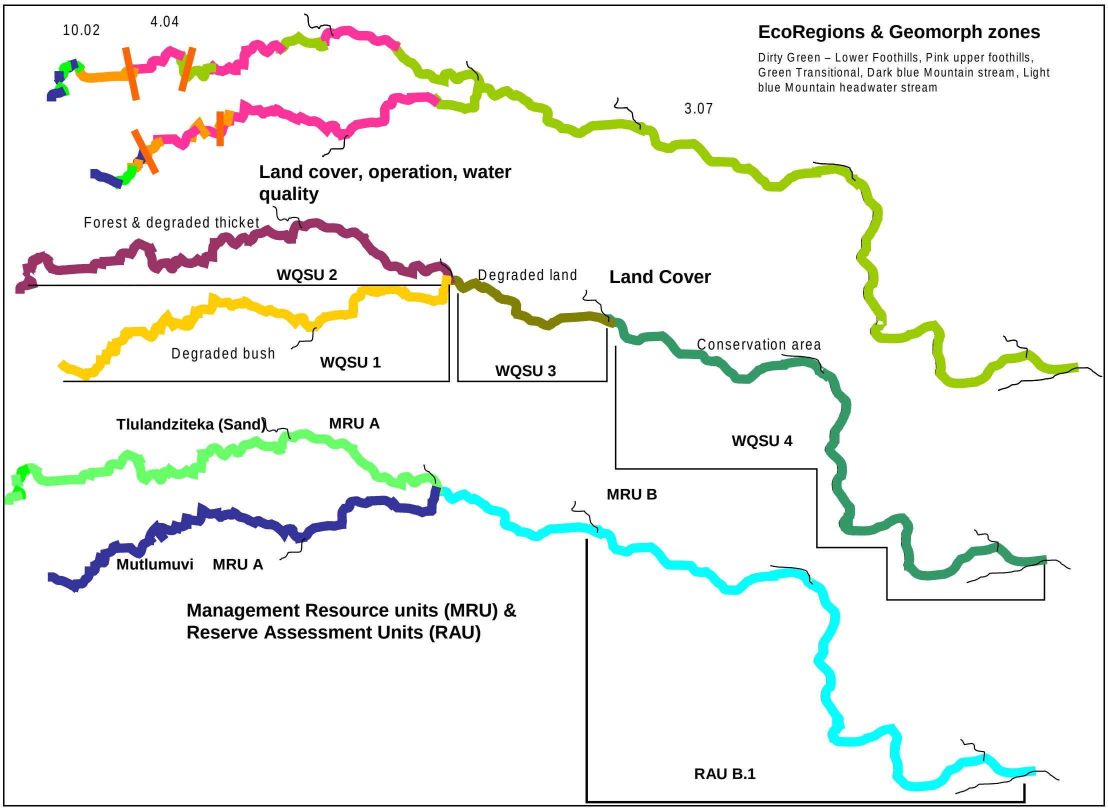


Figure 7.5 Sand River Management Resource Units

Table 7.10 Description and rationale of the Sand River MRUs

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Sand A	*10.02 (15%) 4.04 (5%) 3.07 (80%)*	*Mountain Headwater Stream (5%) Mountain Stream (5%) Transitional (10%) Lower foothills (40%) Upper foothills (40%)*	*Indigenous forest and degraded bush.*	*The river is dominated by EcoRegion 3.07, has similar land cover and land use. The upper river will be different, but this will not warrant a separate RAU as too small. The confluence of the Mutlumuvi river forms a logical end of the MRU due to the change in hydrology. The MRU = primary NRU = WQSU 2.*	*Origin of river to confluence with Mutlumuvi. 30.8900; -24.7333 31.2338; -24.7221*	*X32A X32C*
MRU Mutlumuvi A.	*10.02 (15%) 4.04 (5%) 3.07 (80%)*	*Mountain Headwater Stream (2.5%) Mountain Stream (2.5%) Transitional (2%) Lower foothills (8%) Upper foothills (85%)*	*Degraded bush.*	*The river is dominated by EcoRegion 3.07, Upper Foothills and degraded bush. The upper river will be different, but this will not warrant a separate RAU as too small. The confluence with the Sand River forms a logical end of the MRU due to the change in hydrology. The MRU = primary NRU = WQSU1.*	*Origin of river to confluence with Sand. 30.9243; -24.7921 31.2338; -24.7221*	*X32D X32F*
MRU Sand B	*3.07 (100%)*	*Lower Foothills (100%)*	*Mostly within the conservation areas with the upper areas of the MRU covered with the degraded bush.*	*The river is dominated by EcoRegion 3.07, and conservation areas. Includes both WQSU 3 and 4.*	*Confluence with the Mutlumuvi to the confluence with the Sabie. 31.2338; -24.7221 31.7120; -24.9559*	*X32G X32H X32J*
RAU Sand B.1	*3.07 (100%)*	*Lower Foothills (100%)*	*Within the conservation areas.*	*A RUA was selected due to the change in the landuse. The RAU will be a different (higher) PES than the rest of the MRU due to its protected status. It would be preferable to have a EWR situated in this section as the indicators for EWR assessment will be intact and catering for this RAU will also cater for the rest of the MRU. RAU B.1 = WQSU4*	*Border of Sabie Sand to confluence with the Sabie. 31.3576-24.7539 31.7120; -24.9559*	*X32G X32H X32J*

The results of the delineation of the Sabie River and Sand River are summarized in Table 7.11 and illustrated in Figure 7.6

Table 7.11 Description of MRUs in the Crocodile sub-catchment

MRU	Delineation	Quat
SABIE RIVER		
MRU Sabie A	*Origin of the river to the Marite confluence.*	*X31A, X31B, X31D*
RAU Sabie A.1	*Source of river to end of the Mountain Stream.*	*X31A*
RAU Sabie A.2	*Mac-Mac confluence to Marite confluence.*	*X31D*
MRU Sabie B	*Marite confluence (start of EcoRegion 3.07) to KNP entrance.*	*X31M, X31K*
MRU Sabie B.1	*Point where river forms the border of the KNP to the Kruger Gate.*	*X31M, X31K*
MRU Sabie C	*Kruger Gate to border of KNP with Mozambique.*	*X31M, X33A, X33B, X33D*
RAU Sabie C.1	*Kruger Gate to Sand confluence.*	*X31M*
SAND & MUTLUMUVI		
MRU Sand A	*Origin of river to confluence with Mutlumuvi.*	*X32A, X32C*
MRU Mutlumuvi A	*Origin of river to confluence with Sand.*	*X32D, X32F*
MRU Sand B	*Confluence with the Mutlumuvi to the confluence with the Sabie.*	*X32G, X32H, X32J*
RAU Sand B.1	*Border of the Sabie Sand to the confluence with the Sabie.*	*X32G, X32H, X32J*

7.3.2 EWR sites

The selection of EWR sites was guided by the same key considerations as outlined in Section 7.2.2.

7.3.3 Locality and description of sites

Eight EWR sites were selected in the Sabie-Sand sub-catchment (Figure 7.6, Table 7.11, Table 7.12 and Table 7.13). Details regarding the sites selected are provided in the Table 7.13, summarized in Table 7.12 and the locality is illustrated in the Figure 7.6.

Table 7.12 Locality and characteristics of the Sabie-Sand sub-catchment EWR sites

Site information	EWR sites	Illustration
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	*EWR 1 Upper Sabie Sabie - - -25.0737, 30.84874 S25 04.424, E30 50.924 4.04 Upper Foothills 862 MRU Sabie A X31B - -*	
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) MRU Quaternary Farm name Hydrological gauge	*EWR 2 Aan de Vliet Sabie - X3Sabie-Brand -25.0279, 31.05166 S25 01.675, E31 03.099 4.04 Lower Foothills 463 MRU Sabie A, RAU A.2 X31D Evert 5 X3H023*	
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	*EWR 3 Kidney Sabie IFR 3 X3Sabie-Sekur -24.9876, 31.29287 S24 59.256,E31 17.572 3.07 Lower Foothills 369 MRU Sabie B.1 X31K KNP X3H021*	

Site information	EWR sites	Illustration
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	*EWR 4 Mac Mac Mac Mac - - -25.0133, 31.00405 S25 00.800, E31 00.243 4.04 Upper Foothills 582 MRU Mac A X31C Richmond 573 -*	
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	*EWR 5, Marite Marite IFR 1 X3Mari-Sandf -25.018, 31.13328 S25 01.077, E31 07.997 4.04 Upper Foothills 457 MRU Mar A X31G 291/33 -*	
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	*EWR 6 Mutlumuvi Mutlumuvi IFR 6 X3Mutl-Thula -24.7559, 31.13205 S24 45.352, E31 07.923 3.05 Upper Foothills 503 MRU Mut A X32F New Forest 234 -*	
EWR nr & name River Previous IFR site National RHP site Decimal Degrees Decimal Minutes EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Farm name Hydrological gauge	*EWR 7 Tlulandziteka Tlulandziteka (Sand) - - -24.6805, 31.08647 S24 40.829, E31 05.188 3.07 Lower Foothills 543 MRU Sand A X32C - -*	

Site information	EWR sites	Illustration
EWR nr & name	*EWR 8 Lower Sand*	
River	*Sand*	
Previous IFR site	*IFR 8*	
National RHP site	*X3Sand-Skuku*	
Decimal Degrees	*-24.9674, 31.62734*	
Decimal Minutes	*S24 58.045, E31 37.641*	
EcoRegion (Level II)	*3.07*	
Geomorphic Zone	*Lower Foothills*	
Altitude (m)	*250*	
RU	*MRU Sand B, RAU B.1*	
Quaternary	*X32J*	
Farm name	*KNP*	
Hydrological gauge	*-*	

Table 7.13 Summary of EWR sites in the Sabie-Sand catchment

EWR site number	EWR site name	River	Decimal Min S	Decimal Min E	EcoRegion (Level II)	Geomorphic Zone	Altitude (m)	RU	Quat	Gauge
EWR1	*Upper Sabie*	*Sabie*	*S25 04.424*	*E30 50.924*	*4.04*	*Upper Foothills*	*862*	*MRU Sabie A*	*X31B*	*-*
EWR2	*Aan deVliet*	*Sabie*	*S25 01.675*	*E31 03.099*	*4.04*	*Lower Foothills*	*463*	*MRU Sabie A RAU Sabie A.2*	*X31D*	*X3H023*
EWR3	*Kidney*	*Sabie*	*S24 59.256*	*E31 17.572*	*3.07*	*Lower Foothills*	*369*	*MRU Sabie B*	*X31K*	*X3H021*
EWR4	*Mac Mac*	*Mac Mac*	*S25 00.800*	*E31 00.243*	*4.04*	*Upper Foothills*	*582*	*MRU Mac A*	*X31C*	*-*
EWR5	*Marite*	*Marite*	*S25 01.077*	*E31 07.997*	*4.04*	*Upper Foothills*	*457*	*MRU Mar A*	*X31G*	*-*
EWR6	*Mutlumuvi*	*Mutlumuvi*	*S24 45.352*	*E31 07.923*	*3.05*	*Upper Foothills*	*503*	*MRU Mut A*	*X32F*	*-*
EWR7	*Tlulandziteka*	*Tlulandziteka (Sand)*	*S24 40.829*	*E31 05.188*	*3.07*	*Lower Foothills*	*543*	*MRU Sand A*	*X32C*	*-*
EWR8	*Lower Sand*	*Sand*	*S24 58.045*	*E31 37.641*	*3.07*	*Lower Foothills*	*250*	*MRU Sand B RAU Sand B.1*	*X32J*	*-*

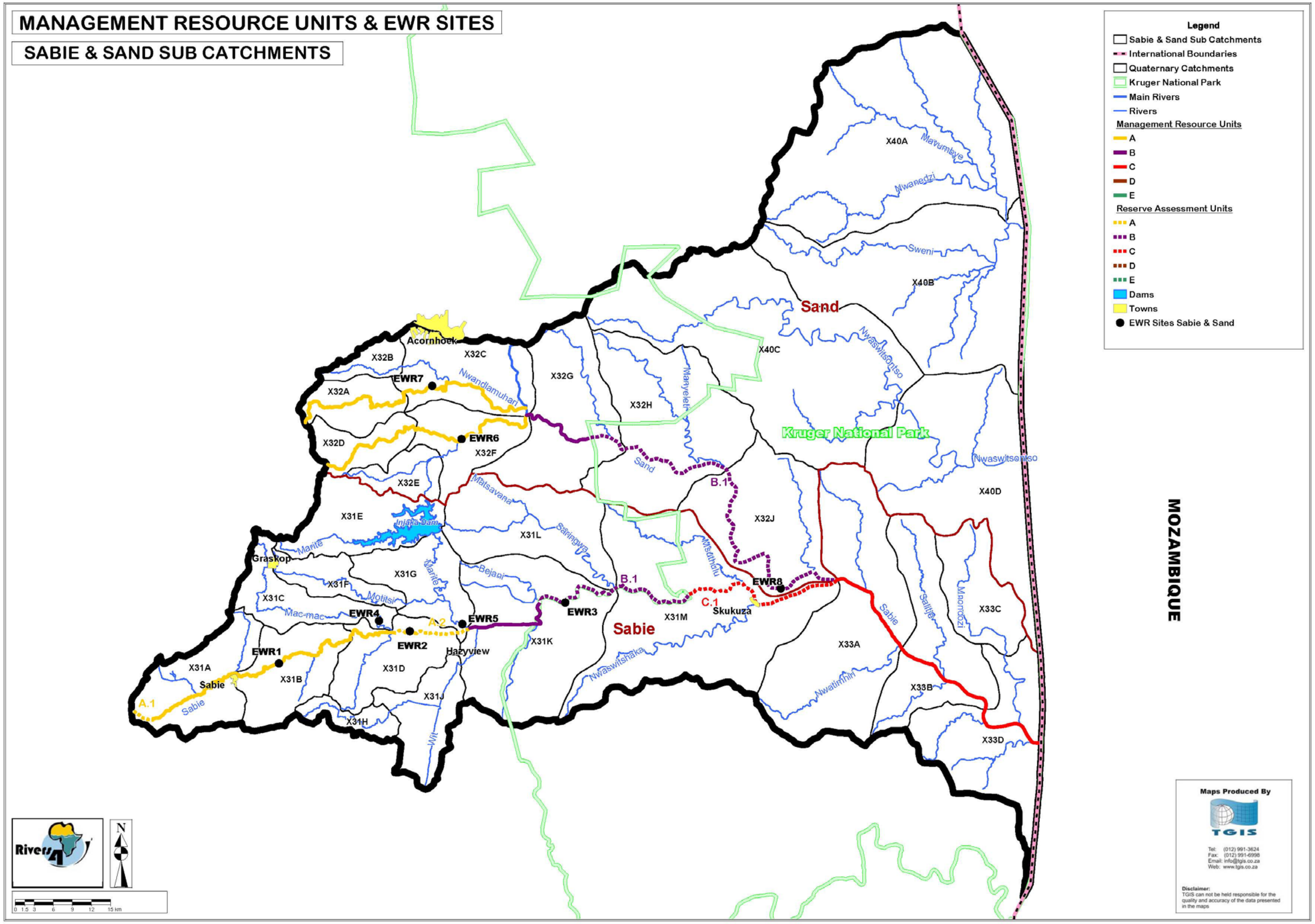


Figure 7.6 MRUs and EWR sites of the Sabie and Sand sub-catchment

7.3.4 Site suitability

The site suitability of each site was assessed and is provided in Table 7.14 and 7.15. The scoring system is the same as discussed under Section 7.2.4 and are applicable to both tables.

Table 7.14 illustrates the site suitability from a biophysical point of view. Any comments regarding outliers are also provided. From a biophysical point of view, the sites were mostly highly suitable for EWR determination.

Table 7.14 Biophysical Site suitability for the Sabie River system

EWR sites	Geomorph	Riparian veg	Fish	Inverts	Average	Median	Max	Min	Comments
EWR 1	2.7	3.8	4.5	3.7	3.6	**3.7**	4.5	2.7	This is a bedload system and required sediment transport modelling to evaluate the geomorphology. As this was not be undertaken at this site, the geomorph suitability was low.
EWR 2	2.6	4.2	4.5	4.6	3.9	**4.2**	4.6	2.6	See above.
EWR 3	3.4	4.2	4.5	4.2	4.2	**4.2**	4.5	3.4	No true morphological cues.
EWR 4	2.6	4.4	4.5	4.0	3.9	**4.0**	4.5	2.6	No true morphological cues. This is a bedload system and required sediment transport modelling to evaluate the geomorphology. As this was not undertaken at this site, the geomorph suitability was low.
EWR 5	3.3	4.3	4.0	4.5	4.0	**4.0**	4.5	3.3	No true morphological cues and sediment transport modelling had to be undertaken.
EWR 6	3.1	4.6	3.0	3.2	3.5	**3.2**	4.6	3.1	
EWR 7	3.2	3.8	3.0	4.1	3.5	**3.5**	4.1	3.0	
EWR 8	3.8	4.6	2.5	3.5	3.6	**3.6**	4.6	2.5	

Hydraulic suitability is however crucial as this converts the biophysical requirements to flow. For the purposes of determining flow requirements, the low flows and high flows are evaluated separately. Geomorphology and vegetation usually are the most crucial components for high flows and fish and invertebrate for low flows (Table 7.15). The suitability of the sites are therefore evaluated for both low and high flows and compared to the corresponding suitability for low and high flow hydraulics.

The low flow suitability was moderate at most sites due to lack of hydraulic suitability. The suitability for high flow determination was high at all sites apart from EWR 1 and 2 (due to lack of hydraulic suitability) (Table 7.15).

Table 7.15 Integrated site suitability for the Sabie River system

EWR SITES	Biophysical		Hydraulics		Suitability		Comment
	Low flows	High flows	Low flows	High flows	Low flows	High flows	
EWR 1	4	3	3	4	3	4	Highly suitable for high flows, less suitable for low flows due to the complicated hydraulics.
EWR 2	5	3	4	2	4	3	Highly suitable for low flows, less suitable for high flows due to the complicated hydraulics.
EWR 3	4	4	2	3	3	3	Moderate suitability for both low and high flows due to complicated hydraulics
EWR 4	4	4	3	2	4	3	Highly suitable for low flows, less suitable for high flows due to the complicated hydraulics.

EWR SITES	Biophysical		Hydraulics		Suitability		Comment
	Low flows	High flows	Low flows	High flows	Low flows	High flows	
EWR 5	*4*	*4*	*3*	*4*	*4*	*4*	*Highly suitable from both low and high flow perspective and both biophysical and hydraulic perspective*
EWR 6	*3*	*4*	*2*	*3*	*3*	*3*	*Moderate suitability for both low and high flows*
EWR 7	*4*	*4*	*4*	*4*	*4*	*4*	*Highly suitable from both low and high flow perspective and both biophysical and hydraulic perspective*
EWR 8	*3*	*4*	*3*	*4*	*3*	*4*	*Highly suitable for high flows, less suitable for low flows due to the complicated hydraulics.*

0: Not suitable | *0.1 – 1: Very low suitability* | *1.1 - 2.0: Low suitability*

2.1 - 3.0: Moderate suitability | *3.1 - 4.0: High suitability* | *4.1 - 5.0: Very high suitability*

8 ECOCLASSIFICATION (LEVEL 4) OF EWR SITES

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

8.1 ECOCLASSIFICATION

The procedure for the EcoClassification of the rivers and Physico-chemical input was according to the revised methods for rivers as outlined in Louw and Hughes (2002), and the EcoClassification manual version 2 (Kleynhans and Louw, 2007) for the EWR sites in the Crocodile and Sabie-Sand sub-catchments. The approach consisted broadly of the following steps:

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

8.2 CROCODILE SUB-CATCHMENT

8.2.1 Results

The EcoClassification results for the Crocodile system are summarised in Table 8.1.

Table 8.1 EcoClassification results – Crocodile sub-catchment

EWR 1 Valeyspruit (Crocodile River)

EIS: Moderate
Highest scoring metric were diversity of sensitive habitat types present e.g. wetlands (including floodplains containing various oxbows).
PES: A/B
Minor impacts, mainly due to farming, exotic vegetation species and trout. Impacts are mostly non-flow related
REC: A/B
Maintain the PES as only moderate EIS.
AEC down: B/C
Scenario includes decreased low flows due to e.g. increased golf estates, trout farms and increased abstractions for Dullstroom. Growth of Dullstroom will also result in increased sewage. Increased grazing causing trampling and destabilisation of banks.

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

EWR 2 Goedehoop (Crocodile River)

EIS: High
Rare and endangered fish spp. which are sensitive to flow and quality changes. High species diversity.
PES: B
Impacts as for EWR 1 with increased agricultural activities and decreased flows. However, impacts mostly still non-flow related.
REC: B
Although the EIS is high, the PES is already a B and as the impacts are mostly non-flow related, it would not be realistic to improve the PES through flow related interventions.
AEC down: C
See EWR 1. Possible zero flow situations and additional impacts on moderate events.

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

EWR 3 Poplar Creek (Crocodile River)

EIS: High
Rare and endangered fish, vegetation and bird spp, some of which are sensitive to flow and quality changes.
PES: B/C
Major problems related to upstream Kwena Dam and its operation, e.g. migration, sedimentation, changed flow regime. The changed flow regime consists of higher than natural flows in the dry season and much lower low flows in the wet season.
REC: B
The EIS is high; therefore the REC is an improvement of the PES. This can be achieved by improving the flow regime (low flows) and removal of exotic vegetation species.
AEC down: C/D
Lower flows than natural in both the dry and wet season. Associated increase in temperature and oxygen.

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

EWR 4 KaNyamazane (Crocodile River)

EIS: High
Rare and endangered species that are sensitive to flow and quality changes are present. There is also a high species taxon richness and a diversity of habitat types
PES: C
Combination of flow and non-flow related impacts. Changes mostly related to changes in flow regime due to upstream Kwena Dam and the operation of upstream system. Abstractions, return flows, landuse mismanagement, water quality issues, and sedimentation.
REC: B
The EIS is HIGH, therefore the REC is an improvement of the PES. Improvements to flow regime will be required. Only successful if combined with removal of exotic vegetation and if there are some improvement in grazing and browsing.
AEC down: C/D
Montrose Dam with decreased floods. Pools will fill in, bars will appear, riffles will be clogged and covered with sediment, reed growth will increase, the marginal zone will expand and vegetation will encroach.

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

EWR 5 Malelane (Crocodile River)

EIS: Very High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on LB.
PES: C
Change in low flows, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.
REC: B
*The EIS is VERY HIGH, therefore the REC is an improvement of the PES***.** *Changes mostly focussing on improving the low flow regime and some land use management.*
AEC down: D
Decreased low flows and periods of zero flows in some stretches of the river which will result in increased algal growth, temperature and nutrient problems, loss of deeper channel sections, increased reed and vegetation growth.

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

EWR 6 Nkongoma (Crocodile River)

EIS: Very High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and diversity of habitat types, KNP on left bank.
PES: C
Change in low flows, even zero flows present, specifically in the dry season. Change in flooding regime. All impacts associated with sugarcane activities.
REC: B
The EIS is VERY HIGH, therefore the REC is an improvement of the PES. Changes mostly focussing on improving the low flow regime and some land use management.
AEC down: D
Decreased low flows and periods of zero flows in some stretches of the river which will result in increased algal growth, temperature and nutrient problems, loss of deeper channel sections, increased reed and vegetation growth.

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

EWR 7 Kaap (Kaap River)

EIS: High
Rare and endangered spp. sensitive to flow and quality changes. High species taxon richness and habitat types sensitive to flow and quality changes.
PES: C
Changes are flow and non-flow related. Low to zero flows present due to upstream abstractions. Land-use activities related to agriculture and mining. Extensive exotic vegetation present.
REC B:
The EIS is high, therefore the REC is an improvement of the PES.
No zero flows, increased low flows, more moderate floods. This must happen in conjunction with exotic vegetation removal.
AEC D:
Mountain View Dam will be present which will result in much lower flows than present and decreased floods. The channel will be narrower, some riffles will be sandier and smaller in general which will result in more reeds and a narrower marginal zone.

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

8.2.2 Conclusions

A summary of confidences for all the sites are given in Table 8.2. Red cells indicate low confidence, yellow cells indicate medium confidence and green cells indicate high confidence.

Table 8.2 Confidence in EcoClassification

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

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

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

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

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

8.2.3 Recommendations

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

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

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

More work has been undertaken at these sites than for most if not any river in South Africa and it is unlikely that further work will increase confidences. A Water Resources Monitoring Programme was recommended where some of the issues listed above could possibly be addressed. Some of the uncertainties were due to the natural nature of the site (which results in difficulties in surveying and interpretation) as well as a lack of measured water quality.

8.3 SABIE-SAND SUB-CATCHMENT

8.3.1 Results

The EcoClassification results for the Crocodile system are summarised in Table 8.3.

Table 8.3 EcoClassification results – Crocodile sub-catchment

EWR 1: Upper Sabie (Sabie River)

EIS: High
Rare and endangered fish and vegetation species. Fish species present that are intolerant to flow and flow related water quality changes. .
PES: B/C
Impacts due to forestry, exotic vegetation species, and abstraction. Impacts largely non-flow related.
REC: B
The EIS is high, therefore the REC is an improvement of the PES. Inactivity of picnic site and removal of aliens is required. Improved fish EC dependent on improved vegetation cover.
AEC down: C/D
Decreased low flows resulting in increased sediment with increased nutrients, turbidity, temperature, additional toxics. Increased vegetation exotics and reeds on bars.

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

EWR 2: Aan de Vliet (Sabie River)

EIS: High
Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.
PES: C
Forestry and landuse activities, mostly non-flow related.
REC: B
Changes in flow are not required to improve the state.
Remove exotic vegetation and cease mowing in the riparian zone. Reduce recreational disturbances. The nutrient status must also be improved.
AEC down: C/D
Increased abstraction could lead to increased return flows that will cause problems due to pesticides, nutrient loading etc. Mismanagement of land use in terms of forestry and agriculture

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

EWR 3 Kidney (Sabie River)

EIS: Very High
Rare and endangered species, taxon richness and species intolerant to flow and flow related water quality changes. Refuge area for biota and an important migration corridor for birds and fish. Within KNP.
PES: A/B
Forestry, abstraction, Inyaka Dam and landuse activities. (Flow and non-flow related)
REC: A/B
As the PES is already an A/B, the REC = the PES.
AEC Down: B/C
Increased abstractions, no Reserve implementation, less floods. Increased nutrients, changes in temperature, oxygen etc. Riffles lost due to sedimentation, channel shallower and sandier. Vegetation exotics will increase.
More reeds will be present in sandier areas.

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

EWR 4 Mac Mac (Mac Mac River)

EIS: High
Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.
PES: B
Forestry, exotic vegetation and wastewater input. Impacts are flow and non-flow related.
REC: A/B
The EIS at EWR 4 is high and the REC is therefore to improve the PES by improving the fish. Improved water quality required.
AEC down: C
Decreased low flows due to e.g. a weir or small dam in the upper catchment. This will result in embedded cobbles. Nutrients and temperature will increase. Increased exotic vegetation in the riparian zone.

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

EWR 5 Marite (Marite River)

EIS: High.
Rare, endangered and unique biota. Species richness high and species intolerant to flow and flow related water quality changes present.
PES: B/C
Increased low flows and landuse activities. Impacts mostly flow related
REC: B
The EIS is high; therefore the REC is an improvement of the PES. More natural distribution of flows required. Reduce grazing and trampling, remove exotic vegetation.
AEC down: C/D
No flow releases for the EWR, less dilution and less floods due to e.g. direct abstraction from the dam. More nutrients and toxics present. Sandier river, some riffles and bedrock areas in the reach will be lost, vegetation encroachment on bars and banks and embedded cobbles. Increased aliens, removal, grazing, and trampling.

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

EWR 6 Mutlumuvi (Mutlumuvi River)

EIS: High
Rare, endangered and unique biota. Taxon species richness high and species intolerant to flow and flow related water quality changes present.
PES: C
Abstraction, forestry, informal settlements and landuse activities. Impacts flow and non-flow related.
REC: B
The EIS is high and improvement requires improved system operation which improves the low flow regime.
AEC down: C/D
Decreased low flows and longer periods of zero flows. Increased algal growth. Less moderate floods will cause some impact on sedimentation. The reedbeds will become less dense and Matumi will disappear.

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

EWR 7 Tlulandziteka (Tlulandziteka River)

EIS: Moderate
Rare and endangered species, high taxon richness, species intolerant to flow and flow related water quality changes.
PES: C
Forestry, abstraction, flow modification and poor landuse management. Impacts flow and non-flow related.
REC: C
Due to the moderate EIS, the REC = the PES.
AEC Up: B
Improved flows through fixing of canals, rehabilitation of forestry areas and improved management of canal system and landuse. Remove exotic vegetation, minimise agricultural disturbance and remove unused orchards.
AEC Down: D
Increased use of the dam with less spills, i.e. less floods. More abstraction and forestry. Nutrients, temperature, oxygen, and turbidity levels will change. Increase in bed height, more subsurface flows and sediment with resulting decrease in riffles and shallower pools. More reeds, alien vegetation and more removal.

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

EWR 8 Lower Sand (Sand River)

EIS: High
Rare and endangered species, high taxon richness and species intolerant to flow and flow related water quality changes. Situated in KNP
PES: B
Abstraction, dams, weirs, poor landuse management. Impacts are flow and non-flow related.
REC: B
Although the EIS is High, the PES is already in a B therefore the REC = PES. Improve the macroinvertebrate EC by increasing low flows.
AEC down: C
More decreased low flows and longer periods of no flow.

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

8.3.2 Conclusions

A summary of confidences for all the sites are given in Table 8.4. Red cells indicate low confidence, yellow cells indicate medium confidence and green cells indicate high confidence.

Table 8.4 Confidence in EcoClassification

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

The results indicated MEDIUM to HIGH confidence for data availability at all the sites except for EWR 7. The confidence at EWR 7 was LOW to MEDIUM as this site was only surveyed at a Rapid

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

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

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

8.3.3 Recommendations

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

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

In general it was recommended that the EWR sites become the RHP sites where in close proximity to one another. The other EWR sites should be included as RHP sites. Most of the problems *above can be addressed within a monitoring programme, and it was not recommended that any specific additional work was undertaken to address the confidences.*

9 EWR SCENARIO ASSESSMENT

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. EWR Scenario Assessment for the Crocodile and Sabie-Sand Systems: Volume 1: Sabie-Sand System Prepared by Rivers for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/010.

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: EWR Scenario Assessment for the Crocodile and Sabie-Sand Systems: Volume 2: Crocodile System. Prepared by Rivers for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/010.

This task consisted of determining the EWR for different ecological river states, i.e. different Ecological Categories.

9.1 APPROACH

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O'Keeffe et al., 2002), a modification of the Building Block Methodology (BBM) (King and Louw, 1998) was used to determine the low (base) flow EWRs. The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM. These results formed the basis against which the ecological consequences of operational flow scenarios were tested.

9.2 CROCODILE SUB-CATCHMENT: EWR AND MOTIVATIONS

The low flow and high flow requirements and motivations are summarised per EWR site as follows:

9.2.1 EWR results for EWR 1: Valeyspruit

Table 9.1 Low flow EWR results for EWR 1

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES and REC: A/B EcoStatus			**FISH: A**		**MACROINVERTEBRATES: B RIP VEG: A**
Oct	*5% drought*	*8 FDI*	*8*	*0.019*	*The maximum velocity of 0.32 m/s will ensure that FDI survive during drought periods.*
	35% maintenance	*6 FDI*	*6*	*0.06*	*Indicator taxa can overwinter without significant detrimental impacts on the overall population.*
Feb	*5% drought*	*4 FDI*	*4*	*0.09*	*Ensures a healthy population is present during summer.*
	35% maintenance	*1.9 Juncus*	*1.9*	*0.20*	*Juncus population will be healthy and abundant.*
AEC: B/C EcoStatus		**FISH: B/C**		**MACROINVERTEBRATES: B/C**	**RIP VEG: B**
Oct	*5% drought*	*8 FDI*	*8*	*0.019*	*See PES.*
	35% maintenance	*7 FDI*	*7*	*0.039*	*Indicator taxa can overwinter without significant detrimental impacts on the overall population.*
Feb	*5% drought*	*4 FDI*	*4*	*0.09*	*See PES.*
	35% maintenance	*3 FDI*	*3*	*0.15*	*Ensures a healthy population is present during summer.*

Table 9.2 High flow EWR functions and motivations for EWR 1

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*0.6 – 2*	**Vegetation:** *Annual inundation of Cliffortia/Juncus/Setaria.*	✓	✓	✓	✓	✓	✓	✓				✓
II	*3 – 5*	**Geomorphology:** *Activate the seasonal channels on the floodplain; scour active channel; recharge the pans.* **Vegetation:** *Inundation / activation of Leucosidea.*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	*> 10*	**Geomorphology:** *Inundate the floodplain; deposit sediment; scour the active channel; create cut / undercut banks.* **Vegetation:** *Inundation of the floodplain, maintain the Miscanthus.*	✓	✓	✓	✓	✓						

Table 9.3 EWR 1: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL[1] (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES and REC SCENARIO: A/B									
I	*0.6 – 2*	*3*	*3*	*2 per annum*		*3*	*Nov, Dec, Mar*	*1*	*3*
II	*3 – 5*	*1*		*1*	*1:2*[2]	*1*	*Jan*	*3*	*3*
III	*> 10*		*1:3*	*1:3*	*1:3*	*1:3*		*N/S*	*N/S*
AEC SCENARIO: B/C									
I	*0.6 – 2*	*2*	*2*	*2 per annum*		*2*	*Nov, Dec, Mar*	*1*	*3*
II	*3 – 5*	*1*		*1*	*1:2*	*1*	*Jan*	*3*	*3*
III	*> 10*			*1:3*	*1:3*	*1:3*		*N/S*	*N/S*

1 Final refers to the agreed on number of events considering the individual requirements for each component
2 Refers to frequency of occurrence, i.e. the flood will occur once in two years.
N/S – none specified

9.2.2 EWR results for EWR 2: Goedehoop

Table 9.4 Low flow EWR results for EWR 2

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES and REC: B EcoStatus FISH: B MACROINVERTEBRATES: B RIP VEG: A/B					
	5% drought	*6 SR*	*6*	*0.21*	*Limited FS and FI habitat, crucial for the survival of the SR guild will be present.*
	35% maintenance	*4.75 SR*	*4.75*	*0.27*	*Reduced presence of FS habitat and therefore a reduced*

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
					abundance of the SR guild.
	5% drought	*3 SR*	*3*	*0.52*	*FD habitats will be lost but adequate FI and FS habitat will be maintained which will ensure spawning.*
	35% maintenance	*1.5 SR*	*1.5*	*1.27*	*Adequate fats habitats with substrate, the optimally preferred habitats for the SR species should be maintained to ensure optimal or acceptable conditions.*
AEC: C EcoStatus		**FISH: C**		**MACROINVERTEBRATES: C**	**RIP VEG: B**
Oct	*5% drought*	*6 SR*	*6*	*0.21*	*See PES.*
	35% maintenance	*5.5 SR*	*5.5*	*0.25*	*FD habitat will be lost and FI and FS will be greatly reduced. Decreased Frequency of Occurrence (FROC) of SR guild.*
Feb	*5% drought*	*3 SR*	*3*	*0.52*	*See PES.*
	35% maintenance	*2.5 SR*	*2.5*	*0.695*	*Reduced FD habitat although adequate for the requirements of all life stages of SR guild, although the guild will occur at a decreased FROC.*

Table 9.5 High flow EWR functions and motivations for EWR 2

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*2 - 5*	**Vegetation:** *Activates and inundates leafy Juncus on the marginal and lower zone.*										✓	✓
II	*6 - 9*	**Geomorphology:** *The effective discharge for sands and gravels. Scour channel, remove fines, and turn the cobbles. Annual flood.* **Vegetation:** *Inundates marginal zone and facilitates new Combretum recruitment and survival.*	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
III	*13 – 25*	**Vegetation:** *Inundate and activate the Combretum population to provide recruitment opportunities.*	✓	✓	✓	✓	✓	✓					
IV	*30 - 35*	**Geomorphology:** *Overtop the levees and inundates the floodplain. Scour active channel; turn cobbles.* **Vegetation:** *Inundates and maintains Miscanthus on the floodplain.*	✓	✓	✓	✓	✓	✓					

Table 9.6 EWR 2: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES and REC SCENARIO: B									
I	*2 - 5*	*4*	*4*	*4*		*4*	*Nov, Dec, Jan, Mar, Apr*	*3*	*3*
II	*6 - 9*	*1*		*1*	*1*	*1*	*Feb*	*9*	*4*
III	*13 – 25*			*1:2*			*Late summer*	*N/S*	*N/S*

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
IV	*30 - 35*			*1:4*	*1:2*		*Dec - Feb*	*N/S*	*N/S*
AEC SCENARIO: C									
I	*2 - 5*			*3*		*3*	*Nov, Jan, Mar, Apr*	*3*	*3*
II	*6 - 9*			*1:2*	*1*	*1*	*Feb*	*9*	*4*
III	*13 – 25*			*1:3*				*N/S*	*N/S*
IV	*30 - 35*			*1:4+*	*1:4+*			*N/S*	*N/S*

9.2.3 EWR results for EWR 3: Poplar Creek

Table 9.7 Low flow EWR results for EWR 3

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: B/C EcoStatus		**FISH: B**			**MACROINVERTEBRATES: C** **RIP VEG: C**
Oct	*5% drought*	*5 FDI*	*6*	*1.13*	*This flow will ensure that a core of selected taxa will survive drought conditions.*
	35% maintenance	*2 FDI*	*3.5*	*2.42*	*All the selected taxa can overwinter without significant detrimental impacts on the overall population.*
Feb	*5% drought*	*4 FDI*	*5*	*1.58*	*Ensures that a healthy population occurs during the summer.*
	35% maintenance	*2 FDI*	*3.5*	*2.42*	*Ensures that a healthy population occurs during the summer.*
REC: B EcoStatus		**FISH: B**			**MACROINVERTEBRATES: B** **RIP VEG: B**
Oct	*5% drought*	*5 FDI*	*6*	*1.13*	*See PES.*
	35% maintenance	*3 FDI*	*4.2*	*2.004*	*See PES.*
Feb	*5% drought*	*4 FDI*	*5*	*1.58*	*See PES.*
	35% maintenance	*1 FDI*	*1.5*	*4.125*	*See PES.*

Table 9.8 High flow EWR functions and motivations for EWR 3

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*8*	**Geomorphology:** *An important flow class for fines - responsible for about 20% of the PBMT (scours and removes fines), inundates and activates the lower bench.* **Vegetation:** *Activation of the S. mucronata.*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	*15*	**Geomorphology:** *An important flow class for fines - responsible for about 20% of the PBMT (scours and removes fines), activates the small cobbles.* **Vegetation:** *Inundate and activate Cliffortia.*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
III	*30*	**Geomorphology:** *The geomorphologically effective flow class; responsible for about 30% of the transport of sands and gravels at the site; activates the cobbles.* **Vegetation:** *Annual wetting of the lower zone limit facilitates Combretum juvenile survival.*	✓	✓	✓	✓	✓	✓					
IV	*> 90*	**Vegetation:** *Initiates Combretum recruitment inundates and activates lower and upper zone Combretum respectively.*	✓	✓	✓	✓	✓	✓					

Table 9.9 EWR 3: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	FLOOD CLASS	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: B/C									
I	*8*	*4*	*4*	*4*	*4*	*4*	*Nov, Dec, Jan, Apr*	*8*	*3*
II	*15*	*2*	*2*	*2*	*2*	*2*	*Nov, Mar*	*15*	*4*
III	*30*		*1*	*1*	*1*	*1*	*Feb*	*30*	*5*
IV	*> 90*			*1:2 to 1:3*			*Late summer*	*N/S*	*N/S*

9.2.4 EWR results for EWR 4: Kanyamazane

Table 9.10 Low flow EWR results for EWR 4

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: C EcoStatus	**FISH: B**		**MACROINVERTEBRATES: C**		**RIP VEG: C**
Sep	*5% drought*	*6 SR*	*6.8*	*1.31*	*Maintenance of fast habitat to support viable populations and allow for recovery after drought period.*
	35% maintenance	*4.5 SR*	*4.5*	*4.1*	*Fast habitats will be maintained to ensure preservation of abundance and cover.*
Feb	*5% drought*	*4.5 LSR*	*4.5*	*4.1*	*Adequate flows to maintain enough fast habitats to support viable populations to recover after drought. Abundance and cover will be greatly reduced but adequate to maintain a viable population.*
	35% maintenance	*2 LSR*	*2.6*	*7.94*	*Good habitats for spawning and suitable habitats for all life stages of this indicator guild.*
REC: B EcoStatus	**FISH: B**		**MACROINVERTEBRATES: B**		**RIP VEG: B**
Sep	*5% drought*	*6 SR*	*6.8*	*1.31*	*See PES.*
	35% maintenance	*4.5 SR*	*4.5*	*4.1*	*See PES.*

Month	% Stress duration	Component stress	Integrated stress	Flow m³/s	Comment
Feb	*5% drought*	*4.5 LSR*	*4.5*	*4.1*	*See PES.*
	35% maintenance	*2 LSR*	*2.6*	*7.94*	*See PES.*
AEC: C/D EcoStatus	**FISH: C**		**MACROINVERTEBRATES: D**		**RIP VEG: D**
Sep	*5% drought*	*6.8 SR*	*6.8*	*1.31*	*See PES.*
	35% maintenance	*5 SR*	*5.3*	*2.975*	*Most aspects will deteriorate (abundance, cover, and connectivity) resulting in reduced FROC of species.*
Feb	*5% drought*	*4.5 LSR*	*4.5*	*4.1*	*See PES.*
	35% maintenance	*4 LSR*	*4*	*4.7*	*Some spawning habitat will be created but the reduced cover and abundance will result in an overall reduced FROC.*

Table 9.11 High flow EWR functions and motivations for EWR 4

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning habitat*	*Spawning substrate*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*25 - 40*	**Geomorphology:** *This flow is responsible for about 15% of the PBMT. This flow class scours the fines from the bed.* **Vegetation:** *Activates and overtops levee on the main channel and inundates the marginal zone. Inundates marginal zone sedges (Cyperus dives) and Persecaria. Lower portions of Phragmites mauritianus and Ludwigia octovalvis become inundated. Will also provide marginal vegetation cover for instream biota.* *Fewer events for AEC down will allow more sediment to settle, and with less flood disturbance marginal zone vegetation will migrate/expand towards the instream.*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	*(40)*	**Geomorphology:** *This flow is responsible for about 15% of the PBMT. This flow class scours the fines from the bed and activate some of the cobble areas, as well as inundate the lower terrace.*	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
III	*60 - 110*	**Geomorphology:** *This flow class represents the effective discharge, and is responsible for about 30% of the PBMT. This flow class would scour the bed, activate gravels and cobbles and inundate and activate middle terraces.* **Vegetation:** *Required to inundate the lower zone. Inundates reed beds (P. mauritianus), L. octovalvis and lower portions of Breonadia salicina. Sustains vigour and reproduction in the height of the growing season. Less frequent event for AEC (down) will result in reduced recruitment opportunities for lower zone woody species (C. erythrophyllum and B. salicina).*	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
IV	*170 - 220*	**Geomorphology:** *This flow is responsible for about 15% of the PBMT. This flow class scours the bed and activates the cobbles.* **Vegetation:** *Required for inundation of upper zone terrace. This will activate and inundate C. erythrophyllum and Nuxia oppositifolia populations, and afford recruitment opportunities.*	✓	✓	✓	✓	✓	✓	✓					

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning habitat*	*Spawning substrate*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
V	*330 +*	**Geomorphology:** *This was historically the range of the 1:3 year flood, and historically accounted for about 20% of the PBMT. This flow will inundate the upper terrace and activate the back flood channel.* **Vegetation:** *Maintains Trichilia emetica and Ficus sur populations on upper portions of the upper zone. Would perform the function of reducing terrestrial species in the riparian zone.*	✓	✓	✓	✓	✓	✓	✓					

Table 9.12 EWR 4: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	FLOOD CLASS	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: C									
I	*25 - 40*	*3*		*4*	*4*	*4*	*Nov, Dec, Jan, Apr*	*25*	*4*
II	*(40)*	*1*			*2*	*2*	*Feb, Mar*	*40*	*4*
III	*60 - 110*	*1*		*1*	*1*	*1*	*Feb*	*70*	*5*
IV	*170 - 220*			*1:2 - 1:3*	*1:3*	*1:2*	*Late summer*	*N/S*	*N/S*
V	*330 +*			*1:3 - 1:5*	*>1:5*	*>1:5*	*Wet season*	*N/S*	*N/S*
REC SCENARIO: B									
I	*25 - 40*	*4*		*4*	*4*	*4*	*Nov, Dec, Jan, Apr*	*25*	*4*
II	*(40)*	*2*			*2*	*2*	*Feb, Mar*	*40*	*7*
III	*60 - 110*	*1*		*1*	*1*	*1*	*Jan*	*70*	*5*
IV	*170 - 220*			*1:2 - 1:3*	*1:2*	*1:2*	*Late summer*	*N/S*	*N/S*
V	*330 +*			*1:3 - 1:5*	*1:3 - 1:5*	*1:3 - 1:5*	*Wet season*	*N/S*	*N/S*
AEC SCENARIO: C/D									
I	*25 - 40*	*2*		*1*	*2*	*2*	*Mar, Dec*	*25*	*4*
II	*(40)*	*1*			*2*	*2*	*Feb, Mar*	*40*	*4*
III	*60 - 110*			*1:2 - 1:3*	*1:2*	*1:2*	*Jan*	*70*	*5*
IV	*170 - 220*			*1:2 - 1:3*	*1:3*	*1:3*	*Late summer*	*N/S*	*N/S*
V	*330 +*				*>1:5*	*>1:5*	*Wet season*	*N/S*	*N/S*

9.2.5 EWR results for EWR 5: Malelane

Table 9.13 Low flow EWR results for EWR 5

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: C EcoStatus	**FISH: C**		**MACROINVERTEBRATES: C**		**RIP VEG: C**
Sep	*5% drought*	*6.5 LSR*	*7.4*	*4.22*	*This is the maximum stress level allowable where this fish guild will survive through dry drought periods without undue stress on their populations and to allow their recovery afterwards.*
	35% maintenance	*5 LSR*	*6.8*	*5.36*	*This fish stress level will maintain adequate FD, FI and abundant FS for maintenance of viable populations of this indicator guild during the dry season to maintain within a category C.*
Feb	*5% drought*	*5 LSR*	*6.8*	*5.36*	*Adequate fast habitats will still be available to allow some spawning of these species and although highly decreased abundance can be expected, they should be able to maintain adequate populations to recover after the drought period.*
	35% maintenance	*5.5 MVI*	*5.5*	*12*	*Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can thrive. At this stress fringing vegetation is inundated and aquatic vegetation will be available to provide adequate habitat for the selected taxa.*
REC: B EcoStatus	**FISH: B**		**MACROINVERTEBRATES: B**		**RIP VEG: B**
Sep	*5% drought*	*6.5 LSR*	*7.4*	*4.22*	*See PES.*
	35% maintenance	*4 LSR*	*6.4*	*6.68*	*These stress levels will result in improvement of preferred habitats for this indicator group during the dry season which should be reflected by increased abundance and overall improved FROC that will result in an improved EC.*
Feb	*5% drought*	*5 LSR*	*6.8*	*5.36*	*See PES.*
	35% maintenance	*4.5 MVI*	*4.5*	*19*	*Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can thrive. At these flows 5% fringing vegetation is inundated and aquatic vegetation will be available to provide adequate habitat for the selected taxa.*
AEC: D EcoStatus	**FISH: D**		**MACROINVERTEBRATES: D**		**RIP VEG: D**
Sep	*5% drought*	*6.7 LSR*	*7.4*	*4.22*	*See PES.*
	35% maintenance	*6 LSR*	*7*	*4.7*	*At this stress level the preferred habitats as refuge during the dry period will be greatly reduced and only adequate to sustain this indicator group in the reach. Decreased abundance and cover will be reflected by an overall decrease in FROC of these species within this river reach with a resultant deterioration in EC.*
Feb	*5% drought*	*5 LSR*	*6.8*	*5.36*	*See PES.*
	35% maintenance	*6.5 MVI*	*6.5*	*6.35*	*Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can thrive. At these flows 2% fringing vegetation is inundated and aquatic vegetation will be available to provide adequate habitat for the selected taxa.*

Table 9.14 High flow EWR functions and motivations for EWR 5

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning habitat*	*Spawning substrate*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*15 - 20*	**Vegetation:** *Inundates marginal zone, Cyperus, Juncus, and Persecaria and activates lower level reed beds (P. mauritianus). More frequent smaller floods will reduce reed expansion and promote more open sediment. Reduced small floods for AEC down will reduce flooding disturbance and facilitate reed encroachment/expansion towards the channel.*	✓	✓	✓	✓	✓	✓	✓	✓			✓	
II	*22 - 50*	**Geomorphology:** *Activates benches and responsible for more than 10% of the PBMT. These flows would scour fines from the bed.* **Vegetation:** *Inundates about 50% of the lower zone, LHB terraces/bars. Inundates reeds on the lower zone. Similar effect as above for REC and AEC down.*	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
III	*(60)*	**Geomorphology:** *Activates benches and responsible for more than 10% of the PBMT. These flows would scour fines from the bed.*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IV	*70 - 100*	**Geomorphology:** *This flow class is responsible for about 25% of the PBMT. This flow class would scour the bed, activate gravels and cobbles and inundate and activate islands.* **Vegetation:** *Inundates lower zone and reeds as above. Similar effect as above for REC and AEC down.*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
V	*370 +*	**Geomorphology:** *This flow class represents the effective discharge for this site, accounting for more than 30% of the PBMT. This flow class would scour the bed, activating cobbles and gravels and inundating the islands and deposition sediment in the vegetation.* **Vegetation:** *Inundates a portion of the upper zone and upper zone reeds.*	✓	✓	✓	✓	✓	✓	✓					

Table 9.15 EWR 5: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: C									
I	*15 - 20*	*4*	*4*	*4*		*4*	*Nov, Dec, Jan, Mar*	*8*	*4*
II	*22 - 50*	*2*	*2*	*2*	*2*	*2*	*Dec, Mar*	*30*	*4*
III	*(60)*				*2*	*2*	*Feb, Mar*	*50*	*4*
IV	*70 - 100*			*1*	*1*	*1*	*Feb*	*90*	*5*
V	*370 +*			*1:3+*	*1:3*	*1:3*	*Summer to late summer*	*N/S*	*N/S*
REC SCENARIO: B									
I	*15 - 20*	*6*	*6*	*6*		*6*	*Nov, Dec, Jan, Feb, Mar*	*8*	*4*
II	*22 - 50*	*3*	*3*	*3*	*3*	*3*	*Dec, Jan, Mar*	*30*	*4*

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
III	*(60)*				*3*	*3*	*Jan, Feb, Mar*	*50*	*4*
IV	*70 - 100*			*1*	*1*	*1*	*Feb*	*90*	*5*
V	*370 +*			*1:3+*	*1:2 - 1:3*	*1:3*	*Summer to late summer*	*N/S*	*N/S*
AEC SCENARIO: D									
I	*15 - 20*	*2*	*2*	*2*		*2*	*Nov and Mar*	*12*	*4*
II	*22 - 50*	*1*	*1*	*1*	*2*	*2*	*Dec, Jan*	*35*	*4*
III	*(60)*				*1*	*1*	*Feb*	*60*	*5*
IV	*70 - 100*			*1:2*	*1:2*	*1:2*	*Summer to late summer*	*N/S*	*N/S*
V	*370 +*			*1:3+*	*1:5*	*1:5*	*Summer to late summer*	*N/S*	*N/S*

9.2.6 EWR results for EWR 6: Nkongoma

Table 9.16 Low flow EWR results for EWR 6

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: C EcoStatus		**FISH: C**			**MACROINVERTEBRATES: C RIP VEG: C**
Sep	*5% drought*	*9.2 SR*	*9.2*	*1.36*	*This is the maximum allowable fish stress level where this indicator guild will be able to sustain viable populations during a dry period drought to enable recovery when conditions improve.*
	30% maintenance	*8.9 SR*	*8.9*	*1.91*	*This recommended fish stress level will maintain some FD, FI and abundant FS for maintenance of viable populations of this indicator guild during the dry season.*
Feb	*5% drought*	*6 LSR*	*6*	*7.25*	*This is the maximum stress level allowable where this fish guild will survive through dry drought periods without undue stress on their populations and to allow their recovery afterwards.*
	35% maintenance	*3.6 LSR*	*3.6*	*10.76*	*This flow and stress level will allow moderate conditions for all requirements (spawning, nursery habitat, cover and abundance, water quality and connectivity). These favourable conditions during the wet season will ensure that the PES is maintained at this site.*
REC: B EcoStatus		**FISH: B**			**MACROINVERTEBRATES: B RIP VEG: B**
Sep	*5% drought*	*9.2 SR*	*9.2*	*1.36*	*See PES.*
	35% maintenance	*7.5 LSR*	*7.5*	*4.58*	*These stress levels will result in improvement of preferred habitats for this indicator group during the dry season which should be reflected by increased abundance and overall improved FROC that will result in an improved ecological category.*
Feb	*5% drought*	*6 LSR*	*6*	*7.25*	*See PES.*
	35% maintenance	*1.9 LSR*	*1.9*	*15.84*	*Increased availability and abundance of critical habitats required during the wet season (especially spawning and nursery) should be reflected by improved reproduction potential and an overall improvement in the composition of this indicator group in this river reach, with an expected improvement towards a category B.*
AEC: D EcoStatus		**FISH: D**			**MACROINVERTEBRATES: C RIP VEG: D**
Sep	*5% drought*	*9.6 SR*	*9.6*	*0681*	*At this stress level the habitat suitability to maintain abundance, provide cover, connectivity and adequate water quality will be very poor to critical and extreme stress on this fish guild will result in critical deterioration in the PES. It can be expected that this fish guild may not be able to survive at this stress level and may*

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
					require recolinisation from other reaches or the downstream Komati River after conditions recover.
	35% maintenance	*9.3 LSR*	*9.3*	*1.19*	*At this stress level the preferred habitats as refuge during the dry period will be greatly reduced and only adequate to sustain this indicator group in the reach. Decreased abundance and cover will be reflected by an overall decrease in FROC of these species within this river reach with a resultant deterioration in EC.*
Feb	*5% drought*	*6 LSR*	*6*	*7.25*	*See PES.*
	35% maintenance	*5.5 LSR*	*5.5*	*7.86*	*Very limited habitats will be available for the critical life stages during the wet season, namely spawning, egg development and nursery areas, which will be reflected in overall decreased abundance and FROC of all these species within this guild.*

Table 9.17 High flow EWR functions and motivations for EWR 6

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning habitat*	*Spawning substrate*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*20 – 30*	**Vegetation:** *Inundates the marginal zone and marginal zone sedges (C. marginatus). Lower portions of P. mauritianus and L. octovalvis also inundated. Fewer events for AEC down will allow more sediment to settle, and with less flood disturbance marginal zone vegetation will migrate / expand towards the instream.*	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
II	*60 - 100*	**Geomorphology:** *This flow class is responsible for more than 10% of the PBMT. These flows would scour fines from the bed.* **Vegetation:** *Required to inundate about 50% of the lower zone. Inundates reed beds (P. mauritianus), Ludwigia and lower portions of B. salicina. Sustains vigour and reproduction in the height of the growing season. Less frequent event for AEC (down) will result in reduced recruitment opportunities for lower zone woody species (C. erythrophyllum, B. salicina).*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	*130 - 160*	**Geomorphology:** *This flow class is responsible for more than 25% of the PBMT. This flow class would scour the bed, activate gravels.* **Vegetation:** *Required for inundation of the lower zone. This will inundate B. salicina and afford recruitment opportunities, as well as upper limit of lower zone reeds.*	✓	✓	✓	✓	✓	✓	✓					
IV	*200 - 350*	**Geomorphology:** *This flow class represents the effective discharge for this site, accounting for more than 35% of the PBMT. This flow class would scour the bed, activating cobbles and gravels.* **Vegetation:** *Activates and inundates portions of the upper zone bars/benches. Maintains N. oppositifolia and Flugea virosa populations and activates upper zone reeds (low density). Would perform the function of reducing terrestrial species in the riparian zone.*	✓	✓	✓	✓	✓	✓	✓					

Table 9.18 EWR 6: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: C									
I	*20 – 30*			*4*		*4*	*Nov, Dec, Jan, Mar*	*12*	*4*
II	*60 - 100*			*2*	*2*	*2*	*Dec, Mar*	*60*	*4*
III	*130 - 160*			*1*	*1*	*1*	*Feb*	*120*	*6*
IV	*200 - 350*			*1:2 - 3*	*1:3*			*N/S*	*N/S*
REC SCENARIO: B									
I	*20 – 30*			*6*		*6*	*Nov, Dec, Jan (2), Feb, Mar*	*10*	*4*
II	*60 - 100*			*3*		*3*	*Dec, Jan, Mar*	*50*	*4*
III	*130 - 160*			*2*	*3*	*2*	*Jan, Feb, Mar*	*100*	*5*
IV	*200 - 350*			*1:2 - 3*	*1*		*Feb*	*180*	*6*
AEC SCENARIO: D									
I	*20 – 30*			*2*		*2*	*Nov, Mar*	*15*	*4*
II	*60 - 100*			*1*		*1*	*Jan*	*70*	*5*
III	*130 - 160*			*1:2*	*1*	*1:2*	*Feb*	*130*	*6*
IV	*200 - 350*			*1:2 - 3*	*1:2*			*N/S*	*N/S*

9.2.7 EWR results for EWR 7: Honeybird

Table 9.19 Low flow EWR results for EWR 7

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: C EcoStatus	**FISH: C**		**MACROINVERTEBRATES: B**		**RIP VEG: C/D**
Oct	*5% drought*	*9 SR*	*9*	*0.086*	*Some FS and very limited FI will be maintained and FD will be lost. FI and FS habitats will support small population that should be able to recover after drought.*
	35% maintenance	*6.5 SR*	*6.5*	*0.374*	*Adequate FS and some FI and FD to support refuge habitats for the small rheophilic species at the site during dry period.*
Feb	*5% drought*	*4.5 LSR*	*4.5*	*0.708*	*Some FS will be maintained to ensure maintenance of acceptable water quality (enough oxygen and limited temperature fluctuations) and allow adequate recovery after the stressed period.*
	35% maintenance	*3 SR*	*3*	*1.370*	*Adequate FD, FI and FS to allow successful breeding and habitats for all life stages. Due to the high stress conditions during dry period it is eminent to maintain adequate conditions during the wet season to ensure the survival of this indicator guild at this site.*
REC: B EcoStatus	**FISH: B**		**MACROINVERTEBRATES: B**		**RIP VEG: B/C**
Oct	*5% drought*	*9 SR*	*9*	*0.086*	*See PES.*
	35% maintenance	*4 SR*	*4*	*0.8*	*FD habitats decrease visibly from those observed under reference dry period conditions but FROC of indicator species will still be better than PES.*
Feb	*5% drought*	*4.5 LSR*	*4.5*	*0.708*	*See PES.*
	35% maintenance	*1.5 SR*	*1.5*	*2.23*	*High abundance of FD, FI and FS will be available at this*

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
					fish stress level to provide excellent habitat for this fish guild to complete all their life stages successfully.
AEC: D EcoStatus	**FISH: D**		**MACROINVERTEBRATES: C**		**RIP VEG: D**
Oct	*5% drought*	*9 SR*	*9*	*0.086*	*See PES.*
	35% maintenance	*8.2 SR*	*8.2*	*0.178*	*This fish stress level will maintain some FS while FI and FD may be lost which may be reflected by a critical decrease in abundance, resulting in decreased FROC.*
Feb	*5% drought*	*4.5 LSR*	*4.5*	*0.708*	*See PES.*
	35% maintenance	*4 SR*	*4*	*0.8*	*FS habitats will be reduced, with some FD and FI still available. It can be expected that this change in habitats (from present conditions) will result in decreased FROC.*

Table 9.20 High flow EWR functions and motivations for EWR 7

FLOOD CLASS	FLOOD RANGE (m3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning habitat*	*Spawning substrate*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*5 - 8*	**Vegetation:** *Required to inundate the marginal zone; activates and inundates portions of P. mauritianus and S. mucronata.*	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
II	*8 – 12*	**Geomorphology:** *This flow class is responsible for about 20% of the PBMT. These flows would inundate the active low bench on the right bank and scour fines from the bed; activating the gravels and some smaller cobbles.* **Vegetation:** *Inundates marginal zone reed beds and about 50% of the lower zone. Inundates the upper limit of S. mucronata, and activates the lower limit of F. sycomorus.*	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
III	*17*	**Geomorphology:** *This flow class represents the effective discharge for this site under present day flow conditions. It is responsible for approximately 35% of the PBMT at the site. These flows would inundate and active the benches on both the left and right banks, and scour fines and activate the gravels and small cobbles.*	✓	✓	✓	✓	✓	✓	✓					
IV	*25 – 80*	**Geomorphology:** *This flow class is responsible for about 20% of the PBMT. These flows would scour inundate the active low bench on the right bank, as well as scour the bed; activate the cobbles and allow for deposition within the dense vegetation of the benches.* **Vegetation:** *Inundates the lower zone and portions of the upper zone; activates and maintains S. cordatum and F. sycomorus populations.*	✓	✓	✓	✓	✓	✓	✓					
V	*> 130*	**Vegetation:** *Activates the lower limit of Acacia robusta on the upper zone.*	✓	✓	✓	✓	✓	✓	✓					

Table 9.21 EWR 7: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: C									
I	*5 - 8*	*4*		*4*		*4*	*Nov, Dec, Jan, Mar*	*5*	*3*
II	*8 – 12*	*2*		*1*	*2*	*2*	*Jan, Feb*	*8*	*3*
III	*(17)*				*1*	*1*	*Feb*	*20*	*4*
IV	*25 – 80*			*1:2*	*1:3*	*1:2*		*N/S*	*N/S*
V	*> 130*			*1:3 +*		*1:3*		*N/S*	*N/S*
REC SCENARIO: B									
I	*5 - 8*	*4*		*4*		*4*	*Nov, Dec, Jan, Mar*	*5*	*3*
II	*8 – 12*	*2*		*2*	*3*	*3*	*Dec, Jan, Feb*	*8*	*3*
III	*(17)*				*1*	*1*	*Jan*	*15*	*4*
IV	*25 – 80*			*1*	*1:3*	*1*	*Feb*	*25*	*4*
V	*> 130*			*1:3*		*1:3*		*N/S*	*N/S*
AEC SCENARIO: D									
I	*5 - 8*	*2*		*2*		*2*	*Dec, Mar*	*6*	*3*
II	*8 – 12*	*2*		*1*	*2*	*2*	*Jan, Feb*	*12*	*4*
III	*(17)*				*1:2*	*1:2*	*Feb*	*15*	*4*
IV	*25 – 80*			*1:2*	*1:5*	*1:2*		*N/S*	*N/S*
V	*> 130*			*1:3*		*1:3*		*N/S*	*N/S*

9.3 RESULTS

The results are summarised in Table 9.22 for the different EWR sites as a percentage of the natural Mean Annual Runoff (nMAR).

Table 9.22 Crocodile sub-catchment: EWR scenario results as a percentage of the nMAR

EWR site	nMAR	PMAR	%PMAR of nMAR	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
	MCM	MCM	MCM		MCM	(%nMAR)	MCM	(%nMAR)	MCM	(%nMAR)	MCM	(% nMAR)
EWR 1	*15.19*	*14.90*	*98%*	*A/B PES, REC*	*3.76*	*24.78*	*1.54*	*10.13*	*0.993*	*6.14*	*4.75*	*30.9*
				B/C AEC	*2.56*	*16.84*	*1.54*	*10.13*	*0.993*	*6.14*	*3.7*	*24.4*
EWR 2	*47.11*	*44.80*	*95%*	*B PES, REC*	*23.53*	*49.94*	*9.23*	*19.58*	*3.50*	*7.43*	*27*	*57*
				C AEC	*11.39*	*24.18*	*9.22*	*19.58*	*3.03*	*6.44*	*17.43*	*37*
EWR 3	*169.9*	*1515.2*	*892%*	*B/C PES*	*74.76*	*44*	*30.75*	*18.1*	*16.7*	*9.8*	*93.78*	*55.2*
				B REC		*A time series of requirements could not be generated as improvement of the PES required flows higher than the reference time series (present day), during the wet season.*						
EWR 4	*754.1*	*528.3*	*70%*	*B PES, REC*	*216.4*	*28.7*	*74.66*	*9.9*	*46.8*	*6.2*	*260.16*	*34.5*
				C/D AEC	*99.54*	*13.2*	*74.66*	*9.9*	*38.7*	*5.1*	*160.62*	*21.3*

EWR 5	1006.2	637.9	63%	C PES	214.3	21.3	121.8	12.1	53.3	5.3	301.87	30
				B REC	349.2	34.7	121.8	12.1	74.5	7.4	404.50	40.2
				D AEC	121.8	12.1	121.8	12.1	29.2	2.9	214.33	21.3
EWR 6	1063.1	525.2	49%	C PES	147.8	13.9	112.7	10.6	78.7	7.4	264.72	24.9
				B REC	323.2	30.4	112.7	10.6	140.3	13.2	466.71	43.9
				D AEC	123	11.6	47.84	4.5	48.9	4.6	152.03	14.3
EWR 7	169	86.6	51%	C PES	25.2	14.9	11.16	6.6	10.82	6.4	38.87	23
				B REC	50	29.6	11.16	6.6	12.51	7.4	62.20	36.8
				D AEC	10.14	6	11.16	6.6	8.96	5.3	27.72	16.4

9.4 CONCLUSIONS AND RECOMMENDATIONS

The confidence in the low and high flow Ecological Reserve requirements for each EWR site is provided in the table below. A score of 1 – 1.9 indicates a low confidence (red), 2 – 3.9 a moderate confidence (yellow) and 4 -5, high confidence (green) in the results.

Table 9.23 Overall Confidence in EFR Results

EWR SITE	HYDROLOGY	LOW FLOWS				HIGH FLOWS			
		BIOLOGICAL RESPONSES	HYDRAULICS	BIOLOGICAL RESPONSES	HYDRAULICS	BIOLOGICAL RESPONSES	HYDRAULICS	BIOLOGICAL RESPONSES	HYDRAULICS
EWR 1	2	4	4	**4**	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows.	3.5	3.5	**3.5**	All the smaller floods fall within the range of measured flows.
EWR 2	2	4	4	**4**	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows.	3.8	3	**3**	Some of the floods fall outside the range of measured flows which results in hydraulic being of a lower confidence than the biophysical responses.
EWR 3	3	2	5	**2**	Various calibrations available for this site since 1999. This resulted in high confidence in the hydraulics. However, due to the lack of understanding around the invertebrates, the confidence is low.	4	3	**3**	Some of the floods fall outside the range of measured flows which results in hydraulic being of a lower confidence than the biophysical responses.
EWR 4	1.5	4	1	**1**	This cross-section was very badly selected during previous EWR studies and do not provide any low flow cues nor any useful hydraulics at low flows. Another section was selection downstream of the old section. As only one hydraulic calibration could be obtained, the confidence was very low.	3.8	4	**4**	All the small and moderate floods fall within the range measured.
EWR 5	2.5	4	3.5	**3.5**	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows. The site does not provide good habitat, however site selection is problematic in this area with safety and access playing an overriding role.	3.3	4	**3.3**	Riparian vegetation is the factor that results in a lower biophysical confidence. This is due to the absence of cues at the site and therefore uncertainty in the flooding requirements.
EWR 6	3	4	4	**4**	Biological responses high as well as hydraulics. The hydraulic requirements for low flows largely within the range of measured flows. There is some uncertainty in flow class modelling as the site is bedrock dominated.	3.8	4	**4**	Limited range of measured flows but the small and moderate floods should maintain sediment transport at this site.
EWR 7	2	4	3	**3**	Complex site. Low flows set are below measurements. There is uncertainty in flow class modelling. The hydraulics therefore is the overriding factor with regards to confidence.	2.3	3	**2.5**	Both riparian and geomorphology cues are lacking and confusing, resulting in a low confidence in the high flows.

Recommendations were determined based on the possibility and necessity of improving the confidence of the individual assessments (biological response and hydraulics) by implementing an Ecological Water Resource Monitoring Programme (EWRM), hydrological monitoring and hydraulic assessments. This will provide the additional information to improve confidence in the EWRs. These recommendations are summarised in Table 9.24.

Table 9.24 Summary of recommendations required to improve confidences

EWR sites	Low flow confidence	High flow confidence	Recommendations
EWR 1	4	3.5	EWRM
EWR 2	4	3	EWRM
EWR 3	2	3	EWRM
EWR 4	1	4	The hydraulics for EWR 4 should be updated with sufficient low flow calibrations to improve the low flow confidence. EWRM.
EWR 5	3.5	3.3	This site did not provide sufficient cues for EWR assessment, neither for hydraulic analysis. As EWR 6 is the critical site, this site should be seen as supplementary. EWRM
EWR 6	4	4	EWRM
EWR 7	3	2.5	EWRM

9.5 SABIE-SAND SUB-CATCHMENT: EWR AND MOTIVATIONS

The low flow and high flow requirements and motivations are summarised per EWR site as follows:

9.5.1 EWR results for EWR 1: Upper Sabie

Table 9.25 Low flow EWR results for EWR 1

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: B/C EcoStatus	**FISH: B/C**		**MACROINVERTEBRATES: B**		**RIP VEG: B/C**
Oct	5% drought	8.5 LR	8.5	0.5	Critical habitats will be maintained to ensure survival of LR guild.
	35% maintenance	4 Phragmites	5.75	1	Leaf wilting/stress commences but is slight, and flower/fruit abortion commences.
Feb	5% drought	6 LR	6	0.8	Critical habitats greatly reduced but will cater for spawning and maintenance of life stages.
	35% maintenance	3 LR	3	1.9	Adequate critical habitat to maintain life stages and biological processes.
REC: B EcoStatus	**FISH: B**		**MACROINVERTEBRATES: A/B**		**RIP VEG: B**
Oct	5% drought	8.5 LR	8.5	0.5	See PES.
	35% maintenance	3.5 Phragmites	5.5	1.1	Similar to PES conditions. Less stress associated with more flows.
Feb	5% drought	6 LR	6	0.8	See PES.
	50% maintenance	2 LR	2	2.5	Improved FI and FD habitat will improve the Fish EC.
AEC: C/D EcoStatus	**FISH: C/D**		**MACROINVERTEBRATES: C**		**RIP VEG: C/D**
Oct	5% drought	8.5 LR	8.5	0.5	See PES.
	35% maintenance	7.5 LR	7.5	0.67	Adequate fast habitat for survival however species occur at reduced abundance.
Feb	5% drought	6 LR	6	0.8	See PES.
	35% maintenance	4.5 LR	4.5	1.55	Less critical habitat available than under PES

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
					conditions. Life stages will be maintained, but species abundances and FROC will decrease resulting in lower EC.

Table 9.26 High flow EWR functions and motivations for EWR 1

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning substrate*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*5 - 7 (6 ave)*	**Geomorphology:** *This flow class is the effective discharge for the fines (sands) at the site preventing infilling of interstitial spaces.* **Vegetation:** *30 – 45 cm inundation of P. mauritianus maintains reedbeds. Also inundates large-leaved aquatic macrophytes. REC has the same flood requirements as the PES since this scenario is due to non-flow related issues (exotic vegetation and recreation activities). Only small floods and base flow reduction occur to result in the AEC (down) with an associated increase in reeds.*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	*10 – 20 (15 ave)*	**Geomorphology:** *This flow class is the effective discharge for the gravels (10 mm) at the site maintaining clean bed conditions.* **Vegetation:** *Wets but does not inundate the fern line; inundates the marginal zone and a high proportion of the reed-beds. Inundates lower portion of the tree-line (Ficus sur).*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	*35 – 55 (30 ave)*	**Geomorphology:** *This flow class is the effective discharge for the small cobbles at the site; maintaining bed mobility and interstitial spaces.* **Vegetation:** *Inundates 50 - 100% of the lower zone; maintains Syzigium cordatum population.*	✓	✓	✓	✓	✓	✓	✓					
IV	*70 +*	**Vegetation:** *Inundates lower portion of the upper zone, wets ephemeral terrace, maintains Combretum erythrophyllum population and provides recruitment opportunities.*	✓	✓	✓	✓	✓	✓	✓					

Table 9.27 EWR 1: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: B/C									
I	*5 - 7*	*4*		*4*	*4*	*4*	*Oct, Dec, Feb, Mar*	*6*	*4*
II	*10 - 20*	*1*		*1*	*1*	*1*	*Jan*	*15*	*5*
III	*35 - 55*			*1:2*	*1:3*	*1:2***		*N/S*	*N/S*
IV	*< 70*			*1:3 to 1:5*		*1:3*		*N/S*	*N/S*
REC SCENARIO: B									
I	*5 - 7*	*4*		*4*	*5*	*5*	*Oct, Nov, Dec, Feb, Apr*	*6*	*4*

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
II	*10 - 20*	*1*		*1*	*1*	*1*	*Jan*	*15*	*5*
III	*35 - 55*			*1:2*	*1:2*	*1:2*		*N/S*	*N/S*
IV	*< 70*			*1:3 to 1:5*		*1:3*		*N/S*	*N/S*
AEC SCENARIO: C/D									
I	*5 - 7*	*3*		*2*	*3*	*3*	*Oct, Dec, Mar*	*6*	*<3*
II	*10 - 20*	*1*		*1*	*1:2*	*1*	*Jan*	*15*	*3*
III	*35 - 55*			*1:2*	*1:4*	*1:2*		*N/S*	*N/S*
IV	*< 70*			*1:3 to 1:5*				*N/S*	*N/S*

9.5.2 EWR results for EWR 2: Aan de Vliet

Table 9.28 Low flow EWR results for EWR 2

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: B/C EcoStatus FISH: B/C MACROINVERTEBRATES: B RIP VEG: B/C					
Oct	*5% drought*	*8 LR*	*8*	*0.845*	*No FD habitats available, but should be adequate for species survival.*
	35% maintenance	*6 LR*	*6*	*1.49*	*Critical habitats will be maintained to ensure survival of LR guild.*
Feb	*5% drought*	*6 LR*	*6*	*1.49*	*Critical habitats are limited, but adequate to allow spawning and maintenance of other life changes.*
	35% maintenance	*3.5 LR*	*3.5*	*2.3*	*Adequate critical habitat to maintain life stages and biological processes.*
REC: B EcoStatus FISH: B MACROINVERTEBRATES: A/B RIP VEG: B					
Oct	*5% drought*	*8 LR*	*8*	*0.845*	*See PES.*
	35% maintenance	*5.5 LR*	*5.5*	*1.6*	*Good availability of preferred habitat.*
Feb	*5% drought*	*6 LR*	*6*	*1.49*	*See PES.*
	50% maintenance	*2 LR*	*2*	*2.93*	*Improved FI and FD habitat will improve the Fish EC.*
AEC: C/D EcoStatus FISH: C/D MACROINVERTEBRATES: C RIP VEG: C/D					
Oct	*5% drought*	*8 LR*	*8*	*0.845*	*See PES.*
	35% maintenance	*6.5 LR*	*6.5*	*1.26*	*Limited FD habitats and adequate FI habitat will cause reduced abundance and FROC of guild.*
Feb	*5% drought*	*6 LR*	*6*	*1.49*	*See PES.*
	35% maintenance	*5 LR*	*5*	*1.73*	*Less critical habitat available than under PES conditions. Life stages will be maintained, but species abundances and FROC will decrease resulting in lower EC.*

Table 9.29 High flow EWR functions and motivations for EWR 2

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning substrate*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*9 – 12*	**Geomorphology:** *The lower flow classes (high base flows and intra-annual floods) play a crucial role in maintaining the movement of fine sands through the site.* **Vegetation:** *Maintains reeds and other grasses at the site (50% inundation); likely to activate back channel which supports marginal zone obligates. Inundates the lower portion of the marginal zone and the lower portion of the B. salicina population. Maintains soil moisture in alluvial bars which supports riparian closed-canopy forests (Syzigium and Breonadia mainly).*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	*15 - 25*	**Geomorphology:** *This annual flood is responsible for a large proportion of both sands and small gravel (10 mm) transport; preventing sedimentation and embeddedness of the riffle. This flow class is also responsible for the activation and scouring of the seasonal back channel.* **Vegetation:** *Inundates marginal zone, the majority of reeds and grasses and all leafy aquatic marginal zone macrophytes. Activates and inundates B. salicina and S. cordatum populations and provides recruitment opportunities. Also facilitates existing juvenile survival. Activates back channel which supports marginal zone obligates.*									✓	✓	✓	✓
III	*35 - 55*	**Geomorphology:** *This flow class is the effective discharge for the gravels (10 mm sediments); maintaining the condition of the riffles and other gravel areas. This flow class also inundates the lower floodplain area.* **Vegetation:** *Floods most of the S. cordatum population and facilitates recruitment of vegetation growing on alluvial lateral/point bar.*												
IV	*70 +*	**Geomorphology:** *This infrequent flood inundates most of the floodplain, and is the effective discharge class for the larger sediments (cobbles) for the site - this would activate the larger cobbles in the riffle areas.* **Vegetation:** *Activate lateral alluvial deposits. Maintains MCB species (C. erythrophyllum, F. sycomorus and Anthocleista mainly). Inundates the lower zone and activates lowest portion of upper zone.*												

Table 9.30 EWR 2: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: C									
I	*9 - 12*	*4*		*4*	*4*	*4*	*Nov, Dec, Jan, Mar*	*10*	*4*
II	*15 - 25*	*1*		*1*	*1*	*1*	*Feb*	*20*	*5*
III	*35 -55*	*1:2*		*1:2*	*1:2*	*1:2*		*N/S*	*N/S*
IV	*70 +*	*1:3*		*1:3+*	*1:5*	*1:3*		*N/S*	*N/S*
REC SCENARIO: B									

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
I	*9 - 12*	*5*		*4**	*5#*	*5*	*Nov, Dec, Jan, Feb, Mar*	*10*	*4*
II	*15 - 25*	*1*		*1*	*1*	*1*	*Feb*	*20*	*5*
III	*35 -55*	*1:2*		*1:2*	*1:2*	*1:2*		*N/S*	*N/S*
IV	*70 +*	*1:3*		*1:3+*	*1:5*	*1:3*		*N/S*	*N/S*
AEC SCENARIO: C/D									
I	*9 - 12*	*3*		*3**	*3#*	*3*	*Nov, Jan, Mar*	*10*	*4*
II	*15 - 25*	*1*		*1*	*1:2*	*1*	*Feb*	*20*	*3*
III	*35 -55*	*1:2*		*1:2*	*1:3*	*1:2*		*N/S*	*N/S*
IV	*70 +*	*1:3+*		*1:3+*	*1:5*	*1:3+*		*N/S*	*N/S*

9.5.3 EWR results for EWR 3: Kidney

Table 9.31 Low flow EWR results for EWR 3

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES and REC: A/B EcoStatus FISH: B MACROINVERTEBRATES: B RIP VEG: A/B					
Oct	*5% drought*	*8 SR*	*8*	*1.46*	*Critical fast habitat is maintained to ensure survival of the SR guild.*
	35% maintenance	*6 SR*	*6*	*2.25*	*Highly stressed condition and maintenance of EC depends on the maintenance of wet season drought conditions.*
Feb	*5% drought*	*5 Phragmites*	*5.75*	*2.8*	*Obvious leaf wilting or vegetative parts begin unseasonal discolouration; flower/fruit abortion is widespread.*
	35% maintenance	*3 SR*	*3.8*	*7.1*	*Adequate critical habitat to maintain life stages and biological processes.*
AEC: B/C EcoStatus FISH: C MACROINVERTEBRATES: C RIP VEG: B/C					
Oct	*5% drought*	*8.9 SR*	*8.9*	*0.95*	*Critical fast habitat at reduced abundance than PES. Guild will occur at decreased FROC and abundance.*
	35% maintenance	*7.8 SR*	*7.8*	*0.67*	*Reduced occurrence of fast habitats, therefore fish occur in reduced abundance and FROC.*
Feb	*5% drought*	*5 Phragmites*	*5.75*	*2.8*	*See PES.*
	35% maintenance	*3 Phragmites*	*4.75*	*5.2*	*Leaf wilting/stress commences but is slight, and the population remains reproductively active.*

Table 9.32 High flow EWR functions and motivations for EWR 3

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	*10 - 15*	*Macroinvertebrates. See Appendix D, Table D11.*	√	√	√	√	√	√	√	√	√	√	√	√
II	*15 - 30*	**Geomorphology:** *This flow class is responsible for the transport of a large proportion of the fines (sands) component through the site, and would activate the gravels on the bed.* **Vegetation:** *Inundates half of reeds, but not to depths greater than about 50 cm. Inundates lower limit of B. salicina population, ensuring survival and recruitment opportunities. Inundates aquatic macrophytes (Persecaria, Ludwigia, and Cyperus).*	√	√	√	√	√	√	√	√	√	√	√	√
III	*45 - 55*	**Vegetation:** *Inundates marginal zone, marginal zone riparian obligates and high density reedbeds. Activates the lower limit of S. cordatum. Also inundates a major portion of the B. salicina population.*	√	√	√	√	√	√	√					
IV	*75 - 100*	**Geomorphology:** *This important flow class is responsible for about 30% of both sand and gravel transport. Maintaining this flow category will scour the active channels of the reach.* **Vegetation:** *Maintains lower zone woody species (N. oppositifolia and C. erythrophyllum). Inundates lower portion of the lower zone and the majority of the reeds.*	√	√	√	√	√	√	√					
V	*150 +*	**Vegetation:** *Inundates the lower zone to the full extent and activates the upper zone.*	√	√	√	√	√	√	√					
VI	*250*	**Geomorphology:** *This large flood is responsible for the bulk of channel maintenance (specifically within these anastomosing reaches) - widening and deepening the channels and removing vegetation.*	√	√	√	√	√	√	√					

Table 9.33 EWR 3: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	FLOOD CLASS	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES and REC SCENARIO: A/B									
I	*10 - 15*	*4*				*4*	*Nov, Dec, Jan, Feb*	*8*	*3*
II	*15 - 30*			*4*	*4*	*4*	*Nov, Dec, Jan, Mar*	*20*	*4*
III	*45 -55*			*1*		*1*	*Mar*	*40*	*5*
IV	*75 - 100*			*1:2*	*1:2*	*1:2*		*N/S*	*N/S*
V	*150 +*			*1:3+*		*1:3*		*N/S*	*N/S*
VI	*250*				*1:5*	*1:5*		*N/S*	*N/S*
AEC SCENARIO: B/C									
I	*10 - 15*	*3*				*3*	*Dec, Jan, Feb*	*8*	*3*
II	*15 - 30*			*3*	*3*	*3*	*Nov, Jan, Mar*	*20*	*4*
III	*45 -55*			*1*		*1*	*Feb*	*40*	*5*
IV	*75 - 100*			*1:2*	*1:2*	*1:2*		*N/S*	*N/S*
V	*150 +*			*1:3+*		*1:3*		*N/S*	*N/S*

FLOOD RANGE (m^3/s)	FLOOD CLASS	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
VI	250			1:5	1:5	1:5		N/S	N/S

9.5.4 EWR results for EWR 4: Mac Mac

Table 9.34 Low flow EWR results for EWR 4

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES and REC: B EcoStatus		**FISH: B/C**		**MACROINVERTEBRATES: A/B**	**RIP VEG: A/B**
Oct	5% - drought	8.5 LR	8.5	0.2	Limited FS and FI to maintain fish.
	35% maintenance	6.5 LR	6.5	0.45	Most critical habitat will be maintained and adequate for fish survival.
Feb	5% - drought	6 LR	6	0.5	Reduced spawning habitat, but sufficient to maintain all life stages and survival of fish.
	35% maintenance	3 SR	3	1.09	Adequate critical habitat to maintain life stages and biological processes.
AEC↓: C EcoStatus		**FISH: C/D**		**MACROINVERTEBRATES: B/C**	**RIP VEG: B/C**
Oct	5% - drought	8.5 LR	8.5	0.2	See PES.
	35% maintenance	7.5 LR	7.5	0.35	Reduced occurrence of fast habitats, therefore fish occur in reduced abundance and FROC.
Feb	5% - drought	6 LR	6	0.5	See PES.
	35% maintenance	5 LR	5	0.59	Fast habitats are reduced but adequate to maintain life stages at a reduced abundance and FROC.

Table 9.35 High flow EWR functions and motivations for EWR 4

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions					
			Migration cues	Migration habitat (depth etc.)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality	Migration cues
I	3 - 5	**Geomorphology:** This flow class initiates movement of the smaller (50 mm) gravels at the site, and would scour any accumulated fines. **Vegetation:** Maintains marginal zone riparian obligates, activates the lower limit of B. salicina, and inundates marginal zone S. cordatum.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	6 - 12	**Geomorphology:** This flow class initiates movement of the larger gravels (100 mm) and maintains bed mobility. **Vegetation:** Inundates the marginal zone and lower portion of the lower zone. Inundates B. salicina, S. cordatum (Hydrochorous species) and Anthocleista grandiflora (medium to low lying forest species) populations.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions					
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning substrate*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*	*Migration cues*
III	*25 - 35*	**Vegetation:** *Inundates the lower zone and activates the lower portion of the upper zone. Inundates facultative riparian species (often also moist forest species) in the upper portions of the lower zone (F. sur).*	✓	✓	✓	✓	✓	✓	✓						
IV	*70 +*	**Geomorphology:** *Inundates the lateral terrace and activates the ephemeral flood channel. Scours the bed and moves the cobbles within the active channel.* **Vegetation:** *Inundates the upper zone woody species (kloof and forest species with some facultative riparian species; also historic B. salicina population). Inundates the lower zone and the lower portion of the upper zone.*	✓	✓	✓	✓	✓	✓	✓						

Table 9.36 EWR 4: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	FLOOD CLASS	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES and REC SCENARIO: B									
I	*3 - 5*	*4*		*4*		*4*	*Nov, Dec, Jan, Mar*	*4*	*3*
II	*6 – 12*	*1*		*1*		*1*	*Feb*	*15*	*4*
III	*25 - 35*			*1:2*		*1:2*		*N/S*	*N/S*
IV	*70 +*			*1:3+*	*1:10*	*1:3*		*N/S*	*N/S*
AEC SCENARIO: C									
I	*3 - 5*	*3*		*4*		*4*	*Nov, Dec, Jan, Mar*	*4*	*3*
II	*6 – 12*			*1*		*1*	*Feb*	*15*	*4*
III	*25 - 35*			*1:2*		*1:2*		*N/S*	*N/S*
IV	*70 +*			*1:3+*	*1:10*	*1:3*		*N/S*	*N/S*

9.5.5 EWR results for EWR 5: Marite

Table 9.37 Low flow EWR results for EWR 5

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: B/C EcoStatus	**FISH: B/C**		**MACROINVERTEBRATES: B/C**		**RIP VEG: B/C**
Oct	*5% drought*	*8.5 LR*	*8.5*	*0.32*	*Limited critical habitat present to ensure survival of LR guild.*
	35% maintenance	*4.5 Breonadia*	*6.5*	*0.6*	*Leaf wilting/stress commences but is slight, and flower/fruit abortion commences although unlikely to occur in dry season).*
Feb	*5% drought*	*6.5 LR*	*6*	*0.6*	*Critical habitat greatly reduced but adequate for spawning.*
	35% maintenance	*3 LR*	*3*	*1.78*	*Maintenance of critical habitat required for most life stages and biological processes.*
REC: B EcoStatus	**FISH: B**		**MACROINVERTEBRATES: B**		**RIP VEG: B**
Oct	*5% drought*	*8.5 LR*	*8.5*	*0.32*	*See PES.*
	35% maintenance	*5.5 SR*	*5.8*	*0.75*	*Improved habitat and therefore improved abundance and FROC.*
Feb	*5% drought*	*6.5 LR*	*6*	*0.6*	*See PES.*
	35% maintenance	*2 LR*	*2.8*	*1.9*	*Improved spawning and nursery habitat for guild.*
AEC: C/D EcoStatus	**FISH: C/D**		**MACROINVERTEBRATES: C**		**RIP VEG: C/D**
Oct	*5% drought*	*8.5 LR*	*8.5*	*0.32*	*See PES.*
	35% maintenance	*8 LR*	*8*	*0.35*	*Limited critical habitat available and therefore reduced abundance and FROC of guild.*
Feb	*5% drought*	*6.5 LR*	*6*	*0.6*	*See PES.*
	35% maintenance	*4.5 LR*	*4.5*	*1.2*	*Some critical habitat available to maintain life stages at reduced abundance and FROC.*

Table 9.38 High flow EWR functions and motivations for EWR 5

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning substrate*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*4 - 6*	**Geomorphology:** *This flow class represents an important component of fines (sand) transport for this site. Maintenance of the transport of sands through the site will prevent excessive bed aggradation and smothering of bedrock/boulders on the bed. It also inundates and activates the lower beach areas on the island.* **Vegetation:** *Inundates the marginal zone, marginal zone obligates and 30 - 50% of B. salicina and P. mauritianus populations. Activates Ishaemum and Setaria grasses and ensures lower level Syzigium sp recruit survival.*	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
II	*8 - 18*	**Geomorphology:** *This flow class is the effective discharge for the fines (sands) at the site; maintaining these flows will, as above, enable the bedrock influence to be maintained in the reach. These flows also inundate most of the island, as well as the seasonal channel.* **Vegetation:** *Inundates marginal zone and lower portion of the lower zone, Ludwigia, Persecaria, C. dives, and about 50% of P. mauritianus, B. salicina and riparian grasses*	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc.)*	*Clean spawning substrate*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
		(Ishaemum and Setaria). Ensures survival of lower level S. cordatum recruits and ensures additional recruitment opportunities. Activates the lower zone terraces and backwaters (channel/pools).												
III	*28 - 42*	**Geomorphology:** *This flow class is the effective discharge for the larger gravels (60 mm) within the reach; maintaining clean bed conditions (and clean gravels within the fast flowing sections). The flow will also scour the seasonal channel and activate the upper ephemeral channel.* **Vegetation:** *Inundates the majority of the lower zone and floods back channels/pools. Inundates B. salicina population and facilitates Syzigium sp recruitment in the lower zone. Floods lower zone riparian grasses (Setaria and Ishaemum).*	✓	✓	✓	✓	✓	✓	✓					
IV	*80 +*	**Geomorphology:** *This flow class is important for gravels activation and transport, as well as for scouring the upper ephemeral channel and inundating terrace areas at the site.* **Vegetation:** *Inundates the lower zone and the lower portion of the upper zone. Activates the upper limit of S. cordatum and maintains N. oppositifolia and C. erythrophyllum populations.*	✓	✓	✓	✓	✓	✓	✓					
V	*250 +*	**Vegetation:** *Activates upper zone terraces. Activates and inundates C. erythrophyllum and T. sericea.*	✓	✓	✓	✓	✓	✓	✓					

Table 9.39 EWR 5: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: B/C									
I	*4 - 6*			*4*	*4*	*4*	*Nov, Dec, Feb, Mar*	*4*	*3*
II	*8 - 18*			*1*	*2*	*2*	*Dec, Jan*	*8*	*4*
III	*28 - 42*			*1:2*	*1:2*	*1:2*	*Feb*	*25*	*5*
IV	*80 +*			*1:3*	*1:5*	*1:3*		*N/S*	*N/S*
V	*250 +*			*1:5+*		*1:5*		*N/S*	*N/S*
REC SCENARIO: B									
I	*4 - 6*			*4*	*5*	*5*	*Nov, Dec, Jan, Feb, Mar*	*4*	*3*
II	*8 - 18*			*1*	*2*	*2*	*Dec, Jan*	*8*	*4*
III	*28 - 42*			*1:2*	*1:2*	*1:2*	*Feb*	*25*	*5*
IV	*80 +*			*1:3*	*1:5*	*1:3*		*N/S*	*N/S*
V	*250 +*			*1:5+*		*1:5*		*N/S*	*N/S*
AEC SCENARIO: C/D									
I	*4 - 6*			*3*	*3*	*3*	*Nov, Dec, Mar*	*4*	*3*
II	*8 - 18*			*1*	*1*	*1*	*Jan*	*8*	*4*
III	*28 - 42*			*1:2*	*1:2*	*1:2*	*Feb*	*25*	*5*
IV	*80 +*			*1:3*	*1:5*	*1:3*		*N/S*	*N/S*
V	*250 +*			*1:5+*		*1:5*		*N/S*	*N/S*

9.5.6 EWR results for EWR 6: Mutlumuvi

Table 9.40 Low flow EWR results for EWR 6

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: C EcoStatus	**FISH: C**		**MACROINVERTEBRATES: B/C**		**RIP VEG: C**
Oct	*5% - drought*	*10 SR*	*10*	*0*	*Prolonged periods of zero flows. Guild however still survives and seeks refuge upstream where perennial flow is present. PES will be maintained if connectivity and wet season flows are ensured.*
	60% maintenance	*9 SR*	*9*	*0.163*	*Adequate habitats available for the survival of the guild although fast habitats are absent.*
Feb	*5% - drought*	*8 SR*	*8*	*0.38*	*Critical habitat greatly reduced but adequate for spawning. Refuge in tributaries if spawning not possible.*
	60% maintenance	*3 SR*	*5.5*	*0.685*	*Maintenance of critical habitat required for most life stages and biological processes.*
REC: B EcoStatus	**FISH: B**		**MACROINVERTEBRATES: B**		**RIP VEG: B**
Oct	*5% - drought*	*9.5 SR*	*9.5*	*0.082*	*Guild survives and seeks refuge upstream where perennial flow is present.*
	60% - maintenance	*8.5 SR*	*8.5*	*0.27*	*Improved habitat and therefore improved abundance and FROC.*
Feb	*5% - drought*	*8 SR*	*8*	*0.38*	*See PES.*
	60% maintenance	*3 SR*	*3*	*0.83*	*Improved spawning and nursery habitat for guild.*
AEC: C/D EcoStatus	**FISH: D**		**MACROINVERTEBRATES: C/D**		**RIP VEG: D**
Oct	*5% - drought*	*10 SR*	*10*	*0*	*See PES.*
	60% - maintenance	*9.5 SR*	*9.5*	*0.082*	*Limited habitat available for guild. However, the guild will be highly stressed and may be eradicated from reach.*
Feb	*5% - drought*	*8 SR*	*8*	*0.38*	*See PES.*
	60% maintenance	*5 SR*	*6.2*	*0.622*	*Some fast habitat available but more reduced than PES. Abundance and FROC will reduce.*

Table 9.41 High flow EWR functions and motivations for EWR 6

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc)*	*Clean spawning substrate*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*1.6 - 2.5*	**Geomorphology:** *This flow class will scour fines (sand) from the beds of the two main active channels, as well as activate the seasonal channel.* **Vegetation:** *Inundates the marginal zone. Inundates B. salicina and facilitates their recruitment. Inundates 50 - 60% reedbeds, Setaria, Cyperus species and about half the population of S. mucronata. Activates seasonal channels.*	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc)*	*Clean spawning substrate*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
II	*10 - 12*	**Geomorphology:** *This flow class will inundate the island and lateral bar areas; as well as scour the active and seasonal channels. These flows would also initiate gravel and small cobble movement, preventing embeddedness.* **Vegetation:** *Inundates marginal zone and lower half of lower zone and seasonal channels. Inundates large proportion of P. mauritianus and all marginal zone riparian obligates.*	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
III	*16 - 30*	**Vegetation:** *Inundates the lower zone and floods seasonal channels and backwaters. Inundates S. cordatum, B. salicina, S. mucronata, C. dives and P. mauritianus.*	✓	✓	✓	✓	✓	✓	✓					
IV	*50 +*	**Geomorphology:** *These floods would transport most of the gravels and small cobbles through the reach.* **Vegetation:** *Activates upper zone terrace and inundates lower portion of the upper zone. Maintains C. erythrophyllum and D. mespiliformis populations.*	✓	✓	✓	✓	✓	✓	✓					
V	*190 +*	**Vegetation:** *Inundates major portion of upper zone and D. mespiliformis.*	✓	✓	✓	✓	✓	✓	✓					

Table 9.42 EWR 6: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: C									
I	*1.6 - 2.5*			*4*	*3*	*4*	*Nov, Dec, Jan, Mar*	*1.6*	*3*
II	*10 - 12*			*1*	*1*	*1*	*Feb*	*10*	*4*
III	*16 - 30*			*1:2*		*1:2*		*N/S*	*N/S*
IV	*50 +*			*1:3*	*1:3*	*1:3*		*N/S*	*N/S*
V	*190 +*			*1:5+*		*1:5*			
REC SCENARIO: B									
I	*1.6 - 2.5*			*4*	*4*	*4*	*Nov, Dec, Jan, Mar*	*1.6*	*3*
II	*10 - 12*			*1*	*1*	*1*		*10*	*4*
III	*16 - 30*			*1:2*		*1:2*		*N/S*	*N/S*
IV	*50 +*			*1:3*	*1:3*	*1:3*		*N/S*	*N/S*
V	*190 +*			*1:5+*		*1:5*		*N/S*	*N/S*
AEC SCENARIO: C/D									
I	*1.6 - 2.5*			*3*	*2*	*3*	*Nov, Dec, Mar*	*1.6*	*3*
II	*10 - 12*			*1*	*1*	*1*	*Feb*	*10*	*4*
III	*16 - 30*			*1:2*		*1:2*		*N/S*	*N/S*
IV	*50 +*			*1:3*	*1:3*	*1:3*		*N/S*	*N/S*
V	*190 +*			*1:5+*		*1:5*		*N/S*	*N/S*

9.5.7 EWR results for EWR 7: Tlulandziteka

Table 9.43 Low flow EWR results for EWR 7

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: C EcoStatus	**FISH: C**		**MACROINVERTEBRATES: B/C**		**RIP VEG: C**
Oct	*5% drought*	*10 SR*	*10*	*0*	*Prolonged periods of zero flows. Guild however still survives and seeks refuge upstream where perennial flow is present. PES will be maintained if connectivity and wet season flows are ensured.*
	60% maintenance	*8.5 SR*	*8.5*	*0.09*	*Some FS habitat available but FI and FD habitat absent. Available habitat should just be adequate to maintain the PES.*
Feb	*5% drought*	*6 LSR*	*6*	*0.19*	*This fish guild will have much reduced spawning habitats, but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species and allow recovery after drought period.*
	60% maintenance	*4 LSR*	*4*	*0.36*	*Critical spawning habitats will be maintained and adequate habitat for rest of life stages.*
REC: B EcoStatus	**FISH: B**		**MACROINVERTEBRATES: B**		**RIP VEG: B**
Oct	*5% drought*	*8.5 LSR*	*9.3*	*0.05*	*Adequate critical refuge areas are available for survival.*
	60% maintenance	*4 FDI*	*7*	*0.19*	*Suitable habitat that will allow for overwintering without significant detrimental impacts.*
Feb	*5% drought*	*6 LSR*	*6*	*0.19*	*See PES.*
	60% maintenance	*3 LSR*	*3*	*0.395*	*Fast habitats available with improvement in abundance of spawning and nursery habitat.*
AEC: C/D EcoStatus	**FISH: D**		**MACROINVERTEBRATES: C/D**		**RIP VEG: D**
Oct	*5% drought*	*10 SR*	*10*	*0*	*See PES.*
	60% maintenance	*9.2 SR*	*9.2*	*0.056*	*Limited fast habitat available leading to reduced abundance and FROC.*
Feb	*5% drought*	*6 LSR*	*6*	*0.19*	*See PES.*
	60% maintenance	*5 LSR*	*5*	*0.24*	*Limited fast habitat available to maintain life stages at reduced abundance and FROC.*

Table 9.44 High flow EWR functions and motivations for EWR 7

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc)*	*Clean spawning substrate*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*1.6 - 2.5*	**Vegetation:** *Inundates the marginal zone, Salix mucronata and about 50% of the reedbeds.*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	*4 - 9*	**Geomorphology:** *This flow transports some of the sand through the reach, and may allow the currently incised; narrowed active channel to widen.* **Vegetation:** *Inundates the marginal zone and lower portion of the lower zone. Activates lower zone low lying areas and backwaters and maintains Cyperus species in these depressions. Reduces terrestrialization on the lower zone: inundates current Acacia sieberiana population. Also inundates P. mauritianus.*	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
III	*15 Ave*	**Geomorphology:** *This flow will activate and turn over the gravels along the riffle sections of the bed.*	✓	✓	✓	✓	✓	✓	✓			✓		
IV	*28 Ave*	**Geomorphology:** *This flow class will activate and scour the ephemeral channel at the back of the macro-channel, and the peak of this flow should inundate sections of the large terrace area.*	✓	✓	✓	✓	✓	✓	✓					
V	*68 +*	**Geomorphology:** *This large, infrequent flood will inundate and activate the terrace; scour the active and ephemeral channel.* **Vegetation:** *Activates the upper zone terrace and fills the lower zone backwater channel. Inundates the lower zone. Activates and inundates the C. erythrophyllum population on the upper zone.*	✓	✓	✓	✓	✓	✓	✓					

Table 9.45 EWR 7: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: C									
I	*1.6 - 2.5*			*4*		*4*	*Nov, Dec, Jan, Mar*	*1.5*	*3*
II	*4 - 9*			*1*	*3*	*1*	*Jan*	*4*	*3*
III	*15 Ave*				*1*	*1*	*Feb*	*9*	*4*
IV	*28 Ave*				*1:2*	*1:2*		*N/S*	*N/S*
V	*68 +*			*1:3+*	*1:10*	*1:3*	*Wet*	*N/S*	*N/S*
REC SCENARIO: B									
I	*1.6 - 2.5*					*4*	*Nov, Dec, Jan, Mar*	*1.5*	*3*
II	*4 - 9*				*4*	*2*	*Dec, Jan*	*4*	*3*
III	*15 Ave*				*1*	*1*	*Feb*	*9*	*4*
IV	*28 Ave*				*1:2*	*1:2*		*N/S*	*N/S*
V	*68 +*				*1:10*	*1:10*		*N/S*	*N/S*
AEC SCENARIO: D									
I	*1.6 - 2.5*			*3*		*3*	*Nov, Dec, Jan, Mar*	*1.5*	*3*
II	*4 - 9*			*1*	*2*	*1*	*Jan*	*4*	*3*
III	*15 Ave*				*1*	*1*	*Feb*	*9*	*4*
IV	*28 Ave*				*1:3*	*1:03*		*N/S*	*N/S*
V	*68 +*			*1:3+*	*1:10*	*1:10*	*Wet*	*N/S*	*N/S*

9.5.8 EWR results for EWR 8: Sand

Table 9.46 Low flow EWR results for EWR 8

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES and REC: C EcoStatus	**FISH: C**		**MACROINVERTEBRATES: B/C**		**RIP VEG: C**
Oct	*5% drought*	*10 MVI*	*10*	*0*	*Pools will persist in the channel, and these will be fringed with MV. Atyidae will persist in this habitat, in very low abundances.*
	60% maintenance	*8.5 SR*	*8.5*	*0.36*	*Some FS and very limited FI will be present while no FD habitats will be available. This habitat composition should be adequate to provide the most critical habitats for the survival of species within this fish guild during the dry season.*
Feb	*5% drought*	*7 MVI*	*10*	*0*	*Adequate depth is present in channel and vegetation to ensure survival of taxa.*
	60% maintenance	*2 FDI*	*3*	*0.36*	*FDI taxa are abundant as critical habitats are present.*
AEC: C EcoStatus	**FISH: C**		**MACROINVERTEBRATES: C/D**		**RIP VEG: B/C**
Oct	*5% drought*	*10 MVI*	*10*	*0*	*See PES.*
	60% maintenance	*6 FDI*	*9.4*	*0.36*	*FDI persist in low numbers but will survive.*
Feb	*5% drought*	*7 MVI*	*10*	*0*	*See PES.*
	60% maintenance	*5 SR*	*5*	*1.34*	*Limited fast habitat available. Reduced abundance and FROC.*

Table 9.47 High flow EWR functions and motivations for EWR 8

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	*Migration habitat (depth etc)*	*Clean spawning substrate*	*Create spawning habitat*	*Create nursery areas*	*Resetting water quality*	*Inundate vegetation for spawning*	*Breeding and hatching cues*	*Clear fines*	*Scour substrate*	*Reach or inundate specific areas*	*Reset water quality*
I	*4 - 7*	**Vegetation:** *Activates seasonal channels. Inundates Persecaria, Cyperus and about half of the reeds. Maintains reedbeds and macro channel floor shrubs.*	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
II	*30 - 65*	**Vegetation:** *Inundates the lower zone and bars on the lower upper zone. Maintains lower-level reeds and shrubs, and lower-level C. erythrophyllum and N. oppositifolia.*	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
V	*150 +*	**Geomorphology:** *This flow class is the geomorphologically effective discharge - it is responsible for nearly half of all the transport of sands (1 and 2 mm) at this site. These results are confirmed by the morphological cues - this discharge will inundate and maintain the large, extensive lateral bar which runs through the reach (on the right bank at this site).* **Vegetation:** *Activates and inundates the upper zone terrace with P. mauritianus, C. erythrophyllum, N. oppositifolia, G. sennegalensis, and D. mespiliformis. Activates ephemeral channels.*	✓	✓	✓	✓	✓	✓	✓					

Table 9.48 EWR 8: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES and REC SCENARIO: B									
I	*1.6 - 2.5*			*4*		*4*	*Nov, Dec, Jan, Mar*	*5*	*4*
II	*4 - 9*			*1*		*1*	*Feb*	*30*	*5*
III	*15 Ave*							*N/S*	*N/S*
IV	*28 Ave*							*N/S*	*N/S*
V	*68 +*			*1:3*	*1:2*	*1:2*		*N/S*	*N/S*
AEC SCENARIO: C									
I	*1.6 - 2.5*			*3*		*3*	*Dec, Jan, Mar*	*5*	*4*
II	*4 - 9*			*1*		*1*	*Feb*	*30*	*5*
III	*15 Ave*							*N/S*	*N/S*
IV	*28 Ave*							*N/S*	*N/S*
V	*68 +*			*1:3*	*1:3*	*1:3*		*N/S*	*N/S*

9.6 RESULTS

The results are summarised in Table 9.49 for each EWR sites as a percentage of the nMAR..

Table 9.49 Sabie-Sand sub-catchment: EWR scenario results as a percentage of the nMAR

EWR site	nMAR	PMAR	%PMAR of nMAR	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
	MCM	MCM	MCM		MCM	(%nMAR)	MCM	(%nMAR)	MCM	(%nMAR)	MCM	(% nMAR)
EWR 1	*140.18*	*109*	*78%*	*B/C PES*	*46.54*	*33.2*	*16.96*	*12.1*	*7.43*	*5.3*	*52.99*	*37.8*
				B REC	*61.82*	*44.1*	*16.96*	*12.1*	*8.55*	*6.1*	*64.90*	*46.3*
				C/D AEC	*29.02*	*20.7*	*16.96*	*12.1*	*6.31*	*4.5*	*43.46*	*31*
EWR 2	*262.1*	*199.5*	*76%*	*B/C PES*	*51.90*	*19.8*	*29.09*	*11.1*	*11.5*	*4.4*	*73.39*	*28*
				B REC	*81.52*	*31.1*	*29.09*	*11.1*	*13.1*	*5*	*93.57*	*35.7*
				C/D AEC	*32.76*	*12.5*	*29.09*	*11.1*	*9.44*	*3.6*	*57.93*	*22.1*
EWR 3	*495.86*	*322.1*	*65%*	*A/B PES/REC*	*155.2*	*31.3*	*48.10*	*9.7*	*31.7*	*6.4*	*183.5*	*37*
				B/C AEC	*101.2*	*20.4*	*48.10*	*9.7*	*26.8*	*5.4*	*134.4*	*27.1*
EWR 4	*65.78*	*51.8*	*79%*	*A/B PES/REC*	*20.59*	*31.3*	*6.38*	*9.7*	*4.21*	*6.4*	*24.34*	*37*
				B/C AEC	*13.42*	*20.4*	*6.38*	*9.7*	*3.55*	*5.4*	*17.83*	*27.1*
EWR 5	*157.09*	*89.7*	*57%*	*B/C PES*	*32.67*	*20.8*	*12.57*	*8*	*10.2*	*6.5*	*44.30*	*28.2*
				B REC	*47.44*	*30.2*	*12.57*	*8*	*11.2*	*7.1*	*57.02*	*36.3*
				C/D AEC	*15.39*	*9.8*	*12.57*	*8*	*8.48*	*5.4*	*31.10*	*19.8*
EWR 6	*44.99*	*29.9*	*66%*	*C PES*	*9.99*	*22.2*	*4.63*	*10.3*	*2.83*	*6.3*	*14.58*	*32.4*
				B AEC	**14.49**	**32.2**	**6.03**	**13.4**	**2.83**	**6.3**	**17.37**	**38.6**
				C/D AEC	*6.21*	*13.8*	*4.63*	*10.3*	*2.56*	*5.7*	*11.56*	*25.7*
EWR 7	*28.88*	*17.3*	*60%*	*C PES*	*5.11*	*17.7*	*2.05*	*7.1*	*3.18*	*11*	*9.15*	*31.7*
				B REC	**7.65**	**26.5**	**3.23**	**11.2**	**3.81**	**13.2**	**11.38**	**39.4**
				D AEC	*2.71*	*9.4*	*2.05*	*7.1*	*2.95*	*10.2*	*7.77*	*26.9*
EWR 8	*133.61*	*88.5*	*66%*	**B PES[2]/REC**	**22.85**	**17.1**	**4.54**	**3.4**	**9.75**	**7.3**	**33.80**	**25.3**

EWR site	nMAR	PMAR	%PMAR of nMAR	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
	MCM	MCM	MCM		MCM	(%nMAR)	MCM	(%nMAR)	MCM	(%nMAR)	MCM	(% nMAR)
				C AEC	12.69	9.5	4.54	3.4	8.82	6.6	24.58	18.4

1 The attainable and realistic objective was to maintain the PES, but improve the macroinvertebrate EC by improving low flows.

9.7 CONCLUSIONS AND RECOMMENDATIONS

The confidence in the low and high flow Ecological Reserve requirements for each EWR site is provided in the table below. A score of 1 – 1.9 indicates a low confidence (red), 2 – 3.9 a moderate confidence (yellow) and 4 -5, high confidence (green) in the results.

Table 9.50 Overall Confidence in EFR Results

EWR SITE	HYDROLOGY	LOW FLOWS: BIOLOGICAL RESPONSES	LOW FLOWS: HYDRAULICS	LOW FLOWS: CONFIDENCE	LOW FLOWS: Comment	HIGH FLOWS: BIOLOGICAL RESPONSES	HIGH FLOWS: HYDRAULICS	HIGH FLOWS: CONFIDENCE	HIGH FLOWS: Comment
EWR 1	2.5	3.5	3.5	3.5	Moderate - High confidence for both biophysical and hydraulic aspects. Hydraulics is not of higher confidence due to EWR being below the measured minimum discharge and the presence of non-uniform flow conditions.	3.3	3	3	Moderate confidence due to hydraulics where flood requirements is above the measured maximum discharge and the presence of non-uniform conditions.
EWR 2	3	3.5	3.5	3.5	Moderate - High confidence for both biophysical and hydraulic aspects. Hydraulics is not of higher confidence due to some of the EWR recommendations being below the measured minimum.	3	3	3	Moderate confidence. The hydraulics is complex as during flood conditions various channels form in a floodplain on a bend.
EWR 3	3	4	3.5	3.5	Moderate - High confidence for hydraulics due to uncertainty with low flow 2-D modelling.	4	4	4	The site is complex with multi-distributary channels, however the flood recommendations are below the highest measured flow.
EWR 4	0.5	4	4	4	High confidence for both hydraulics and biophysical aspects.	2.3	3	2.3	Moderate confidence for hydraulics due to downstream bridge that can cause back-up during flooding conditions. Biophysical confidence lower due to the lack of geomorphological cues and a nearby gauge with reliable data.
EWR 5	2.5	4	3.5	3.5	Two channels at different stages and some flows recommended lower than measured discharge.	2.8	3	3	Confidence related to lack of hydrological data and geomorphological cues at the site and moderate hydraulic confidence as flood recommendations are mostly above measured maximum.
EWR 6	1	3.5	4	3.5	Lower confidence in the fish than the other components, mostly due to the position of the cross-section which does not represent the most critical habitats for fish.	2.8	3	3	Complex hydraulic site. Bedrock nature of site - lack of geomorphological cues and hydrological information.
EWR 7	0.5	2.5	3.5	2.5	The site was approached at a rapid level and only one biological survey was undertaken. Confidence therefore relates to lack of surveyed and any historical information. Only one low flow hydraulic point was available.	2.3	3	2.3	Geomorphological confidence low due to lack of a gauge, no hydrology, paired terraces, bedrock and lack of cues. Only one hydraulic measurement at the bottom of the high flow range was available.

EWR SITE	HYDROLOGY	LOW FLOWS				HIGH FLOWS			
		BIOLOGICAL RESPONSES	HYDRAULICS	CONFIDENCE	Comment	BIOLOGICAL RESPONSES	HYDRAULICS	CONFIDENCE	Comment
EWR 8	1.5	3	2	2	*Although this is an old EWR site, the cross-section had to be moved as the previous one was overgrown with reeds. Previous hydraulic data could not be used. Minimal measurements at low flows were available and the bed and channel is mobile. There is backup from bedrock and uncertainty with the flow class modelling.*	4	3	3	*Confidence due to the hydraulics is moderate as recommended floods are above the measured maximum and vegetation resistance in the channel is problematic.*

Recommendations were determined based on the possibility and necessity of improving the confidence of the individual assessments (biological response and hydraulics) by implementing an Ecological Water Resource Monitoring Programme (EWRM), hydrological monitoring and hydraulic assessments. This will provide the additional information to improve confidence in the EWRs. These recommendations are summarised in Table 9.51.

Table 9.51 Summary of recommendations required to improve confidences

EWR sites	Low flow confidence	High flow confidence	Recommendations
EWR 1	3.5	3	EWRM.
EWR 2	3.5	3	EWRM.
EWR 3	3.5	4	EWRM.
EWR 4	4	2.3	EWRM.
EWR 5	3.5	3	EWRM.
EWR 6	3.5	3	Hydrological monitoring. EWRM.
EWR 7	2.5	2.3	Hydrological monitoring. EWRM.
EWR 8	2	3	Additional low flow hydraulic information for calibration purposes. Hydrological monitoring. EWRM.

10 OPERATIONAL SCENARIOS

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. Crocodile River and Sabie-sand system: Operation Scenarios and Consequences Report. Volume 1: Description of Operational Scenarios. Authored by Mallory, SJL for Rivers for Africa. Edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/011.

During this part of an Ecological Reserve study, aspects other than ecology are also considered for the evaluation of various operational flow scenarios and/or future development scenarios. The purpose of this is to provide the decision-maker with sufficient information to make informed decisions regarding the implications of the flow scenario and the Ecological Category which will be signed off as the Ecological Reserve. This will in future form part of the Classification System.

Operational scenarios are any flow scenarios other than the present which could be implemented in future.

10.1 DESIGN OF OPERATIONAL SCENARIOS: CROCODILE SUB-CATCHMENT

The scenarios were subdivided into those scenarios in which the Ecological Reserve were not met, referred to below as Group 1, and those in which it was met, referred to as Group 2. The final scenarios are described in detail below. The comparison of one scenario versus another was carried out by comparing water availability under Present Day (PD) (Table 10.1) conditions versus that of the scenario in question, where water availability was expressed as the average annual volume of water supplied to each sector, as well as the assurance of supply to each sector. Assurance of supply in this context was defined as the percentage of time that a user obtained his full demand.

Table 10.1 Base scenario (PD) restriction rule

Storage in Kwena Dam	Restriction (% of demand)		
(% of full supply capacity)	*Industrial*	*Urban*	*Irrigation*
> 55		*0*	*0*
55 to 20		*5*	
55 to 10			*25*
20 to 10		*10*	
< 10	*10*	*20*	*65*

During scenario modelling it was found that while one set of rules satisfied the EWR on the main stem of the Crocodile River, a second set of rules was required for the Kaap River in order to meet the EWR at site 7. Hence the system was divided in two zones, referred to further in this chapter as Zone 1 and Zone 2 where:

- *Zone 1: The majority of water users within the Crocodile River catchment abstract water directly from the river, and this is supplemented when required by releases from the Kwena Dam. Restrictions are imposed on users in this zone based on the water level in the Kwena Dam. The restriction rule that was assumed for in the Base Scenario was that being used at the time that the PD scenario was modelled and is given in Table 10.1. Note that this rule has recently changed since Mallory et al. (2008).*
- *Zone 2: Water users in the Kaap River catchment do not benefit from releases from the Kwena Dam and only have access to run-of-river flow in the Kaap River, with the exception of irrigators in the Louws Creek Irrigation Board, who are supplied from the*

Shiyalongobu Dam, located on a tributary of the Lomati River, and the town of Barbeton which received most of its water from the Lomati Dam. The restriction rules developed for this zone were based on the natural flow at the EWR 7.

10.2 CROCODILE SUB-CATCHMENT

10.2.1 Group 1: EWR demands excluded

Scenarios C1 to C6: A combination of operating rules, restrictions, and/or curtailments applied.

A range of plausible operational scenarios were modelled and the scenario flow at each EWR site provided for the determination of ecological consequences. The scenarios related mainly to the option to either introduce curtailments to water users (by means of compulsory licensing) or to introduce harsher restrictions than assumed in the Base scenario. While a wide range of possible options were modelled, the river flow was very similar for many of the scenarios. For economic purposes, therefore, the range of combinations was thus narrowed to only six, namely three levels of curtailment and two levels of restrictions (Table 10.2). The two restriction rules used are given in Table 10.3. Note that the '35 Rule' is the same as the Base scenario rule (Table 10.1).

Table 10.2 Description of Group 1 Scenarios

Scenario	Restriction Rule (refer to Table 2.1)	Curtailment
C1	*35% Rule*	*Zero*
C2	*35% Rule*	*15%*
C3	*35% Rule*	*30%*
C4	*Zero Rule*	*15%*
C5	*Zero Rule*	*30%*
C6	*Zero Rule*	*45%*

Table 10.3 Group 1: Scenario rule applied to the irrigation sector

Storage in Kwena Dam (% of full supply capacity	Percentage of full demand supplied	
	35% Rule	Zero Rule
> 70	*100%*	*100%*
70 to 55	*100%*	*65%*
55 to 10	*75%*	*40%*
< 10	*35%*	*0%*

Two additional scenarios were evaluated at a later stage for ecological consequences evaluation. These are referred to as Sc 3.1 and Sc 6.1. Sc C3 and Sc C6 resulted in increased yield of Kwena Dam. Effectively, the water saved by the restrictions of irrigation results in increased yield of Kwena Dam. For Sc 3.1 and 6.1, the increased yield was released down the river to determine how much that would supply in terms of EWRs. This resulted in an improved assurance of supply to users and increased flow at all EWR sites 3, 4, 5 and 6.

Scenario C7: New dam at Montrose

In this scenario it was assumed that a new dam will be constructed at the Montrose site which is to be located just downstream of the confluence of the Crocodile and Elands Rivers. The assumed physical characteristics of the dam are as follows:

- *Full supply capacity: 254 MCM*
- *Full supply area: 10.3 km^2*

- *Dead storage: 5 MCM*
- *Area/capacity relationship: Area = 0.49 x Storage 0.55*

The additional yield that could be made available from the dam depends on a large number of factors, probably the most important being where in the system the intended new users of this dam were to be located. In order to keep this analysis uncomplicated, the following assumptions were made:

- *The Montrose Dam would replace the Kwena Dam as being the main regulator of flow in the Crocodile River. Kwena Dam would supplement the Montrose Dam by making releases when the storage in Montrose Dam dropped to below 10% of its full supply capacity.*
- *Montrose Dam would not contribute to the ecological flow requirements of the Crocodile River (in this scenario).*
- *The water abstracted from the Montrose Dam (i.e. yield) was supplied directly from the dam and not released into the Crocodile River to supplement downstream users. No restriction was imposed on the yield i.e. it is the historic firm yield of the dam.*
- *The Base Scenario restriction rules were applied to existing users in the catchment.*

Scenario C8: New dam at Mountain View

It was assumed when modelling this scenario that a new dam was to be constructed at the Mountain View site which was located a few kilometres upstream of the confluence of the Kaap and Crocodile Rivers. The assumed physical characteristics of the dam were as follows:

- *Full supply capacity: 187 MCM*
- *Full supply area: 7.3 km^2*
- *Dead storage: 5 MCM*
- *Area/capacity relationship: Area = 0.41 x Storage 0.77*

As in the case of the Montrose Dam, the additional yield made available from the dam depended on a large number of factors and the same assumptions made for the Montrose Dam were applied to the Mountain View Dam.

Scenario C9: New dams at Montrose and Mountain View

In this scenario it was assumed that new dams would be constructed at the Mountain View and Montrose site. Details of these dams and the assumptions made regarding their operation and additional yield are discussed under Scenario C7 and C8.

Scenario C11: No cross-border flows

One of the main drivers of the low flow under current operating conditions was the cross-border flows. As the lower Crocodile River had in the past flowed at very low flows, it was requested that the scenario of not supplying these minimum flows be modelled.

10.2.2 Group 2 Scenarios: EWR demands included

The scenarios presented in this section pertain specifically to implementing the EWR for the REC and the Present Ecological State (PES) (basically EWR scenarios). The operating rules that were developed to meet the EWR scenarios entailed a combination of restrictions and curtailments. In order to limit the number of operational scenarios to be evaluated from an economic point of view, the latest restriction rule that was being used to operate the system (see Table 10.4) was applied to irrigators in Zone 1, while a separate restriction rule was developed for Zone 2.

Note however that small adjustments were required to the level in the Kwena Dam at which this first restriction was applied in order to maintain the assurance of supply at 70%, which was assumed to be the target assurance for the irrigation sector. If the restriction rule alone did not result in the EWR scenarios being met (which is always the case), a curtailment was applied by reducing irrigated areas across the whole catchment. These scenarios were therefore similar to scenarios 1, 2 and 3 with the difference that the EWR scenarios were supplied as a first priority user and that the latest restriction rule had been used which differed to the present day restriction rule applied in the Group 1 scenarios (Table 11.2). Note that this latest restriction rule was only tabled very recently at the Crocodile River Operation forum and therefore represented the most likely restriction rule to be applied in the future.

Table 10.4 Group 2: Scenario restriction rules for the irrigation sector (typical)

Storage in Kwena Dam (% of full supply capacity)	Restriction (% of demand)
> 65	*100%*
55 to 30	*35%*
30 to 10	*60%*
< 10	*0%*

Scenario C10 and C12: Reduced releases from Kwena Dam to meet the PES (Sc C10) and REC (Sc C12) EWR at EWR 3

Under the current operation of the Crocodile system water is released out of the Kwena Dam into the Crocodile River to supplement the water supply to irrigators riparian to the river. Due to the large irrigation water demands throughout winter, the flow in the Crocodile River at EWR 3 is often **higher than natural during the winter***. As summer releases are often not made due to sufficient inflow from tributaries to supply irrigation requirements, the* **low flows in summer is abnormally low***, resulting in a seasonal reversal. In order to assess the economic impact of avoiding this unseasonal flow, this scenario modelled releases into the Crocodile River only to meet the EWR 3 requirements. Although the total supply to the irrigation sector remained relatively high, the irrigators located near the end of the Crocodile River would experience very low assurance of supply. Also, the international requirements would not be met.*

Scenario C13: Meet the Present Ecological Status at EWR 6

The PES would be maintained with PRESENT DAY HYDROLOGY, i.e. the Base Scenario. A PES EWR scenario was also generated which resulted in a higher requirement than the present day hydrology. This was due to the following:

- *The PES biotic stress requirements were very close to and lower than present day hydrology in the key months required.*
- *However, in some of the other months, it was slightly higher. Slightly higher in terms of stress, was significantly different in terms of flow volumes.*
- *Additionally, the present day hydrology had minimal variability within months (i.e., a flat line in terms of a flow duration graph). The EWR would be generated for the months following the natural variability, thereby exceeding the present day flows.*

THEREFORE, the PES EWR had to be seen as a range of flows that would meet the PES but would result in a higher PES than the present hydrology. The PES EWR was therefore a scenario of a flow regime that would also maintain the PES. This flow scenario would imply a decreased *risk of the river degrading from the PES, whereas the risk of degradation associated with the present day flows was higher.*

In order to meet the PES EWR, irrigators would need to be curtailed by 25%. Given this curtailment, a restriction rule was developed to meet the PES at EWR 7 located on the Kaap River. Note that the restriction rule applied to irrigators in Zone 2 (Kaap River) was a function of the natural flow at EWR 7 and not the state of storage in the Kwena Dam as assumed in the Group 1 scenarios. This restriction rule was more complex than the one applied to releases out of Kwena Dam since it consisted of a different rule for every month.

Scenario C14: Meet the REC of EWR 6

In order to meet the EWR for the REC, irrigators would needed to be curtailed by 50%. The restriction rule to meet EWR 7 was more complicated that applied in Zone 1 since the restriction applied varied from month to month.

10.3 SABIE-SAND SUB-CATCHMENT

10.3.1 Sabie River

Eight hypothetical scenarios were modelled in the Sabie River catchment. These scenarios entailed increasing the current irrigation requirements in steps up to 30 million m^3/annum. In addition, varying levels of water restriction were imposed on users. Table 10.5 below presents the range of additional water requirement and the restriction levels applied during the modelling of the scenarios.

Table 10.5 List of scenarios modelled for the Sabie River system

Scenario	Additional User Requirements (MCM/a)	Restriction Rule
1	*0*	*None*
2	*10*	*None*
3	*10*	*Rule 1*
4	*10*	*Rule 2*
5	*25*	*None*
6	*30*	*None*
7	*30*	*Rule 1*
8	**30**	**Rule 2**

The ecological consequences of the shaded scenarios were assessed (See Chapter 12).

Restriction Rule 1 and 2 are described in Table 10.6.

Table 10.6 Restriction rules applied in the Sabie River catchment

Natural flow at EWR 3	Rule 1	Rule 2
	Demand restricted by (% of full demand)	Demand restricted by (% of full demand)
10	*60%*	*30%*
55	*60%*	*30%*
70	*50%*	*20%*
100	*50%*	*20%*

10.3.2 Sand River

The scenarios were based on the assumption that the four abstraction weirs in the upper Sand River would be rehabilitated, thus improving the flow downstream. Scenario modelling included:

- *The amount of water that each abstraction weir diverted was reduced to 50% and 25% (i.e. an improvement of 50% and 75% of downstream flow).*
- *Curtailments of 20% were imposed on the irrigators in the Sand River system.*
- *Restriction levels (R5) were imposed upon the irrigators in the Sand River system. The restrictions were based upon the natural river flow i.e. when the level of the river drops to a certain point, a restriction is imposed upon the users. The levels of the river and the respective restrictions are tabulated in Table 10.7.*

Table 10.7 Sand River operational scenarios: River levels and restrictions imposed

Natural River Flow Level (%)	Restriction: R5 Assurance (%) [Restriction (%)]
0	40 [60]
10	40 [60]
55	50 [50]
70	50 [50]
100	100 [0]

Scenarios consisting of combinations of weir improvement, curtailment and restrictions were simulated and listed in Table 10.8.

Table 10.8 List of scenarios modelled for the Sand River system

Scenario	Improvement to downstream flow at abstraction weirs	Curtailments (%)	Restriction Level
Sc 1(Sellick Rule)	**See description below**		
Sc 2	0	0	None
Sc 3	50	0	None
Sc 4	50	0	R5
Sc 5	**50**	**20**	**None**
Sc 6	75	0	None
Sc 7	75	20	None
Sc 8	75	0	R5
Sc 9	**75**	**20**	**R5**

The ecological consequences of the shaded scenarios were assessed (See Chapter 12).

The scenarios were compared to the EWR requirements for a range of Ecological Categories (EC) and those requirements sufficiently different from the range of ECs requirements were selected to determine the ecological consequences. The scenarios selected are those highlighted in the above table.

10.3.3 Sellick Rule

In accordance with the Sabie River Catchment Operating Rules (DWAF, 2003), a proportion of the flow in the river is supposed to be allowed to flow past the abstraction points down the river in order to meet the EWR. This proportion varies from one abstraction site to the next depending on *its location within the catchment (See Table 10.9). This rule, referred to here as the Sellick rule (after Charles Sellick) only comes into effect when the river flow drops to the level indicated under "River Flow" and the capacity of these canals is based on the percentage of off-take at this flow threshold.*

Table 10.9 Proportions of water released at certain river flows in the Sand River

Canal	Capacity (m^3/s)	% Releases	River Flow (m^3/s)
Champagne	*0.127*	*35%*	*0.1954*
Dingleydale	*0.962*	*35%*	*1.48*
New Forest	*0.283*	*50%*	*0.566*
Edinburgh	*1.150*	*65%*	*3.28*

10.4 RESULTS

The results of the various scenarios modelled are summarised in terms of demand, supply and assurance of supply in the tables below.

10.4.1 Crocodile sub-catchment

Table 10.10 Results of all Crocodile Group 1 Scenarios (No EWR demand)

Crocodile Scenarios	Description	Zone 1			Zone 2			Additional Yield*#
		Demand*	Supplied*	Assurance of supply (%)	Demand*	Supplied*	Assurance of supply (%)	
C1	C^1: Zero; R^2 = 35%	400	344	72	77	67	65	
C2	C: 15%; R = 35%	340	315	90	66	62	87	
C3	C: 30%; R = 35%	280	265	97	54	53	96	
C4	C: 15%; R = 0%	340	322	97	66	62	87	
C5	C: 15%; R = 0%	280	266	98	54	53	95	
C6	C: 15%; R = 0%	220	211	98	42	42	98	
C7	Montrose Dam	400	357	76	77	67	65	88
C8	Mountain View Dam	400	338	62	77	67	68	55
C9	Both dams	400	356	86	77	67	65	129
C11	Cross-border = 0;	400	344	74	77	73	84	

** Demand, supply and additional yield units are in million m^3/annum.*
 # Additional yield is expressed as historic firm yield supplied directly out of the proposed dams.
1 Curtailment 2 Restriction

Table 10.11 Results of all Crocodile Group 2 Scenarios (EWRs met)

Crocodile Scenarios	Description	Zone 1			Zone 2		
		Demand*	Supplied*	Assurance of supply (%)	Demand	Supplied	Assurance of supply (%)
C10	Reduce releases from Kwena to meet PES at EWR 3	400	344	74%	77	72	84%
C12	Reduce releases from Kwena to meet REC at EWR 3	400	365	88%	77	72	84%
C13	Meet PES	300	251	70%	58	52	77%
C14	Meet REC	200	173	70%	39	34	75%

**Demand and supply units are in million m^3/annum*

10.4.2 Sabie-Sand sub-catchment

Table 10.12 Results of all Sabie Scenarios

Sabie Scenarios	Description	Demand*	Supplied*	Assurance of supply (%)
Sabie1	*Base*	*80.3*	*70.7*	*62*
Sabie5	*+25 - No Restriction*	*105.3*	*95.7*	*71*
Sabie6	*+30 - No Restriction*	*110.3*	*100.7*	*72*
Sabie7	*+30 - R2 Restriction*	*110.3*	*79.8*	*80*
Sabie8	*+30 - R5 Restriction*	*110.3*	*53.1*	*89*

** Demand and supply units are in MCM/a*

Table 10.13 Results of all Sand Scenarios

Sand Scenarios	Description	Demand*	Supplied*	Assurance of supply (%)
Sellick	*Sellick proportional flow rule*	*23.6*	*19.0*	*78*
Sand2	*+50 improvement, 20% Curt, R2 Restriction*	*27.4*	*21.3*	*71*
Sand3	*+75 improvement, 20% Curt, R5 Restriction*	*17.9*	*8.1*	*77*

** Demand and supply units are in MCM/a*

11 ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

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. Crocodile River and Sabie-sand system: Operation Scenarios and Consequences Report. Volume 2: Ecological and Goods and Services Consequences. Edited by Louw, MD and Koekemoer, S for Rivers for Africa. RDM Report no 26/8/3/10/12/011.

11.1 APPROACH

The purpose of this task was to predict the driver and biota responses to each operational scenario and derive the Ecological Category (EC) for the EWR site and Management Resource Unit (MRU).

All information used during the EcoClassification step (the suite of EcoClassification models set up for different ECs) (Chapter 8) and the Ecological Water Requirement (EWR) scenario step (Chapter 9) was used as baseline for this assessment.

The following steps were required to determine the ecological consequences of the flow scenarios.

- *The operational scenarios (Chapter 10; Volume 1) were modelled and a time series was provided for each scenario at each EWR site.*
- *The time series was converted to a flow duration table and both was provided to the physico chemical and geomorphology specialist.*
- *These specialists had to provide a conclusion and resulting EC of the operational scenario assessed at the EWR to the biological responses team.*
- *These specialists completed the Physico-chemical Assessment Index (PAI) and Geomorphology Assessment Index (GAI) models to predict the driver EC.*
- *The riparian vegetation specialist then assessed the response on the marginal and other riparian zones and supplied this information to the instream biota specialists. This was done prior to the instream biota assessment as riparian vegetation is a driver in terms of important habitat for the instream biota.*
- *Where required, the riparian vegetation specialist ran the Vegetation Response Assessment Index (VEGRAI) model to predict the EC for the operational scenario.*

Assessment of the economic impacts of the various scenarios essentially identified the direction of change (either positive or negative), and estimated the magnitude of the change in benefits and costs that could be experienced within the River System. The process adopted was the analysis of potential economic changes based on a valuation of the status quo, that was, the value of the Goods and Services (G&S) currently provided by the water in River systems, identifying the potential change that each of the key G&S may have undergone in each of the scenario clusters. And where required the current value of G&S was then multiplied by these factors for each scenario, to provide an indication of the potential future value of the Goods and Services. The change in value was thus measured.

11.2 OPERATIONAL SCENARIOS

11.2.1 Crocodile sub-system

The results of the preliminary screening of scenarios are provided in Table 11.1. Red shading indicates that the scenario did not impact on the site compared to present operation. Green indicates that the scenario was assessed and grey indicates that the scenario was assessed and is represented by the corresponding 'green' scenario.

Table 11.1 Scenarios evaluated at EWR 3 – EWR5 in the Crocodile sub-system

Site	Sc C3	Sc C4	Sc C6	Sc C7	Sc C8	Sc C9	Sc C10	Sc C11	Sc C12
EWR 3									
EWR 4				7 = 9		7 = 9	10 = 12		10 = 12
EWR 5	3 = 6 = 11		3 = 6 = 11	7 = 9		7 = 9	10 = 12	3 = 6 = 11	10 = 12
EWR 6				7 = 9		7 = 9	10 = 11 = 12	10 = 11 = 12	10 = 11 = 12
EWR 7					8 = 9	8 = 9			

11.2.2 Sabie-Sand sub-system

Eight hypothetical scenarios were modelled in the Sabie River catchment. The flows generated for each of the eight scenarios were compared to the EWR requirements for a range of Ecological Categories (EC) and those sufficiently different from the range of ECs were selected to determine ecological consequences. These scenarios are Scenarios 5 – 8.

Four abstraction weirs (viz. Champagne, Dingleydale, New Forest, and Edinburgh) in the Upper Sand River exist but are not operating correctly. All the water (i.e. 100%) is diverted and only the high flow spills continue downstream. Scenario simulation was based on the assumption that the four abstraction weirs in the upper Sand River would be rehabilitated, thus improving the flow downstream and consisted of combinations of weir improvement, curtailment and restrictions. The scenarios were compared to the EWR requirements for a range of Ecological Categories (EC) and those sufficiently different from the range of ECs were selected to determine ecological consequences and included Sc 1 (Sellick rule), Sc 5 and Sc 9.

11.3 RESULTS: CROCODILE SUB-CATCHMENT

Results are summarised according to whether the scenarios meet the REC or not, and if not, to what degree. Colour coding and symbols should be interpreted as follows:

- *REC EcoStatus or REC instream IS met.*

X REC EcoStatus or REC instream is NOT met.

Light green with black ✓:	*Meets REC EcoStatus including all components.*
Light green with red ✓:	*Meets REC instream, but not riparian vegetation (this is usually because the vegetation REC cannot be met due to non-flow related problems).*
Dark Green with black ✓:	*Meets the REC EcoStatus, but not all the components.*
Turquoise with X:	*The scenario is an improvement of the PES but does not meet any of the REC versions as in green above.*
Orange with X:	*The scenario does not meet REC requirements but meets the PES.*
Purple with X:	*The scenario results in an EC below the PES, but still above a D EC.*
Red with X:	*The results are below an E EC.*

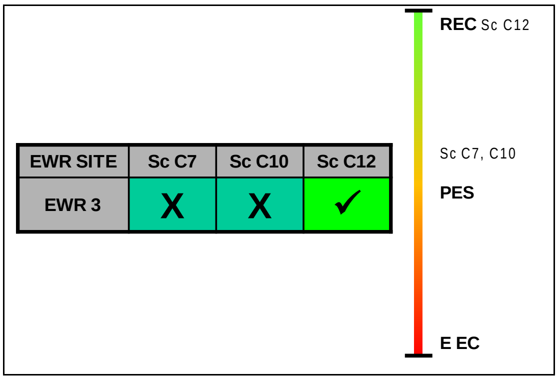
Table 11.2 provides the consequences at each of the EWR sites on the Ecological Category and the changes from the PES are shown. This is followed by a summary comparison of the consequences.

Table 11.2 The consequences of the operational scenarios at each EWR site in the Crocodile sub-catchment

Ecological consequences of the operational flow scenarios	Degree to which each scenario meets the REC

EWR 3 Poplar Creek (Crocodile River)

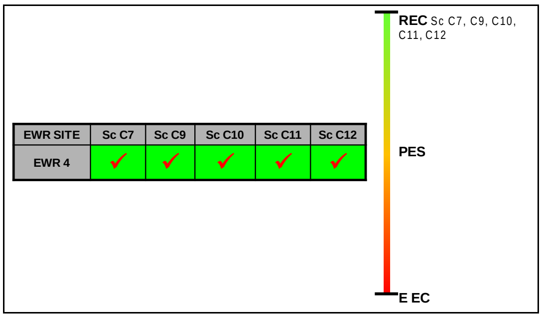
Driver Components	PES	REC	Sc C7	Sc C10	Sc C12
WATER QUALITY	C	B/C	C	C	C
GEOMORPHOLOGY	C	C	C/D	C	C
Response Components	**PES**	**REC**	**Sc C7**	**Sc C10**	**Sc C12**
FISH	B	B	A/B	A/B	A/B
MACRO INVERTEBRATES	C	B	C	C	B
INSTREAM	B/C	B	B	B	A/B
RIPARIAN VEGETATION	C	B	B/C	B/C	B/C
ECOSTATUS	B/C	B	B/C	B/C	B



Scenario C7 and C10 resulted in a B/C EcoStatus which is an improvement of the PES for the fish and instream component. Although Sc C10 and C12 were very similar the improvement in dry season flows under Sc C12 resulted in the REC requirements being met.

EWR 4 KaNyamazane (Crocodile River)

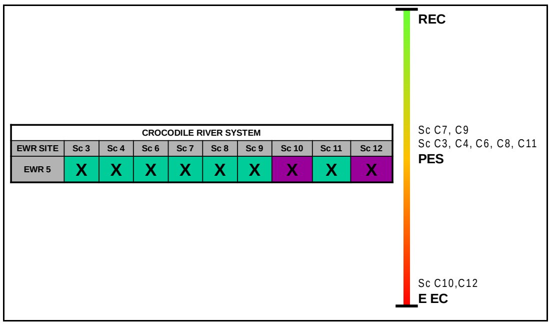
Driver Components	PES	REC	Sc C7, C9	Sc C10, C12	Sc C11
WATER QUALITY	C	B	C	C	C
GEOMORPHOLOGY	B/C	B	C	C	B/C
Response Components	**PES**	**REC**	**Sc C7, C9**	**Sc C10, C12**	**Sc C11**
FISH	B	B	A/B	B	B
MACRO INVERTEBRATES	C	B	B/C	B	B
INSTREAM	B/C	B	B	B	B
RIPARIAN VEGETATION	C	B	C	C	C
ECOSTATUS	C	B	B (C)*	B (B/C)*	B (C)*



**EcoStatus is representative of the instream EC. The EC in brackets refer to what the calculated EcoStatus would be if riparian vegetation was considered. However non-flow related impacts such as the presence of aliens prevent the riparian vegetation to respond in the same manner as the biota and the instream EC represents a more realistic EcoStatus. All the scenarios meet the REC requirements.*

EWR 5 Malelane (Crocodile River)

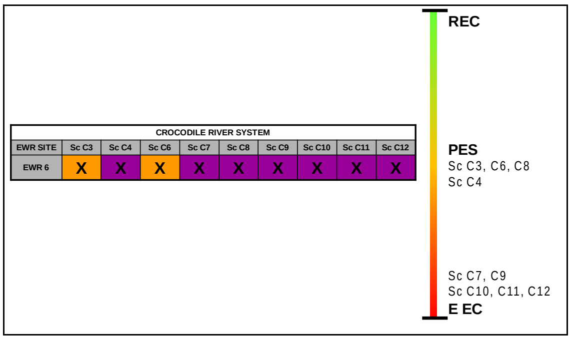
Driver Components	PES	REC	Sc C3, C6, C11	Sc C4, C8	Sc C7, C9	Sc C10, C12
HYDROLOGY	C	B				
WATER QUALITY	C	B	C	C	C	D
GEOMORPHOLOGY	C/D	C	C	C	D	D
Response Components	**PES**	**REC**	**Sc C3, C6, C11**	**Sc C4, C8**	**Sc C7, C9**	**Sc C10, C12**
FISH	C	B	C	C	B/C	D
MACRO INVERTEBRATES	C	B	C	C	C	D/E
INSTREAM	C	B	C	C	B/C	D
RIPARIAN VEGETATION	C	B	B/C	B/C	C	D
ECOSTATUS	C	B	C	C	C	D



Scenario C10 and C12 impacts severely on EWR 5 and results in the deterioration of all the components notably macroinvertebrates with a D EcoStatus. The other scenarios do not meet the REC requirements but is a slight improvement in the PES. Sc C7 and C9 are marginally better than the other scenarios as the fish and instream both improve.

EWR 6 Nkongoma (Crocodile River)

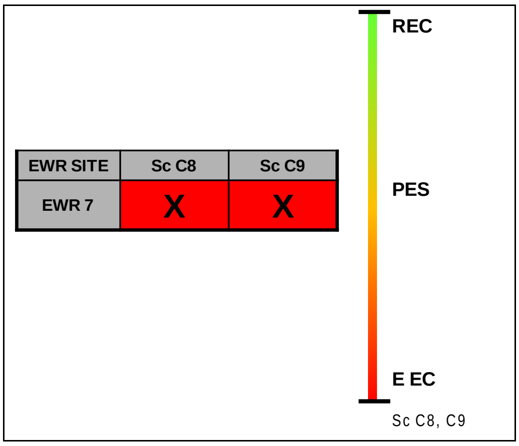
Driver Components	PES	REC	Sc C3	Sc C4	Sc C6	Sc C7, C9	Sc C8	Sc C10, C11, C12
WATER QUALITY	C	B	C	D	C	C	C	D/E
GEOMORPHOLOGY	C	C	C	C	C	C/D	C/D	C
Response Components	**PES**	**REC**	**Sc C3**	**Sc C4**	**Sc C6**	**Sc C7, C9**	**Sc C8**	**Sc C10, C11, C12**
FISH	C	B	D	D/E	D	D	C	D
MACRO INVERTEBRATES	C	B	C	C	C	D	C	D/E
INSTREAM	C	B	C	D	C	D	C	D
RIPARIAN VEGETATION	C	B	B/C	B/C	B	C/D	C/D	D
ECOSTATUS	C	B	C	C	C	D	C	D



Scenario C3, C4, C6 and C8 all meet the PES EcoStatus to varying degrees. Scenario C3 and C6 impact negatively on fish, but vegetation improves. Scenario C4 meets the PES EcoStatus; the fish component however deteriorates to an unacceptable level and therefore the overall PES requirement is not met and is ranked below the PES in Figure 8-7. Scenario C8 impacts negatively on geomorphology and riparian vegetation while the biotic components are the same as for the PES and was ranked below the PES in Figure 8-7. Scenario C7 and C9 impact on all the biotic components and therefore do not meet the requirements of the PES. Sc C10, C11 and C12 do not meet the requirements of the PES and have the most severe impact especially on water quality and fish with all the other components except geomorphology degrading from present state.

EWR 7 Kaap (Kaap River)

Driver Components	PES	REC	Sc C8, C9
WATER QUALITY	B	B	E
GEOMORPHOLOGY	B	B	D
Response Components	**PES**	**REC**	**Sc C8, C9**
FISH	C	B	E
MACRO INVERTEBRATES	B	B	F
INSTREAM	B/C	B	E/F
RIPARIAN VEGETATION	C/D	B/C	E/F
ECOSTATUS	C	B	E/F



It is evident that Sc C8 and C9 have devastating impacts on the site due to the long duration of zero flows. The deterioration in water quality and overall loss of habitat results in an EcoStatus of an E/F.

11.3.1 Crocodile sub-system: Curtailment and restriction irrigation scenarios

An overall assessment was undertaken for the various sub-systems for scenarios of the same type. The table below provides a summary of the results at each EWR site. The overall evaluation usually reflects the results at the site which is least likely to meet the REC. The reasoning is that even if you meet the REC at other EWR sites, the scenario fails within a system context if it does not meet the REC at one of the sites.

Figure 11-1 provides the ranking of operational scenarios per EWR site as well as a summarised ranking for the Crocodile River system as a whole in terms of a traffic diagram.

Within a system context none of the scenarios met the REC at any of the EWR sites. The PES was maintained under Sc C3 and C6. Scenario C4 met the PES EcoStatus; the fish component however deteriorated to an unacceptable level and therefore the overall PES requirement was not met and was ranked below the PES in the Figure 11-1 below. Scenario C10 – C12 resulted in a deterioration of the PES EcoStatus. The overall assessment is provided as the traffic diagram on the right.

Table 11.3 Summary of the consequences of the operational scenarios at each EWR site in the Crocodile sub-system

EWR SITE	SC 3	SC 4	SC 6	SC 10	SC 11	SC 12
EWR 5	X	X	X	X	X	X
EWR 6	X	X	X	X	X	X
EWR 4				✓	✓	✓
EWR 3				X		✓
OVERALL	X	X	X	X	X	X

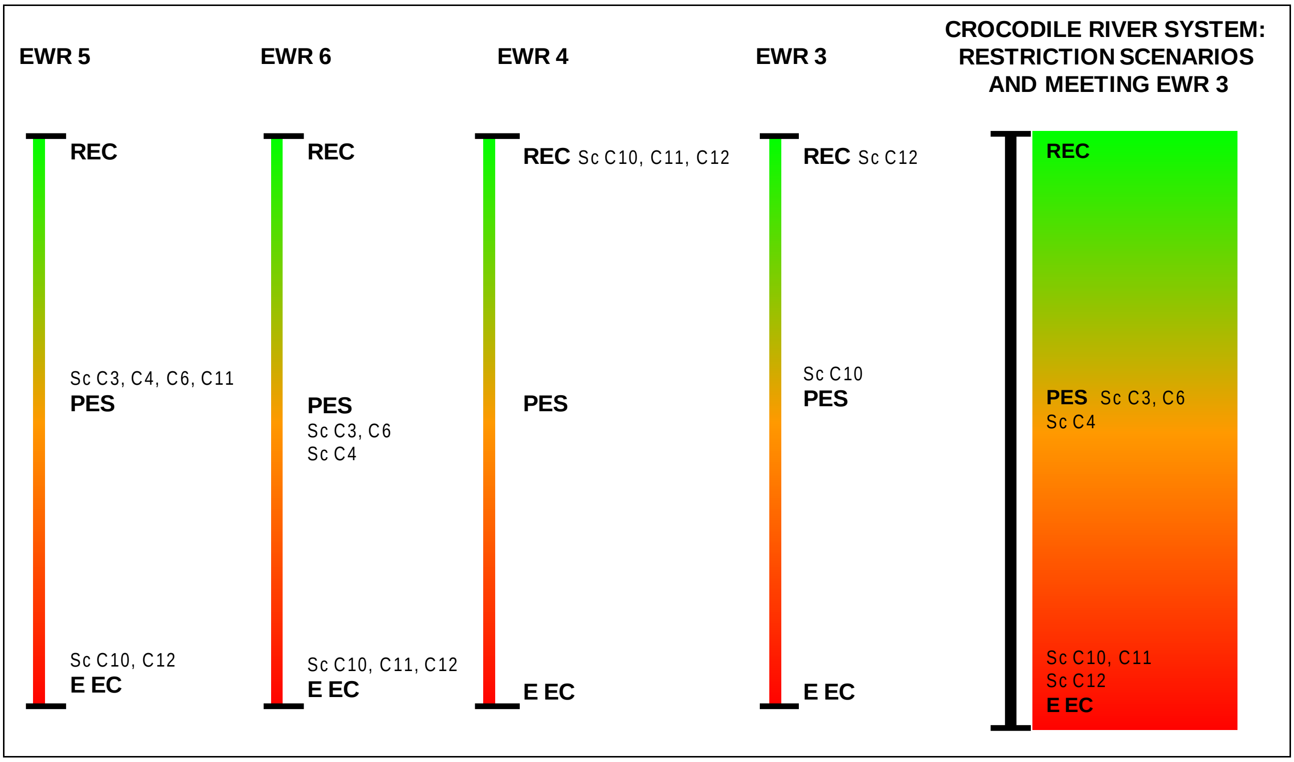


Figure 11.1 Ranking of operational scenarios per EWR site and a summarised ranking in terms of a traffic diagram

11.3.2 Crocodile Sub-system: Development (new dam) scenarios

These scenarios were not evaluated in detail as each dam and combination would require a whole range of different operating rules for useful comparison. The results are provided below in Table 11.4.

Table 11.4 Summary of the consequences of the future development (new dam) scenarios at each EWR site

EWR SITE	Sc C7	Sc C8	Sc C9
EWR 5	X	X	X
EWR 6	X	X	X
EWR 4	✓		✓
EWR 3	X		X
OVERALL	X	X	X
EWR 7		X	X

Scenario C7 – C9 did not maintain the PES at EWR 6. Scenario C8 maintained the PES EcoStatus but did not maintain the riparian vegetation and geomorphology PES. Scenario C8 was therefore ranked lower than the PES (Figure 11-2) at EWR 6. Looking at EWR 7 in isolation, the scenarios with Mountain View Dam and the no releases downstream of the dam resulted in an unacceptable condition. The overall assessment is provided as the traffic diagram on the right.

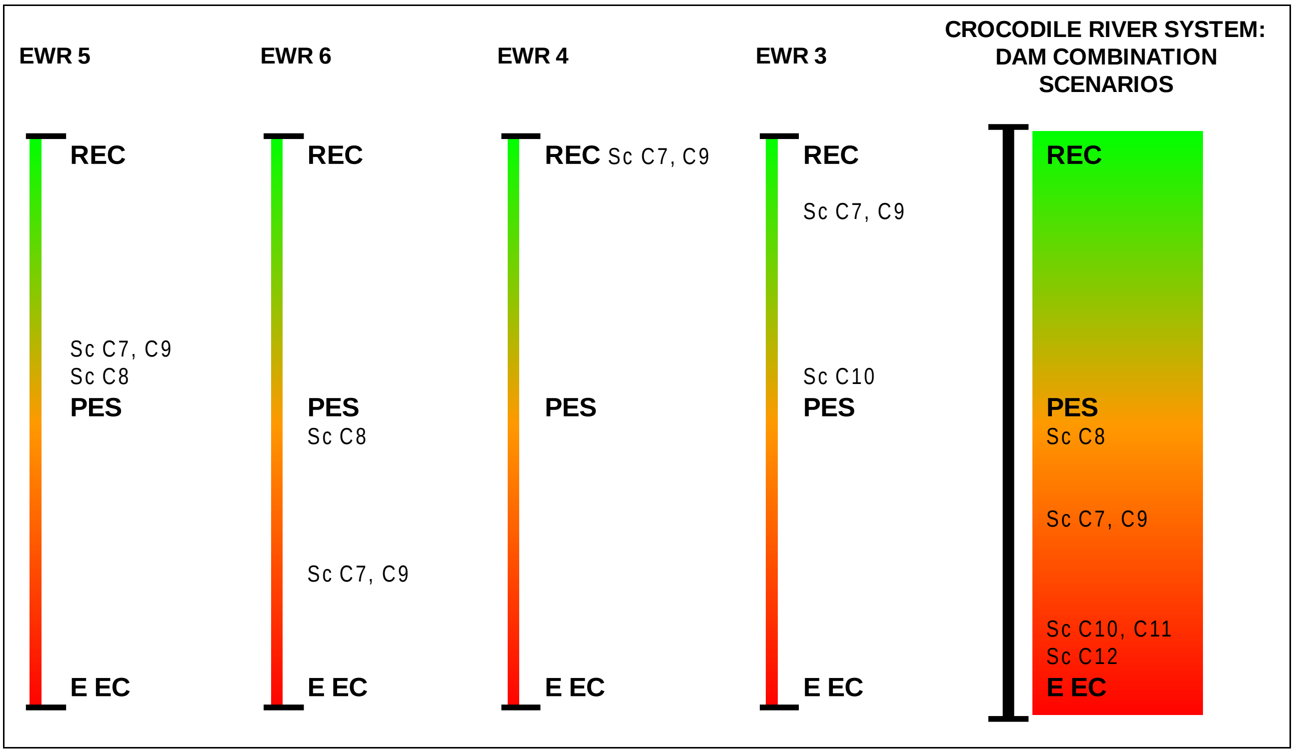


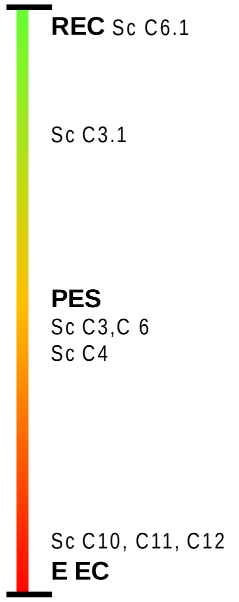
Figure 11.2 Ranking of future (dam) development scenarios

11.3.3 Crocodile River: Additional scenarios evaluated at EWR 6

Two optimised scenarios were developed as a modification of Sc 3 and Sc 6. For both of them the additional yield stored through the restrictions on agriculture was used to supply the Reserve. These scenarios are referred to as Sc C3.1 and Sc C6.1. Both were evaluated at EWR 6 as the key site. Sc C6.1 achieved the REC and Sc C3.1 improved the PES. The comparison is provided in Table 11.5 below.

Table 11.5 Summary of ecological consequences of Sc C3.1 and Sc C6.1 at EWR 6

Driver Components	PES	REC	Sc C3	Sc C4	Sc C6	Sc C10-C12	Sc C3.1	Sc C6.1
HYDROLOGY	D	B						B
WATER QUALITY	C	B	C	D	C	D/E	C	B
GEOMORPHOLOGY	C	C	C	C	C	C	C	C
Response Components	**PES**	**REC**	**Sc C3**	**Sc C4**	**Sc C6**	**Sc C10-C12**	**Sc C3.1**	**Sc C6.1**
FISH	C	B	D	D/E	D	D	B/C	B
MACRO INVERTEBRATES	C	B	C	C	C	D/E	C	B
INSTREAM	C	B	C	D	C	D	B/C	B
RIPARIAN VEGETATION	C	B	B/C	B/C	B	D	B/C	B
ECOSTATUS	C	B	C	C	C	D	B/C	B



CROCODILE RIVER SYSTEM								
EWR SITE	Sc C3	Sc C4	Sc C6	Sc C10	Sc C11	Sc C12	Sc C3.1	Sc C6.1
EWR 6	X	X	X	X	X	X	X	✓

11.4 RESULTS: SABIE-SAND SUB-CATCHMENT

Results are summarised according to whether the scenarios meet the REC or not, and if not, to what degree. Colour coding and symbols used in the interpretation of results are provided in Section 11.3.

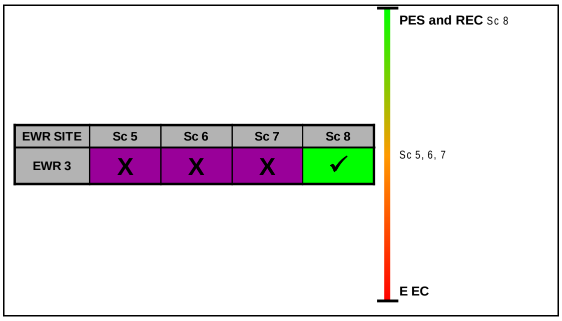
Table 11.6 provides the consequences at each of the EWR sites on the Ecological Category and the changes from the PES are shown. This is followed by a summary comparison of the consequences.

Table 11.6 The consequences of the operational scenarios at each EWR site in the Sabie-Sand sub-catchment

Ecological consequences of the operational flow scenarios	Degree to which each scenario meets the REC

EWR 3 Kidney (Sabie River)

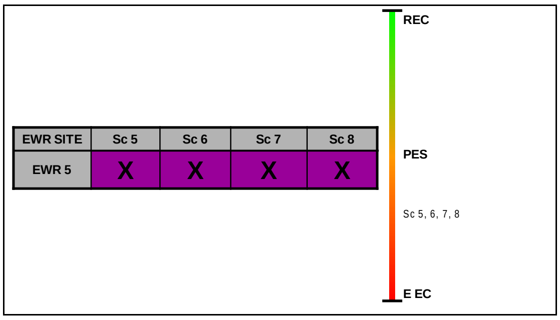
Driver Components	PES & REC	Sc 5	Sc 6	Sc 7	Sc 8
WATER QUALITY	B	B	C	B	B
GEOMORPHOLOGY	B	B/C	B/C	B	B
Response Components	**PES & REC**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
FISH	B	B	B/C	B	B
MACRO INVERTEBRATES	B	C	C	C	B
INSTREAM	B	B/C	B/C	B/C	B
RIPARIAN VEGETATION	A/B	B	B	A/B	A/B
ECOSTATUS	A/B	B	B	B	A/B



Only Sc 8 achieves the ecological requirements of the site with an A/B EcoStatus. The rest of the scenarios all result in a B EcoStatus which is lower than the PES and REC requirements.

EWR 5 Marite (Marite River)

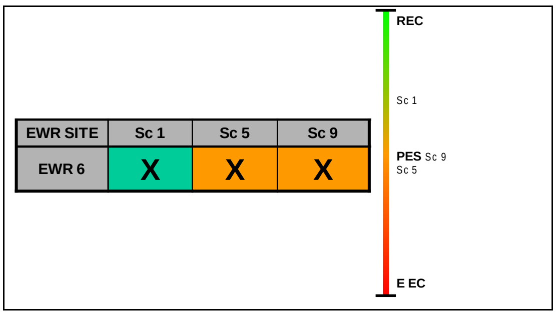
Driver Components	PES	REC	Sc 5-8
WATER QUALITY	B	B	B
GEOMORPHOLOGY	C	C	D
Response Components	**PES**	**REC**	**Sc 5-8**
FISH	B/C	B	C
MACRO INVERTEBRATES	B/C	B	C
INSTREAM	B/C	B	C
RIPARIAN VEGETATION	B/C	B	C/D
ECOSTATUS	B/C	B	C



Scenario 5 – 8 results in a C EcoStatus which is lower than the PES and REC requirements of EWR 5.

EWR 6 Mutlumuvi (Mutlumuvi River)

Driver Components	PES	REC	Sc 1	Sc 5	Sc 9
WATER QUALITY	B/C	B	B/C	C	B/C
GEOMORPHOLOGY	C	C	C	C	C
Response Components	**PES**	**REC**	**Sc 1**	**Sc 5**	**Sc 9**
FISH	C	B	B/C	C	C
MACRO INVERTEBRATES	B/C	B	B	C	B/C
INSTREAM	C	B	B/C	C	C
RIPARIAN VEGETATION	C	B	C	C	C
ECOSTATUS	C	B	B/C	C	C



No scenario achieved the ecological requirements of the REC at this site. Sc 1 is an improvement of the PES (B/C EcoStatus). Scenario 9 is similar to the PES with all the components in the same EC as under the PES and fish and macroinvertebrates improving slightly within the respective PES ECs. Scenario 5 also results in a C EcoStatus, however macroinvertebrates are impacted under this scenario and water quality deteriorates. The fish deteriorate slightly within the PES EC.

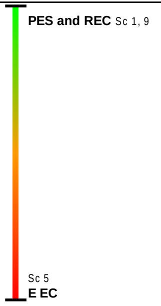
EWR 7 Tlulandziteka (Tlulandziteka River)

Ecological consequences of the operational flow scenarios

Driver Components	PES & REC	Sc 1	Sc 5	Sc 9
WATER QUALITY	C	B	D	B
GEOMORPHOLOGY	C/D	C	C/D	C
Response Components	**PES &REC**	**Sc 1**	**Sc 5**	**Sc 9**
FISH	C	B	D	B
MACRO INVERTEBRATES	B/C	B	D	B
INSTREAM	C	B	D	B
RIPARIAN VEGETATION	C	B	D	B
ECOSTATUS	C	B	D	B

Degree to which each scenario meets the REC

EWR SITE	Sc 1	Sc 5	Sc 9
EWR 7	✓	X	✓



Scenario 1 and 9 results in a B EcoStatus which meet the PES and REC requirements as these scenarios are an improvement of the PES/REC. Scenario 5 is an unacceptable scenario as the components have all deteriorated to an EC below the PES. It must be noted that due to the extreme uncertainty regarding the hydrology and operation at this site, the confidence in these evaluations are low.

EWR 8 Lower Sand (Sand River)

Driver Components	PES	REC	Sc 1	Sc 5	Sc 9
WATER QUALITY	B	B	A/B	A/B	A/B
GEOMORPHOLOGY	C	C	C	C	C
Response Components	**PES**	**REC**	**Sc 1**	**Sc 5**	**Sc 9**
FISH	B	B	B	B	B
MACRO INVERTEBRATES	C	B	B	B	B
INSTREAM	B/C	B	B	B	B
RIPARIAN VEGETATION	B	B	B	B	B
ECOSTATUS	B	B	B	B	B

EWR SITE	Sc 1	Sc 5	Sc 9
EWR 8	✓	✓	✓

Scenarios 1, 5 and 9 all improve the macroinvertebrates to a B REC and the REC EcoStatus has therefore been achieved. Scenario 5 is ranked slightly below the other scenarios due to higher stress values. The risk of the B REC failing is therefore higher than Sc 1 en 9.

11.4.1 Sabie River: Ecological consequences of operational scenarios (Sc 5 – 9)

Table 11.7 provides a summary of the ecological consequences at each EWR site in the Sabie River system. An overall assessment was undertaken to compare the scenarios that consist of different levels of irrigation restrictions to meet increasing current irrigation requirements that represent increased flows at EWR 5 and decreased flows at EWR 3.

Table 11.7 Summary of the consequences of the operational scenarios (Sc 5 - 8) at EWR 3 and 5 in the Sabie River system

SABIE RIVER SYSTEM				
EWR SITE	Sc 5	Sc 6	Sc 7	Sc 8
EWR 3	X	X	X	✓
EWR 5	X	X	X	X
OVERALL	X	X	X	X

Scenario 8 met the PES/REC at EWR 3 in KNP but not at EWR 5 (Marite). Therefore it was significantly better than the other scenarios which were lower than the PES at both sites. The results provided in Table 11.7 for the Sabie River were ranked and illustrated in Figure 11-4 in terms of a traffic diagram. EWR 3 was the key site in the system.

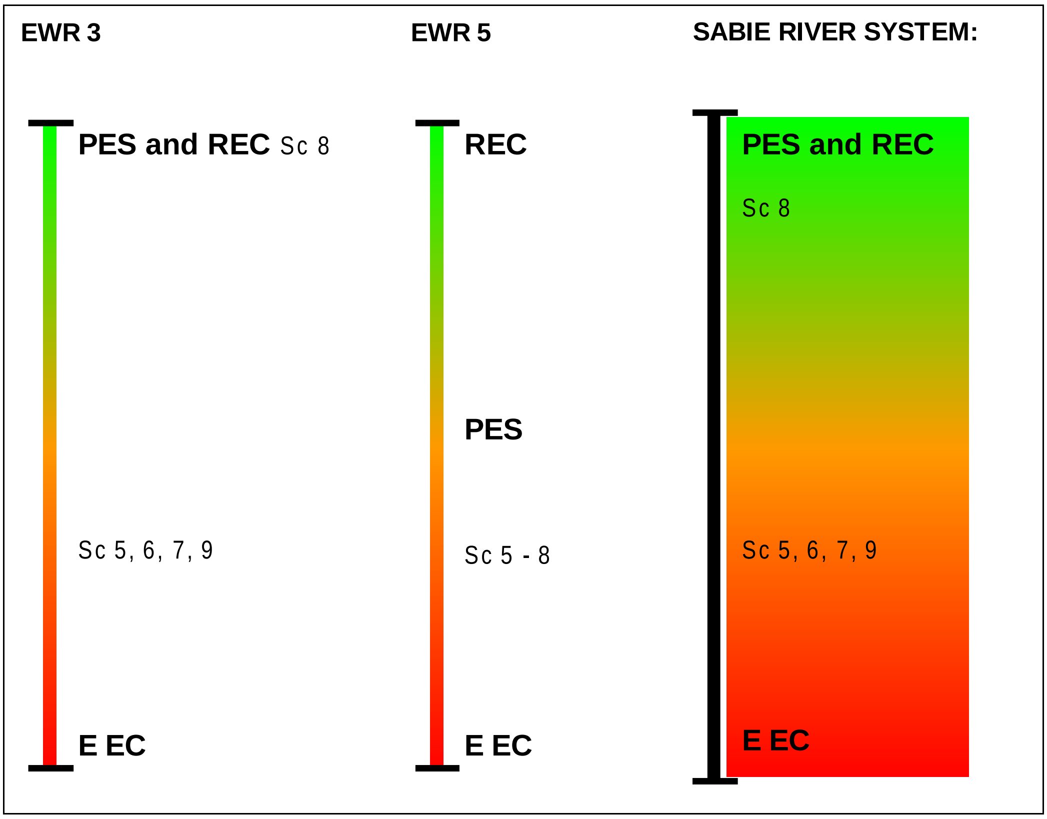


Figure 11.3 Ranking of operational scenarios per EWR site and a summarised ranking in terms of a traffic diagram

11.4.2 Sand River: Ecological consequences of operational scenarios (Sc 1, 5 and 9)

Table 11.8 provides a summary of the ecological consequences at each EWR site in the Sand River system.

Table 11.8 Summary of the consequences of the operational scenarios (Sc 1, 5 and 9) at each EWR site

SAND RIVER SYSTEM			
	Sc 1	Sc 5	Sc 9
EWR 6	X	X	X
EWR 7	✓	X	✓
EWR 8	✓	✓	✓
OVERALL	X	X	X

Scenario 1 was an improvement of the PES at EWR 6 and met the REC at EWR 7 and 8. It was a better scenario than Sc 9 which only met the PES at EWR 6 and did not improve it as was the case with Sc 1. Scenario 5 was the worst scenario as it did not meet the PES/REC at EWR 7.

Figure 11-5 provides the ranking of operational scenarios per EWR site as well as a summarised ranking for the Sand River system as a whole in terms of a traffic diagram.

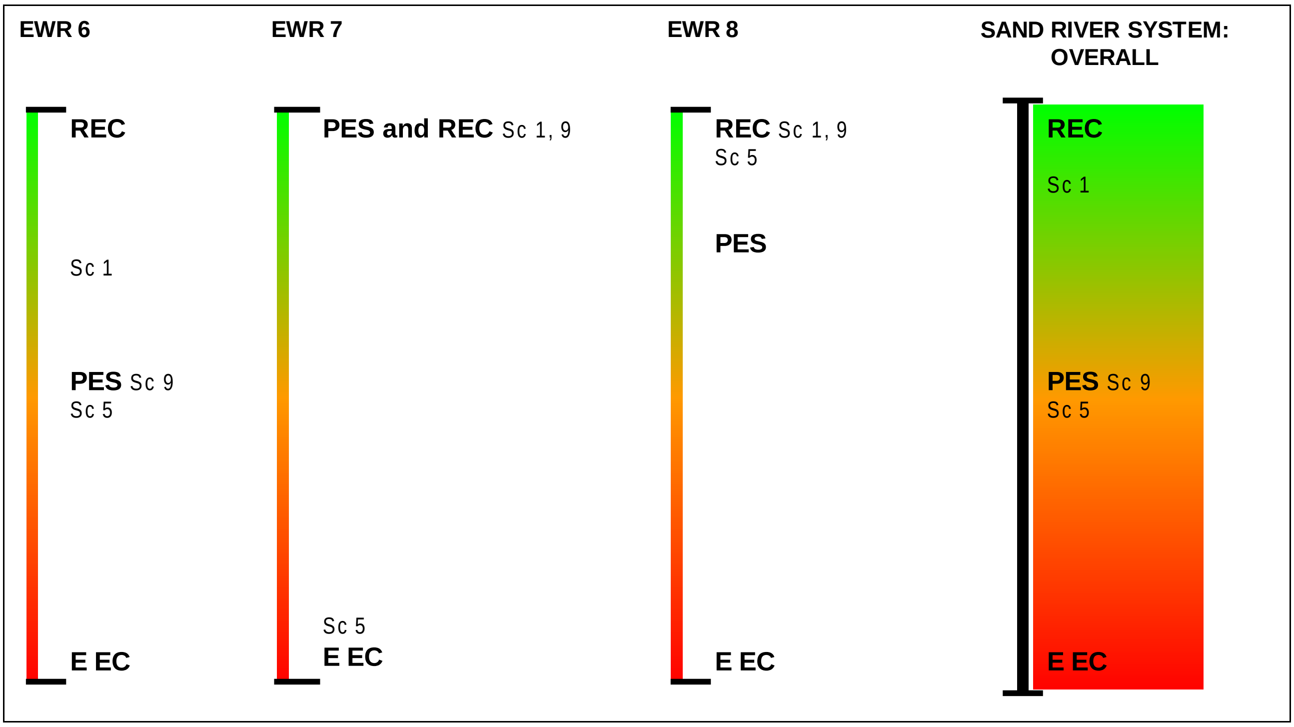


Figure 11.4 Ranking of operational scenarios per EWR site and a summarised ranking in terms of a traffic diagram

11.5 GOODS AND SERVICES CONSEQUENCES OF OPERATIONAL SCENARIOS

Author G Huggins (Nomad Consulting)

11.5.1 Approach

The method that was employed was essentially scenario-based. Assessment of the economic impacts of the various scenarios identified the direction of change (either positive or negative), and estimated the magnitude of the change in benefits and costs that may be experienced within the River systems. The process adopted was as follows:

- *The analysis of potential economic changes was based on a valuation of the status quo, that is, the value of the Goods and Services (G&S) currently provided by the water in the Inkomati River system.*
- *The biophysical specialists then identified the potential change that each of the key G&S may undergo in each of the scenario clusters. The potential change was noted as a factor and used in later calculations. For example, no change = 1, a 50% increase = 1.5, and a 20% decrease = 0.8.*
- *Where required the current value of G&S was then multiplied by these factors for each scenario, to provide an indication of the potential future value of the Goods and Services.*

The change in value was thus measured. The following calculation, as an example, would then be used:

- *Future value (FV) of fishing = Change Factor x The Current Value of Fishing.*
- *FV = 0.9 x rate.*
- *FV = rate per annum.*
- *This equates to a reduction or increase a specified rate annum.*

From detailed work at the EWR sites the potential impacts of scenarios on the G&S were estimated by the specialists. Only scenarios relevant to sites were evaluated and only G&S deemed to be relevant were considered. The G&S that were deemed to be important in at least parts of the catchment are set out in Table 11.9.

Table 11.9 Good and services identified as relevant to the catchment

Category	Species	Common Name
Subsistence fishing - seine/scoop/cast/shade netting and fish traps		*Barbs, minnows, juveniles, small tilapias*
Subsistence fishing - gill netting		*Yellowfish, labeos, catfish, tilapias*
Subsistence fishing - angling		*Yellowfish, labeos, catfish, tilapias*
Sedges	*Cyperus spp.*	*Sedges*
Reeds	*Phragmites mauritianus*	*Reeds*
Grazing	*Panicum maximum/duestum*	*Guinea grass/Broad-leaved Panicum*
	Cynodon dactylon	*Couch grass*
Trees-other flora	*Eucalyptus camaldulensis*	*Blue Gum (firewood)*
	Rhus lancea	*Karee (firewood)*
	Rhus pyroides	*(firewood)*
	Ziziphus mucronata	*(fruits and firewood)*
Waste assimilation		
Waste dilution		
Wetland Cultivation		
Recreational Fishing'		*Bass, Kurper*
Ritual Use		
Flood Attenuation		
Bank Protection		
Groundwater recharge		
Ecotourism - Aesthetic		
Ecotourism - Game Watering		
Hunting/poaching		
Sand Winning		
Disservices as costs		
Pathogens treatments		
Pathogens productivity loss		
Toxin		
Water consumption by exotic plants		

For analytical purposes, the Crocodile sub-catchment was divided into seven economic zones (EZ) and the Sabie-Sand area was sub-divided into three economic zones (refer to Chapter 12) for more detail. A summary of scenarios considered by economic zone is set out in Table 11.10 below.

Table 11.10 Economic Zones and associated scenarios analysed

Economic Zone	Scenarios	Applicable EWR Site
Crocodile-East sub-catchment		
Upper Croc	*None*	*EWR 1, 2*
Elands	*None*	
Lower Kwena	*3, 7, 10, 12*	*EWR 3*
Middle Croc	*7, 9, 10, 11, 12*	*EWR 4*
Kaap	*8,9*	*EWR 7*
White River	*None*	
Lower Croc	*3, 4, 6, 7, 8, 9, 10,12*	*EWR 5, 6*
Sabie-Sand sub-catchment		
Sabie	*None*	*EWR 1, 2, 4*
Maritsane/Inyaka	*5*	*EWR 3, 5*
Sand	*1, 5, 9*	*EWR 6 - 8*

11.5.2 Consequences

Lower Kwena Economic Zone

The utilisation of G&S was ranked as low. There were few communities that were dependent on the basket of G&S that were available as the formal market dominated this portion of the catchment. All scenarios had a positive impact on the availability of G&S. Scenario 3 while still beneficial was deemed to be least positive. The remaining scenarios (7, 10 and 12) were more beneficial but not significantly so. Results are provided in Table 11.11[3] below.

[3] *Scores are based on a 0 – 2 scale where 0 = complete collapse of the system and 2 = doubling of the availability of the goods or delivery of the service. The potential change was noted as a factor and used in later calculations. For example, no change = 1, a 50% increase = 1.5, and a 20% decrease = 0.8.*

Table 11.11 Assessment of G&S change under scenarios for Lower Kwena EZ

G&S as benefits								
Resources	**Common name**	**Scientific**	**Importance**	**Utilisation**	**Sc 3**	**Sc 7**	**Sc 10**	**Sc 12**
Fish	*Tilapias and barbs*		*Moderate*	*Low*	*1.1*	*1.1*	*1.1*	*1.1*
Sedges	*Sedge*	*Cyprus spp.*	*Important*	*Low*	*1*	*1.2*	*1.1*	*1.1*
Reeds	*Reeds*	*Phragmites*	*Important*	*Low*	*1*	*1.2*	*1.1*	*1.1*
Grazing		*P. maximum/duestum*	*Moderate*	*Low*	*1*	*1.1*	*1.2*	*1.2*
		Cynodon dactylon	*Moderate*	*Low*	*1*	*1.1*	*1.1*	*1.1*
Trees	*Blue Gum*	*E. camaldulensis*	*Important*	*Low*	*1*	*1.1*	*1.2*	*1.2*
	Indigenous trees		*Important*	*Low*	*1*	*1.1*	*1.2*	*1.2*
	Wattle		*Important*	*Low*	*1*	*1.1*	*1.2*	*1.2*
Hunting/poaching			*Marginal*	*Low*	*1*	*1*	*1*	*1*
Sand Winning			*Moderate*	*Low*	*1*	*1.1*	*0.9*	*0.9*
Waste assimilation			*Marginal*	*Low*	*1*	*1*	*1*	*1*
Waste dilution			*Marginal*	*Low*	*1*	*1*	*1*	*1*
Cultivated floodplains			*Moderate*	*Low*	*1*	*1.1*	*0.9*	*0.9*
Wetland cultivation			*Moderate*	*Low*	*1*	*1.1*	*0.9*	*0.9*
Recreational fishing'			*Marginal*	*Low*	*1*	*1*	*1*	*1*
Recreational river use			*Moderate*	*Low*	*1*	*1*	*1*	*1*
Flood attenuation			*Moderate*	*Low*	*1*	*1*	*1.1*	*1.1*
Bank protection			*Important*	*Low*	*1*	*1.1*	*1.1*	*1.1*
Stream flow regulation			*Moderate*	*Low*	*1*	*1.1*	*1.1*	*1.1*
Groundwater recharge			*Moderate*	*Low*	*1*	*1*	*1*	*1*
Disservices as costs								
Pathogens treatments			*Very Low*	*Low*	*1*	*1*	*1*	*1*
Pathogens productivity loss			*Very Low*	*Low*	*1*	*1*	*1*	*1*

Middle Crocodile Economic Zone

The utilisation of G&S was ranked as high to medium high. A number of communities were dependent on the basket of G&S that were available. Overall all scenarios had a positive impact on the availability of G&S. Scenario 10 was deemed to be overall most positive followed by Sc 11 and Sc 12. Scenario 7 and 9 were deemed to bring about somewhat less positive results on availability of G&S. Results are provided in Table 11.12 below.

Table 11.12 Assessment of G&S change under scenarios for Middle Crocodile EZ

G&S as benefits									
Resources	**Common name**	**Scientific name**	**Importance**	**Utilisation**	**Sc 7**	**Sc 9**	**Sc 10**	**Sc 11**	**Sc 12**
Fish	*Barbs and labeos*		*Important*	*High*					*1.1*
	Mozambique tilapia	*Oreochromis mossambicus*	*Important*	*High*					*1*
	Large scale yellowfish	*Labeobarbus marequensis*	*Very Important*	*High*					*1*
	Catfish	*Clarias gariepinus*	*Important*	*High*					*1*
Sedges	*Sedge*	*Cyprus spp.*	*Marginal*	*High*	*1.2*	*1.2*	*1*	*1.2*	*1.2*
Reeds	*Reeds*	*Phragmites*	*Moderate*	*High*	*1.2*	*1.2*	*1*	*1.2*	*1*
Grazing	*Grasses*	*P. maximum/ duestum*	*Moderate*	*High*	*1*	*1*	*1.2*	*1.2*	*1.2*
		C. dactylon	*Moderate*	*High*	*1.2*	*1.2*	*1.3*	*1.3*	*1.3*
Trees	*Syringa*		*Marginal*	*Medium*	*0.8*	*0.8*	*1.1*	*1.1*	*1.1*

G&S as benefits									
Resources	**Common name**	**Scientific name**	**Importance**	**Utilisation**	**Sc 7**	**Sc 9**	**Sc 10**	**Sc 11**	**Sc 12**
	Blue Gum	*E. camaldulensis*	*Marginal*	*Low*	*0.8*	*0.8*	*1.1*	*1.1*	*1.1*
	Indigenous trees		*Important*	*High*	*0.8*	*0.8*	*1.1*	*1.1*	*1.1*
	Wattle		*Marginal*	*Medium*	*0.8*	*0.8*	*1.2*	*1.2*	*1.2*
Sand winning			*Moderate*	*Medium-High*	*1*	*1*	*1*	*1*	*1*
Waste assimilation			*Important*	*High*	*0.9*	*0.9*	*1*	*0.8*	*0.8*
Waste dilution			*Important*	*High*	*0.9*	*0.9*	*1*	*0.8*	*0.8*
Cultivated floodplains			*Marginal*	*Low*	*1.2*	*1.2*	*0.9*	*0.95*	*0.9*
Wetland cultivation	*Wetland destruction*		*Moderate*	*Medium*	*1*	*1*	*0.9*	*1*	*0.9*
Recreational fishing'	*Yellowfish*		*Marginal*	*Medium*					*1*
Flood attenuation			*Moderate*	*Low*	*1*	*1*	*1*	*1*	*1*
Bank protection			*Moderate*	*Low*	*1*	*1*	*1*	*1.1*	*1*
Stream flow regulation			*Marginal*	*Low*	*1*	*1*	*1*	*1*	*1*
Groundwater recharge			*Marginal*	*Low*	*0.9*	*0.9*	*0.9*	*1.1*	*0.9*
Disservices as costs									
Bilharzia productivity loss			*Marginal*	*Medium*	*1*	*1*	*1*	*1.2*	*1.2*
Pathogens treatments			*Marginal*	*Low*	*1*	*1*	*1*	*1.2*	*1.2*

Kaap Economic Zone

The utilisation of G&S was ranked as low although there were pockets of G&S dependence. The only scenarios evaluated were 8 and 9. These had a dramatic negative impact on the G&S with collapses in fish stocks and riparian vegetation. The ability of the river to regulate itself with regard to flood protection and erosion and protect water quality was regarded as declining to crisis point. Results are provided in Table 11.13 below.

Table 11.13 Assessment of G&S change under scenarios for Kaap EZ

G&S as Benefits					
Resources	**Common name**	**Scientific name**	**Importance**	**Utilisation**	**Sc 8, 9**
Fish	*Large scale yellowfish*	*L. marequensis*	*Moderate*	*Medium*	*0*
	Tilapia		*Moderate*	*Medium*	*0.1*
	Barbs		*Moderate*	*Medium*	*0.1*
	Bass		*Very Low*	*Low*	*0*
Sedges	*Sedge*	*Cyprus spp.*	*Marginal*	*Low*	*0.1*
	Reeds	*Arundo donax*	*Very Low*	*Low*	*1.5*
Reeds	*Reeds*	*Phragmites*	*Marginal*	*Low*	*0.4*
Grazing	*Grasses*	*P. maximum/duestum*	*Very Low*	*Low*	*1*
		C. dactylon	*Very Low*	*Low*	*0.6*
Trees	*Pine*		*Moderate*	*Top part of area only*	*1*
	Blue Gum	*E. camaldulensis*	*Marginal*	*Top part of area only*	*0.8*
	Wattle		*Marginal*	*Top part of area only*	*1*
	Indigenous	*B. salicina, S. guineense, F. sycomorus*	*Very Low*		*0.6*
Hunting/poaching			*Very Low*	*Low*	
Sand winning			*Very Low*	*Low*	*1.3*
Waste assimilation			*Moderate*	*Medium*	*0.1*
Waste dilution			*Moderate*	*Medium*	*0.2*
Cultivated floodplains			*Very Low*	*Low*	*1.2*
Wetland cultivation	*Wetland destruction*		*Marginal*	*Low*	*1.2*
Flood attenuation			*Very Low*		*0.8*
Bank protection			*Moderate*		*0.4*
Stream flow regulation			*Very Low*		*0.2*
Disservices as costs					
Bilharzia productivity loss			*Very low*	*Low*	*1*

Lower Crocodile Economic Zone

This was largely the land associated with the Kruger National Park (KNP) although parts of the KaNyamazane community were also present. As such, G&S as they related to the aesthetic aspects of the park and impact on tourism were important. Direct utilisation by certain members of the greater KaNyamazane community was also important. Scenarios 3, 6, 7 and 9 were considered as a single scenario as they had very similar impact. Scenarios 10 and 12 were also combined. Scenarios 4 and 8 were considered on their own. The only scenario that had a neutral to marginally positive result on the availability of G&S was Sc 8. For the rest the impact was negative. Of these the most negative appeared to be Sc 10 and 12 followed by Sc 4. Scenarios 3, 6, 7 and 9 while still negative performed slightly better. Overall the best scenario appeared to be Sc 8. Results are provided in Table 11.14 below.

Table 11.14 Assessment of G&S change under scenarios for Lower Crocodile EZ

G&S As Benefits								
Resources	**Common name**	**Scientific name**	**Importance**	**Utilisation**	**Sc 3,6, 7,9**	**Sc 10, 12**	**Sc 8**	**Sc 4**
Fish	Small tilapias and barbs		Very Low	KNP no utilisation	0.7	0.7	1	0.6
	Mozambique tilapia	O. mossambicus	Very Low	Outside KNP only	1	1	1	0.9
	Large scale yellowfish	L. marequensis	Very Low	Outside KNP only	0.6	0.6	1	0.5
	Catfish	C. gariepinus	Very Low	Outside KNP only	1	1	1	1
	Tigerfish	Hydrocynus vittatus	Very Low	Outside KNP only	0.6	0.6	1	0.5
Sedges	Sedge	Cyprus spp.	Marginal	Outside KNP only	1	0.6	1	1
Reeds	Reeds	Phragmites	Moderate	Outside KNP only	1.3	0.6	1.3	1.3
Grazing	Grasses	P. maximum/ duestum		Outside KNP only	1.1	0.8	1.1	1.1
Trees	Indigenous		Moderate	Outside KNP only	1.1	0.8	1.1	1.1
Hippos			Very Important	Outside KNP only	0.9	0.9	1	0.8
Crocodiles			Very Important	Aesthetic in KNP	0.9	0.9	1	0.8
Riverine birdlife			Very Important	Aesthetic in KNP	0.9	0.9	1	0.8
Sand winning			Very Low	Aesthetic in KNP	1.1	1.3	1.1	0.9
Waste assimilation			Moderate	High	1	0.5	1	0.8
Waste dilution			Moderate	High	1	0.5	1	0.8
Cultivated floodplains			Moderate	Medium	0.9	1.1	1.1	0.9
Wetland cultivation			Marginal	Low	0.9	1.1	1.1	0.9
Recreational river use			5	High	0.9	0.9	1	0.8
Flood attenuation			Marginal	Medium	1.1	0.8	0.8	1.1
Bank protection			Marginal	Medium	1.1	0.7	0.7	1.1
Stream flow regulation			Very Low	Medium	1.1	0.5	0.5	1.1
Groundwater recharge			Marginal	Medium	1.1	0.5	0.5	1.1
Disservices as costs			Marginal	Medium				
Pathogens treatments			Marginal	Low	1	1.3	1	1.1
Pathogens productivity loss			Marginal	Low	1	1.5	1	1.1
Malaria			Important	Medium	1.2		1	1.3

Maritsane/Inyaka Economic Zone

The utilisation of G&S was ranked as medium. Only Sc 5 was considered and overall the scenario was neutral to marginally negative for the basket of G&S. Results are provided in Table 11.15 below.

Table 11.15 Assessment of G&S under Scenario 5 for Maritsane/Inyaka EZ

G&S As Benefits					
Resources	**Common name**	**Scientific name**	**Importance**	**Utilisation**	**Sc 5**
Fish	*Tilapia*		*Very Important*	*High*	*1*
	Mozambique tilapia	*O. mossambicus*	*Very Important*	*High*	*1*
	Large scale yellowfish	*L. marequensis*	*Very Important*	*High*	*1*
	Catfish	*C. gariepinus*	*Very Important*	*High*	*1*
	Barbs, labeos		*Very Important*	*High*	*1*
Sedges	*Sedge*	*Cyprus spp.*	*Moderate*	*High*	*1*
Reeds	*Reeds*	*Phragmites*	*Moderate*	*High*	*1.2*
Grazing	*Grasses*	*P. maximum/ duestum*	*Moderate*	*High*	*0.8*
		C. dactylon	*Moderate*	*High*	*1*
Trees	*Syringa*		*Marginal*	*High*	*0.8*
	Blue Gum	*E. camaldulensis*	*Very Low*	*High*	*0.8*
	Indigenous		*Important*	*High*	*0.6*
	Wattle		*Marginal*	*High*	*0.8*
Sand winning			*Important*	*High*	*1.3*
Waste assimilation			*Marginal*	*Medium*	*1.1*
Waste dilution			*Marginal*	*Medium*	*0.9*
Cultivated floodplains			*Moderate*	*Medium*	*1.2*
Wetland cultivation	*Wetland destruction*		*Marginal*	*Medium*	*1.2*
Flood attenuation			*Marginal*	*Medium*	*1.3*
Bank protection			*Very Low*	*Medium*	*1.3*
Stream flow regulation			*Very Low*	*Medium*	*0.8*
Groundwater recharge			*Marginal*	*Medium*	*0.8*
Disservices as costs					
Pathogens treatments			*Very Low*	*Low*	*0.8*
Pathogens productivity loss			*Very Low*	*Low*	*0.8*

Sand Economic Zone

The utilisation of G&S was ranked as high to medium high. Scenarios considered were Sc 1 and 9 (combined) and Sc 5. Scenarios 1 and 9 have largely positive results on the abundance of fish and Phragmites. They were also deemed to be positive for water quality services as well as for groundwater recharge, stream flow regulation and flood attenuation. Scenario 5 had largely negative results on the abundance of fish and but marginally positive impacts on riparian vegetation. Impacts were deemed to be largely negative for water quality services as well as for groundwater recharge, stream flow regulation and flood attenuation. Results are provided in Table 11.16 below.

Table 11.16 Assessment of G&S under scenarios for Sand River EZ

G&S as Benefits						
Resources	**Common name**	**Scientific name**	**Importance**	**Utilisation**	**Sc 5**	**Sc 1, 9**
Fish	*Mozambique and redbreasted tilapia*	*O. mossambicus, Tilapia rendalli*	*Important*	*High*	*1*	*1.4*
	Yellowfish, labeos	*L. marequensis*	*Important*	*High*	*0.7*	*1.4*
	Catfish	*C. gariepinus*	*Important*	*High*	*1*	*1*
	Barbs		*Important*	*High*	*0.9*	*1.4*
Sedges	*Sedge*	*Cyprus spp.*	*Important*	*High*	*1.1*	*1.1*
Reeds	*Reeds*	*Phragmites*	*Moderate*	*High*	*1.3*	*1.3*

G&S as Benefits						
Resources	**Common name**	**Scientific name**	**Importance**	**Utilisation**	**Sc 5**	**Sc 1, 9**
Grazing	*Grass*	*P. maximum/duestum*	*Very Important*	*High*	*1*	*1*
		Cynodon dactylon	*Very Important*	*High*	*1.1*	*1.1*
Trees	*Blue Gum*	*E. camaldulensis*	*Very Low*	*High*	*1*	*1*
	Indigenous		*Marginal*	*High*	*1*	*1*
	Wattle		*Very Low*	*High*	*1*	*1*
Sand Winning			*Important*	*High*	*0.9*	*0.9*
Waste assimilation			*Moderate*	*High*	*0.8*	*1.3*
Waste dilution			*Moderate*	*High*	*0.7*	*1.1*
Cultivated floodplains			*Moderate*	*Medium*	*0.95*	*0.95*
Wetland cultivation			*Very Important*	*High*	*0.95*	*0.95*
Recreational fishing'			*Very Low*	*Low*	*0.9*	*1*
Flood attenuation			*Marginal*	*Medium*	*1.2*	*1.2*
Bank protection			*Very Low*	*Medium*	*1.1*	*1.1*
Stream flow regulation			*Very Low*	*Medium*	*1.2*	*1.2*
Groundwater recharge			*Marginal*	*Medium*	*1.2*	*1.2*
Pathogens treatments			*Marginal*	*Low*	*1.2*	*0.8*
Pathogens productivity loss			*Marginal*	*Low*	*1.2*	*0.8*
Malaria			*Moderate*	*Medium*	*1.1*	*0.9*

11.5.3 Summary and Conclusions

Table 11.17 represents a summary of consequences of the operational scenarios on the G&S by economic zone. Those in green are positive and relates to the scenario providing increased resources for the utilization of goods and services; negative (shaded red) relates to a decrease in resources. Those scenarios shaded in yellow are neutral and indicates either (a) no change in resources and will be the same as present or (b) some G&S will be positively affected and some will be negatively affected but overall there is no driving indicator that would suggest either a positive or a negative overall outcome.

Table 11.17 Summary of predicted impact of scenarios on G&S in the Crocodile and Sabie-Sand River catchment

Economic Zone	EWR Site	Scenarios							
Crocodile sub-catchment									
Upper Crocodile	*EWR 1, 2*	*None*							
Elands		*None*							
Lower Kwena	*EWR 3*	*3*	*7*	*10*	*12*				
Middle Crocodile	*EWR 4*	*7*	*9*	*10*	*11*	*12*			
Kaap	*EWR 7*	*8*	*9*						
White River		*None*							
Lower Crocodile	*EWR 5, 6*	*3*	*4*	*6*	*7*	*8*	*9*	*10*	*12*
Sabie-Sand sub-catchment									
Sabie	*EWR 1, 2, 4*	*None*							
Maritsane/Inyaka	*EWR 3, 5*	*5*							
Sand	*EWR 6 - 8*	*1*	*5*	*9*					

11.6 RECOMMENDATIONS

11.6.1 Crocodile sub-system

Of all the scenarios evaluated in the Crocodile River system the optimization scenarios (Sc C3.1 and 6.1) were the best scenarios from an ecological and G&S viewpoint. Scenario C6.1 met the REC requirement at EWR 6 (critical site in the Crocodile River system) while Sc C3.1 resulted in an improvement of the PES at this site.

Due to the socio economic impact of Sc C6.1 it was acknowledged that it was unlikely to be considered. Therefore Sc C3.1 was therefore a better option, although the potential socio-economic consideration could be significant. However; considering the position of the Kruger National Park in the system, and the general High to Very High EIS of the system, it would be irresponsible not to make some attempt to meet Sc C3.1, or investigate further optimization options to determine other scenario options. As Sc C3.1 resulted in the improvement of the PES, the risk associated with the PES not degrading further would be minimised and, more important, considering the resolution which one is dealing with in terms of ecological and hydrological results, it is even possible that one could reach the B REC (for EWR 6 in the lower Crocodile River). From an ecological and G&S point of view, this would be the recommended scenario.

There are also options to investigate the daily operation of the system which, due to the abstraction regime, results in extreme localised changes in hydrology and impacts negatively on the ecological health of the system. There might be options to recommend a change in the manner of abstraction which could improve the system.

11.6.2 Sabie-Sand sub-system

No operational scenarios were required for evaluation in the Sabie System. Theoretical scenarios that consisted of different levels of irrigation restrictions to meet increasing irrigation requirements were investigation. These represented increased flows to various degrees at EWR 5 (Marite) and decreased flows at EWR 3 (Kidney). Scenario 8 was the only scenario that still met the PES and REC at EWR 3 in the KNP. The Marite REC was not achieved. The present flow regime resulted in the same situation and it was therefore recommended that the status quo is maintained. If increased flow for irrigation is ever required, Sc 8 would be the recommended option.

The scenarios in the Sand system were all based on improving the irrigation supply structures (small dams, canals, weirs) in the system. Scenario 1, the original Sellick Rule set up to operate the system would be the best scenario as this scenario improved the PES at EWR 6 and met the REC requirements at EWR 7 and 8. Scenario 1 was therefore recommended from the ecological and G&S viewpoint.

12 PRESENT STATE EVALUATION AND MACRO ECONOMIC CONSEQUENCES

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: Socio Economic Present State Evaluation Report. Prepared by Conningarth Economists for Water for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/013.

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. Crocodile River and Sabie-sand system: Operation Scenarios and Consequences Report. Volume 3: Macro Economic Consequences. Authored by Conningarth Economists for Water for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/011.

12.1 PRESENT STATE EVALUATION

This task provided the economic baseline of the current water allocation status in the Crocodile East and the Sabie-Sand sub-catchments and was intended to provide the basis to evaluate the implication, so as to contribute to the national debate on those issues. The report addressed the identification and quantification of the economic and commodity benefits derived from the water use in the two sub-catchments. The primary sectors that were identified were irrigation agriculture, forestry and mining. The secondary industries that were analysed were the raw water user industries and major municipal based water users.

12.1.1 Economic Zones

The two sub-catchments were divided into economic zones (EZs), i.e. the Crocodile East was divided into seven EZs and the Sabie-Sand into three EZs.

For analysis purposes, the Crocodile East sub-catchment was divided into seven economic zones:

- *Upper Crocodile EZ.*
- *Lower Kwena EZ.*
- *Elands EZ.*
- *White EZ.*
- *Middle Crocodile EZ.*
- *Kaap River EZ, and the*
- *Lower Crocodile EZ.*

Regarding economic activities, the Sabie-Sand sub-catchment were sub-divided into three economic zones, namely the Sabie River, Maritsane/Inyaka and Sand River. The economic activities within these EZs included irrigation agriculture, commercial forestry, manufacturing and electricity supply. The area's mining activities were limited to minor sand quarrying.

12.2 OBJECTIVES OF THE STUDY

The specific objectives of this study as outlined in the terms of reference were to:

- *Identify the sectors directly and indirectly using water from the Crocodile River and the Sabie-Sand River systems.*
- *Determine economic zones (EZs) in the Crocodile River and Sabie-Sand River systems and current water allocation to each category of use.*
- *Determine an appropriate valuation technique for each use category.*
- *Analyse economic value of water use by each category.*

12.3 INTRODUCTION

The economic baseline of irrigation agriculture water use was established per allocation zone and the value of water was expressed in terms of the contribution to Gross Domestic Production (GDP), Employment and Low Income Households. The aim of this task was to measure the incremental deviation from the baseline as described in the present State Evaluation report (DWA, 2010).

The Crocodile River catchment was delineated into Water Allocation Zones. Zone 1 consisted of the whole Crocodile East sub-catchment excluding the Kaap River catchment. The Kaap River, was analysed separately and was named Zone 2.

The Sabie scenarios were not further evaluated as all scenarios related to an improved assurance and supply to agriculture.

The Sand system was not further evaluated as all scenarios included the improvement of the current irrigation system and structures which would maintain or improve the current irrigation activities, as well as improve the runoff in the river system.

12.4 APPROACH

The approach for the economic modelling, was in the form of a dynamic computerised water entitlement model which can be used to identify and quantify the following indicators:

- *Economic benefits.*
- *Maximum possible water reduction.*
- *Proposed water reduction.*
- *Capitalised impact.*

As a first step the macro-economy of the basin was established and then sub-divided into the sub-catchments. Production and employment data were used for the Basin and its sub-catchments where after a macro economic Impact model was constructed for the Basin and the identified sub-catchments. The model is water driven and gives the direct and indirect/induced results for the following activities:

- *Agriculture.*
- *Forestry.*
- *Industry.*
- *Households.*

Regarding agriculture, the model can accommodate up to ten individual products and for forestry it makes provision for pine, wattle and gum sub-species.

The following direct impacts are estimated by the Water Impact Model:

- *Gross Domestic Product (GDP).*
- *Low Income Households and Total Households.*
- *Employment Creation.*

A group of economic multipliers was then developed to compare different water use activities in terms of Gross Domestic Product (GDP/m^3), employment creation (number/Mm^3) and the low-income households.

The Water impact Model (WIM) comprises various sub-models which were used in determining the values of the above economic variables. The primary impetus drivers of the WIM are:

- *The volume of water allocated to the various water users in each sub-catchment.*
- *The level of water assurance given to each water user in each sub-catchment.*
- *Hectares under irrigation.*
- *Production.*
- *Economic data in the form of a Social Accounting Matrix (SAM), and*
- *Economic multipliers.*

By using a Social Accounting Matrix[4] *(SAM) applicable to the study area, multipliers were calculated. The multipliers used in this study to determine the economic impacts for the WIM were:*

- *Economic growth (i.e. the impact on GDP).*
- *Job creation (i.e. the impact on labour requirements).*
- *Income distribution (i.e. the impact on low income households).*

An example of the agriculture sector multipliers used in this study was:

- **Direct effect***: Refers to effects occurring directly in the agriculture sector.*
- **Indirect effects***: Refers to those effects occurring in the different economic sectors that link backward to agriculture due to the supply of intermediate inputs, i.e. fertilisers, seed, etc.*
- **Induced effects***: Refers to the chain reaction triggered by the salaries and profits (less retained earnings) that are ploughed back into the economy in the form of private consumption expenditure.*

The inputs towards the irrigation sector consist of COMBUD-budgets that were applied to a farm model. The Computer Based Budgets (COMBUD) compiled by the Department of Agriculture was used as base documents to develop the 2007/2008 production budgets. They were updated and adapted for the different production areas in terms of yield, production prices and input costs. The COMBUD budget provided data up to Gross Margin on a hectare basis, after which the fixed costs were subtracted to get Net Farm Income per hectare and in the end the Net Income or Profits per hectare.

For the use of the macro-economic impacts determination, these costs in the budget were allocated to structures in such a way that it was allocated to the different sectors of the economy. These were applied to determine the direct, and indirect and induced effects. Production costs included:

- *Total costs (Intermediate inputs and labour requirements).*
- *Agriculture.*
- *Mining.*
- *Manufacturing (fuel, fertilizer, pharmaceuticals and other).*
- *Water.*
- *Construction.*
- *Trade and accommodation.*
- *Transport and communication.*
- *Financial and business services.*

[4] *A Social Accounting Matrix (SAM) represents flows of all economic transactions that take place within an economy (regional or national). It is at the core, a matrix representation of the National Accounts for a given country, but can be extended to include non-national accounting flows, and created for whole regions or area. SAMs refer to a single year providing a static picture of the economy (www.wikipedia.org).*

- *Community services.*
- *Salaries and wages (skilled, semi-skilled and unskilled).*

The path followed by the industries; namely mining and power generation, consist of the inputs of turnover and direct employment. The turnover was converted into production. The following step was to determine the costs and divide those with the structure of the economy. Their multipliers, calculated from the SAM, were then used to determine the impact.

12.5 ASSUMPTIONS FOR THE OPERATIONAL SCENARIOS

For purposes of the economic impact analyses the following general assumptions were formulated:

- *The impact analysis was only done for irrigation agriculture as no other water user would be affected by the restrictions of water availability.*
- *It was accepted that the management levels of the irrigators and equipment use was already at very high efficiency levels and no provision was made for improvement in management efficiency or equipment.*
- *It was assumed that a volume curtailment leaded to a reduction in an irrigation area.*
- *It was further assumed that an improvement in assurance of supply resulted in increased yields over a period of time.*

In applying the above assumptions the following practical applications were used in the WIM:

- *The cultivation of annual crops such as vegetables, wheat and pastures were reduced in accordance with the curtailments applied.*
- *As sugar cane was more resistant to drought and cost less to replant, the water supply was reduced as curtailments increased.*
- *Orchards were maintained in all scenarios, only to be affected by area curtailments as a last resort.*
- *Changes in assurance of supply not only resulted in a loss of production but also in the quality of produce.*
- *As the Crocodile River in the present state report consisted of 7 Zones and for the purposes of the scenarios combined into one Zone, weighted economic multipliers were applied.*

12.6 LIMITATIONS

The application of the above assumptions put in place the following limitations in calculating the impacts of the different scenarios.

- *Changes in irrigation management practices were not taken into account.*
- *Irrigation efficiency levels were maintained at the current levels.*
- *No sensitivity analysis or cost effective analysis was conducted on input production costs. Sensitivity and cost effective analysis could be used to measure the effectiveness of present production practices.*
- *Changes in market prices were not taken into account.*
- *Fiscal impacts of changes in economic activity were not evaluated because the WIM model is a static model and makes no provision for measurement of the fiscal impact.*
- *The impact of removing old orchard trees and replanting young trees was not evaluated.*
- *Provincial economic multipliers were used because Mpumalanga provincial Social Accounting Matrix was used.*
- *Impact on different farming size units was not evaluated.*

12.7 CROCODILE RIVER CATCHMENT RESULTS

The macro economic impacts of the scenarios C1 to C14 (excluding Scenario C11) on Zone 1 are provided in Table 12.1.

Table 12.1 Results of different scenarios applied to Zone 1: Crocodile River catchment

Scenarios	Total GDP (R Million)	Total Employment (Numbers)	Low Income Households (R Million)	Estimated jobs lost
GROUP 1 (no EWR)				
Sc C1 (baseline)	*1 411.97*	*22 689*	*391.73*	*0*
Sc C2	*1 198.76*	*19 287*	*332.58*	*3 403*
Sc C3	*987.22*	*15 883*	*273.89*	*6 806*
Sc C4	*1 198.76*	*19 287*	*332.58*	*3 403*
Sc C5	*987.22*	*15 883*	*273.89*	*6 806*
Sc C6	*775.67*	*12 480*	*215.20*	*10 210*
*Sc C7**	*1 995.02*	*25 435*	*515.55*	
Sc C8	*1 547.51*	*20 543*	*444.13*	
Sc C9	*2 181.10*	*27 558*	*541.65*	
Sc C10	*1 551.80*	*21 164*	*412.32*	
GROUP 2 (EWR included)				
Sc C13 (PES)	*1 069.19*	*13 492*	*298.71*	
Sc C14 (REC)	*918.17*	*11 096*	*253.76*	

** Yellow refers to scenarios that include the new dam developments.*

The socio-economic implications for the key scenarios (Scenario 2 – 6) are illustrated in Figure 12.1.

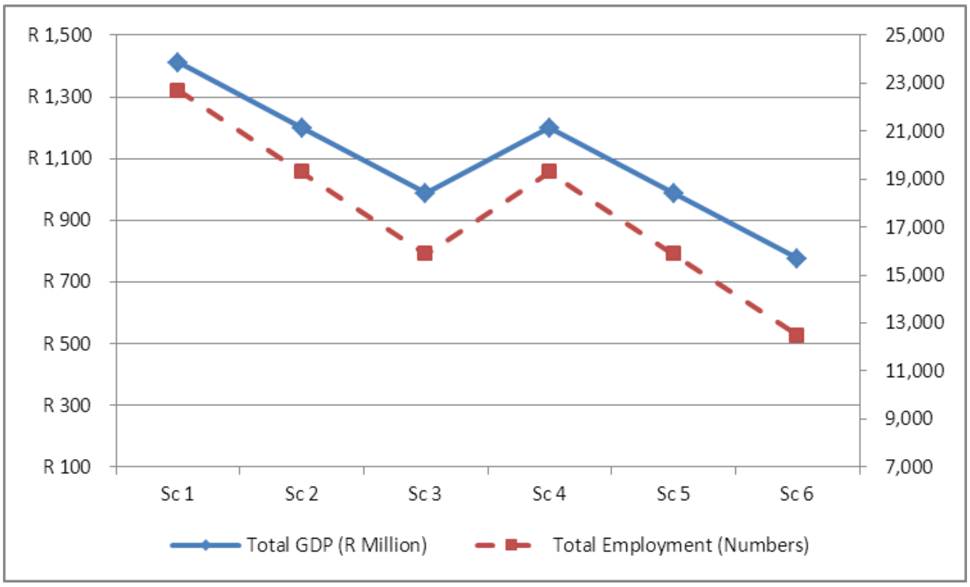


Figure 12.1 Zone 1: Economic consequences in terms of GDP and Total employment compared to the baseline (Sc C1)

The above table as well as the graph indicate that Scenarios 2 and 4 are, in terms of economic parameters, the preferable scenarios. In Table 2 we observe that each of the scenarios have the potential to cause a major number of job losses. Scenario 6 can lead to 10 210 jobs lost while Scenarios 2 and 4 lead to 3 403 jobs lost.

12.8 . KAAP RIVER CATCHMENT RESULTS

The macro economic impacts of the scenarios on Zone 2 are provided in Table 12.2.

Table 12.2 Results of different scenarios applied to Zone 2: Kaap River catchment

Scenarios	Total GDP (R Million)	Total Employment (Numbers)	Low Income Households (R Million)
Sc C1	*305.46*	*3 836*	*82.38*
Sc C2	*378.91*	*4 449*	*88.53*
Sc C3	*391.79*	*4 649*	*87.31*
Sc C4	*378.91*	*4 408*	*88.53*
Sc C5	*387.77*	*4 641*	*86.73*
Sc C6	*368.42*	*4 378*	*80.92*
*Sc C7**	*343.45*	*4 142*	*87.79*
Sc C9	*397.71*	*4 734*	*95.53*
Sc C13	*277.98*	*2 916*	*68.76*
Sc C14	*267.36*	*2 792*	*65.33*

** Yellow refers to scenarios that include the new dam developments.*

The macro economic impacts of the scenarios on Zone 2 are provided in the figure below. The results reflected that Sc C9 was the best economic impact performer. These economic impacts were expressed in total GDP, total number of employment opportunities as well as the distribution towards Low Income Households. If the development scenarios were excluded, Sc C3 was the most recommended scenario in terms of GDP and employment. This is graphically illustrated in the Figure 12-2 with respect to GDP and employment for all the scenarios assessed. Low income households followed mostly the trend of GDP and were therefore not included in the graph.

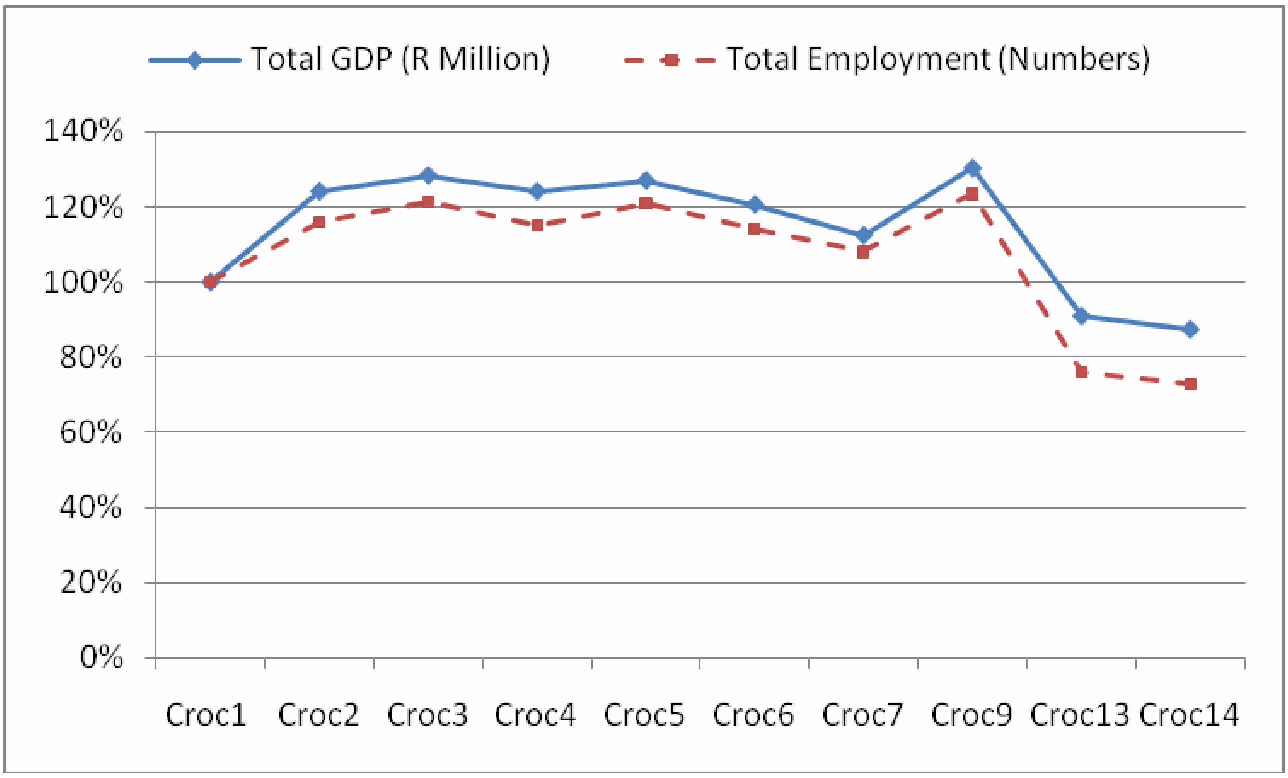


Figure 12.2 Kaap River Deviation from the Base Scenario: GDP and Employment

Based on the results presented in Figure 12-2 all the scenarios had a positive deviation from the GDP, except for Sc C13. Scenario C3 was the best scenario if the development scenarios (Sc C7 – C9) were excluded.

13 RECOMMENDATION OF FINAL SCENARIO TO BE SIGNED OFF

Author: MD Louw (Rivers for Africa)

The consequences of all the scenarios on the ecological state, G&S and socio-economics are compared and a recommendation made; first by the direct project team, then by a wider internal DWA meeting and finally, if necessary by a presentation to DWA management and stakeholders.

The consequences are summarised using traffic diagrams with green implying good and red implying bad. A numberless scale is also provided to indicate how much better or worse certain scenarios are from the baseline.

The EWR Rule and EWR Tables that will be recommended as the final Ecological Reserve are provided in Appendix A.

13.1 CROCODILE RIVER: RESERVE RECOMMENDATION

The scenarios that were finally considered were only those that implied restrictions and curtailments of irrigation. (Sc C2 to C6). Sc C7, C8 and C9, future dam scenarios, were not further considered as a detailed evaluation would require various operational dam rules including different sized dams. This information is not presently available. Sc C11 was undertaken for demonstration purposes only (to determine what would happen if cross-border flows were not supplied). Sc 10 and 12 were also only evaluated for background information. These two scenarios included decreased releases from Kwena Dam during certain times of the year, and increased releases during other times with the purpose of meeting the REC at EWR 3 downstream of the dam. This, as predicted, will have a severe negative impact on both irrigation and the ecological requirements at the downstream sites.

Sc C3.1 and C6.1 is a modification of Sc C3 and C6 as it uses the increased yield in Kwena Dam resulting from the agricultural restrictions and curtailments to supply the Reserve.

Figure 13-1 illustrates the ecological, Goods and Services and socio-economic consequences. All the EWR sites considered (EWR 3 to 7) was of High importance and the REC consisted of an improvement of the PES. The figure illustrates that there are no scenario that will meet the REC apart from Sc C6.1. The socio-economic cost to this scenario is however not acceptable according to DWA.

Sc C3.1 was the ecological recommendation as the prediction is that it will improve the PES, however not to the REC level. It is however possible that with non-flow related measurements and with monitoring to verify, the REC could be achieved. This scenario also improved the Goods and Services and but however had a negative socio-economic input (in terms of a los of GDP and job losses). The decision was made that at this stage, the present hydrology must be signed off which will maintain the PES. A phased approach associated with potential future development and compulsory licensing will be followed to achive Sc C3.1. It should also be investigated whether there are any localised operational improvements that can be made to improve the REC. For example, one of the major problems in the lower Crocodile River in the vicinity of EWR 5 and 6 is the fluctuating flow and localised zero flow conditions. This happens due to the localised abstraction via large pumps which decrease flow in place to zero. Flows then also increase during weekends when the pumps are not functioning.

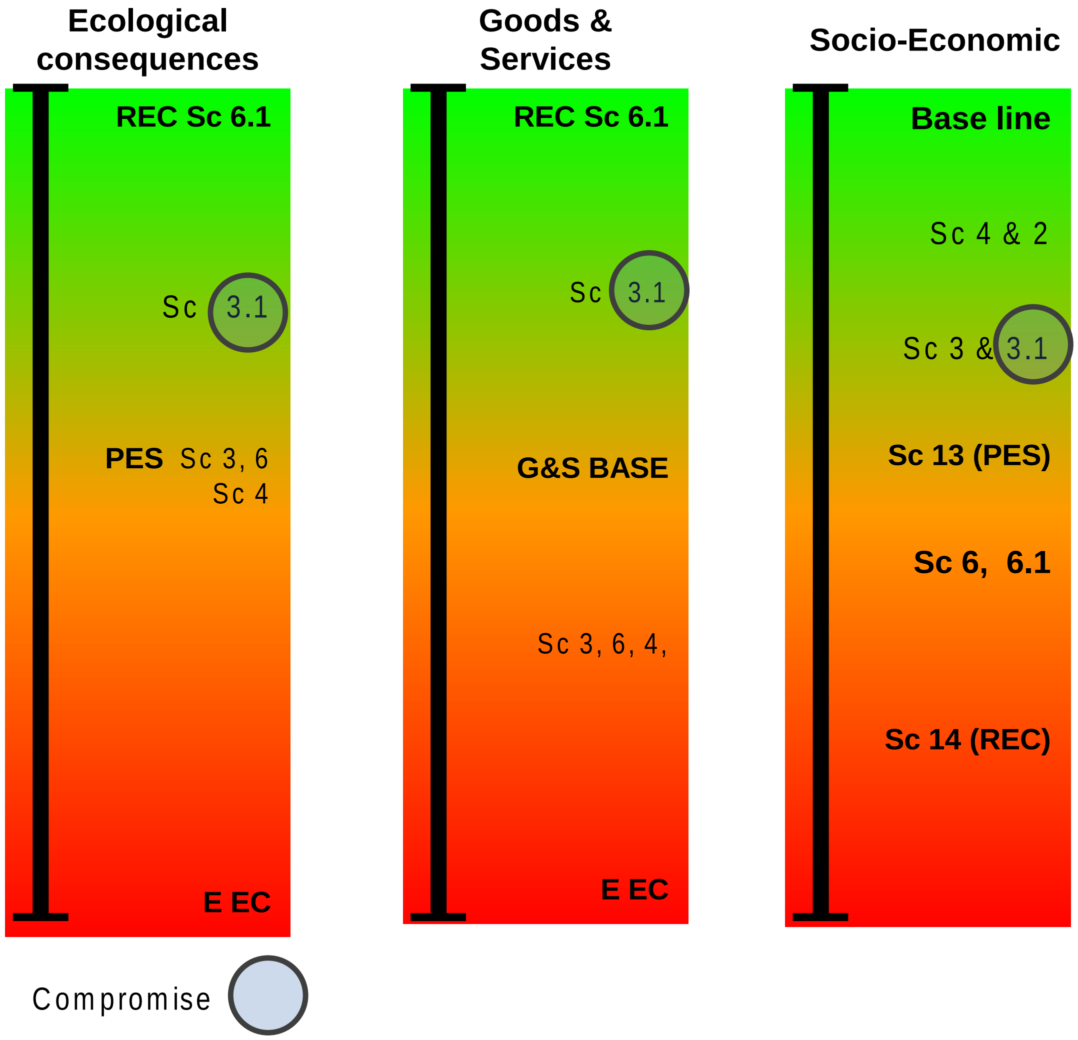


Figure 13.1 Consequences of various operational scenarios in the Crocodile River

13.2 SABIE RIVER: RESERVE RECOMMENDATION

Socio-economic scenarios were not evaluated for the Sabie River as all the scenarios were an improvement of the present agriculture. Goods and Services followed the ecological consequences trend and the decision regarding the Reserve recommendation was based on the ecological consequences.

The REC of all the EWR sites apart from EWR 5 (Marite River) can be achieved with the present day flows. Achieving the Marite River REC will require a different operation of Inyaka dam which would result in economic consequences and the REC in the lower EWR sites will not be achieved.

The recommendation was therefor made to sign off the REC at EWR 1, 2, 3, 4 and the PES at EWR 5.

13.3 SAND RIVER: RESERVE RECOMMENDATION

Socio-economic scenarios were not evaluated for the Sand River as all the scenarios will result in an improvement of water supply to agriculture. Goods and Services followed the ecological consequences trend and the decision regarding the Reserve recommendation was based on the ecological consequences.

The scenarios were based on the assumption that the four abstraction weirs in the upper Sand River would be rehabilitated, thus improving the flow downstream. Of the various scenarios evaluated, only Sc 1 (the so-called Sellick-rule) will achieve the REC at the key site, EWR 8 in the lower Sabie. This scenario will improve the PES (and REC which was set to maintain the PES) at EWR 7 (upper Sand River). It will also improve the PES towards the REC at EWR 6 and hopefully, with some non-flow related measures (specifically removal of alien vegetation) combined with flow related improvements, the REC will be met.

The recommendation was therefore made that the Sellick Rule should be implemented as the advantages would be much wider than just to ensure the Ecological Reserve. The Ecological Categories that must be signed off is:

- *EWR 6 – REC. It must be acknowledged that without some crucial catchment management improvements, the increased flows on their own will not achieve the REC but could likely achieve an improvement of the PES.*
- *EWR 7 – REC (=PES). Scenario 1 will achieve the AEC up, however the main motivation for applying Scenario 1 is to meet the REC at EWR 8.*
- *EWR 8 – REC.*

14 IDENTIFICATION OF ECOSPECS

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.

The purpose of this task was to set EcoSpecs and TPCs that could be used for future Ecological Water Resource Monitoring (EWRM). Further information on Ecological Water Resources Monitoring can be obtained from DWA (2009), and Kleynhans et al. (2009).

14.1 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 monitoring guidelines and a Decision Support System (DSS) for Ecological Water Requirements (EWR) as required for the Ecological Reserve determination. River Health Programme (RHP) monitoring as such was not included. However, the implications of simultaneously operating two separate ecological monitoring programmes (Ecological Resource monitoring (ERM) and RHP) 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 EWR studies, EcoSpecs are developed and specified in terms of the Resource Quality Objectives (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). 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 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 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.

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 inform the management objectives supported by the other drivers. Note that the word 'could' is used as the biological responses to driver conditions are all predicted and must be tested through monitoring. Determining the Ecological Response through monitoring, examines the predictions made during an EWR study, and/or whether adjustments to the EcoSpecs and TPCs are required. and of course, 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 to provide the detailed EcoSpecs and to define the TPC for the BEC, i.e. the current or initial PES. *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

14.2 RESULTS

EcoSpecs and TPCs are listed in detail 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 are provided as Appendix B.

14.3 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.

15 ESTIMATION AND EXTRAPOLATION OF EWRS AT SELECTED HYDRONODES

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: Estimation and extrapolation of Ecological Water Requirements (EWRs) at selected hydronodes. Prepared by Rivers for Africa, Authored by Louw, MD and Birkhead, AL. RDM Report no 26/8/3/10/12/007.

15.1 INTRODUCTION

A comprehensive Reserve study assesses EWRs at EWR sites that are usually situated on the main rivers and large tributaries. For the purpose of, amongst others, Compulsory Licensing and general licensing, Reserves have to be set at many points (hydronodes) in the catchment. Additional EWR sites to provide EWRs at each of these nodes will become time consuming and therefore costly.

The objective of this task was to provide an estimate which would be of higher confidence than the Desktop Reserve Model at every hydronode in the Sabie, Crocodile and Mokolo River systems (the Komati information was already supplied through a WRC/DWA research project).

The Desktop Reserve Model is being refined as part of the current WRC project K5/1856. This should give higher confidence answers than the current Desktop Reserve Model but will highly likely only be finalised in 2011. A prototype approach is however available that can be used in the interim.

15.2 APPROACH

Extrapolation consists of

- *Determining which sites are sufficiently similar to the comprehensive EWR sites in terms of biophysical similarity as well as indicator guilds used for setting EWRs; and*
- *Deriving the EWRs for these sites using the comprehensive EWR results at the EWR sites.*

Estimation consists of a process to estimate the EWRs at each hydronode for the Recommended Ecological Category (REC) (using the information generated as part of the Desktop EcoClassification (Kleynhans & Louw, 2007)). This estimation will entail the prediction of indicator species at various hydronodes, and the determination of the EWRs at these hydronodes using a higher confidence method than the Desktop Ecological Reserve Model.

The decision-making process to determine whether to estimate or extrapolate is summarised in the flow diagram (Figure 14-1).

15.3 HYDRONODES AND DATABASE

Hydronodes are points on a map which represents a catchment, usually at the quinary scale. These points were provided and were included in an Excel database. Additional points were also provided in the database, the so-called known fish sites. This inclusion was required as the database was finally used to compare the known fish sites with hydronodes to derive the indicator fish guild for which the EWR must be set. For each point in the database, a range of biophysical information was provided to characterise the nodes and fish sites.

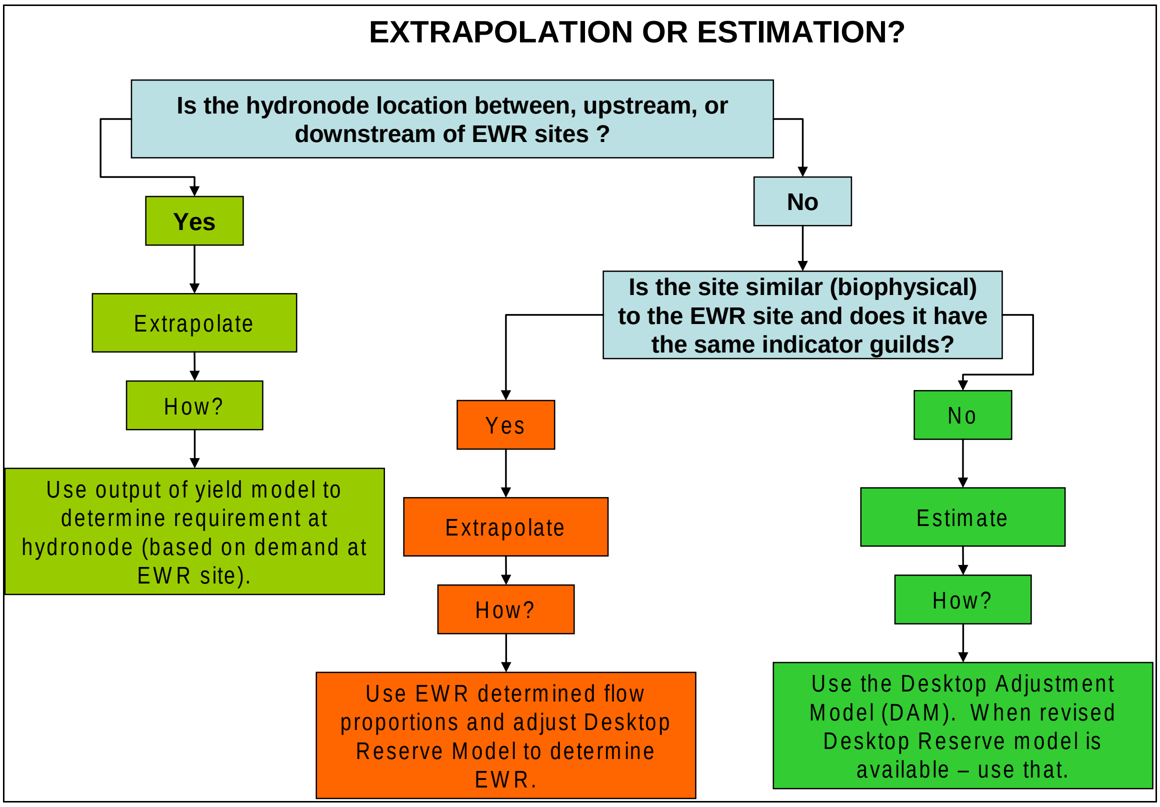


Figure 15.1 Flow diagram showing when it is appropriate to extrapolate or when estimation is required

15.4 PREDICTION OF INDICATOR FISH GUILDS

Conceptually the prediction approach is based on the physical similarity between sites were fish information is available and hydronodes without fish information. If sites are physically similar to a high degree, then the assumption can be made that the same indicator fish guild would be present at both sites.

The results of the Mokolo, Crocodile and Sabie River systems are provided in excel format as part of the electronic information (RDM Report no (26/8/3/10/14/016)). This work was undertaken by CJ Kleynhans (DWA, RQS).

15.5 CALIBRATION SITES USED FOR EWR ESTIMATION

Various EWR sites (Rapid Level III, Intermediate and Comprehensive) were used to develop an EWR estimation method for hydronodes where no hydraulic data existed. The locality of these sites and other pertinent information are provided in the Table 14.1.

Table 15.1 Sites used for hydronode EWR estimation

Quat	Site nr	River	Alt (m)	Co-ordinates		MAR (Mm^3)	Discharge (m^3/s)[1]	Ind fish guild[2]		Ind invert taxa[3]		% pt FDT[4]	
				Latitude	Longitude			Dry	Wet	Dry	Wet	Maint[5]	Dry
NKOMATI RIVER CATCHMENT													
Calibration sites													
X12K	*X12K1*	*Phalangampepe*	*731*	*-26.0453*	*31.0503*	*4.2*	*0.050*	*SR*	*SR*	*FDCD*[6]	*FDCD*	*70*	*95*
X12G	*X12G2*	*Bergstroom*	*1200*	*-25.9678*	*30.8333*	*4.8*	*0.026*	*SR*	*SR*	*FDCD*	*FDCD*	*70*	*95*
X11F	*X11F1*	*Bankspruit*	*1545*	*-25.8469*	*30.3506*	*6.7*	*0.075*	*SR*	*SR*	*FDCD*	*FDCD*	*70*	*95*
X12G	*X12G1*	*Mawelawala*	*1144*	*-25.9652*	*30.8216*	*9.9*	*0.037*	*SR*	*SR*	*FDCD*	*FDCD*	*70*	*95*

Quat	Site nr	River	Alt (m)	Co-ordinates		MAR (Mm^3)	Discharge (m^3/s)[1]	Ind fish guild[2]		Ind invert taxa[3]		% pt FDT[4]	
				Latitude	Longitude			Dry	Wet	Dry	Wet	Maint[5]	Dry
X12H	X12H2	Sandspruit	800	-26.0497	30.8972	10.5	0.037	SR	SR	FDCD	FDCD	70	95
X11A	X11A1	Vaalrivierspruit	1531	-26.0069	30.02664	10.6	0.019	SR	SR	FDCD	FDCD	70	95
X11D	X11D1	Klein Komati	1640	-25.8881	30.1203	10.7	0.050	SR	SR	FDCD	FDCD	70	95
X12K	X12K2	Mlondozi	1098	-26.0472	31.0442	14.2	0.17	SR	SR	FDCD	FDCD	70	95
X11E	X11E1	Swartspruit	1444	-25.93695	30.235	15.4	0.045	SR	SR	FDCD	FDCD	70	95
X12B	X12B1	Buffelspruit	1562	-26.0628	30.3939	27.9	0.086	SR	SR	FDCD	FDCD	70	95
X11G	X11G3	Komati	935	-25.9531	30.7249	370	1.5	LSR	LSR	FDCD	FDCD	70	95
SABIE and CROCODILE RIVER CATCHMENTS													
Calibration sites													
X32A	E8Sek	Sekgamarago	886	-24.69327	30.92953	1.0	0.02	SR	SR	FDCD	FDCD	70	95
X21D	E2aBKS	Buffelskloofspruit	1184	-25.43842	30.44713	10.8	0.10	SR	SR	FDCD	FDCD	70	95
X21D	E2bBKS	Buffelskloofspruit				10.8	0.10	SR	SR	FDCD	FDCD	70	95
X31G	E9Lon	Lonely Creek	1146	-25.10324	30.71097	11.2	0.34	SR	SR	FDCD	FDCD	70	95
X31D	E6Saban (a)	Sabane	533	-25.03414	31.01989	16.4	0.031	SSR	SSR	FDCD	FDCD	70	95
X31D	EcSaban (b)	Sabane						SSR	SSR	FDCD	FDCD	70	95
X22A	E3Bly	Blystaanspruit	1032	-25.28752	30.59633	19.3	0.51	SR	SR	FDCD	FDCD	70	95
X31A	E10Sab	Sabie	1099	-25.12100	30.71700	26.5	0.41	SR	SR	FDCD	FDCD	70	95
X22D	E5Nels	Nels	1065	-25.28945	30.76464	30.4	1.2	SR	SR	FDCD	FDCD	70	95
X32B	E1Kaap	Kaap(North)	678	-25.60761	30.97650	43.5	0.27	SR	SR	FDCD	FDCD	70	95
X22A	E4Hout	Houtbosloop	865	-25.35516	30.66591	56.8	0.78	SR	SR	FDCD	FDCD	70	95
EWR sites													
X31B	EWR 1	Sabie	862	-25 04.424	30 50.924	140.2		SR/LR	SR/LR	FDCD	FDCD	70	95
X31D	EWR 2	Sabie	463	-25 01.675	31 03.099	262.1		SR/ R	SR/LR	FDCD	FDCD	70	95
X31K	EWR 3	Sabie	369	-24 59.256	31 17.572	495.9		SR/SR	SR/SR	FDCD	FDCD	70	95
X31C	EWR 4	Mac Mac	582	-25 00.800	31 00.243	65.8		SR/ R	SR/LR	FDCD	FDCD	70	95
X31G	EWR 5	Marite	457	-25 01.077	31 07.997	157.1		SR/ R	SR/LR	FDCD	FDCD	70	95
X32C	EWR 7	Tlulandziteka	543	-24 40.829	31 05.188	28.9		SR/LSR	SR/LSR	FDCD	FDCD	40	95
X21A	EWR 1	Crocodile	1852	-25 29.647	30 08.656	15.2				FDCD	FDCD	70	95
X21B	EWR 2	Crocodile	1207	-25 24.555	30 18.955	47.1		SR	SR	FDCD	FDCD	70	95
X24H	EWR 6	Crocodile	470	-25 38.968	31 14.572	1063		SR/LSR	SR/LSR		FDCD	70	95
MOKOLO RIVER CATCHMENT													
Calibration sites													
A42F	8	Taaibos	1011	-24 11.128	27 51.673	1.8	0.49	SSR	MSR	FDCD	FDCD	50	95
A42B	2XSA	Renosterbos-spruit	1284	-24.50804	27.86574	1.9	0.081	SSR	MSR	FDCD	FDCD	50	95
A42B	2XSB	Renosterbos-spruit						SR	SR	FDCD	FDCD	50	95
A42A	1	Sand	1356	-24.65283	28.231	2.1	0.14	SR	SR	FDCD	FDCD	50	95
A42E	11	Klein Vaalrivierspruit	1098	-24.21941	28.05363	2.7	0.42	SSR	LSR	FDCD	FDCD	50	95
A42E	6	Jim se Loop	1209	-24.27184	28.20002	2.8	0.19	SSR	MSR	FDCD	FDCD	50	95
A42H	7XSB	Tambotie	983	-23.81291	27.94885	2.8	0.52	MSR	MSR	FDCD	FDCD	50	95
A24D	9	Frikkie se Loop	1221	-24.31397	27.95724	3.9	0.66	SR	SR	FDCD	FDCD	50	95
A42E	4	Upper Dwars	1188	-24.26661	28.21718	10.3	0.46	SSR	LSR	FDCD	FDCD	50	95
A42E	5XSA	Lower Dwars	1212	-24.26736	28.21873	14.1	0.66	SSR	LSR	FDCD	FDCD	50	95
A42E	5XSB	Lower Dwars						SSR	LSR	FDCD	FDCD	50	95
A24D	10	Sterk	1191	-24.30554	27.89699	26.1	2.2	SR	SR	FDCD	FDCD	50	95
UPPER VAAL RIVER CATCHMENT													
C13C	8 (UVKlip)	Klip	1757	-27.82105	29.64983	5.75	0.14	SSR	SSR	FDCD	FDCD	60	95
C82F	3B(UV36)	Grootspruit	1643	-27.49946	28.95117	6.24		LSR	LSR	FDCD	FDCD	60	95

Quat	Site nr	River	Alt (m)	Co-ordinates		MAR (Mm^3)	Discharge (m^3/s)[1]	Ind fish guild[2]		Ind invert taxa[3]		% pt FDT[4]	
				Latitude	Longitude			Dry	Wet	Dry	Wet	Maint[5]	Dry
C82A	7(UVCor)	Cornelius	1852	-27.83821	29.35921	7.93	0.006	LSR	LSR	FDCD	FDCD	60	95
C11E	9(UV9)	Skulpspruit	1635	-27.02988	29.88956	12.11	0.004	LSR	LSR	FDCD	FDCD	60	95
C23B	1(UV53)	Kromelmboog-spruit	1416	-26.79594	27.56550	14.36	0.006	LSR	LSR	FDCD	FDCD	60	95
C83K	2(UV45)	Kromspruit	1492	-27.25842	28.40691	25.72	0.006	LSR	LSR	FDCD	FDCD	60	95
C81L	6B(UV25)	Meul	1691	-27.97461	29.31991	26.50	0.35	LSR	LSR	FDCD	FDCD	60	95
C82G	5(UV31)	Holspruit	1558	-27.67999	28.79244	32.93	0.049	SR	LSR	FDCD	FDCD	60	95
C81M	6A(UV28)	Meul	1588	-27.96968	28.89911	103.85	0.94	LSR	LSR	FDCD	FDCD	60	95
C12G	4(UVWV)	Waterval	1499	-26.96028	28.74577	176.80	0.48	LR	LR	FDCD	FDCD	60	95

1 Single measured discharge for Rapid III level assessment
2 Indicator fish guild
3 Indicator invertebrate guild
4 Percentage point (time equalled or exceeded) on the flow duration table
5 Maintenance
6 Flow Dependant Cobble Dwelling invertebrates

15.6 EWR ESTIMATION METHOD

The EWR data for the sites in the above table were provided (for the comprehensive level sites) from the Reserve studies. These results are for specific Ecological Categories (ECs) (may include the Present Ecological State (PES), Recommended Ecological Category (REC) and/or the Alternative Ecological Category (AEC)), specified separately for fish and macroinvertebrates. For the Rapid Level III sites (Komati, Sabie, Crocodile, Mokolo and upper Vaal River catchments), the Fish Flow Habitat Assessment (FFHA) model (developed by Dr C.J. Kleynhans) was used for estimating the EWRs (the model was modified for application to macroinvertebrates). The FFHA model provides a consistent procedure for estimating EWRs (at the Rapid Level III and higher) and gives requirements for the A to D range of Ecological Categories (ECs).

The EWR data were entered into an Excel data base for processing, together with the tabulated (modelled) hydraulic information (or lookup tables) for the site cross-sections. Code was written in Visual Basic Applications (VBA) to compile EWR and hydraulic data as a function of ecological and hydrological parameters. The ecological information included the indicator fish guild and macroinvertebrate taxa, and the hydrological information included the season and percentage (time) exceedence of maintenance and drought conditions on the flow duration table (FDT).

For each of the four fish guilds (Small Semi-Rheophilic (SSR), Large Semi-Rheophilic (LSR), Small Rheophilic (SR) and Large Rheophilic (LR), and a single macro-invertebrate taxa (flow dependant cobble dwelling (FDCD)), there were three variables to consider. These included hydrological season (wet or dry), percentage point on the FDT (the points denoting maintenance and drought conditions) and EC (B, C or D - the FFHA model considered an A to be natural). Thirty-six data sets for fish and 12 for macroinvertebrates were used.

For each of these 48 data sets, the EWR requirement (from the Comprehensive and Rapid Level III (FFHA model) studies), hydrological (natural flow) and relevant hydraulic information (wetted channel width, maximum depth, average depth and average velocity) were compiled. Following from the findings of a previous EWR estimation study (Birkhead, 2008), the data was analysed to assess whether the EWR could be expressed as a constant unit-width value (i.e. a constant discharge per unit (wetted) width of channel).

A regression procedure was coded (using VBA) to automate the curve-fitting for the 48 data sets, and allowed the regressions to be easily re-determined with changes to the data sets.

15.7 APPLICATION OF ESTIMATION TO HYDRONODES

A procedure for applying the EWR estimation method as a Desktop Adjustment Method (DAM - refer to Birkhead, 2008) was developed using MS-Excel and VBA. The procedure consists of the various steps which were used to provide EWR estimates for 66 and 85 hydronodes in the Sabie and Crocodile catchments, respectively. The above spreadsheet and data are provided in the electronic data (RDM Report no 26/8/3/10/12/016 and 26/8/3/10/14/016) as well as the .rul and .tab tables.

15.8 ANALYSIS OF THE RESULTS: DETERMINATION OF THE DEGREE TO WHICH THE RESERVE IS BEING MET UNDER CURRENT OPERATING RULES

An analysis was undertaken to determine whether the Ecological Reserve is being met under current operating rules and, if not, to what degree it was not being met. The results were rated (0 – 5) and these results were used to accordingly shade the different quaternary catchments. The shadings are described below and the maps and conclusions are provided below. Tables with the results are provided in the report, Chapter 9.

RED (5): Insufficient water is available to meet the Ecological Reserve under present conditions.
No licenses that will decrease flow should be considered as the Reserve is currently not being met. This means that there will be no yield available for additional users. Even if the Reserve is a low confidence Reserve based on an estimate, it is unlikely that revision will change the situation sufficiently that the Reserve will be met, AND that there will be yield available. It must be considered however that these are broad estimates and that there is uncertainty in the hydrology as well as the EWR estimates. Therefore, as a first check to confirm the red evaluation, the confidence in the hydrology and the reasons why the Reserve is not being met should be checked. EG, it is often the case that the hydrological modelling results in an underestimate of hydrology in areas high up in the catchment such as first order stream. In those cases, the estimated EWR is often higher than the modelled hydrology and shows an Ecological Reserve deficit when that is not really the case. All results must therefore be treated with caution and prior to decisions being made on these ratings, the specific situation should be evaluated and the results unpacked. *It must also be noted that the application of the Desktop Level EcoClassification to derive at the REC is only done for a specific river within the catchment under consideration. A future development may be applicable for a tributary of the river that was assessed and the EC and specific EWR may well be very different.*
ORANGE (4): There is a high likelihood that there is not enough water to meet the REC under present conditions.
This means that there is a high likelihood that there will be no yield available for additional users. See section in red above.
PALE ORANGE (3): There is a moderate likelihood that there is not enough water to meet the REC.
Assess the most cost-effective steps to take to investigate the situation. Confirmation of the REC as part of a Rapid III should be sufficient as a first step. If the REC has changed, the appropriate level of Reserve determination for the new EC (if lower than previous estimate) must be undertaken. An assessment must then be undertaken to determine whether the revised EWR still result in the EWR not being met. If not, then the available yield for future development must be calculated.
CREAM (2): There is a low likelihood that there is not enough water to meet the REC.
Assess the most cost-effective steps to take to investigate the situation. Confirmation of the REC through scoping should be sufficient as a first step. A Desktop assessment of the flows if the EC

changes should be sufficient for a revision of the water balance. Even if the Reserve is infrequently not met, this still means that there could be yield available in this system. Refer to 9.2 to determine whether yield will be available and the scale of the available yield.
WHITE (1): There is a high likelihood that there is sufficient water in the system to meet the REC.
This does not necessarily mean that there is yield available for additional users. Refer to 9.2 to determine whether yield is available and the scale of available yield.

15.8.1 Crocodile River

The results supplied were only for catchments with hydronodes. To determine the results, the EWRs for the EWR sites had to be provided as first option. As the decision was made that the current hydrology will be signed off as the Ecological Reserve, all the catchments which includes the Crocodile and the lower Kaap Rivers are evaluated as a zero, i.e. the Ecological Reserve is currently being met.

The Crocodile catchment does not show many areas where the Reserve is currently not being met. However, it MUST be remembered that the REC cannot be met in the main Crocodile River. This is not illustrated in the map as the main Crocodile has been modelled on the basis that present operation and hydrology will be signed off.

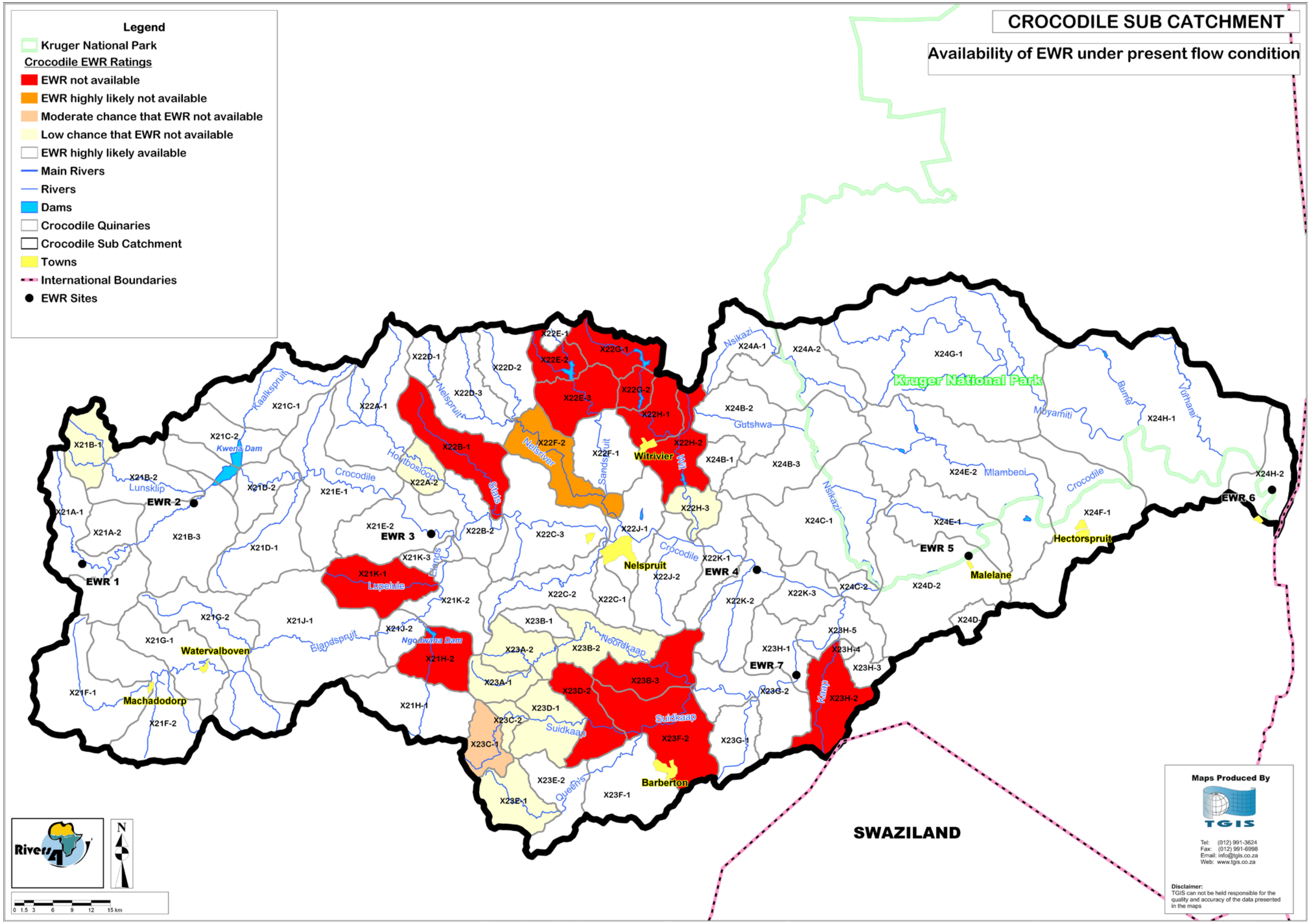


Figure 15.2 Crocodile River EWR availability map

15.8.2 Sabie-Sand Rivers

To determine the results, the EWRs for the EWR sites had to be provided as first option. The following was undertaken for this catchment:

- *Sabie Catchment: REC*
- *Sand Catchment: The Sellick-Rule was recommended and modelled. This will result in the RECs being met at the three EWR sites. As the REC is available in the Sabie River, the Sabie from EWR 1 is evaluated as a zero, i.e. the Ecological Reserve is currently being met. The Sellick rule situation is similar.*

There are very few stressed areas in this catchment. The red areas in the upper Sand are probably an artifact of the modelled hydrology inaccurately reflecting very low to zero flows. **It must be noted that there is low confidence in the Sand hydrology and this should be considered when decisions must be made. It must furthermore be noted that the Sellick-rule is currently NOT in place and the evaluation of the Sand River would show mostly a red rating if this rule is not applied.**

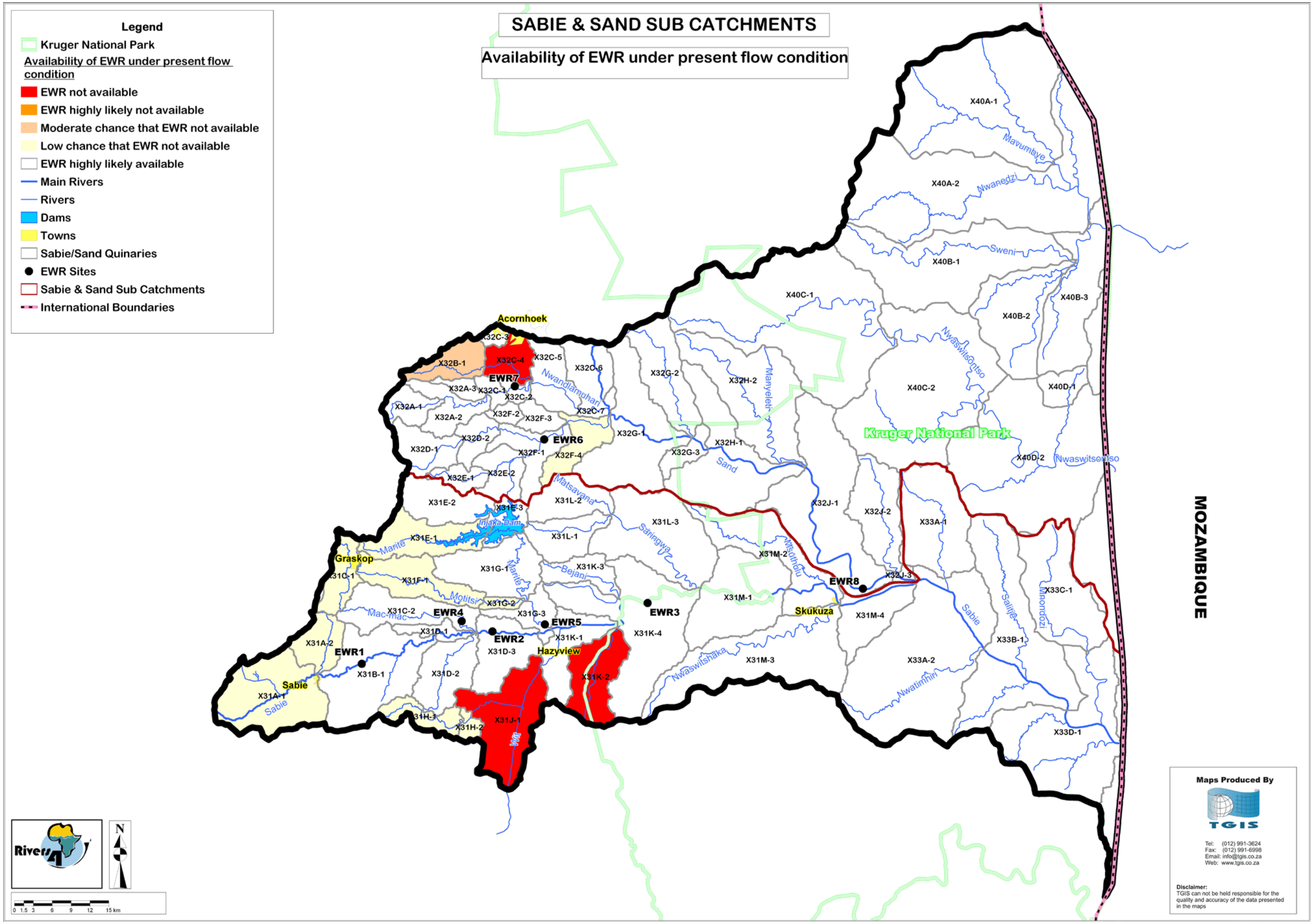


Figure 15.3 Sabie-Sand Rivers EWR availability map

15.9 ANALYSIS OF THE RESULTS: AVAILABLE YIELD IN CATCHMENTS WHERE THE RESERVE IS CURRENTLY BEING MET

The analysis undertaken and presented in Section 14.8 does not indicate whether there is spare yield available for future development in the areas where the Reserve is being met (white shaded and light cream shaded areas rated zero or one). An analysis was undertaken to determine the available yield in the system and these results are provided in tables (Chapter 9) and as maps (Figure 14-3). The colour grading used on the map is provided below.

Grey: No yield available and EWR cannot be met under current operation.
The grey catchments reflect all the catchments that were rated in section 17.8 from a 1.1 to 5. I.E., the Ecological Reserve cannot be met under current circumstances which automatically indicate that there is no yield available. If licenses and further developments are considered in these areas, appropriate work (such as described below) should be undertaken to confirm the degree to which the Reserve is not being met as well as to whether the proposed development will have an impact.
No yield available (5)
No licenses that will decrease flow should be considered. If however, further confirmation is required, more detailed studies are required to confirm these results. The first step should be to confirm the REC in the catchments where the REC has been derived from the Desktop EcoClassification. This is necessary as this is usually a low confidence estimate, and if the EC is found (after more detailed investigation) to be lower than the EC used in this modelling, then the EWR will be lower. The water balance will then have to be recalculated.
Very low yield (4)
As the likelihood of no water being available is high, licences should be considered only for special cases. If further confirmation is required, follow the same process as above.
Low yield (3)
Assess the most cost-effective steps to investigate the situation if development or licences are required. It is likely that a Level 3 EcoClassification and a Rapid III Reserve assessment might be sufficient. Then check water balance to see whether yield increases if the Reserve is less than estimated.
Moderate yield (2)
Assess the most cost-effective steps to investigate the situation if development or licences are required. It is likely that a Level 3 EcoClassification and a Rapid III Reserve assessment might be sufficient. Then check water balance to see whether yield increases if the Reserve is less than estimated.
High yield (1)
Assess the most cost-effective steps to take to investigate the situation. Confirmation of the REC through scoping should be sufficient as a first step. A Desktop assessment of the flows if the EC changes should be sufficient for a revision of the water balance.
Very high yield (5)
See steps described in Figure 15-3.

15.9.1 Crocodile River available yield

The relatively high yields available in the X24B and X24C catchments are due to return flows from the Nzikazi North urban area.

As the EWR at the main river has been signed off as the present flows, it is obvious that there will be no available yield in the system. As is well known, this is a very stressed catchment and this is supported by these results.

Further licensing and development should therefore not be allowed in most areas. Any further development in the catchment could have a cumulative effect and further influence the lower Komati River.

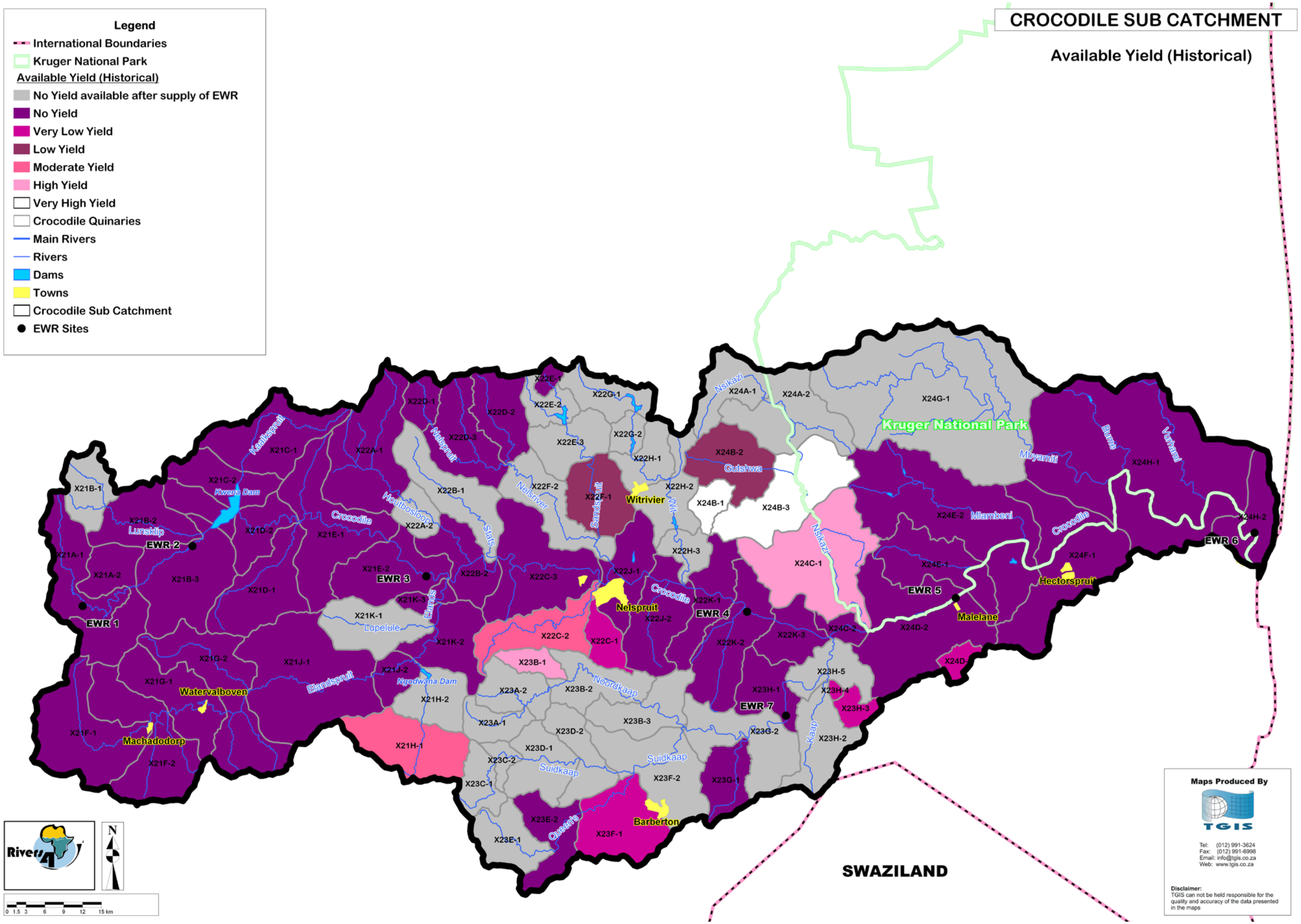


Figure 15.4 Crocodile available yield map

15.9.2 Sabie River available yield

Approximately 30% of the catchment includes rivers that more or less lie completely within the Kruger National Park. These rivers were not evaluated and were shaded gray as available yield is not applicable within these areas (see grey areas north of the Sand and Sabie Rivers within the KNP)

The REC is available in the Sabie River under current operation. However, limited to no spare yield is available in the Sabie River downstream from EWR 2. Therefore, even if the map illustrates that there is yield available upstream of EWR 2, any development in that area could result in the REC not being met in the lower Sabie River.

The Sand River is problematic as the hydrology is inaccurate due to the lack of gauging stations in the system. Local use and mismanagement of the current infrastructure has resulted in heavy river losses and problems in the lower Sand River. The signed off Reserve will be on the basis that Scenario 1 (Sellick-Rule) (26/8/3/10/12/011) will be implemented. This will result in the Ecological Reserve being available. The available yield calculations are based on this scenario being implemented. Therefore, apart from the additional yield which will be available once this rule is implemented, no further additional yield will be available.

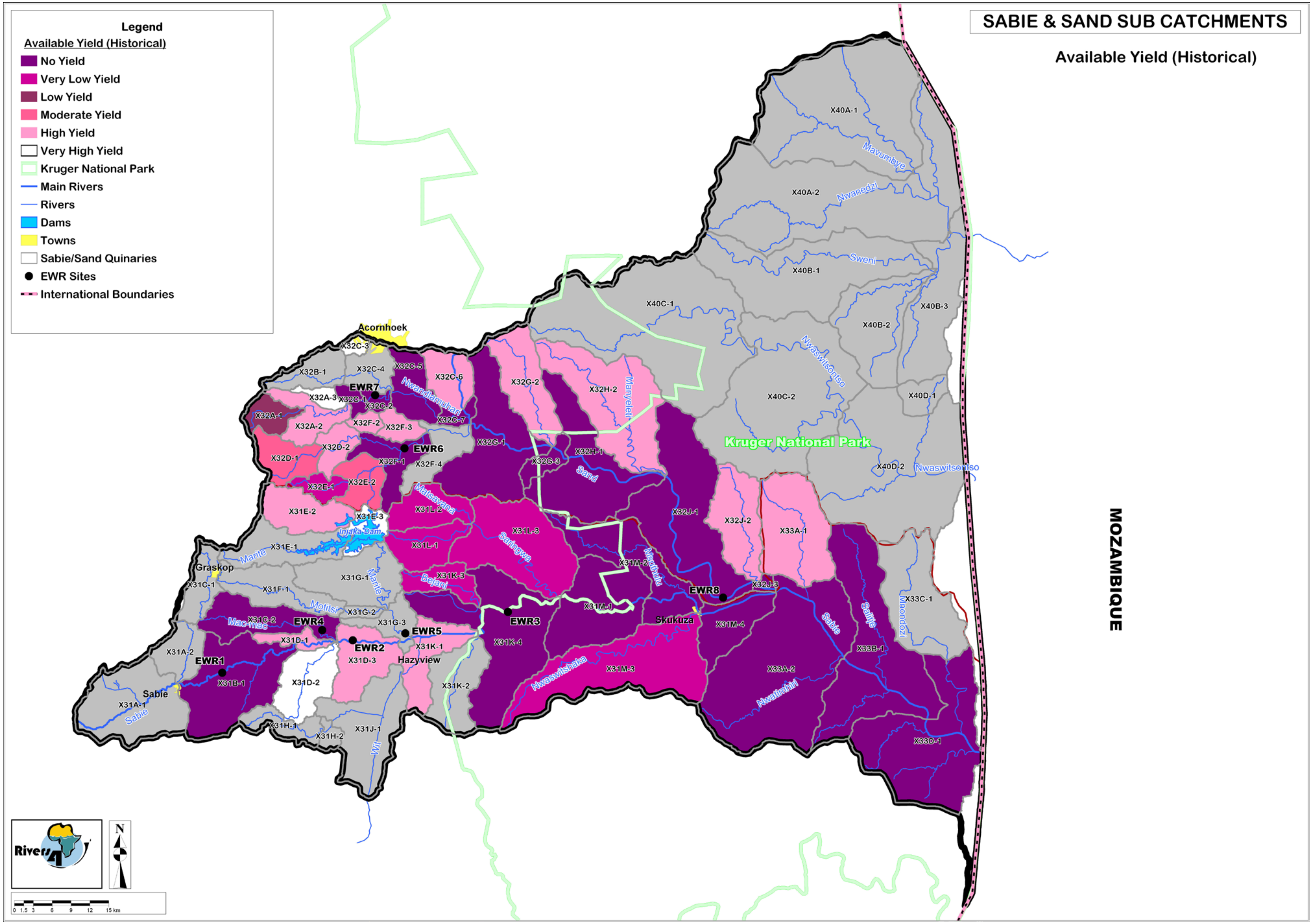


Figure 15.5 Sabie-Sand available yield map

15.10 GUIDANCE ON THE USE AND INTERPRETATION OF THE EWR AVAILABILITY AND AVIALABLE YIELD MAPS

Both maps contain much information at various levels of confidence and must therefore be used with care when further development is considered. This information can be an extremely useful aid when considering further development in the catchment. However, all the other information available within these Reserve study results should also be considered prior to decision-making.

A process summarised in a flow diagram (Figure 14-4) that can be used as a guideline for decision-making is provided.

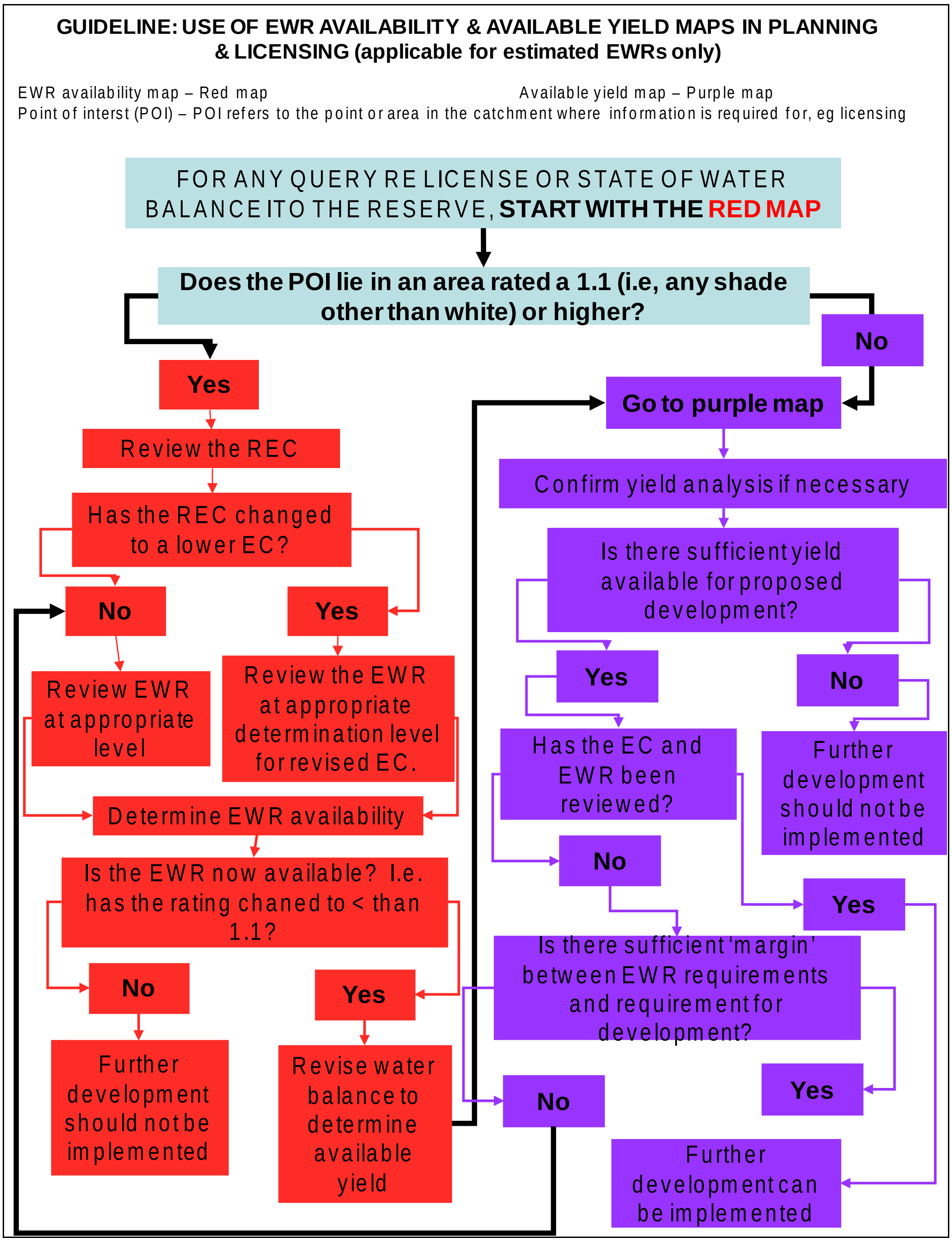


Figure 15.6 Guideline in the use of the Reserve and yield availability maps in planning and licensing

16 WHERE TO FROM HERE

Author: MD Louw (Rivers for Africa)

16.1 ECOLOGICAL WATER RESOURCES MONITORING PROGRAMME

A detailed monitoring programme as part of the Ecological Water Resources Monitoring (EWRM) programme must be designed by the PSP appointed to undertake the monitoring according to the guidelines set out by DWA. It was not part of the TOR of this Reserve study to undertake this. However, the design of the technical Ecological Specifications (EcoSpecs) to be used when interpreting the EWRM results was part of this study and is provided in Appendix B. It must be noted that the specifications are technical specifications which is used to interpret monitoring results by specialists and not for use for providing specifications for licensing.

During the comprehensive Reserve study, the PES was set based on biophysical surveys. This PES acts as the Baseline Ecological Category (BEC) and all EcoSpecs and TPCs were identified for the BEC. Unless monitoring is implemented within a short time frame, the baseline could/will have changed and the information generated during this study will not be valid anymore. This is not a cost-effective approach and it is recommended that monitoring should be implemented as soon as possible.

The section below provides ONLY broad details and certain key aspects of the Ecological Water Resources Monitoring (EWRM) programme. Technical detail of the EWRM is still in development by CD:RQS, DWA and the latest methods and models must be incorporated into the EWRM.

- *The EWRM must be followed according to the specifications provided broadly in: Department of Water Affairs, South Africa. 2009. Operationalise the Reserve: Main Report. Prepared by Water for Africa. Compiled by D Louw and S Louw. Report no. RDM/NAT/05/CON/0907.*
- *The further refinements of EWRM and exact specifications as currently being developed by RQS, DWA should be used as baseline.*
- *EcoSpecs and Threshold of Concern provided in Appendix B should be applied during the EWRM.*
- *EWRM should be implemented at all the EWR sites as the minimum.*
- *The EWRM should be implemented immediately so that the information gained during the EWR study can form part of the baseline.*
- *The EWRM monitoring must be undertaken within a structured DSS.*

17 CAPACITY BUILDING

Author: PA Scherman

One of the tasks of the Comprehensive Reserve studies co-ordinated by the CD:RDM of the DWA from 2007 to 2010, was the development of an Integrated Technical Training Programme (ITTP) for the studies. An integrated Training Report will be produced as output of this task, i.e. Report number RDM/TR-S/CRITR/01/2010, entitled Comprehensive Reserve Integrated Training Report - Training for Reserve specialists as part of the Vaal, Outeniqua, Mokolo and Crocodile east Comprehensive Reserves (2007 – 2010). The information provided in this chapter of the Main Report is therefore an outline of activities, with all analyses and detailed feedback for all specialist trainees appearing in the Integrated Training Report.

17.1 OBJECTIVE

The objective of the training task undertaken during the Comprehensive Reserve studies was to build capacity and conduct effective training on Reserve principles and methods. Training was focussed at the level of specialist trainees, i.e. persons who would act in the role of specialists in future Reserve studies. Note that the training programme presumed that trainees have an understanding of the Reserve concept and process. Training was primarily conducted in the form of specialist workshops, fieldwork and one-on-one training.

17.2 AIMS

The main aims of the training were to ensure that specialist trainees have developed or enhanced a range of Reserve-related skills:

- *Developed an understanding of Ecological Water Requirements (EWR) and the process to be followed during the steps of a Reserve study.*
- *Developed an understanding of the role of each specialist within the broader Reserve process.*
- *Worked within a team to achieve EcoClassification, define EcoStatus and set flow requirements (where relevant).*
- *Understand the links between physical driver processes and biotic responses.*
- *Understand data formats (e.g. hydrological data), and the link between data collection in the field and how the data are presented.*
- *The ability to use the tools or software required by a specific discipline, and to understand the use of these tools.*
- *The ability to interpret information related to a specific discipline within the Reserve process.*
- *Developed an understanding of how flow requirements are set per indicator (where relevant).*
- *Developed an understanding of how to operate as a specialist within a particular field or component.*
- *Developed some knowledge regarding various components of a Reserve study, including setting Reserve requirements for different water resources (e.g. rivers, estuaries, groundwater, and wetlands).*

17.3 OUTPUTS

The outputs of the training process were as follows:

- *Training for specialists with limited Reserve experience, e.g. learning to set flow requirements for biological indicators and using EcoClassification models. These trainees were referred to as specialist trainees, and their training was considered an extension of their specialist skills. Note that specialist trainees were paired with mentors (i.e. study specialists) in their relevant field.*
- *Introducing trainees to the use of their specialist tools within a Reserve context. This category refers to less experienced trainees.*
- *Broadening the pool of specialists in fields where expertise is severely limited, i.e. hydrology, hydraulics and water quality specialists for Reserve assessment studies (Weston, CD: RDM, pers. comm.). Another specialist field that can be added to this list is geomorphology.*
- *Exposing staff from DWA's scientific services, e.g. Directorate: Resource Quality Services (D: RQS) and CD: RDM, to Reserve process and methods.*

The Training Report being produced for this task, which will be finalized upon completion of the Vaal Reserve study, outlines activities, shortcomings and list recommendations for future training. The Training Report will contain the following information:

- *An audit and evaluation of the training process.*
- *An assessment of each trainee's ability to operate within a Reserve team.*
- *A critical assessment of the training programme, within the confines of its scope and objectives.*
- *Additional training needs and recommendations.*
- *An evaluation of the success of training amongst previously disadvantaged groups, and specialist fields earmarked for capacity building (e.g. hydraulics).*
- *A database of specialists available for Reserve studies, and a comment on each person's level of expertise and experience within the Reserve field.*

17.4 MENTOR-TRAINEE TEAMS

Mentor	Trainee	Component
Delana Louw	*Shileen Louw*	*Financial administration and coordination*
Denis Hughes	*Ryan Gray*	*SPATSIM and hydrology*
	Simon Johnson	
Patsy Scherman	*Chris Dickens*	*Water quality*
	Victor Wepener	
Drew Birkhead	*Ahmed Desai*	*Hydraulics*
Neels Kleynhans	*Piet Kotzé*	*Fish*
Mark Rountree	*Lindo Hlongwane*	*Geomorphology and wetlands (until mid-2009)*
	Nonkanyiso Maphumlo	*Wetlands (until mid-2009)*
Mandy Uys	*Ntaki Senoge*	*Macroinvertebrates*
	Petro Jordaan	
James Mackenzie	*Tony de Castro*	*Riparian vegetation*
Adhishri Singh	*Byron Grant*	*Administrative management*
	Petro Jordaan	*Financial management/training coordination*
Koos Vivier	*Stephanie Zimmerman*	*Groundwater*

17.5 TRAINING ACTIVITIES/APPROACH

Training activities need to be divided into project-specific activities vs. those related to the Integrated Technical Training Programme. Project-specific activities included trainee attendance at project workshops or training workshops, while activities of the ITTP included the following workshops:

- **Workshop 1, 22-23 January 2008:** *Multi-disciplinary roles in defining EcoStatus and setting flow requirements during an Ecological Reserve study.*

Aim: *The training workshop focused on the links between flows and biotic responses. The principles of Ecological Water Requirements (EWR) were discussed per discipline, as well as the principle of integrating the various metrics to achieve EcoClassification and define EcoStatus. The workshop also covered the general process followed to set flow requirements per metric, i.e. for both driver and response indicators.*

- **Workshop 2, 26-27 March 2008:** *Habitat Flow Stressor-Response workshop. The agenda is shown in Appendix 2. A course evaluation questionnaire was not distributed as this workshop formed the basis of the one-to-one specialist training, which was covered in a questionnaire of November 2009.*

Aim: *This training workshop focussed on the application of the Habitat Flow-Stressor Response (HFSR) process during a specialist river workshop. The workshop was aimed at specialist trainees who worked within the following specialist teams:*

- *Invertebrate team led by Christa Thirion*
- *Fish team led by Neels Kleynhans*
- *Riparian vegetation team led by James Mackenzie*
- *Geomorphology team led by Mark Rountree*
- *Hydrological support provided by Delana Louw (with prior assistance by Denis Hughes)*
- *Hydraulic input provided by Drew Birkhead*
- *Yield modelling information provided by Stephen Mallory on day 2 of the workshop*

17.6 TRAINING FEEDBACK

The success of training was evaluated with the use of the following:

- *Questionnaire to gather training evaluation information from trainees. Questionnaires were completed following workshops, as well as for the training programme.*
- *Short reports from mentors.*

17.7 TRAINEE DATABASE

One of the outcomes of this task is an evaluation of the training process and assessment of each trainee's ability and knowledge regarding EWRs. This information should be captured on a trainee database housed at CD:RDM, so that the following type of information can be available per trainee:

- *Specialist field and mentor details per Reserve study*
- *Project exposure and dates, e.g. worked as a specialist trainee on the Thukela and Croc East Reserve studies.*
- *Level of expertise, e.g. specialist trainee level 1 (no previous exposure to Reserve studies). This information will enable CD: RDM to identify appropriately trained specialist for future studies, as well as build further capacity in fields where skills are lacking.*
- *Outcomes of performance evaluations on Reserves studies.*
- *It must be noted that the training provided by this study may be one step in the training process and that additional exposure to Reserve studies may be required for certain trainees before they are sufficiently capacitated to operate as specialists.*

18 ELECTRONIC DATA

Electronic data supplied as part of this study are summarised in a Read Me file in Excel according to the structure of the electronic data. The Read Me file is provided below to indicate the information available electronically.

WILL BE INCLUDED WHEN COMPLETED

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APPENDIX A

Table A. 1: EWR Table and Rule for the Crocodile River at the EWR 1 in Quaternary Catchment X21A

EWR Table

Desktop version:		2	Virgin MAR (MCM)	15.191
BFI index	0.5	Distribution type		Eastern escarpment

MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	*0.065*	*0.020*		
NOVEMBER	*0.093*	*0.035*	*1*	*3*
DECEMBER	*0.111*	*0.045*	*1*	*3*
JANUARY	*0.157*	*0.069*	*3*	*3*
FEBRUARY	*0.200*	*0.090*		
MARCH	*0.173*	*0.077*	*1*	*3*
APRIL	*0.166*	*0.073*		
MAY	*0.138*	*0.059*		
JUNE	*0.114*	*0.046*		
JULY	*0.091*	*0.034*		
AUGUST	*0.071*	*0.023*		
SEPTEMBER	*0.060*	*0.018*		
TOTAL MCM	*3.765*	*1.539*	*0.933*	
% OF VIRGIN	*24.78*	*10.13*	*6.14*	

EWR Rule

Total Ecological Reserve flows										
Month	*10%*	*20%*	*30%*	*40%*	*50%*	*60%*	*70%*	*80%*	*90%*	*99%*
Oct	*0.078*	*0.077*	*0.077*	*0.075*	*0.073*	*0.068*	*0.059*	*0.047*	*0.033*	*0.021*
Nov	*0.177*	*0.176*	*0.174*	*0.171*	*0.164*	*0.152*	*0.132*	*0.104*	*0.07*	*0.044*
Dec	*0.196*	*0.195*	*0.193*	*0.19*	*0.182*	*0.169*	*0.148*	*0.117*	*0.081*	*0.054*
Jan	*0.526*	*0.48*	*0.44*	*0.404*	*0.367*	*0.307*	*0.266*	*0.209*	*0.142*	*0.093*
Feb	*0.239*	*0.238*	*0.236*	*0.232*	*0.225*	*0.211*	*0.189*	*0.158*	*0.121*	*0.094*
Mar	*0.32*	*0.304*	*0.29*	*0.276*	*0.259*	*0.232*	*0.205*	*0.167*	*0.121*	*0.087*
Apr	*0.198*	*0.198*	*0.197*	*0.194*	*0.188*	*0.177*	*0.159*	*0.132*	*0.1*	*0.076*
May	*0.165*	*0.165*	*0.164*	*0.161*	*0.157*	*0.148*	*0.133*	*0.11*	*0.083*	*0.062*
Jun	*0.136*	*0.136*	*0.135*	*0.133*	*0.13*	*0.122*	*0.11*	*0.09*	*0.066*	*0.048*
Jul	*0.109*	*0.109*	*0.108*	*0.107*	*0.104*	*0.098*	*0.088*	*0.072*	*0.051*	*0.036*
Aug	*0.085*	*0.085*	*0.084*	*0.083*	*0.08*	*0.075*	*0.067*	*0.053*	*0.037*	*0.025*
Sep	*0.072*	*0.072*	*0.071*	*0.07*	*0.067*	*0.063*	*0.055*	*0.044*	*0.03*	*0.019*
Reserve flows without High Flows										
Oct	*0.078*	*0.077*	*0.077*	*0.075*	*0.073*	*0.068*	*0.059*	*0.047*	*0.033*	*0.021*
Nov	*0.111*	*0.111*	*0.11*	*0.108*	*0.104*	*0.097*	*0.086*	*0.07*	*0.051*	*0.037*
Dec	*0.133*	*0.132*	*0.131*	*0.129*	*0.124*	*0.116*	*0.103*	*0.085*	*0.063*	*0.047*
Jan	*0.188*	*0.187*	*0.185*	*0.182*	*0.175*	*0.164*	*0.147*	*0.122*	*0.093*	*0.072*

Feb	0.239	0.238	0.236	0.232	0.225	0.211	0.189	0.158	0.121	0.094
Mar	0.207	0.206	0.205	0.201	0.195	0.183	0.164	0.137	0.104	0.08
Apr	0.198	0.198	0.197	0.194	0.188	0.177	0.159	0.132	0.1	0.076
May	0.165	0.165	0.164	0.161	0.157	0.148	0.133	0.11	0.083	0.062
Jun	0.136	0.136	0.135	0.133	0.13	0.122	0.11	0.09	0.066	0.048
Jul	0.109	0.109	0.108	0.107	0.104	0.098	0.088	0.072	0.051	0.036
Aug	0.085	0.085	0.084	0.083	0.08	0.075	0.067	0.053	0.037	0.025
Sep	0.072	0.072	0.071	0.07	0.067	0.063	0.055	0.044	0.03	0.019
Natural Duration curves										
Oct	0.314	0.261	0.224	0.179	0.161	0.149	0.138	0.119	0.105	0.09
Nov	0.683	0.536	0.436	0.367	0.328	0.305	0.255	0.239	0.212	0.147
Dec	1.292	0.743	0.638	0.556	0.485	0.452	0.407	0.362	0.276	0.175
Jan	2.838	1.915	0.795	0.68	0.597	0.553	0.508	0.459	0.37	0.276
Feb	2.414	1.736	1.062	0.885	0.74	0.69	0.599	0.525	0.475	0.38
Mar	1.307	0.87	0.765	0.724	0.635	0.594	0.519	0.47	0.414	0.287
Apr	0.729	0.656	0.586	0.513	0.482	0.444	0.428	0.363	0.313	0.224
May	0.47	0.377	0.362	0.329	0.295	0.276	0.246	0.217	0.179	0.157
Jun	0.336	0.255	0.239	0.224	0.212	0.197	0.181	0.162	0.139	0.116
Jul	0.254	0.231	0.187	0.175	0.164	0.157	0.149	0.134	0.119	0.105
Aug	0.198	0.175	0.157	0.146	0.134	0.131	0.119	0.112	0.101	0.09
Sep	0.224	0.174	0.147	0.135	0.123	0.112	0.108	0.096	0.085	0.073

Table A. 2: EWR Table and EWR Rule for the Crocodile River at the EWR 2 in X21B

EWR Table

Desktop version:		2	Virgin MAR (MCM)	47.111
BFI index	0.5	Distribution type		Eastern escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.384	0.187		
NOVEMBER	0.568	0.242	3	3
DECEMBER	0.692	0.275	3	3
JANUARY	0.987	0.360	3	3
FEBRUARY	1.270	0.450	9	4
MARCH	1.104	0.394	3	3
APRIL	1.057	0.383	3	3
MAY	0.874	0.328		
JUNE	0.716	0.285		
JULY	0.567	0.240		
AUGUST	0.425	0.199		
SEPTEMBER	0.350	0.180		
TOTAL MCM	23.528	9.225	3.499	
% OF VIRGIN	49.94	19.58	7.43	

EWR Rule

Total Ecological Reserve flows										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.459	0.458	0.455	0.449	0.436	0.413	0.373	0.316	0.246	0.194

Total Ecological Reserve flows										
Month	*10%*	*20%*	*30%*	*40%*	*50%*	*60%*	*70%*	*80%*	*90%*	*99%*
Nov	*0.876*	*0.873*	*0.865*	*0.849*	*0.819*	*0.764*	*0.674*	*0.544*	*0.39*	*0.275*
Dec	*1.017*	*1.013*	*1.004*	*0.984*	*0.947*	*0.882*	*0.776*	*0.623*	*0.444*	*0.31*
Jan	*1.518*	*1.467*	*1.416*	*1.36*	*1.286*	*1.16*	*1.016*	*0.812*	*0.576*	*0.401*
Feb	*2.828*	*2.649*	*2.488*	*2.333*	*2.164*	*1.876*	*1.632*	*1.28*	*0.867*	*0.559*
Mar	*1.657*	*1.608*	*1.559*	*1.502*	*1.427*	*1.296*	*1.139*	*0.911*	*0.64*	*0.438*
Apr	*1.263*	*1.26*	*1.25*	*1.229*	*1.188*	*1.112*	*0.986*	*0.799*	*0.574*	*0.405*
May	*1.044*	*1.043*	*1.036*	*1.02*	*0.988*	*0.929*	*0.828*	*0.675*	*0.488*	*0.346*
Jun	*0.856*	*0.855*	*0.837*	*0.806*	*0.752*	*0.706*	*0.652*	*0.565*	*0.414*	*0.3*
Jul	*0.678*	*0.678*	*0.674*	*0.635*	*0.597*	*0.564*	*0.538*	*0.46*	*0.342*	*0.252*
Aug	*0.508*	*0.508*	*0.505*	*0.498*	*0.485*	*0.46*	*0.417*	*0.351*	*0.269*	*0.207*
Sep	*0.418*	*0.418*	*0.416*	*0.41*	*0.4*	*0.38*	*0.346*	*0.296*	*0.233*	*0.186*
Reserve flows without High Flows										
Oct	*0.459*	*0.458*	*0.455*	*0.449*	*0.436*	*0.413*	*0.373*	*0.316*	*0.246*	*0.194*
Nov	*0.679*	*0.677*	*0.671*	*0.66*	*0.638*	*0.6*	*0.536*	*0.444*	*0.335*	*0.253*
Dec	*0.827*	*0.824*	*0.816*	*0.802*	*0.774*	*0.724*	*0.643*	*0.527*	*0.39*	*0.289*
Jan	*1.179*	*1.173*	*1.161*	*1.138*	*1.094*	*1.018*	*0.896*	*0.725*	*0.527*	*0.38*
Feb	*1.517*	*1.511*	*1.497*	*1.468*	*1.414*	*1.318*	*1.162*	*0.937*	*0.673*	*0.476*
Mar	*1.319*	*1.315*	*1.303*	*1.279*	*1.233*	*1.151*	*1.016*	*0.821*	*0.59*	*0.417*
Apr	*1.263*	*1.26*	*1.25*	*1.229*	*1.188*	*1.112*	*0.986*	*0.799*	*0.574*	*0.405*
May	*1.044*	*1.043*	*1.036*	*1.02*	*0.988*	*0.929*	*0.828*	*0.675*	*0.488*	*0.346*
Jun	*0.856*	*0.855*	*0.837*	*0.806*	*0.752*	*0.706*	*0.652*	*0.565*	*0.414*	*0.3*
Jul	*0.678*	*0.678*	*0.674*	*0.635*	*0.597*	*0.564*	*0.538*	*0.46*	*0.342*	*0.252*
Aug	*0.508*	*0.508*	*0.505*	*0.498*	*0.485*	*0.46*	*0.417*	*0.351*	*0.269*	*0.207*
Sep	*0.418*	*0.418*	*0.416*	*0.41*	*0.4*	*0.38*	*0.346*	*0.296*	*0.233*	*0.186*
NaturalDurationcurves										
Oct	*1.09*	*0.922*	*0.795*	*0.65*	*0.586*	*0.541*	*0.5*	*0.444*	*0.381*	*0.336*
Nov	*2.114*	*1.782*	*1.47*	*1.235*	*1.092*	*1.042*	*0.876*	*0.822*	*0.725*	*0.509*
Dec	*3.252*	*2.319*	*2.012*	*1.773*	*1.553*	*1.441*	*1.281*	*1.154*	*0.885*	*0.571*
Jan	*6.941*	*4.529*	*2.509*	*2.121*	*1.859*	*1.71*	*1.542*	*1.422*	*1.15*	*0.851*
Feb	*6.01*	*4.543*	*3.237*	*2.708*	*2.278*	*2.125*	*1.844*	*1.62*	*1.463*	*1.195*
Mar	*4.208*	*2.856*	*2.427*	*2.36*	*2.012*	*1.897*	*1.65*	*1.478*	*1.288*	*0.9*
Apr	*2.423*	*2.184*	*1.914*	*1.717*	*1.566*	*1.431*	*1.373*	*1.192*	*1.007*	*0.741*
May	*1.617*	*1.296*	*1.21*	*1.098*	*1.019*	*0.956*	*0.829*	*0.743*	*0.62*	*0.53*
Jun	*1.204*	*0.91*	*0.837*	*0.806*	*0.752*	*0.706*	*0.652*	*0.579*	*0.513*	*0.417*
Jul	*0.922*	*0.825*	*0.687*	*0.635*	*0.597*	*0.564*	*0.538*	*0.485*	*0.437*	*0.373*
Aug	*0.713*	*0.646*	*0.579*	*0.534*	*0.5*	*0.474*	*0.437*	*0.418*	*0.381*	*0.336*
Sep	*0.802*	*0.633*	*0.536*	*0.494*	*0.451*	*0.421*	*0.397*	*0.367*	*0.324*	*0.274*

Table A. 3: EWR Rule for the Crocodile River at the EWR 3 in X21E

Determination based on modelled present day hydrology in m3/s

Regional Type: E. Escarpment **PES = B/C**

Present day hydrology as the EWR

Months	**0.1%**	**1%**	**5%**	**10%**	**15%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**85%**	**90%**	**95%**	**99%**	**99.9%**
Jan	*45.53*	*36.91*	*27.73*	*21.13*	*17.26*	*11.88*	*7.85*	*6.66*	*5.59*	*4.41*	*3.21*	*2.63*	*2.06*	*1.63*	*1.34*	*0.98*	*0.89*
Feb	*75.57*	*69.38*	*36.07*	*22.12*	*19.20*	*15.95*	*12.58*	*9.54*	*7.58*	*6.46*	*5.25*	*4.29*	*3.39*	*2.43*	*1.73*	*1.49*	*1.19*
Mar	*34.74*	*32.83*	*24.85*	*17.43*	*14.92*	*12.82*	*10.40*	*9.00*	*7.38*	*6.39*	*5.53*	*4.31*	*4.11*	*3.47*	*2.52*	*1.93*	*1.48*
Apr	*22.47*	*17.96*	*13.13*	*11.11*	*9.49*	*8.83*	*7.69*	*6.54*	*5.95*	*5.07*	*4.62*	*4.29*	*3.78*	*3.10*	*2.35*	*1.44*	*1.40*
May	*9.42*	*8.82*	*7.73*	*6.73*	*5.86*	*5.44*	*4.82*	*4.42*	*4.15*	*3.79*	*3.48*	*3.02*	*2.79*	*2.64*	*2.36*	*1.77*	*1.65*
Jun	*7.35*	*7.34*	*6.92*	*5.84*	*5.44*	*5.15*	*4.80*	*4.25*	*3.98*	*3.67*	*3.17*	*2.93*	*2.69*	*2.55*	*2.29*	*1.71*	*1.69*
Jul	*6.51*	*6.33*	*5.96*	*5.32*	*4.86*	*4.55*	*3.82*	*3.58*	*3.16*	*3.02*	*2.82*	*2.56*	*2.46*	*2.11*	*1.89*	*1.64*	*1.12*
Aug	*6.03*	*5.98*	*5.61*	*5.05*	*4.81*	*4.36*	*4.10*	*3.72*	*3.48*	*3.19*	*2.81*	*2.29*	*2.09*	*1.97*	*1.65*	*1.30*	*1.21*
Sep	*4.42*	*4.31*	*4.02*	*3.52*	*3.30*	*3.17*	*2.54*	*2.22*	*1.92*	*1.73*	*1.44*	*1.28*	*1.14*	*1.01*	*0.68*	*0.57*	*0.53*

Oct	*6.56*	*5.71*	*4.53*	*4.23*	*3.95*	*3.70*	*2.99*	*2.78*	*2.41*	*2.02*	*1.43*	*1.12*	*1.06*	*0.91*	*0.78*	*0.72*	*0.70*
Nov	*28.80*	*25.03*	*8.52*	*6.62*	*5.63*	*5.17*	*3.77*	*3.08*	*2.55*	*1.91*	*1.57*	*1.09*	*1.02*	*0.96*	*0.86*	*0.72*	*0.70*
Dec	*26.75*	*20.78*	*14.77*	*9.92*	*8.56*	*7.28*	*5.81*	*4.25*	*3.45*	*2.66*	*1.87*	*1.56*	*1.53*	*1.35*	*1.14*	*0.96*	*0.87*

Table A. 4: EWR Rule for the Crocodile River at the EWR 4 in X22K

Determination based on modelled present day hydrology in m3/s
Regional Type: E. Escarpment **PES = C**
Present day hydrology as the EWR

Months	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Jan	*120.96*	*110.14*	*82.85*	*71.69*	*54.06*	*42.06*	*35.29*	*25.52*	*20.65*	*18.02*	*13.70*	*11.70*	*10.56*	*9.80*	*8.02*	*7.55*	*7.21*
Feb	*264.03*	*256.99*	*146.77*	*96.66*	*91.59*	*68.97*	*44.51*	*29.45*	*25.28*	*21.95*	*18.48*	*15.09*	*14.56*	*13.38*	*10.94*	*9.74*	*8.04*
Mar	*217.56*	*188.53*	*100.62*	*75.06*	*65.04*	*46.69*	*33.05*	*27.72*	*21.80*	*18.63*	*16.67*	*14.82*	*13.48*	*11.82*	*10.42*	*7.72*	*6.85*
Apr	*135.26*	*66.45*	*40.27*	*32.31*	*29.44*	*26.90*	*22.47*	*19.51*	*16.93*	*14.63*	*13.29*	*12.00*	*10.69*	*9.84*	*7.93*	*6.76*	*6.69*
May	*23.89*	*23.14*	*20.10*	*17.05*	*14.66*	*13.12*	*11.22*	*10.34*	*9.17*	*7.58*	*6.56*	*6.43*	*6.37*	*6.18*	*5.83*	*4.85*	*4.82*
Jun	*15.08*	*14.72*	*12.32*	*11.44*	*9.67*	*8.31*	*7.01*	*6.51*	*6.40*	*6.35*	*6.29*	*6.11*	*5.97*	*5.90*	*5.60*	*5.05*	*4.41*
Jul	*11.02*	*10.81*	*10.07*	*8.98*	*7.87*	*7.34*	*5.98*	*5.91*	*5.87*	*5.76*	*5.66*	*5.47*	*5.32*	*5.24*	*5.07*	*4.85*	*4.56*
Aug	*14.01*	*10.36*	*8.89*	*7.21*	*6.38*	*5.93*	*5.81*	*5.78*	*5.72*	*5.63*	*5.59*	*5.50*	*5.45*	*5.30*	*5.22*	*4.95*	*4.93*
Sep	*14.62*	*12.44*	*10.85*	*9.15*	*8.14*	*6.73*	*6.00*	*5.92*	*5.72*	*5.65*	*5.54*	*5.44*	*5.37*	*5.26*	*5.18*	*4.93*	*4.88*
Oct	*16.61*	*16.24*	*12.72*	*11.43*	*10.55*	*8.88*	*6.72*	*6.16*	*6.04*	*5.94*	*5.91*	*5.82*	*5.71*	*5.59*	*5.46*	*5.14*	*4.88*
Nov	*59.07*	*45.79*	*30.05*	*20.68*	*18.38*	*17.08*	*14.63*	*12.07*	*9.83*	*7.92*	*7.21*	*7.11*	*7.01*	*7.00*	*6.47*	*6.20*	*5.96*
Dec	*91.78*	*61.45*	*52.21*	*43.67*	*29.39*	*25.22*	*21.39*	*17.59*	*14.26*	*11.86*	*10.04*	*8.71*	*8.24*	*7.41*	*7.16*	*6.76*	*6.59*

Table A. 5: EWR Rule for the Crocodile River at the EWR 5 in X24D

Determination based on modelled present day hydrology in m3/s
Regional Type: E. Escarpment **PES = C**
Present day hydrology as the EWR

Months	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Jan	*140.42*	*134.23*	*111.35*	*87.74*	*75.19*	*52.02*	*38.51*	*29.73*	*23.78*	*20.31*	*14.44*	*10.23*	*9.41*	*7.40*	*7.30*	*6.57*	*5.82*
Feb	*349.02*	*292.11*	*165.23*	*124.83*	*112.88*	*81.55*	*48.90*	*33.75*	*25.32*	*22.75*	*18.68*	*15.07*	*14.02*	*10.57*	*8.39*	*6.19*	*6.11*
Mar	*270.17*	*236.43*	*133.02*	*90.90*	*68.18*	*47.91*	*37.88*	*31.01*	*22.99*	*17.24*	*14.71*	*10.95*	*9.45*	*7.56*	*5.57*	*5.36*	*5.32*
Apr	*192.44*	*99.24*	*54.63*	*36.77*	*31.07*	*30.11*	*26.64*	*19.09*	*15.74*	*12.38*	*8.84*	*7.68*	*6.79*	*5.89*	*5.53*	*5.29*	*5.26*
May	*41.35*	*30.13*	*20.15*	*17.67*	*13.74*	*11.71*	*8.50*	*7.40*	*6.62*	*5.81*	*5.63*	*5.54*	*5.44*	*5.33*	*5.22*	*5.01*	*4.96*
Jun	*19.21*	*15.55*	*10.58*	*8.29*	*7.89*	*7.06*	*5.83*	*5.75*	*5.69*	*5.59*	*5.54*	*5.46*	*5.37*	*5.28*	*5.03*	*4.68*	*4.62*
Jul	*9.69*	*8.88*	*7.88*	*7.21*	*6.91*	*5.84*	*5.54*	*5.46*	*5.37*	*5.30*	*5.27*	*5.20*	*5.04*	*4.99*	*4.79*	*2.69*	*1.96*
Aug	*11.70*	*8.15*	*6.78*	*6.49*	*6.20*	*5.98*	*5.48*	*5.39*	*5.35*	*5.32*	*5.22*	*5.09*	*5.02*	*4.89*	*3.58*	*3.08*	*2.05*
Sep	*13.56*	*12.33*	*9.69*	*6.48*	*6.38*	*6.35*	*6.17*	*5.71*	*5.57*	*5.50*	*5.34*	*5.30*	*5.16*	*5.09*	*3.24*	*2.19*	*2.03*
Oct	*17.37*	*16.26*	*11.83*	*10.24*	*7.86*	*6.63*	*6.32*	*6.16*	*6.04*	*5.48*	*5.40*	*5.28*	*5.06*	*4.94*	*3.44*	*2.40*	*1.95*
Nov	*64.83*	*60.08*	*40.97*	*24.55*	*20.16*	*18.34*	*14.10*	*11.41*	*8.96*	*7.39*	*6.68*	*6.10*	*5.90*	*5.86*	*5.65*	*3.99*	*1.88*
Dec	*124.47*	*85.19*	*71.92*	*56.46*	*38.87*	*35.18*	*27.41*	*18.68*	*14.05*	*10.64*	*8.80*	*7.43*	*7.09*	*6.55*	*5.85*	*3.97*	*3.85*

Table A. 6: EWR Rule for the Crocodile River at the EWR site 6 in X24H

Determination based on modelled present day hydrology in m3/s
Regional Type: E. Escarpment **PES = C**
Present day hydrology as the EWR

Months	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Jan	*163.34*	*146.49*	*125.56*	*93.13*	*72.10*	*49.15*	*35.19*	*26.30*	*19.43*	*16.08*	*9.76*	*5.58*	*5.07*	*3.48*	*2.85*	*2.05*	*1.46*

Feb	*390.37*	*365.45*	*176.05*	*129.68*	*111.69*	*87.93*	*44.01*	*30.60*	*20.90*	*18.86*	*13.83*	*11.26*	*9.68*	*6.13*	*3.87*	*1.02*	*0.94*
Mar	*313.36*	*307.18*	*128.50*	*96.95*	*66.72*	*44.47*	*34.84*	*27.75*	*19.79*	*13.46*	*10.80*	*6.90*	*5.97*	*4.44*	*1.13*	*0.95*	*0.91*
Apr	*260.62*	*115.51*	*51.98*	*41.43*	*27.57*	*26.14*	*22.59*	*15.82*	*12.21*	*8.79*	*4.68*	*3.61*	*2.52*	*1.42*	*1.13*	*0.89*	*0.89*
May	*54.90*	*32.57*	*18.08*	*13.72*	*10.97*	*7.96*	*5.07*	*3.88*	*3.06*	*1.69*	*1.50*	*1.36*	*1.32*	*1.27*	*1.05*	*0.92*	*0.89*
Jun	*20.79*	*12.62*	*6.43*	*4.97*	*4.25*	*3.24*	*1.92*	*1.65*	*1.58*	*1.54*	*1.42*	*1.38*	*1.35*	*1.33*	*1.30*	*1.17*	*1.07*
Jul	*7.37*	*5.59*	*4.20*	*4.06*	*3.48*	*2.82*	*2.18*	*1.64*	*1.59*	*1.53*	*1.48*	*1.38*	*1.30*	*1.26*	*1.15*	*0.90*	*0.60*
Aug	*7.98*	*5.06*	*3.86*	*3.38*	*3.25*	*3.03*	*2.19*	*1.64*	*1.60*	*1.56*	*1.48*	*1.42*	*1.38*	*1.27*	*1.00*	*0.51*	*0.43*
Sep	*9.55*	*8.42*	*5.76*	*3.54*	*3.35*	*3.27*	*3.07*	*2.08*	*1.52*	*1.44*	*1.41*	*1.37*	*1.33*	*1.26*	*1.10*	*0.80*	*0.65*
Oct	*13.92*	*12.95*	*7.58*	*6.16*	*3.85*	*3.50*	*3.18*	*3.04*	*2.36*	*1.70*	*1.45*	*1.30*	*1.22*	*1.15*	*1.05*	*0.83*	*0.48*
Nov	*61.45*	*56.58*	*37.40*	*19.92*	*17.12*	*14.32*	*10.55*	*7.39*	*5.10*	*3.80*	*3.09*	*1.46*	*1.14*	*1.03*	*0.95*	*0.72*	*0.10*
Dec	*135.56*	*85.16*	*68.36*	*53.28*	*35.56*	*31.96*	*23.76*	*14.20*	*10.41*	*6.17*	*4.51*	*3.57*	*3.21*	*2.37*	*1.47*	*1.14*	*1.14*

Table A. 7: EWR Rule for the Crocodile River at the EWR 7 in X23H

Determination based on modelled present day hydrology in m3/s
Regional Type: E. Escarpment **PES = C**
Present day hydrology as the EWR

Months	0.1%	1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	99%	99.9%
Jan	*32.35*	*22.56*	*17.47*	*8.49*	*6.12*	*5.75*	*4.45*	*3.37*	*2.64*	*1.88*	*1.32*	*0.82*	*0.72*	*0.42*	*0.22*	*0.00*	*0.00*
Feb	*74.39*	*54.72*	*23.28*	*16.21*	*14.47*	*7.46*	*4.16*	*3.38*	*2.84*	*2.27*	*1.80*	*1.25*	*0.95*	*0.85*	*0.47*	*0.39*	*0.05*
Mar	*42.19*	*40.79*	*20.66*	*13.14*	*9.15*	*7.20*	*4.74*	*3.44*	*2.80*	*2.15*	*1.67*	*1.27*	*1.01*	*0.65*	*0.34*	*0.07*	*0.02*
Apr	*14.62*	*13.75*	*7.08*	*6.15*	*4.91*	*3.95*	*3.24*	*2.87*	*2.32*	*1.85*	*1.23*	*0.76*	*0.54*	*0.34*	*0.20*	*0.00*	*0.00*
May	*5.39*	*4.99*	*3.47*	*2.79*	*2.46*	*1.98*	*1.53*	*1.17*	*0.97*	*0.80*	*0.47*	*0.09*	*0.02*	*0.00*	*0.00*	*0.00*	*0.00*
Jun	*3.22*	*2.85*	*2.44*	*1.88*	*1.49*	*1.28*	*0.92*	*0.65*	*0.52*	*0.40*	*0.29*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Jul	*2.09*	*2.03*	*1.81*	*1.40*	*1.19*	*0.96*	*0.78*	*0.53*	*0.38*	*0.28*	*0.20*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Aug	*2.59*	*1.90*	*1.36*	*1.18*	*0.94*	*0.77*	*0.58*	*0.44*	*0.34*	*0.20*	*0.16*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sep	*2.87*	*2.82*	*2.29*	*1.60*	*1.25*	*1.12*	*0.88*	*0.72*	*0.64*	*0.55*	*0.47*	*0.41*	*0.35*	*0.22*	*0.14*	*0.07*	*0.05*
Oct	*3.18*	*3.04*	*2.54*	*2.09*	*1.74*	*1.38*	*0.93*	*0.77*	*0.60*	*0.43*	*0.33*	*0.25*	*0.21*	*0.09*	*0.01*	*0.00*	*0.00*
Nov	*9.11*	*7.65*	*5.72*	*4.66*	*3.94*	*3.59*	*2.78*	*1.89*	*1.14*	*0.82*	*0.58*	*0.18*	*0.12*	*0.00*	*0.00*	*0.00*	*0.00*
Dec	*21.01*	*14.79*	*8.16*	*7.27*	*5.98*	*4.60*	*3.01*	*2.34*	*1.79*	*1.29*	*0.81*	*0.51*	*0.35*	*0.19*	*0.02*	*0.00*	*0.00*

Table A. 8: EWR Table and Rule for the Sabie River at the EWR 1 in X31B: B REC

EWR Table: B REC

Desktop version:		**2**	**Virgin MAR (MCM)**	**140.18**
BFI index	**0.517**		**Distribution type**	**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	*1.25*	*0.4*	*6*	*4*
NOVEMBER	*1.5*	*0.451*	*6*	*4*
DECEMBER	*1.8*	*0.494*	*6*	*4*
JANUARY	*2.1*	*0.569*	*15*	*5*
FEBRUARY	*2.8*	*0.722*	*6*	*4*
MARCH	*2.75*	*0.677*		
APRIL	*2.6*	*0.661*	*6*	*4*
MAY	*2.25*	*0.598*		
JUNE	*2.1*	*0.567*		
JULY	*1.7*	*0.492*		
AUGUST	*1.44*	*0.439*		
SEPTEMBER	*1.3*	*0.417*		
TOTAL MCM	*61.81*	*17.007*	*8.515*	
% OF VIRGIN	*44.09*	*12.13*	*6.07*	
TOTAL IFR	*70.324*			
% OF NMAR	*50.17*			

EWR Rule: B REC

Total Ecological Reserve flows										
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	1.938	1.932	1.909	1.732	1.534	1.456	1.299	0.959	0.64	0.464
Nov	2.251	2.241	2.21	2.144	2.017	1.798	1.476	1.083	0.72	0.52
Dec	2.594	2.58	2.542	2.461	2.308	2.049	1.671	1.215	0.796	0.567
Jan	4.911	4.515	4.165	3.82	3.204	2.822	2.278	1.634	1.049	0.729
Feb	4.287	4.121	3.951	3.747	3.371	2.991	2.436	1.766	1.151	0.814
Mar	3.284	3.268	3.223	3.125	2.936	2.612	2.134	1.552	1.013	0.718
Apr	3.564	3.553	3.508	3.41	3.214	2.868	2.344	1.694	1.084	0.748
May	2.687	2.682	2.654	2.588	2.454	2.209	1.828	1.345	0.885	0.631
Jun	2.508	2.505	2.48	2.422	2.301	2.078	1.725	1.272	0.838	0.598
Jul	2.03	2.03	2.013	1.972	1.882	1.711	1.434	1.07	0.714	0.517
Aug	1.72	1.718	1.702	1.664	1.584	1.436	1.203	0.904	0.618	0.46
Sep	1.553	1.55	1.535	1.499	1.426	1.293	1.086	0.823	0.573	0.435
Reserve flows without High Flows										
Oct	1.493	1.489	1.472	1.434	1.359	1.227	1.027	0.778	0.546	0.417
Nov	1.792	1.784	1.76	1.71	1.613	1.446	1.2	0.901	0.624	0.472
Dec	2.15	2.138	2.107	2.043	1.92	1.712	1.408	1.041	0.704	0.52
Jan	2.508	2.49	2.45	2.368	2.217	1.968	1.612	1.19	0.808	0.599
Feb	3.343	3.325	3.277	3.175	2.98	2.65	2.169	1.588	1.055	0.763
Mar	3.284	3.268	3.223	3.125	2.936	2.612	2.134	1.552	1.013	0.718
Apr	3.105	3.095	3.057	2.973	2.806	2.51	2.063	1.507	0.986	0.7
May	2.687	2.682	2.654	2.588	2.454	2.209	1.828	1.345	0.885	0.631
Jun	2.508	2.505	2.48	2.422	2.301	2.078	1.725	1.272	0.838	0.598
Jul	2.03	2.03	2.013	1.972	1.882	1.711	1.434	1.07	0.714	0.517
Aug	1.72	1.718	1.702	1.664	1.584	1.436	1.203	0.904	0.618	0.46
Sep	1.553	1.55	1.535	1.499	1.426	1.293	1.086	0.823	0.573	0.435
Natural Duration curves										
Oct	2.599	2.266	1.971	1.732	1.534	1.456	1.359	1.273	1.116	0.971
Nov	5.694	4.001	3.576	3.171	2.805	2.485	2.157	1.825	1.47	1.138
Dec	8.714	7.116	5.727	4.966	4.085	3.562	3.147	2.789	2.431	1.665
Jan	14.363	10.488	8.02	6.369	5.608	5.141	4.096	3.726	3.091	2.767
Feb	20.685	16.1	11.76	7.688	6.758	6.114	4.952	4.415	3.191	2.501
Mar	16.831	10.895	8.621	8.094	6.16	4.884	4.238	3.775	3.338	2.263
Apr	8.931	7.222	6.046	5.285	4.699	4.109	3.789	3.383	3.09	2.153
May	4.54	4.088	3.864	3.539	3.442	3.017	2.722	2.55	2.296	1.725
Jun	3.546	3.079	2.859	2.735	2.689	2.6	2.265	2.068	1.867	1.454
Jul	2.819	2.483	2.352	2.147	2.05	1.968	1.826	1.669	1.508	1.292
Aug	2.236	2.087	1.874	1.807	1.688	1.62	1.512	1.441	1.325	1.094
Sep	2.211	2.06	1.69	1.609	1.52	1.447	1.366	1.3	1.188	1.003

Table A. 9: EWR Table and EWR Rule for the Sabie River at the EWR 2 in X31D: B REC

EWR Table: B REC

Desktop version:		**2**	**Virgin MAR (MCM)**	**262.106**
BFI index	**0.517**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	1.598	0.747		
NOVEMBER	1.904	0.815	10	4
DECEMBER	2.265	0.861	10	4
JANUARY	2.797	0.952	10	4
FEBRUARY	3.772	1.170	10 20	4 5
MARCH	3.619	1.093	10	4
APRIL	3.461	1.082		
MAY	3.028	0.992		

JUNE	2.774	0.964		
JULY	2.274	0.863		
AUGUST	1.897	0.798		
SEPTEMBER	1.692	0.779		
TOTAL MCM	81.420	29.155	13.159	
% OF VIRGIN	31.06	11.12	5.02	
TOTAL IFR	94.597			
% OF NMAR	36.08			

EWR Rule: B REC

Total Ecological Reserve flows										
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	1.91	1.907	1.893	1.866	1.811	1.711	1.544	1.297	1	0.776
Nov	3.041	3.031	3.004	2.948	2.841	2.65	2.336	1.881	1.342	0.939
Dec	3.447	3.434	3.4	3.332	3.204	2.977	2.608	2.079	1.455	0.991
Jan	4.657	4.465	4.281	4.084	3.84	3.424	2.98	2.355	1.63	1.093
Feb	9.243	8.598	8.022	7.476	6.892	5.9	5.092	3.933	2.567	1.55
Mar	5.638	5.449	5.261	5.052	4.777	4.3	3.741	2.933	1.973	1.256
Apr	4.134	4.124	4.089	4.017	3.874	3.612	3.173	2.526	1.746	1.159
May	3.617	3.612	3.585	3.528	3.413	3.196	2.824	2.265	1.579	1.059
Jun	3.314	3.311	3.289	3.239	3.139	2.949	2.619	2.117	1.497	1.025
Jul	2.717	2.717	2.701	2.666	2.592	2.449	2.193	1.796	1.296	0.912
Aug	2.267	2.265	2.251	2.221	2.158	2.039	1.833	1.519	1.131	0.836
Sep	2.023	2.02	2.008	1.98	1.926	1.823	1.647	1.382	1.057	0.811
Reserve flows without High Flows										
Oct	1.91	1.907	1.893	1.866	1.811	1.711	1.544	1.297	1	0.776
Nov	2.276	2.269	2.25	2.212	2.14	2.01	1.798	1.49	1.124	0.851
Dec	2.706	2.696	2.672	2.622	2.528	2.362	2.091	1.704	1.247	0.907
Jan	3.341	3.324	3.289	3.22	3.092	2.87	2.516	2.018	1.438	1.01
Feb	4.505	4.487	4.442	4.353	4.183	3.882	3.394	2.693	1.867	1.253
Mar	4.322	4.307	4.266	4.183	4.023	3.736	3.266	2.585	1.777	1.173
Apr	4.134	4.124	4.089	4.017	3.874	3.612	3.173	2.526	1.746	1.159
May	3.617	3.612	3.585	3.528	3.413	3.196	2.824	2.265	1.579	1.059
Jun	3.314	3.311	3.289	3.239	3.139	2.949	2.619	2.117	1.497	1.025
Jul	2.717	2.717	2.701	2.666	2.592	2.449	2.193	1.796	1.296	0.912
Aug	2.267	2.265	2.251	2.221	2.158	2.039	1.833	1.519	1.131	0.836
Sep	2.023	2.02	2.008	1.98	1.926	1.823	1.647	1.382	1.057	0.811
NaturalDurationcurves										
Oct	4.828	4.182	3.704	3.166	2.838	2.707	2.55	2.378	2.08	1.807
Nov	9.869	7.284	6.508	5.768	5.193	4.506	4.035	3.376	2.758	2.153
Dec	17.723	13.766	10.82	9.256	7.628	6.627	5.873	5.052	4.533	3.02
Jan	25.414	19.12	14.539	11.862	10.73	9.177	7.803	6.918	5.899	5.178
Feb	39.249	30.638	21.077	14.335	12.831	11.351	9.206	8.011	5.824	4.506
Mar	32.239	20.677	17.443	15.308	11.193	9.334	7.833	6.918	5.985	4.159
Apr	17.215	13.519	11.304	9.776	8.731	7.793	7.029	6.265	5.694	3.931
May	8.434	7.643	7.243	6.694	6.437	5.701	5.089	4.772	4.297	3.174
Jun	6.694	5.849	5.417	5.174	5.085	4.784	4.244	3.87	3.534	2.704
Jul	5.335	4.663	4.421	4.025	3.846	3.737	3.401	3.155	2.864	2.386
Aug	4.282	3.943	3.543	3.409	3.203	3.043	2.838	2.692	2.468	2.012
Sep	4.147	3.897	3.241	3.025	2.897	2.728	2.585	2.423	2.238	1.852

Table A. 10: EWR Table and EWR Rule for the Sabie River at the EWR 3 in X31K: A/B REC

EWR Table: A/B REC

Desktop version:		**2**	**Virgin MAR (MCM)**	**495.858**
BFI index	**0.499**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	2.703	1.090		
NOVEMBER	3.362	1.234	8	3

Desktop version:		2	Virgin MAR (MCM)	495.858
BFI index	0.499	Distribution type		Eastern Escarpment
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
			20	*4*
DECEMBER	*4.274*	*1.386*	*8* *20*	*3* *4*
JANUARY	*5.546*	*1.626*	*8* *20*	*3* *4*
FEBRUARY	*7.843*	*2.121*	*8*	*3*
MARCH	*7.508*	*1.995*	*20* *40*	*4* *5*
APRIL	*6.941*	*1.908*		
MAY	*5.794*	*1.673*		
JUNE	*5.120*	*1.565*		
JULY	*4.086*	*1.351*		
AUGUST	*3.326*	*1.208*		
SEPTEMBER	*2.881*	*1.143*		
TOTAL MCM	*155.440*	*47.960*	*31.847*	
% OF VIRGIN	*31.35*	*9.67*	*6.42*	
TOTAL IFR	*187.28*			
% OF NMAR	*37.78*			

EWR Rule: A/B REC

Total Ecological Reserve flows										
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	3.23	3.223	3.199	3.148	3.048	2.864	2.557	2.103	1.556	1.144
Nov	6.082	6.06	6.001	5.88	5.65	5.236	4.558	3.575	2.409	1.539
Dec	7.104	7.073	6.999	6.851	6.569	6.07	5.259	4.096	2.725	1.706
Jan	10.172	9.664	9.19	8.7	8.118	7.132	6.15	4.766	3.159	1.971
Feb	20.234	18.756	17.44	16.198	14.88	12.642	10.847	8.273	5.241	2.984
Mar	11.597	11.217	10.834	10.402	9.828	8.828	7.636	5.911	3.863	2.334
Apr	8.289	8.269	8.196	8.044	7.745	7.198	6.281	4.928	3.296	2.069
May	6.92	6.911	6.857	6.742	6.511	6.078	5.335	4.217	2.847	1.808
Jun	6.115	6.11	6.066	5.971	5.777	5.409	4.77	3.798	2.597	1.683
Jul	4.881	4.881	4.851	4.784	4.643	4.37	3.883	3.127	2.175	1.444
Aug	3.974	3.971	3.944	3.886	3.768	3.544	3.156	2.566	1.835	1.28
Sep	3.443	3.439	3.415	3.365	3.264	3.074	2.748	2.258	1.657	1.202
Reserve flows without High Flows										
Oct	3.23	3.223	3.199	3.148	3.048	2.864	2.557	2.103	1.556	1.144
Nov	4.017	4.004	3.968	3.897	3.759	3.512	3.106	2.52	1.823	1.303
Dec	5.105	5.085	5.035	4.935	4.746	4.411	3.866	3.084	2.163	1.478
Jan	6.624	6.588	6.514	6.37	6.102	5.638	4.898	3.855	2.644	1.748
Feb	9.366	9.326	9.229	9.035	8.666	8.013	6.951	5.429	3.635	2.3
Mar	8.966	8.933	8.844	8.664	8.319	7.7	6.685	5.215	3.471	2.169
Apr	8.289	8.269	8.196	8.044	7.745	7.198	6.281	4.928	3.296	2.069
May	6.92	6.911	6.857	6.742	6.511	6.078	5.335	4.217	2.847	1.808
Jun	6.115	6.11	6.066	5.971	5.777	5.409	4.77	3.798	2.597	1.683
Jul	4.881	4.881	4.851	4.784	4.643	4.37	3.883	3.127	2.175	1.444
Aug	3.974	3.971	3.944	3.886	3.768	3.544	3.156	2.566	1.835	1.28
Sep	3.443	3.439	3.415	3.365	3.264	3.074	2.748	2.258	1.657	1.202
NaturalDurationcurves										
Oct	8.86	7.624	6.814	5.761	5.111	4.723	4.488	4.178	3.711	3.088
Nov	18.808	14.742	11.802	10.093	9.086	8.221	7.272	5.76	4.911	3.746
Dec	33.923	25.989	21.229	16.726	13.922	12.291	10.275	9.491	7.706	5.066
Jan	55.88	37.817	26.202	23.749	19.71	17.111	13.702	11.645	10.447	8.18
Feb	82.507	64.559	41.46	31.754	23.177	20.747	16.923	13.368	10.074	7.647
Mar	66.439	45.318	34.009	28.054	20.968	16.599	14.501	11.787	10.122	6.776
Apr	32.28	25.035	20.359	17.535	14.271	13.499	12.222	11.084	9.63	6.227

May	15.17	13.355	12.444	11.391	10.783	9.849	8.703	8.18	7.396	5.115
Jun	11.682	10.073	9.525	9.136	8.6	8.194	7.353	6.632	6.03	4.568
Jul	9.58	8.162	7.646	7.042	6.735	6.452	6.022	5.451	5.052	4.036
Aug	7.553	7.105	6.254	6	5.679	5.417	5.01	4.749	4.238	3.435
Sep	7.612	7.06	5.741	5.409	5.235	4.842	4.552	4.209	3.866	3.14

Table A. 11: EWR Table and EWR Rule for the Mac Mac River at the EWR 4 in X31C: A/B REC

EWR Table: A/B REC

Desktop version:		**2**	**Virgin MAR (MCM)**	**65.782**
BFI index	**0.499**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	*0.047*	*0.160*		
NOVEMBER	*0.561*	*0.200*	*4*	*3*
DECEMBER	*0.675*	*0.254*	*4*	*3*
JANUARY	*0.836*	*0.329*	*4*	*3*
FEBRUARY	*1.133*	*0.459*	*15*	*4*
MARCH	*1.098*	*0.449*	*4*	*3*
APRIL	*1.053*	*0.427*		
MAY	*0.915*	*0.365*		
JUNE	*0.840*	*0.329*		
JULY	*0.682*	*0.258*		
AUGUST	*0.565*	*0.204*		
SEPTEMBER	*0.500*	*0.172*		
TOTAL MCM	*24.435*	*9.442*	*5.210*	
% OF VIRGIN	*37.15*	*14.35*	*7.92*	
TOTAL IFR	*29.65*			
% OF NMAR	*45.07*			

EWR Rule: A/B REC

Total Ecological Reserve flows										
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	*0.561*	*0.56*	*0.556*	*0.546*	*0.527*	*0.493*	*0.435*	*0.35*	*0.247*	*0.17*
Nov	*0.933*	*0.929*	*0.92*	*0.902*	*0.867*	*0.804*	*0.701*	*0.551*	*0.374*	*0.242*
Dec	*1.061*	*1.056*	*1.046*	*1.025*	*0.985*	*0.914*	*0.799*	*0.635*	*0.441*	*0.297*
Jan	*1.45*	*1.385*	*1.324*	*1.261*	*1.185*	*1.057*	*0.927*	*0.744*	*0.531*	*0.374*
Feb	*3.539*	*3.245*	*2.988*	*2.753*	*2.517*	*2.118*	*1.839*	*1.439*	*0.969*	*0.619*
Mar	*1.763*	*1.7*	*1.638*	*1.573*	*1.491*	*1.349*	*1.193*	*0.967*	*0.699*	*0.499*
Apr	*1.258*	*1.256*	*1.246*	*1.226*	*1.187*	*1.116*	*0.997*	*0.82*	*0.608*	*0.448*
May	*1.093*	*1.092*	*1.085*	*1.069*	*1.037*	*0.976*	*0.873*	*0.718*	*0.528*	*0.384*
Jun	*1.004*	*1.003*	*0.996*	*0.982*	*0.954*	*0.899*	*0.804*	*0.66*	*0.482*	*0.346*
Jul	*0.815*	*0.815*	*0.81*	*0.8*	*0.777*	*0.734*	*0.658*	*0.538*	*0.388*	*0.273*
Aug	*0.675*	*0.675*	*0.67*	*0.66*	*0.64*	*0.602*	*0.536*	*0.435*	*0.311*	*0.216*
Sep	*0.597*	*0.597*	*0.592*	*0.583*	*0.564*	*0.529*	*0.469*	*0.378*	*0.267*	*0.183*
Reserve flows without High Flows										
Oct	*0.561*	*0.56*	*0.556*	*0.546*	*0.527*	*0.493*	*0.435*	*0.35*	*0.247*	*0.17*
Nov	*0.67*	*0.668*	*0.662*	*0.65*	*0.627*	*0.585*	*0.516*	*0.417*	*0.3*	*0.212*
Dec	*0.807*	*0.803*	*0.796*	*0.781*	*0.753*	*0.703*	*0.622*	*0.506*	*0.369*	*0.268*
Jan	*0.999*	*0.994*	*0.984*	*0.965*	*0.929*	*0.867*	*0.768*	*0.628*	*0.465*	*0.345*
Feb	*1.354*	*1.349*	*1.337*	*1.313*	*1.268*	*1.187*	*1.056*	*0.868*	*0.646*	*0.481*
Mar	*1.312*	*1.308*	*1.297*	*1.275*	*1.232*	*1.155*	*1.03*	*0.848*	*0.632*	*0.471*
Apr	*1.258*	*1.256*	*1.246*	*1.226*	*1.187*	*1.116*	*0.997*	*0.82*	*0.608*	*0.448*
May	*1.093*	*1.092*	*1.085*	*1.069*	*1.037*	*0.976*	*0.873*	*0.718*	*0.528*	*0.384*

Jun	1.004	1.003	0.996	0.982	0.954	0.899	0.804	0.66	0.482	0.346
Jul	0.815	0.815	0.81	0.8	0.777	0.734	0.658	0.538	0.388	0.273
Aug	0.675	0.675	0.67	0.66	0.64	0.602	0.536	0.435	0.311	0.216
Sep	0.597	0.597	0.592	0.583	0.564	0.529	0.469	0.378	0.267	0.183
NaturalDurationcurves										
Oct	1.198	1.038	0.896	0.773	0.691	0.665	0.624	0.594	0.508	0.437
Nov	2.373	1.79	1.601	1.431	1.273	1.111	1.003	0.845	0.671	0.525
Dec	4.379	3.465	2.696	2.3	1.983	1.777	1.449	1.269	1.12	0.769
Jan	6.168	4.869	3.674	3.035	2.74	2.304	2.001	1.732	1.538	1.307
Feb	10.342	7.358	5.25	3.869	3.204	2.931	2.323	2.046	1.509	1.145
Mar	8.255	5.399	4.26	3.999	2.707	2.389	1.956	1.788	1.553	1.079
Apr	4.433	3.422	2.917	2.442	2.184	1.96	1.833	1.597	1.447	1.003
May	2.053	1.889	1.822	1.706	1.632	1.445	1.322	1.213	1.109	0.806
Jun	1.628	1.478	1.37	1.319	1.277	1.204	1.069	0.984	0.887	0.694
Jul	1.284	1.157	1.068	1.004	0.96	0.933	0.833	0.788	0.709	0.601
Aug	1.072	0.974	0.889	0.851	0.795	0.75	0.706	0.657	0.605	0.493
Sep	1.038	0.949	0.795	0.756	0.71	0.675	0.629	0.59	0.544	0.448

Table A. 12: EWR Table and EWR Rule for the Marite River at the EWR 5 in X31G: B/C PES

EWR Table: B/C PES

Desktop version:		2	Virgin MAR (MCM)	157.094
BFI index	**0.436**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	0.491	0.277		
NOVEMBER	0.650	0.317	4	3
DECEMBER	0.904	0.366	4, 8	3, 4
JANUARY	1.247	0.440	8	4
FEBRUARY	1.849	0.587	4 25	3 5
MARCH	1.783	0.555	4	3
APRIL	1.553	0.511		
MAY	1.163	0.422		
JUNE	0.970	0.386		
JULY	0.752	0.333		
AUGUST	0.608	0.302		
SEPTEMBER	0.521	0.290		
TOTAL MCM	32.657	12.537	10.524	
% OF VIRGIN	20.79	7.98	6.70	
TOTAL IFR	43.18			
% OF NMAR	27.49			

EWR Rule: B/C PES

Total Ecological Reserve flows										
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	0.612	0.611	0.607	0.599	0.583	0.554	0.506	0.435	0.35	0.285
Nov	1.078	1.074	1.065	1.046	1.01	0.944	0.837	0.681	0.497	0.359
Dec	1.996	1.987	1.966	1.925	1.846	1.706	1.478	1.152	0.768	0.482
Jan	2.604	2.456	2.321	2.187	2.034	1.776	1.539	1.206	0.819	0.533
Feb	6.912	6.293	5.752	5.262	4.772	3.945	3.383	2.576	1.626	0.919
Mar	2.669	2.602	2.53	2.444	2.323	2.11	1.837	1.443	0.974	0.625
Apr	1.932	1.928	1.911	1.878	1.811	1.689	1.485	1.184	0.82	0.547
May	1.447	1.445	1.435	1.413	1.367	1.283	1.138	0.919	0.651	0.448
Jun	1.207	1.206	1.198	1.181	1.146	1.08	0.965	0.789	0.572	0.407
Jul	0.936	0.936	0.931	0.92	0.896	0.849	0.766	0.636	0.474	0.349

Aug	0.757	0.757	0.752	0.743	0.723	0.686	0.623	0.525	0.405	0.314
Sep	0.649	0.648	0.645	0.637	0.621	0.591	0.541	0.464	0.37	0.299
Reserve flows without High Flows										
Oct	0.612	0.611	0.607	0.599	0.583	0.554	0.506	0.435	0.35	0.285
Nov	0.809	0.807	0.801	0.788	0.764	0.72	0.648	0.544	0.421	0.329
Dec	1.125	1.121	1.111	1.091	1.052	0.983	0.872	0.713	0.525	0.385
Jan	1.552	1.544	1.527	1.495	1.436	1.332	1.168	0.936	0.666	0.467
Feb	2.3	2.291	2.268	2.222	2.135	1.98	1.729	1.369	0.945	0.629
Mar	2.218	2.211	2.189	2.146	2.064	1.916	1.674	1.323	0.907	0.596
Apr	1.932	1.928	1.911	1.878	1.811	1.689	1.485	1.184	0.82	0.547
May	1.447	1.445	1.435	1.413	1.367	1.283	1.138	0.919	0.651	0.448
Jun	1.207	1.206	1.198	1.181	1.146	1.08	0.965	0.789	0.572	0.407
Jul	0.936	0.936	0.931	0.92	0.896	0.849	0.766	0.636	0.474	0.349
Aug	0.757	0.757	0.752	0.743	0.723	0.686	0.623	0.525	0.405	0.314
Sep	0.649	0.648	0.645	0.637	0.621	0.591	0.541	0.464	0.37	0.299
NaturalDurationcurves										
Oct	2.427	2.057	1.732	1.568	1.251	1.165	1.064	0.993	0.904	0.698
Nov	6.273	4.853	3.781	2.924	2.384	2.215	1.728	1.335	1.161	0.887
Dec	11.88	8.804	6.366	5.458	4.182	3.607	2.733	2.333	1.863	1.236
Jan	22.357	14.804	9.371	7.874	6.269	4.734	3.913	3.536	2.543	1.829
Feb	30.853	22.83	14.339	9.809	7.626	6.453	4.803	3.542	2.65	1.521
Mar	23.174	16.114	11.649	9.293	6.459	4.663	4.01	3.192	2.599	1.546
Apr	10.729	8.183	6.709	4.776	4.001	3.65	3.202	2.805	2.446	1.412
May	4.043	3.454	3.185	3.032	2.726	2.543	2.337	1.983	1.8	1.131
Jun	2.924	2.704	2.442	2.28	2.149	1.952	1.813	1.624	1.481	1.154
Jul	2.363	2.109	1.927	1.815	1.65	1.576	1.434	1.34	1.247	0.978
Aug	2.035	1.688	1.583	1.493	1.363	1.303	1.221	1.139	1.049	0.825
Sep	2.072	1.674	1.424	1.308	1.235	1.161	1.069	1.011	0.922	0.725

Table A. 13: EWR Table and EWR Rule for the Mutlumuvi River at the EWR 6 in X32F: B REC

EWR Table: B REC

Desktop version:		2	Virgin MAR (MCM)	45.007
BFI index	0.473	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.270	0.150		
NOVEMBER	0.300	0.160	1.6	3
DECEMBER	0.280	0.170	1.6	3
JANUARY	0.510	0.190	1.6	3
FEBRUARY	0.740	0.272		
MARCH	0.733	0.271	1.6	3
APRIL	0.660	0.243		
MAY	0.520	0.185		
JUNE	0.460	0.175		
JULY	0.420	0.170		
AUGUST	0.350	0.160		
SEPTEMBER	0.300	0.150		
TOTAL MCM	14.506	6.016	2.810	
% OF VIRGIN	32.23	13.37	6.24	
TOTAL IFR	17.32			
% OF NMAR	38.47			

EWR Rule: B REC

Total Ecological Reserve flows										
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	0.323	0.322	0.32	0.316	0.308	0.293	0.268	0.232	0.188	0.154
Nov	0.464	0.462	0.459	0.451	0.436	0.41	0.368	0.305	0.232	0.177
Dec	0.437	0.435	0.432	0.425	0.412	0.389	0.351	0.297	0.233	0.186
Jan	0.79	0.763	0.736	0.707	0.668	0.603	0.528	0.423	0.302	0.212
Feb	2.341	2.145	1.973	1.816	1.554	1.343	1.112	0.889	0.615	0.372
Mar	1.056	1.03	1.002	0.969	0.923	0.843	0.743	0.598	0.426	0.297
Apr	0.789	0.787	0.781	0.768	0.742	0.695	0.617	0.501	0.362	0.257
May	0.621	0.62	0.616	0.606	0.587	0.551	0.489	0.397	0.283	0.196
Jun	0.55	0.549	0.546	0.538	0.522	0.491	0.439	0.359	0.26	0.185
Jul	0.502	0.502	0.499	0.493	0.48	0.454	0.408	0.337	0.247	0.179
Aug	0.418	0.418	0.416	0.41	0.399	0.378	0.342	0.287	0.219	0.167
Sep	0.359	0.358	0.356	0.352	0.342	0.325	0.296	0.251	0.197	0.155
Reserve flows without High Flows										
Oct	0.323	0.322	0.32	0.316	0.308	0.293	0.268	0.232	0.188	0.154
Nov	0.359	0.358	0.355	0.35	0.34	0.323	0.294	0.252	0.202	0.165
Dec	0.335	0.334	0.332	0.327	0.319	0.304	0.28	0.245	0.204	0.174
Jan	0.609	0.606	0.6	0.588	0.566	0.527	0.465	0.377	0.275	0.2
Feb	0.884	0.881	0.873	0.856	0.825	0.77	0.68	0.551	0.4	0.287
Mar	0.876	0.873	0.865	0.85	0.82	0.766	0.678	0.55	0.399	0.286
Apr	0.789	0.787	0.781	0.768	0.742	0.695	0.617	0.501	0.362	0.257
May	0.621	0.62	0.616	0.606	0.587	0.551	0.489	0.397	0.283	0.196
Jun	0.55	0.549	0.546	0.538	0.522	0.491	0.439	0.359	0.26	0.185
Jul	0.502	0.502	0.499	0.493	0.48	0.454	0.408	0.337	0.247	0.179
Aug	0.418	0.418	0.416	0.41	0.399	0.378	0.342	0.287	0.219	0.167
Sep	0.359	0.358	0.356	0.352	0.342	0.325	0.296	0.251	0.197	0.155
NaturalDurationcurves										
Oct	0.653	0.579	0.511	0.47	0.399	0.381	0.362	0.351	0.299	0.202
Nov	1.269	0.984	0.795	0.664	0.594	0.552	0.471	0.382	0.324	0.212
Dec	2.856	1.919	1.449	1.157	0.87	0.717	0.609	0.564	0.429	0.28
Jan	5.638	3.663	2.188	1.52	1.262	1.064	0.904	0.747	0.605	0.381
Feb	11.615	5.824	3.125	1.914	1.554	1.343	1.112	0.889	0.744	0.372
Mar	7.389	4.338	3.342	2.091	1.396	1.184	1.008	0.825	0.706	0.321
Apr	3.985	2.658	1.551	1.389	1.161	1.011	0.914	0.799	0.71	0.37
May	1.359	1.191	1.086	0.997	0.851	0.806	0.717	0.687	0.586	0.31
Jun	1.042	0.934	0.88	0.81	0.706	0.675	0.606	0.583	0.505	0.285
Jul	0.818	0.728	0.683	0.642	0.605	0.553	0.515	0.467	0.429	0.269
Aug	0.709	0.642	0.579	0.549	0.523	0.474	0.437	0.418	0.366	0.243
Sep	0.644	0.583	0.532	0.486	0.448	0.428	0.394	0.37	0.328	0.224

Table A. 14: EWR Table and EWR Rule for the Tlulandizeka (Sand) River at the EWR 7 in X32C: C REC

EWR Table: C REC (PES)

Desktop version:		2	Virgin MAR (MCM)	28.896
BFI index	0.472	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m3/s)	Drought (m3/s)	Daily average (m3/s) on top of base flow	Duration (days)
OCTOBER	0.07	0		
NOVEMBER	0.07	0	1.5	3
DECEMBER	0.12	0.05	1.5	3
JANUARY	0.2	0.1	1.5, 4	3, 3
FEBRUARY	0.26	0.14	9	4
MARCH	0.27	0.16	1.5	3
APRIL	0.25	0.12		

Desktop version:		2	Virgin MAR (MCM)	28.896
BFI index	0.472	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m3/s)	Drought (m3/s)	Daily average (m3/s) on top of base flow	Duration (days)
MAY	0.2	0.09		
JUNE	0.18	0.06		
JULY	0.15	0.04		
AUGUST	0.1	0.02		
SEPTEMBER	0.08	0		
TOTAL MCM	5.105	2.037	3.188	
% OF VIRGIN	17.67	7.05	11.03	
TOTAL IFR	8.29			
% OF NMAR	28.7			

EWR Rule: C REC (PES)

Total Ecological Reserve flows										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.097	0.097	0.096	0.094	0.089	0.081	0.067	0.046	0.021	0.002
Nov	0.205	0.204	0.201	0.196	0.187	0.169	0.141	0.099	0.05	0.014
Dec	0.271	0.27	0.267	0.261	0.251	0.231	0.2	0.156	0.103	0.064
Jan	0.899	0.815	0.743	0.677	0.613	0.505	0.436	0.339	0.227	0.143
Feb	1.674	1.499	1.349	1.217	1	0.86	0.719	0.575	0.38	0.228
Mar	0.546	0.522	0.501	0.479	0.454	0.41	0.367	0.305	0.231	0.176
Apr	0.349	0.348	0.345	0.34	0.329	0.309	0.277	0.228	0.17	0.126
May	0.279	0.278	0.277	0.272	0.264	0.249	0.222	0.182	0.132	0.095
Jun	0.251	0.251	0.249	0.245	0.237	0.221	0.194	0.154	0.103	0.065
Jul	0.209	0.209	0.207	0.204	0.198	0.184	0.161	0.125	0.079	0.044
Aug	0.139	0.139	0.138	0.135	0.13	0.121	0.104	0.079	0.047	0.023
Sep	0.111	0.111	0.11	0.108	0.103	0.093	0.078	0.054	0.025	0.003
Reserve flows without High Flows										
Oct	0.097	0.097	0.096	0.094	0.089	0.081	0.067	0.046	0.021	0.002
Nov	0.097	0.097	0.096	0.093	0.088	0.08	0.066	0.045	0.021	0.002
Dec	0.167	0.167	0.165	0.162	0.156	0.145	0.128	0.104	0.075	0.053
Jan	0.279	0.278	0.275	0.27	0.26	0.244	0.217	0.18	0.136	0.104
Feb	0.363	0.361	0.358	0.352	0.341	0.321	0.288	0.242	0.187	0.146
Mar	0.377	0.376	0.373	0.367	0.357	0.337	0.306	0.26	0.206	0.165
Apr	0.349	0.348	0.345	0.34	0.329	0.309	0.277	0.228	0.17	0.126
May	0.279	0.278	0.277	0.272	0.264	0.249	0.222	0.182	0.132	0.095
Jun	0.251	0.251	0.249	0.245	0.237	0.221	0.194	0.154	0.103	0.065
Jul	0.209	0.209	0.207	0.204	0.198	0.184	0.161	0.125	0.079	0.044
Aug	0.139	0.139	0.138	0.135	0.13	0.121	0.104	0.079	0.047	0.023
Sep	0.111	0.111	0.11	0.108	0.103	0.093	0.078	0.054	0.025	0.003
NaturalDurationcurves										
Oct	0.418	0.37	0.325	0.302	0.258	0.246	0.235	0.22	0.194	0.131
Nov	0.822	0.625	0.502	0.421	0.378	0.355	0.301	0.247	0.208	0.135
Dec	1.856	1.232	0.933	0.739	0.553	0.459	0.388	0.358	0.276	0.175
Jan	3.786	2.333	1.523	0.982	0.821	0.687	0.59	0.478	0.381	0.246
Feb	7.374	3.592	2.001	1.232	1	0.86	0.719	0.575	0.471	0.236
Mar	4.831	2.916	2.136	1.296	0.889	0.754	0.653	0.526	0.455	0.213
Apr	2.515	1.69	0.988	0.876	0.752	0.644	0.586	0.517	0.459	0.243
May	0.889	0.777	0.694	0.624	0.556	0.515	0.463	0.444	0.377	0.202
Jun	0.667	0.602	0.556	0.521	0.455	0.44	0.394	0.37	0.324	0.193
Jul	0.523	0.467	0.437	0.414	0.388	0.358	0.336	0.306	0.28	0.179
Aug	0.455	0.411	0.37	0.351	0.336	0.302	0.284	0.269	0.235	0.153
Sep	0.409	0.374	0.34	0.313	0.289	0.27	0.251	0.243	0.208	0.143

Table A. 15: EWR Table and EWR Rule for the Sand River at the EWR 8 in X32J: B REC

EWR Table: B REC

Desktop version:		2	Virgin MAR (MCM)	133.6
BFI index	0.425	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	*0.26*	*0*		
NOVEMBER	*0.34*	*0.05*	*5*	*4*
DECEMBER	*0.56*	*0.1*	*5*	*4*
JANUARY	*0.9*	*0.2*	*5*	*4*
FEBRUARY	*1.63*	*0.3*	*30*	*5*
MARCH	*1.52*	*0.3*	*5*	*4*
APRIL	*1.17*	*0.25*		
MAY	*0.72*	*0.2*		
JUNE	*0.62*	*0.15*		
JULY	*0.5*	*0.1*		
AUGUST	*0.39*	*0.05*		
SEPTEMBER	*0.3*	*0.02*		
TOTAL MCM	*23.23*	*4.49*	*9.77*	
% OF VIRGIN	*17.39*	*3.36*	*7.31*	
TOTAL IFR	*33*			
% OF NMAR	*24.7*			

EWR Rule: B REC

Total Ecological Reserve flows										
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	*0.362*	*0.359*	*0.354*	*0.343*	*0.324*	*0.29*	*0.237*	*0.161*	*0.074*	*0.009*
Nov	*0.891*	*0.885*	*0.873*	*0.85*	*0.807*	*0.732*	*0.613*	*0.444*	*0.249*	*0.105*
Dec	*1.184*	*1.174*	*1.152*	*1.108*	*1.026*	*0.891*	*0.699*	*0.47*	*0.263*	*0.15*
Jan	*1.963*	*1.845*	*1.734*	*1.616*	*1.402*	*1.231*	*0.982*	*0.682*	*0.406*	*0.255*
Feb	*7.673*	*6.839*	*6.131*	*4.551*	*3.509*	*3.038*	*2.381*	*2.03*	*1.129*	*0.622*
Mar	*2.902*	*2.785*	*2.665*	*2.525*	*2.26*	*1.995*	*1.593*	*1.094*	*0.626*	*0.369*
Apr	*1.629*	*1.62*	*1.594*	*1.54*	*1.438*	*1.264*	*1.011*	*0.706*	*0.425*	*0.271*
May	*1.003*	*0.996*	*0.979*	*0.945*	*0.883*	*0.779*	*0.632*	*0.457*	*0.299*	*0.212*
Jun	*0.863*	*0.857*	*0.842*	*0.812*	*0.757*	*0.665*	*0.534*	*0.379*	*0.238*	*0.161*
Jul	*0.696*	*0.692*	*0.683*	*0.666*	*0.634*	*0.579*	*0.49*	*0.366*	*0.221*	*0.115*
Aug	*0.543*	*0.539*	*0.532*	*0.518*	*0.491*	*0.446*	*0.373*	*0.27*	*0.15*	*0.062*
Sep	*0.417*	*0.415*	*0.409*	*0.397*	*0.376*	*0.339*	*0.28*	*0.197*	*0.101*	*0.03*
Reserve flows without High Flows										
Oct	*0.362*	*0.359*	*0.354*	*0.343*	*0.324*	*0.29*	*0.237*	*0.161*	*0.074*	*0.009*
Nov	*0.473*	*0.47*	*0.464*	*0.452*	*0.429*	*0.39*	*0.327*	*0.239*	*0.136*	*0.06*
Dec	*0.78*	*0.773*	*0.759*	*0.731*	*0.678*	*0.59*	*0.466*	*0.318*	*0.184*	*0.11*
Jan	*1.253*	*1.246*	*1.227*	*1.185*	*1.107*	*0.975*	*0.781*	*0.548*	*0.334*	*0.216*
Feb	*2.351*	*2.343*	*2.311*	*2.24*	*2.1*	*1.852*	*1.476*	*1.01*	*0.573*	*0.332*
Mar	*2.192*	*2.185*	*2.155*	*2.09*	*1.961*	*1.732*	*1.385*	*0.955*	*0.552*	*0.33*
Apr	*1.629*	*1.62*	*1.594*	*1.54*	*1.438*	*1.264*	*1.011*	*0.706*	*0.425*	*0.271*
May	*1.003*	*0.996*	*0.979*	*0.945*	*0.883*	*0.779*	*0.632*	*0.457*	*0.299*	*0.212*
Jun	*0.863*	*0.857*	*0.842*	*0.812*	*0.757*	*0.665*	*0.534*	*0.379*	*0.238*	*0.161*
Jul	*0.696*	*0.692*	*0.683*	*0.666*	*0.634*	*0.579*	*0.49*	*0.366*	*0.221*	*0.115*
Aug	*0.543*	*0.539*	*0.532*	*0.518*	*0.491*	*0.446*	*0.373*	*0.27*	*0.15*	*0.062*
Sep	*0.417*	*0.415*	*0.409*	*0.397*	*0.376*	*0.339*	*0.28*	*0.197*	*0.101*	*0.03*
NaturalDurationcurves										
Oct	*1.62*	*1.456*	*1.299*	*1.18*	*1.012*	*0.915*	*0.866*	*0.818*	*0.694*	*0.459*
Nov	*3.549*	*2.859*	*1.971*	*1.686*	*1.447*	*1.289*	*1.165*	*0.93*	*0.806*	*0.521*
Dec	*10.45*	*5.462*	*3.573*	*2.655*	*2.363*	*1.695*	*1.441*	*1.31*	*0.967*	*0.635*

Jan	*18.089*	*9.558*	*5.395*	*3.655*	*3.3*	*2.729*	*2.173*	*1.77*	*1.37*	*0.829*
Feb	*38.538*	*16.286*	*9.077*	*4.551*	*3.509*	*3.038*	*2.381*	*2.03*	*1.674*	*0.798*
Mar	*26.43*	*10.57*	*7.486*	*4.958*	*2.987*	*2.714*	*2.195*	*1.792*	*1.512*	*0.691*
Apr	*9.267*	*5.127*	*3.573*	*2.998*	*2.5*	*2.215*	*1.941*	*1.779*	*1.535*	*0.795*
May	*3.177*	*2.815*	*2.52*	*2.184*	*1.923*	*1.729*	*1.602*	*1.497*	*1.262*	*0.683*
Jun	*2.442*	*2.23*	*2.091*	*1.806*	*1.663*	*1.505*	*1.381*	*1.292*	*1.111*	*0.648*
Jul	*2.046*	*1.807*	*1.676*	*1.52*	*1.404*	*1.296*	*1.18*	*1.079*	*0.978*	*0.609*
Aug	*1.759*	*1.557*	*1.411*	*1.333*	*1.213*	*1.113*	*1.045*	*0.96*	*0.833*	*0.538*
Sep	*1.601*	*1.489*	*1.35*	*1.223*	*1.115*	*1.026*	*0.941*	*0.876*	*0.772*	*0.494*

B1 APPENDIX B

The EcoSpecs and TPCs for the different components per EWR site is provided below.

B1.1 CROCODILE SUB-CATCHMENT

There was no available baseline RHAM data for EWR 4, 5, and 7, so EcoSpecs and TPCs tied to this format of physico-chemical data could not be generated. No Geomorphology RHAM data was available for EWR 4 and 5 and EcoSpecs and TPC data provided is based on GAI data.

Table B1 EWR 1: EcoSpecs and TPCs: Geomorphology

METRIC	ECOSPEC	TPC
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:**
		Fines should not exceed 25%.
		Sand (< 6 mm) should not exceed 10%.
		Cobbles should exceed 25%.
		Within all of the fast habitats:
		Neither sands nor fines should exceed 5%.
		Cobbles should exceed 5%.
Proportion of embedded sediments.	*Maintain minimum embeddedness to ensure bed mobility and create habitat for instream biota.*	**Overall for the in-channel sediments:**
		Most of the embedded material should be found in the shallow habitats.
		Per substrate type:
		Proportion of GRAVELS that are embedded should be less than 25%.
		Proportion of COBBLES that are embedded should be less than 40%.
		Proportion of BOULDERS that are embedded should be less than 50%.
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.*
Lower bank stability.	*Extent of undercut banks.*	*Overall for the site, the proportion of undercut banks should not exceed 50%.*

Table B2 EWR 1: EcoSpecs and TPCs: Physico-chemical (Visual)

METRIC	ECOSPEC	TPC
Water odour type and extent	*None*	*Cattle: ≥ 3*
		Chemical pollution: ≥ 1
		Other sources: ≥ 2
Filamentous algae in water column	*0.5*	*>3*
Water colour and extent	*0.5, Green*	*Green: ≥ 3.*
		All other colours: ≥ 1
Turbidity/clarity	*1*	*≥ 2*
Water surface indicator and extent	*1, Scum*	*All indicators: ≥ 2*
		Salt deposits: ≥ 1
Algal cover on hard surfaces	*4*	*> 4*

EWR 1: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Maintain an absence of perennial exotic species.*	*An occurrence of perennial exotic species.*
	Maintain cover (%) of perennial exotic species at 1% or lower.	*An increase in perennial exotic species cover > 5%.*
Terrestrialisation.	*Maintain absence of terrestrial woody species.*	*An increase in terrestrial woody species cover > 2%.*
	Maintain cover (%) of terrestrial grasses at 5% or lower.	*An increase in terrestrial grass species cover > 10%.*
Indigenous Riparian Woody Cover.	*Maintain cover (%) of riparian woody species below 5%.*	*Increases in riparian woody species cover above 10%.*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*Maintain grass, sedge and dicotyledonous forb cover between 80% and 100%.*	*A decrease in sedge, grass and dicotyledonous forb cover below 70%.*
Phragmites (reed) cover.	*Maintain absence of reed cover.*	*An increase in reed cover above 5%.*

Table B3 EWR 1: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness	*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, deteriorate (to be quantified by RHAM).*
Relative abundance	*During recent surveys BANO were sampled at 0.75 individuals per minute (indiv/min).*	*Relative abundance of less than 0.5 BANO individual per minute sampled at the site (during same season as baseline data).*	
Alien fish species	*No alien fish species sampled at site during recent surveys.*	*Presence of any alien/introduced fish species at site during any survey.*	*N/A*
SD habitats	*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 indiv/min.*	*BANO absent during any survey or with relative abundance < 0.5 indiv/min.*	*Reduced suitability of SD, SS, overhanging and instream vegetation habitats (to be quantified with RHAM).*
SS habitats			
Overhanging vegetation			
Instream vegetation			

Table B4 EWR 1: EcoSpecs and TPCs: Macroinvertebrates

HABITAT ECOSPECS	HABITAT TPC
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 are 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 TPC**
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 (cobbles) to support the following flow-dependent taxa in the VFCS (Very fast flow over coarse sediment) biotope: • *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 (cobbles) to support the following flow-dependent taxa in the FFCS (Fast flow over coarse sediment) biotope: • *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: • *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.	

Table B5 EWR 2: EcoSpecs and TPCs: Geomorphology

METRIC	ECOSPEC	TPC
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:**
		Fines should not exceed 20%.
		Sand should not exceed 15%.
		Cobbles should exceed 30%.
		Within all of the fast habitats:
		Neither sands nor fines should exceed 5%.
		Cobbles should exceed 20%.
Proportion of embedded sediments.	*Maintain minimum embeddedness to ensure bed mobility and create habitat for instream biota.*	**Overall for the in-channel sediments:**
		Most of the embedded material should be found in the shallow habitats.
		And per substrate type:
		Proportion of GRAVELS that are embedded should be less than 20%.
		Proportion of COBBLES that are embedded should be less than 30%.
		Proportion of BOULDERS that are embedded should be less than 15%.
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.*
Lower bank stability.	*Extent of undercut banks.*	*Overall for the site, the proportion of undercut banks should not exceed 50%.*

Table B6 EWR 2 EcoSpecs and TPCs: Physico-chemical (Visual)

METRIC	ECOSPEC	TPC
Water odour type and extent	*None*	*Cattle: ≥ 3*
		Chemical pollution: ≥ 1
		Other sources: ≥ 2
Filamentous algae in water column	*2*	*>3*
Water colour and extent	*None*	*Green: ≥ 3.*
		All other colours: ≥ 1
Turbidity/clarity	*None*	*≥ 2*
Water surface indicator and extent	*None*	*All indicators: ≥ 2*
		Salt deposits: ≥ 1
Algal cover on hard surfaces	*3*	*> 4*

Table B7 EWR 2: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Maintain an absence of perennial exotic species.*	*An occurrence of perennial exotic species.*
	Maintain cover (%) of perennial exotic species at 1% or lower.	*An increase in perennial exotic species cover > 5%.*
Terrestrialisation.	*Maintain absence of terrestrial woody species.*	*An increase in terrestrial woody species cover > 2%.*
	Maintain cover (%) of terrestrial grasses at 5% or lower.	*An increase in terrestrial grass species cover > 10%.*
Indigenous Riparian Woody Cover.	*Maintain cover (%) of riparian woody species below 5%.*	*An increase in riparian woody species covers above 15% (15% based on VEGRAI max).*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*Maintain grass, sedge and dicotyledonous forb cover between 80% and 100%.*	*A decrease in sedge, grass and dicotyledonous forb cover below 70%.*
Phragmites (reed) cover.	*Maintain reed cover at 2% or lower.*	*An increase in reed cover above 5%.*

Table B8 EWR 2: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During recent surveys (baseline/PES) fish were sampled at 2.2 5 indiv/min electrofishing.*	*Relative abundance of less than 1.5 5 indiv/min electrofishing at the site (during same season as baseline data).*	
Alien fish species.	*No alien fish species sampled at site during baseline surveys.*	*Presence of any alien/introduced fish species at site during any*	*N/A.*

		survey.	
FD[2] Habitats.	*During baseline survey CPRE was present at site at relative abundance of 1.4 indiv/min electrofishing, while ANAT was present at 0.2 5 indiv/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 indiv/min electrofishing, and < 0.1 indiv/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).*
FS[3] habitats.			
Flow dependant spp (flow alteration).			
Water quality intolerance.			
Substrate.	*During baseline survey CPRE was present at site at relative abundance of 1.4 indiv/min electrofishing, while BNEE was present at 0.24 5 indiv/min.*	*CPRE & BNEE present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of CPRE below 1 indiv/min electrofishing, and < 0.1 indiv/min for BNEE.*	*Reduced suitability (abundance & quality) of substrates (i.e. excessive algal growth on substrates, sedimentation) [To be quantified with RHAM].*
SD habitats.	*During baseline survey BNEE was present at 0.24 indiv/min.*	*BNEE present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.1 indiv/min for BNEE.*	*Reduced suitability (abundance & quality) of substrates (i.e. excessive algal growth on substrates, sedimentation) (to be quantified with RHAM).*
SS habitats.			
Overhanging vegetation.	*During baseline survey PPHI was present at site at relative abundance of 0.29 indiv/min electrofishing, while BNEE was present at 0.24 5 indiv/min.*	*PPHI and BNEE present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of PPHI below 0.15 indiv/min electrofishing, and < 0.1 indiv/min for BNEE.*	*Reduced suitability (abundance & quality) of overhanging vegetation habitats (to be quantified with RHAM).*
Undercut banks.			*Significant change in undercut bank habitats (to be quantified with RHAM).*
Instream vegetation.	*None available at site.*		

Table B9 EWR 2: EcoSpecs and TPCs: Macroinvertebrates

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 (cobbles) to support the following flow-dependent taxa in the VFCS (Very fast flow over coarse sediment) biotope: • *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 (cobbles) to support the following flow-dependent taxa in the FFCS: • *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: • *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.	

Table B10 EWR 3: EcoSpecs and TPCs: Geomorphology

METRIC	ECOSPEC	TPC
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 should NOT BE LESS THAN 5%.
		Cobbles should NOT BE LESS THAN 5%.
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.*

Table B11 EWR 3 EcoSpecs and TPCs: Physico-chemical (Visual)

METRIC	ECOSPEC	TPC
Water odour type and extent	*None*	*Cattle: ≥ 3*
		Chemical pollution: ≥ 1
		Other sources: ≥ 2
Filamentous algae in water column	*1*	*>3*
Water colour and extent	*0.5, Green*	*Green: ≥ 3.*
		All other colours: ≥ 1
Turbidity/clarity	*1*	*≥ 2*
Water surface indicator and extent	*0*	*All indicators: ≥ 2*
		Salt deposits: ≥ 1
Algal cover on hard surfaces	*5*	*> 4*

Table B12 EWR 3: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Maintain cover (%) of perennial exotic species at 5% or lower.*	*An increase in perennial exotic species cover > 10%.*
	Maintain cover (%) of perennial exotic species at 15% or lower.	*An increase in perennial exotic species cover > 20%.*
Terrestrialisation. Indigenous Riparian Woody Cover.	*Maintain cover (%) of terrestrial woody species at 25% or lower.*	*An increase in terrestrial woody species cover > 40%.*
	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%.*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*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%.*
Phragmites (reed) cover.	*Maintain reed cover below 10%.*	*An increase in reed cover above 10% on the marginal zone.*
Exotic Invasion (perennial exotics).	*Maintain cover (%) of perennial exotic species at 5% or lower.*	*An increase in perennial exotic species cover > 10%.*

Table B13 EWR 3: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During baseline (EWR/PES) surveys fish were sampled at 1.3 indiv/min electrofishing.*	*Relative abundance of less than 0.9 indiv/min sampled at the site (during same season as baseline data).*	
Alien fish species.	*No alien fish species sampled at site during recent surveys, but one introduced species CGAR present at relative abundance of 0.03 indiv/min electrofishing.*	*Presence of any alien/introduced fish species at site during any survey or increased abundance (> 0.06 indiv/min) of CGAR.*	*N/A.*
FD Habitats.	*During baseline survey CPRE was present at site at relative abundance of 0.63 indiv/min electrofishing, while AURA was present at 0.6 indiv/min.*	*CPRE & AURA present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.3 indiv/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).*
FS habitats.			
Flow dependant spp (flow alteration).			
Water quality intolerance.			
Substrate.	*During baseline survey CPRE was*	*CPRE & AURA present less*	*Reduced suitability (abundance*

METRIC	ECOSPEC	TPC	HABITAT
	present at site at relative abundance of 0.63 indiv/min electrofishing, while AURA was present at 0.6 indiv/min. BARG were only sampled with cast net.	*than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.3 indiv/min for CPRE or AURA. Absence of BARG during 2 consecutive surveys.*	*& quality) of substrates, increased sedimentation, and excessive algal growth on (to be quantified with RHAM).*
SD habitats.	*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.*		
SS habitats. *Overhanging vegetation.* *Undercut banks.*	*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 indiv/min.*	*PPHI absent more than 50% of time (absent during 2 consecutive surveys) or present with relative abundance < 0.03 indiv/min.*	*Significant change in SS, overhanging vegetation and undercut bank habitats (to be quantified with RHAM).*
Instream vegetation.	*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.*		

Table B14 EWR 3: EcoSpecs and TPCs: Macroinvertebrates

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 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 following flow-dependent taxa in the VFCS: • *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 (cobbles) to support the following flow-dependent taxa in the FFCS (Fast flow over coarse sediment) biotope: • *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: • *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.*

Table B15 EWR 4: EcoSpecs and TPCs: Geomorphology

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:** *Fines and Sands (< 6 mm diameter) should not exceed 10%.* • *GAI level IV in 2007 measured 7%.* *Gravels (6 – 60 mm diameter) should not be less than 10%.*

Metric	EcoSpec	TPCs
		• GAI level IV in 2007 measured 13%. Cobbles (< 60 mm) should not be less than 60%. • GAI level IV in 2007 measured 80%. **Sampling protocol:** *Sediment is to be sampled in the active channel riffle.*
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 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%.*	

Table B16 EWR 4: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Maintain cover (%) of perennial exotic species at 20% or lower.*	*An increase in perennial exotic species cover > 30%.*
Terrestrialisation.	*Maintain cover (%) of terrestrial woody species at 10% or lower within the riparian zone.*	*An increase in terrestrial woody species cover > 10%.*
	Maintain cover (%) of terrestrial woody species at 30% or lower within the riparian zone.	*An increase in terrestrial woody species cover > 30%.*
Indigenous Riparian Woody Cover.	*Maintain cover (%) of riparian woody species between 5 and 60%.*	*A decrease in riparian woody species cover below 5% OR above 60%.*
	Maintain cover (%) of riparian woody species between 20 and 70%.	*A decrease in riparian woody species cover below 20% OR above 70%.*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*Maintain grass, sedge and dicotyledonous forb cover above 30%.*	*A decrease in sedge, grass and dicotyledonous forb cover below 30%.*
Phragmites (reed) cover.	*Maintain reed cover between 10% and 20%.*	*An increase in reed cover above 80% or a decrease below 40%.*
	Maintain reed cover between 10% and 20% OR between 80% and 90%.	*An increase in reed cover above 70% or a decrease below 40%.*

Table B17 EWR 4: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During the baseline (EWR-PES) surveys fish were sampled at 0.9 indiv/min (should be higher during optimal sampling conditions).*	*Relative abundance of less than 1 individual per minute sampled at the site (during optimal sampling conditions).*	*N/A.*
Alien fish species.	*No alien fish species sampled at site during recent surveys.*	*Presence of any alien/introduced fish species at site during any survey.*	*N/A.*
FD habitats. *FS habitats.*	*During the baseline survey CPRE was present at site at relative abundance of 0.13 indiv/min electrofishing, while BMAR was present at 0.32 indiv/min.*	*CPRE and BMAR absent from site during any survey AND/OR present at relative abundance < 0.1 indiv/min for CPRE and < 0.2 indiv/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).*
Substrate.	*During the baseline survey CPRE was present at site at relative abundance of 0.13 indiv/min electrofishing, while LMOL was present at 0.05 indiv/min electrofishing.*	*CPRE and LMOL absent from site during any survey AND/OR present at relative abundance < 0.1 indiv/min for CPRE and < 0.03 indiv/min for LMOL.*	
Flow dependant spp (flow alteration).	*OPER & CPRE will be most appropriate indicators of flow at the site. Both*	*OPER and CPRE absent during any survey or with*	

METRIC	ECOSPEC	TPC	HABITAT
Water quality intolerance.	*species were present during baseline (EWR-PES) survey) with OPER at relative abundance of 0.26 indiv/min and CPRE at 0.13 indiv/min.*	*relative abundance < 0.15 indiv/min for OPER and < 0.1 indiv/min for CPRE.*	*Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).*
SD habitats.	*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 indiv/min, while LMOL were present 0.05 indiv/min.*	*BMAR & LMOL absent during any survey or with relative abundance < 0.2 indiv/min for BMAR and < 0.03 indiv/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).*
Water column.	*OPER & BMAR are the best indicators of water column habitats and were present during the baseline survey at relative abundance of 0.26 indiv/min for OPER and 0.32 indiv/min for BMAR.*	*OPER &/or BMAR absent during any survey or present at relative abundance < 0.15 indiv/min for OPER and < 0.2 indiv/min for BMAR.*	*Reduction in suitability of water column (i.e. increased sedimentation of pools).*
SS habitats.	*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 indiv/min for PPHI and 0.32 indiv/min for BMAR.*	*PPHI & BMAR absent during any survey or PPHI present at relative abundance < 0.04 indiv/min and BMAR at < 0.2 indiv/min.*	*Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).*
Overhanging vegetation.	*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 indiv/min, while BPAU occurred at 0.03 indiv/min.*	*PPHI &/or BPAU absent during any survey or PPHI present with relative abundance < 0.04 indiv/min and BPAU < 0.01 indiv/min.*	*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*
Undercut banks.	*PPHI is the best indicators of undercut banks, it was present during baseline surveys at a relative abundance of 0.08ind/min.*	*PPHI absent during any survey or present with relative abundance < 0.04 indiv/min.*	*Significant change in undercut bank habitats (to be quantified with RHAM).*
Instream vegetation.	*Species with high indicator value for instream vegetation is BPAU. BPAU should be present 100%, sampled during baseline surveys at 0.03 indiv/min.*	*BPAU absent during any survey or with relative abundance < 0.01 indiv/min.*	*Significant change in instream vegetation habitats (to be quantified with RHAM).*

Table B18 EWR 4: EcoSpecs and TPCs: Macroinvertebrates

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 are 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 (Very fast flow over coarse sediment) 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 (Fast flow over coarse sediment) biotope: • *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: • *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.*

Table B19 EWR 5: EcoSpecs and TPCs: Geomorphology

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:** *Fines and Sands (< 6 mm diameter) should not exceed 85%.* • *GAI level IV in 2007 measured 78%.* *Gravels (6 – 60 mm) should not be less than 10%.* • *GAI level IV in 2007 measured 15%.* **Sampling protocol:** *Sediment is to be sampled across the active channel.*
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%.*	

Table B20 EWR 5: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Maintain cover (%) of perennial exotic species at 10% or lower.*	*An increase in perennial exotic species cover > 15%.*
Terrestrialisation.	*Maintain cover (%) of terrestrial woody species at 10% or lower within the riparian zone.*	*An increase in terrestrial woody species cover > 10%.*
	Maintain cover (%) of terrestrial woody species at 30% or lower within the riparian zone.	*An increase in terrestrial woody species cover > 30%.*
Indigenous Riparian Woody Cover.	*Maintain cover (%) of riparian woody species between 5 and 60%.*	*A decrease in riparian woody species covers below 5% OR above 60%.*
	Maintain cover (%) of riparian woody species between 20 and 70%.	*A decrease in riparian woody species covers below 20% OR above 70%.*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*Maintain grass, sedge and dicotyledonous forb cover above 40% (in summer).*	*A decrease in sedge, grass and dicotyledonous forb cover below 30%.*
Phragmites (reed) cover.	*Maintain reed cover above 10%.*	*A decrease in reed cover below 10%.*
	Maintain reed cover between 10% and 90%.	*An increase in reed cover above 90% or a decrease below 10%.*
	Maintain reed cover below 50%.	*An increase in reed cover above 50%.*

Table B21 EWR 5: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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 indiv/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).*
Relative abundance.		*Relative abundance of less than 1.5 indiv/min sampled at the site (during optimal sampling conditions).*	*N/A.*
Alien fish species.	*One alien fish species (CCAR) sampled at site during baseline (EWR) survey at relative abundance of 0.02*	*Presence of more than 1 (CCAR) alien/introduced fish species at site during any survey, AND/OR an*	*N/A.*

METRIC	ECOSPEC	TPC	HABITAT
	indiv/min electrofishing.	*increase in relative abundance of CCAR becoming > 0.02 indiv/min electrofishing.*	
FD habitats.	*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 indiv/min electrofishing.*	*CPAR present less than 50% of time (not sampled for more than 2 consecutive surveys) and BMAR absent during any survey AND/OR decrease in relative abundance below 0.5 indiv/min for BMAR.*	*Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows), (to be quantified with RHAM).*
FS habitats. *Substrate.*	*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).*
Flow dependant spp (flow alteration). *Water quality intolerance.*	*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 indiv/min electrofishing.*	*CPRE & OPER present less than 33% of time (not sampled for more than 3 consecutive surveys) AND/OR OPER present at relative abundance below 0.02 indiv/min.*	*Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).*
SD habitats.	*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 indiv/min electrofishing, and BMAR at 0.93 indiv/min electrofishing.*	*OMOS & BMAR absent during any survey AND/OR OMOS present at relative abundance < 0.15 indiv/min and < 0.5 indiv/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).*
Water column.	*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 indiv/min electrofishing.*	*MBRE present less than 50% of time (not sampled for more than 2 consecutive surveys) and BMAR absent during any survey AND/OR decrease in relative abundance below 0.5 indiv/min for BMAR.*	*Reduction in suitability of water column (i.e. increased sedimentation of pools).*
SS habitats.	*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 indiv/min electrofishing.*	*BRAD present less than 50% of time (not sampled for more than 2 consecutive surveys) and BVIV absent during any survey AND/OR decrease in relative abundance below 0.3 indiv/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).*
Overhanging vegetation.	*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 indiv/min electrofishing.*	*BTRI present less than 75% of time and BVIV absent during any survey AND/OR decrease in relative abundance below 0.3 indiv/min for BVIV.*	*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*
Undercut banks.	*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).*
Instream vegetation.	*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 indiv/min electrofishing.*	*TREN & BVIV absent during any survey AND/OR decrease in relative abundance below 0.3 indiv/min for BVIV.*	*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*

Table B22 EWR 5: EcoSpecs and TPCs: Macroinvertebrates

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 are 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 algae.	*More than 23% of the coarse substrates are covered with 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 (cobbles) to support the following flow-dependent taxa in the FFCS (Fast flow over coarse sediment) biotope: • *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: • *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: • *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.*

Table B23 EWR 6: EcoSpecs and TPCs: Geomorphology

METRIC	ECOSPEC	TPC
In-channel sediment (substrate) distribution.	*Maintain the physical habitat diversity; specifically preventing the loss of bedrock habitat through smothering by sands.*	**Overall for the site:** *Bedrock should be more than 30%.*
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.*

Table B24 EWR 6 EcoSpecs and TPCs: Physico-chemical (Visual)

METRIC	ECOSPEC	TPC
Water odour type and extent	*None*	*Cattle: ≥ 3*
		Chemical pollution: ≥ 1
		Other sources: ≥ 2
Filamentous algae in water column	*2*	*>3*
Water colour and extent	*0.5, Green*	*Green: ≥ 3.*
		All other colours: ≥ 1
Turbidity/clarity	*2*	*≥ 2*
Water surface indicator and extent	*None*	*All indicators: ≥ 2*
		Salt deposits: ≥ 1
Algal cover on hard surfaces	*4*	*> 4*

Table B25 EWR 6: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Maintain the absence of perennial exotic species.*	*An increase in perennial exotic species cover > 5%.*
Indigenous Riparian Woody Cover.	*Maintain cover (%) of riparian woody species between 5 and 60%.*	*A decrease in riparian woody species covers below 5% OR above 60%.*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*Maintain grass, sedge and dicotyledonous forb cover above 30% (in summer).*	*A decrease in sedge, grass and dicotyledonous forb cover below 30%.*
Phragmites (reed) cover.	*Maintain reed cover above 10%.*	*A decrease in reed cover below 10%.*
	Maintain reed cover between 10% and 90%.	*An increase in reed cover above 90% or a decrease below 10%.*
	Maintain reed cover below 50%.	*An increase in reed cover above 50%.*

Table B26 EWR 6: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During previous surveys (not baseline EWR survey) conducted under optimal sampling conditions, fish were sampled at > 10 indiv/min.*	*Relative abundance of less than 7 individual per minute sampled at the site (during optimal sampling conditions).*	
Alien fish species.	*No alien species previously sampled at site.*	*Presence of any alien fish species during any survey.*	*N/A.*
FD Habitats.	*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).*
FS habitats.	*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).*
Substrate.			*Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).*
Flow dependant spp (flow alteration).	*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.*	
Water quality intolerance.	*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).*
SD habitats.	*TREN and OMOS should always be present at the site under baseline conditions (based on available data for site: TREN sampled 100% of time and OMOS 67% of time).*	*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).*
Water column.	*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).*
SS habitats.	*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).*
Overhanging vegetation.	*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).*
Instream vegetation.			*Significant change in instream vegetation habitats (to be quantified with RHAM).*
Undercut banks.	*No indicator species of undercut banks previous sampled at site.*		

Table B27 EWR6: EcoSpecs and TPCs: Macroinvertebrates

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	*The average width of the river in the riffle are is less than 51 m.*

than 50 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 (Fast flow over coarse sediment) biotope: • *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: • *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.	

Table B28 EWR 7: EcoSpecs and TPCs: Geomorphology

METRIC	ECOSPEC	TPC
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 should not exceed 10%.
		Cobbles should exceed 5%.
		Within all of the fast habitats:
		Sands should not exceed 5%.
		Cobbles should exceed 5%.
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.*
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.*
Lower bank stability.	*Extent of undercut banks.*	*Overall for the site, the proportion of undercut banks should not exceed 20%.*

Table B29 EWR 7: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Maintain cover (%) of perennial exotic species at 30% or lower.*	*An increase in perennial exotic species cover > 30%.*
Terrestrialisation.	*Maintain cover (%) of terrestrial woody species at 15% or lower.*	*An increase in terrestrial woody species cover > 10%.*
Indigenous Riparian Woody Cover.	*Maintain cover (%) of riparian woody species below 70%, but always present.*	*An increase in riparian woody species cover above 70% OR below 1%.*
	Maintain cover (%) of riparian woody species between 5 and 60%.	*A decrease in riparian woody species covers below 5% OR above 60%.*
	Maintain cover (%) of riparian woody species between 20 and 70%.	*A decrease in riparian woody species covers below 20% OR above 70%.*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*Maintain grass, sedge and dicotyledonous forb cover above 30% (in summer).*	*A decrease in sedge, grass and dicotyledonous forb cover below 30%.*
Phragmites (reed) cover.	*Maintain reed cover above 10%.*	*A decrease in reed cover below 10%.*
	Maintain reed cover between 10% and 90%.	*An increase in reed cover above 90% or a decrease below 10%.*
	Maintain reed cover below 50%.	*An increase in reed cover above 50%.*

Table B30 EWR 7: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	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).
Relative abundance.	During recent baseline survey fish were sampled at 2.6 indiv/min.	Relative abundance of less than 1.8 individual per minute sampled at the site (during same season as baseline data).	N/A.
Alien fish species.	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.
FD Habitats.	During the recent baseline survey BEUT was present at relative abundance of 0.13 indiv/min and CPRE at relative abundance of 0.75 indiv/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).
FS habitats.			
Flow dependant spp (flow alteration).			
Substrate.	During recent baseline survey BMAR was present at a relative abundance of 1.27 indiv/min and CPRE at relative abundance of 0.75 indiv/min.	BMAR and CPRE absent from a site during any survey and/or present at relative abundance < 1 indiv/min for BMAR and < 0.5 for CPRE.	
Water quality intolerance.	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 indiv/min and CPRE at 0.75 indiv/min.	BEUT and CPRE absent during any survey or BEUT with relative abundance < 0.09 indiv/min and CPRE < 0.5 indiv/min.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).
SD habitats.	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 indiv/min and BMAR at 1.27 indiv/min.	BMAR absent during any survey or with relative abundance < 1 indiv/min and or BUNI present less than 50% of time (absent for 2 consecutive surveys) or present with relative abundance of < 0.06 indiv/min.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).
Water column.	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 indiv/min and MACU at 0.05 indiv/min.	BMAR absent during any survey or present at relative abundance < 1 indiv/min, and MACU resent less than 50% of time (absent for 2 consecutive surveys) or with relative abundance of < 0.02 indiv/min.	Reduction in suitability of water column (i.e. increased sedimentation of pools).
SS habitats.	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 indiv/min., while BMAR was present at 1.27 indiv/min.	BUNI present less than 50% of time (absent for 2 consecutive surveys) or with relative abundance of < 0.06 indiv/min AND/OR MAR absent during any survey or present at relative abundance < 1 indiv/min.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).
Overhanging vegetation.	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 indiv/min, and BEUT at 0.13 indiv/min.	BUNI & BEUT present less than 50% of time (absent for 2 consecutive surveys) or BUNI with relative abundance of < 0.06 indiv/min and BEUT with relative abundance of < 0.09 indiv/min.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).
Undercut banks.	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 indiv/min.	BEUT present less than 50% of time (absent for 2 consecutive surveys) I with relative abundance of < 0.09 indiv/min.	Significant change in undercut bank habitats (to be quantified with RHAM).

Table B31 EWR 7: EcoSpecs and TPCs: Macroinvertebrates

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 are 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: • *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 (Fast flow over coarse sediment) biotope: • *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: • *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.	

B1.2 SABIE-SAND SUB-CATCHMENT

There was no available baseline RHAM data for EWR 2, 4, 5, 6 and 7, so EcoSpecs and TPCs tied to this format of physico-chemical data could not be generated. No Geomorphology RHAM data was available for EWR 2, 6 and 7 and EcoSpecs and TPC data provided is based on GAI data.

Table B32 EWR 1: EcoSpecs and TPCs: Geomorphology

METRIC	ECOSPEC	TPC
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 (< 6 mm) should not exceed 25%.
		Gravels should be more than 5%.
		And within all of the fast habitats:
		Sand should not exceed 10%.
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.*
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 metres wide.*

Table B33 EWR 1 EcoSpecs and TPCs: Physico-chemical (Visual)

METRIC	ECOSPEC	TPC
Water odour type and extent	*None*	*Cattle: ≥ 3*
		Chemical pollution: ≥ 1
		Other sources: ≥ 2
Filamentous algae in water column	*1*	*>3*
Water colour and extent	*0.5, Green*	*Green: ≥ 3.*
		All other colours: ≥ 1
Turbidity/clarity	*1.5*	*≥ 2*
Water surface indicator and extent	*None*	*All indicators: ≥ 2*
		Salt deposits: ≥ 1
Algal cover on hard surfaces	*4*	*> 4*

Table B34 EWR 1: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Exotic species cover between 10 - 15%.*	*An increase in exotic species covers above 15%.*
Indigenous Riparian Woody Cover.	*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%.	*An increase in riparian woody species cover above 60% OR a decrease below 30%.*
	Riparian woody species cover between 30% and 60%.	*An increase in riparian woody species cover above 60% OR a decrease below 30%.*
Phragmites (reed) cover.	*Reed covers between 30% and 40%.*	*An increase in reed cover above 40%.*
	Reed covers between 20% and 30%.	*An increase in reed cover above 30%.*

Table B35 EWR 1: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During the baseline (EWR-PES) surveys fish were sampled at 2.8 indiv/min.*	*Relative abundance of less than 1.5 indiv/min sampled at the site (during optimal sampling conditions).*	*N/A.*
Alien fish species.	*No alien fish species sampled at site during recent surveys.*	*Presence of any alien/introduced fish species at site during any survey.*	*N/A.*
FD Habitats.	*During the baseline survey VNEL was present at site at relative abundance of 2 indiv/min electrofishing, while CANO was present at 0.76 indiv/min.*	*VNEL and CANO absent from site during any survey OR present at relative abundance < 1 indiv/min for VNEL and < 0.4 indiv/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).*
FS habitats.			
Substrate.			
Flow dependant spp (flow alteration).			
Water quality intolerance.			
SD habitats.	*AMOS only SD indicator sampled at EWR site during baseline survey, present at relative abundance of 0.01 indiv/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).*
Water column.	*No indicator species available at site or in reach for water column as cover.*		
SS habitats.	*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).*
Overhanging vegetation.			*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*
Undercut banks.	*AMOS only undercut bank indicator sampled at EWR site during baseline survey, present at relative abundance of 0.01 indiv/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).*
Instream vegetation.	*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).*

Table B36 EWR 1: EcoSpecs and TPCs: Macroinvertebrates

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 > 2spp.	*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.*

Table B37 EWR 2: EcoSpecs and TPCs: Geomorphology

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 (< 6 mm diameter) should not exceed 20%.* • *GAI level IV in 2007 measured 9%.* *Gravels (< 60 mm diameter) should not be less than 20%.* • *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.*	*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.*
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%.*	

Table B38 EWR 2: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Exotic species cover between 10 - 15%.*	*An increase in exotic species covers above 15%.*
Indigenous Riparian Woody Cover.	*Riparian woody species cover between 20% and 70%.*	*An increase in riparian woody species cover above 70% OR a decrease below 20%.*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*Non-woody cover between 50 and 60%.*	*An increase in non-woody cover above 60%.*

Table B39 EWR 2: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During the baseline (EWR-PES) surveys fish were sampled at 4.3 indiv/min.*	*Relative abundance of less than 2.5 indiv/min sampled at the site (during optimal sampling conditions).*	*N/A.*
Alien fish species.	*No alien fish species sampled at site during recent surveys.*	*Presence of any alien/introduced fish species at site during any survey.*	*N/A.*
FD Habitats.	*During the baseline survey VNEL was present at site at relative abundance of 0.43 indiv/min electrofishing, while BEUT was present at 0.57 indiv/min (electrofishing).*	*VNEL and BEUT absent from site during any survey OR present at relative abundance < 0.25 indiv/min for VNEL and < 0.3 indiv/min for BEUT.*	*Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows) (to be quantified with RHAM).*
FS habitats.	*During the baseline survey VNEL was present at site at relative abundance of 0.43 indiv/min while*	*VNEL and CANO absent from site during any survey OR present at relative abundance < 0.25*	*Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero*

	CANO was present at 1.82 indiv/min (electrofishing).	*indiv/min for VNEL and < 1.2 indiv/min for CANO.*	*flows) (to be quantified with RHAM).*
Substrate.	*During the baseline survey VNEL was present at site at relative abundance of 0.43 indiv/min while BPOL was present at 0.15 indiv/min (electrofishing).*	*VNEL absent from site during any survey and BPOL absent during 2 consecutive surveys OR present at relative abundance < 0.25 indiv/min for VNEL and < 0.08 indiv/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).*
Flow dependant spp (flow alteration).	*During the baseline survey OPER was present at site at relative abundance of 0.12 indiv/min while CANO was present at 1.82 indiv/min (electrofishing).*	*OPER and CANO absent from site during any survey OR present at relative abundance < 0.05 indiv/min for OPER and < 1.2 indiv/min for CANO.*	
Water quality intolerance.	*During the baseline survey BEUT was present at site at relative abundance of 0.57 indiv/min while CANO was present at 1.82 indiv/min (electrofishing).*	*BEUT and CANO absent from site during any survey OR present at relative abundance < 0.3 indiv/min for BEUT and < 1.2 indiv/min for CANO.*	*Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).*
SD habitats.	*During the baseline survey BMAR was present at site at relative abundance of 0.42 indiv/min while BPOL was present at 0.15 indiv/min (electrofishing).*	*BMAR absent from site during any survey and BPOL absent during 2 consecutive surveys OR present at relative abundance < 0.25 indiv/min for BMAR and < 0.08 indiv/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).*
Water column.	*During the baseline survey BMAR was present at site at relative abundance of 0.42 indiv/min while BPOL was present at 0.15 indiv/min (electrofishing).*	*BMAR absent from site during any survey and BPOL absent during 2 consecutive surveys OR present at relative abundance < 0.25 indiv/min for BMAR and < 0.08 indiv/min for BPOL.*	*Reduction in suitability of water column (i.e. increased sedimentation of pools).*
SS habitats.	*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 indiv/min while PPHI was present at 0.25 indiv/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 indiv/min.*	*Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).*
Overhanging vegetation.	*During the baseline survey BEUT was present at site at relative abundance of 0.57 indiv/min while PPHI was present at 0.25 indiv/min (electrofishing).*	*BEUT and PPHI absent from site during any survey OR present at relative abundance < 0.3 indiv/min for BEUT and < 1.5 indiv/min for PPHI.*	*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*
Undercut banks.			*Significant change in undercut bank habitats (to be quantified with RHAM).*
Instream vegetation.	*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 indiv/min.*	*TSPA absent during 2 consecutive surveys or present with relative abundance < 0.03 indiv/min.*	*Significant change in Instream vegetation habitats (to be quantified with RHAM).*

Table B40 EWR 2: EcoSpecs and TPCs: Macroinvertebrates

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.*

Table B41 EWR 3: EcoSpecs and TPCs: Geomorphology

METRIC	ECOSPEC	TPC
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 (<6 mm) should not exceed 50%.
		Bedrock should be more than 20%.
		Within all of the fast habitats:
		Sand should not exceed 30%.
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.*
		Embedded boulders should be less than 30% of the site.
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.*

Table B42 EWR 3 EcoSpecs and TPCs: Physico-chemical (Visual)

METRIC	ECOSPEC	TPC
Water odour type and extent	*None*	*Cattle: ≥ 3*
		Chemical pollution: ≥ 1
		Other sources: ≥ 2
Filamentous algae in water column	*0.5*	*>3*
Water colour and extent	*0.5, Green*	*Green: ≥ 3.*
		All other colours: ≥ 1
Turbidity/clarity	*0.5*	*≥ 2*
Water surface indicator and extent	*None*	*All indicators: ≥ 2*
		Salt deposits: ≥ 1
Algal cover on hard surfaces	*4*	*> 4*

Table B43 EWR 3: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Exotic species cover between 1 and 5%.*	*An increase in exotic species covers above 5%.*
Terrestrialisation.	*The absence of terrestrial woody species.*	*A presence of terrestrial woody species.*
	The absence of terrestrial woody species.	*An increase in terrestrial woody species covers above 5%.*
	Terrestrial woody cover between 10 and 20%.	*An increase in terrestrial woody species covers above 20%.*
Indigenous Riparian Woody Cover.	*Indigenous riparian woody cover between 20 and 40%.*	*A decrease in riparian woody species cover below 10% OR an increase above 40%.*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*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%.*

METRIC	ECOSPEC	TPC
Phragmites (reed) cover.	*Reed covers between 20 and 40%.*	*An increase in reed cover above 80% OR a decrease below 20%.*
	Reed covers between 20 and 40%.	*An increase in reed cover above 80% OR a decrease below 20%.*
	Reed covers between 1 and 20%.	*An increase in reed cover above 30% OR a total loss of reed cover.*

Table B44 EWR 3: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During recent surveys fish were sampled at 4.5 indiv/min.*	*Relative abundance of less than 3.5 indiv/min sampled at the site (during same season as baseline data) when habitat can be sampled efficiently.*	*N/A.*
Alien fish species.	*No alien fish species sampled at site during recent surveys.*	*Presence of any alien/introduced fish species at site during any survey.*	*N/A.*
FD Habitats.	*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 indiv/min), and BMAR 100% present during historical surveys, and sampled at relative abundance of 0.74 indiv/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 indiv/min for BMAR and < 1.5 indiv/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).*
FS habitats.	*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 indiv/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 indiv/min for both species.*	*Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows), (to be quantified with RHAM).*
Substrate.			*Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM).*
Flow dependant spp (flow alteration).	*CANO is expected to always be present at the site (conditions similar to baseline conditions) and OPER sampled 60% of the historical surveys. 192 indiv CANO sampled during EWR survey (2.02 indiv/min.), and OPER sampled at a relative abundance of 0.14 indiv/min under baseline conditions.*	*OPER present less than 50% of time (not sampled for more than 2 consecutive surveys) and CANO absent during any survey AND/OR decrease in relative abundance of < 1.5 indiv/min. for CANO.*	
Water quality intolerance.	*Both species were sampled during baseline survey: OPER sampled at a relative abundance of 0.14 indiv/min (60% of historical surveys), and BEUT sampled at a relative abundance of 0.12 indiv/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).*
SD habitats.	*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 indiv/min electrofishing, and TREN at 0.01 indiv/min electrofishing. BMAR have a lower indicator value (0.88), but is more abundant (0.74 indiv/min electrofishing) and thus should be used in conjunction with TREN & OMOS.*	*BMAR absent during any survey (or with relative abundance < 0.5 indiv/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).*
Water column.	*OPE & MBRE were sampled during baseline survey: OPER sampled at a relative abundance of 0.14 indiv/min (60% of historical surveys), and*	*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).*

METRIC	ECOSPEC	TPC	HABITAT
	MBRE sampled at a relative abundance of 0.01 indiv/min (80% of historical surveys). BMAR have a lower indicator value (0.82), but is more abundant (0.74 indiv/min electrofishing) and could be used in conjunction with MBRE & OPER.		
SS habitats.	*BVIV was present during baseline EWR survey at relative abundance of 0.17 indiv/min electrofishing.*	*BVIV absent during any survey AND/OR decrease in relative abundance below 0.1 indiv/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).*
Overhanging vegetation.	*Both species were sampled during 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 indiv/min electroshocking. 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 indiv/min during baseline survey and it occurred 60% of surveys conducted at site.*	*BVIV absent during any survey AND/OR decrease in relative abundance below 0.1 indiv/min for BVIV. PPHI 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).*
Undercut banks.	*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 indiv/min, and PPHI at 0.25 indiv/min. electrofishing.*	*Both BEUT & PPHI absent during any survey AND/OR decrease in relative abundance below 0.07 indiv/min for BEUT and < 0.15 indiv/min for PPHI.*	*Significant change in undercut bank habitats (to be quantified with RHAM).*
Instream vegetation.	*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 indiv/min electrofishing). BVIV were sampled at 0.17 indiv/min electroshocking.*	*BVIV absent during any survey AND/OR decrease in relative abundance below 0.1 indiv/min for BVIV.AND/OR 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).*

Table B45 EWR 3: EcoSpecs and TPCs: Macroinvertebrates

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.*
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: 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 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.	*The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.*

Table B46 EWR 4: EcoSpecs and TPCs: Geomorphology

METRIC	ECOSPEC	TPC
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 30%.
		Gravels should be more than 15%.
		Cobbles should not be less than 10%.
		Within all of the fast habitats:
		Sand should not exceed 10%.
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.*
		Embedded boulders should be less than 30% of the site.
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.*

Table B47 EWR 4: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Exotic species cover between 1 and 5%.*	*An increase in exotic species covers above 5%.*
Terrestrialisation	*The absence of woody kloof species.*	*A presence of woody kloof species.*
Indigenous Riparian Woody Cover.	*Indigenous riparian woody cover between 20 and 60%.*	*A decrease in riparian woody species covers below 20%.*
	Indigenous riparian woody cover between 60 and 80%.	*A decrease in riparian woody species covers below 60%.*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*Non-woody cover between 30 and 60%.*	*An increase in non-woody cover above 70%.*
Phragmites (reed) cover.	*The absence of reeds.*	*The presence of reeds.*

Table B48 EWR 4: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During recent surveys fish were sampled at 3.1 indiv/min.*	*Relative abundance of less than 1.6 indiv/min sampled at the site (during same season as baseline data).*	
Alien fish species.	*No alien fish species sampled at site during recent surveys.*	*Presence of any alien/introduced fish species at site during any survey.*	*N/A.*
FD Habitats.	*During the baseline survey VNEL was present at site at relative abundance of 1.58 indiv/min electrofishing, while BEUT was present at 0.25 indiv/min (electrofishing).*	*VNEL and BEUT absent from site during any survey OR present at relative abundance < 1 indiv/min for VNEL and < 0.1 indiv/min for BEUT.*	*Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows) (to be quantified with RHAM).*
FS habitats.	*During the baseline survey VNEL was present at site at relative abundance of 1.58 indiv/min electrofishing, while CANO was present at 0.81 indiv/min (electrofishing).*	*VNEL and CANO absent from site during any survey OR present at relative abundance < 1 indiv/min for VNEL and < 0.4 indiv/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).*
Substrate.			
Flow dependant spp (flow alteration).	*During the baseline survey CANO was present at site at relative abundance of 0.81 indiv/min electrofishing, while BEUT was present at 0.25 indiv/min (electrofishing).*	*CANO and BEUT absent from site during any survey OR present at relative abundance < 0.4 indiv/min for CANO and < 0.1 indiv/min for BEUT.*	
Water quality intolerance.			*Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).*
SD habitats.	*OPER was only indicator of SD habitats sampled during baseline conditions and it was present in very low abundance (0.02 indiv/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).*
Water column.	*OPER was only indicator of water*	*Due to low abundance of OPER at*	*Reduction in suitability of water*

METRIC	ECOSPEC	TPC	HABITAT
	column sampled during baseline conditions and it was present in very low abundance (0.02 indiv/min).	*site, it may not be a valid indicator and will require verification. Preliminary TPC: Absence of OPER for 2 consecutive surveys.*	*column (i.e. increased sedimentation of pools).*
SS habitats.	*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).*
Overhanging vegetation.	*During the baseline survey BEUT was present at 0.25 indiv/min (electrofishing).*	*BEUT absent from site during any survey OR present at relative abundance < 0.1 indiv/min.*	*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*
Undercut banks.			*Significant change in undercut bank habitats (to be quantified with RHAM).*
Instream vegetation.	*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).*

Table B49 EWR 4: EcoSpecs and TPCs: Macroinvertebrates

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).	*The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.*
No group to dominate the fauna i.e. be present in C abundance (> 100) over more than two consecutive surveys.	

Table B50 EWR 5: EcoSpecs and TPCs: Geomorphology

METRIC	ECOSPEC	TPC
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 30%.
		Within all of the fast habitats:
		Sand should not exceed 10%.
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.*

Table B51 EWR 5: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Exotic species cover between 10 - 15%.*	*An increase in exotic species covers above 15%.*
Terrestrialisation	*The absence of terrestrial woody species.*	*The presence of terrestrial woody species.*
	Terrestrial woody cover between 1 and 5%.	*An increase in terrestrial woody species cover > 5%.*
	Terrestrial woody cover between 15 and 20%.	*An increase in terrestrial woody species cover > 20%.*

METRIC	ECOSPEC	TPC
Indigenous Riparian Woody Cover.	*Indigenous riparian woody cover between 70 and 80%.*	*A decrease in riparian woody cover below 30% OR an increase above 80%.*
Non-woody Indigenous Cover (grasses, sedges & dicotyledonous forbs).	*Non-woody cover between 40% and 50%.*	*A decrease in sedge, grass and dicotyledonous forb cover below 40% OR an increase above 90%.*
Phragmites (reed) cover.	*Reed covers between 20 and 30%.*	*A decrease in reed cover below 30%.*
	Reed covers between 20 and 30%.	*An increase in reed cover above 80% or a decrease below 20%.*
	Reed covers below 20%.	*An increase in reed cover above 40%.*

Table B52 EWR 5: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During recent surveys fish were sampled at 4 indiv/min.*	*Relative abundance of less than 3 individual per minute sampled at the site (during same season as baseline data).*	
Alien fish species.	*No alien fish species sampled at site during recent surveys.*	*Presence of any alien/introduced fish species at site during any survey.*	*N/A.*
FD Habitats.	*During the baseline survey CANO was present at site at relative abundance of 1.36 indiv/min electrofishing, while BMAR was present at 1 indiv/min (electrofishing).*	*CANO and BMAR absent from site during any survey OR present at relative abundance 1 indiv/min for CANO and < 0.6 indiv/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).*
FS habitats.			
Substrate.			
Flow dependant spp (flow alteration).	*During the baseline survey CANO was present at site at relative abundance of 1.36 indiv/min electrofishing, while AURA was present at 0.15 indiv/min (electrofishing).*	*CANO and AURA absent from site during any survey OR present at relative abundance 1 indiv/min for CANO and < 0.05 indiv/min for AURA.*	
Water quality intolerance.	*During the baseline survey CANO was present at site at relative abundance of 1.36 indiv/min electrofishing, while BEUT was present at 0.39 indiv/min (electrofishing).*	*CANO and BEUT absent from site during any survey OR present at relative abundance < 1 indiv/min for CANO and < 0.2 indiv/min for BEUT.*	*Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).*
SD habitats.	*During the baseline survey CGAR was present at site at relative abundance of 0.1 indiv/min electrofishing, while BMAR was present at 1 indiv/min (electrofishing).*	*CGAR and BMAR absent from site during any survey OR present at relative abundance 0.05 indiv/min for CGAR and < 0.6ind/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).*
Water column.	*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 indiv/min electrofishing, while BMAR was present at 1 indiv/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).*
SS habitats.	*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 indiv/min for PPHI and 0.02 indiv/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).*
Overhanging vegetation.			*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*
Undercut banks.	*During the baseline survey MMAC was present at site at relative abundance of 0.13 indiv/min electrofishing, while BEUT was present at 0.39 indiv/min (electrofishing).*	*MMAC and BEUT absent from site during any survey OR present at relative abundance < 0.05 indiv/min for MMAC and < 0.2 indiv/min for BEUT.*	*Significant change in undercut bank habitats (to be quantified with RHAM).*
Instream vegetation.	*TSPA is the best indicators of instream vegetation habitats at site. During the baseline survey it was*	*TSPA absent for 2 consecutive surveys.*	*Significant change in Instream vegetation habitats (to be quantified with RHAM).*

METRIC	ECOSPEC	TPC	HABITAT
	sampled at very low relative abundance of 0.02 indiv/min (electrofishing).		

Table B53 EWR 5: EcoSpecs and TPCs: Macroinvertebrates

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).	*The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.*
No group to dominate the fauna i.e. be present in C abundance (> 100) over more than two consecutive surveys.	

Table B54 EWR 6: EcoSpecs and TPCs: Geomorphology

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 mobile sediments (i.e. bedrock excluded):** *Sands (<6 mm) should not exceed 10%.* • *GAI level IV in 2007 measured 0%.* *Gravels (<60 mm) should be more than 5%.* • *GAI level IV in 2007 measured 11%.* *Cobbles (60 – 250 mm) should not be less than 50%.* • *GAI level IV in 2007 measured 78%.* **Sampling protocol:** *Sediment is to be sampled in the active channel (bedrock) riffle at the EWR cross-section.*
ACTIVE CHANNEL MORPHOLOGY		
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 dines 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%.*	

Table B55 EWR 6: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Exotic species cover between 15 - 20%.*	*An increase in exotic species covers above 20%.*
Indigenous Riparian Woody Cover.	*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%.	*An increase in riparian woody cover of more than 50% OR a decrease below 10%.*
	Riparian woody cover between 20 and 70%.	*A decrease in riparian woody species covers below 20% OR above 70%.*
Phragmites (reed) cover.	*Reed covers between 10% and 20%.*	*A decrease in reed cover below 20%.*
	Reed covers between 10% and 90%.	*An increase in reed cover above 80% or a decrease below 20%.*
	Reed covers between 40% and 50%.	*An increase in reed cover above 40%.*

Table B56 EWR 6: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During recent baseline (EWR) fish were sampled at 5.2 indiv/min.*	*Relative abundance of less than 4.5 indiv/min sampled at the site (during same season as baseline data).*	*N/A.*
Alien fish species.	*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.*
FD Habitats.	*During the recent baseline (EWR) survey CANO was present at a relative abundance of 0.50 indiv/min and BMAR at 0.55 indiv/min.*	*CANO and BMAR absent during any survey or present at relative abundance of < 0.30 indiv/min for CANO and < 0.35 indiv/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).*
FS habitats.	*During the recent baseline (EWR) survey CANO was present at a relative abundance of 0.50 indiv/min, CSWI at 0.03 indiv/min and BMAR at 0.55 indiv/min.*	*CANO and BMAR absent during any survey or present at relative abundance of < 0.30 indiv/min for CANO and < 0.35 indiv/min for BMAR and CSWI absent for two consecutive surveys.*	
Substrate.	*During the recent baseline (EWR) survey CANO was present at a relative abundance of 0.50 indiv/min, LMOL at 0.08 indiv/min and BMAR at 0.55 indiv/min.*	*CANO and BMAR absent during any survey or present at relative abundance of < 0.30 indiv/min for CANO and < 0.35 indiv/min for BMAR and LMOL absent for two consecutive surveys.*	
Flow dependant spp (flow alteration).	*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 indiv/min, CSWI at 0.03 indiv/min and BEUT at 0.43 indiv/min.*	*CANO and BEUT absent during any survey or present at relative abundance of < 0.30 indiv/min for CANO and < 0.20 indiv/min for BEUT and CSWI absent for two consecutive surveys.*	
Water quality intolerance.	*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 indiv/min and BEUT at 0.43 indiv/min.*	*CANO and BEUT absent during any survey OR present at relative abundance of < 0.30 indiv/min for CANO and < 0.20 indiv/min for BEUT.*	*Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).*
SD habitats.	*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 indiv/min and BMAR at 0.55 indiv/min.*	*OMOS and BMAR absent during any survey or present at relative abundance of < 0.35 indiv/min for BMAR and < 0.50 indiv/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).*
Water column.	*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 indiv/min and BMAR at 0.55 indiv/min.*	*BMAR absent during any survey or present at a relative abundance of < 0.35 indiv/min and MBRE absent for two consecutive surveys.*	*Reduction in suitability of water column (i.e. increased sedimentation of pools).*
SS habitats.	*BVIV & MACU will be most appropriate indicators of SS habitats*	*BVIV absent during any survey or present at a relative abundance of*	*Significant change in SS habitat suitability (i.e. increased flows,*

METRIC	ECOSPEC	TPC	HABITAT
	at the site. During the recent baseline (EWR) survey BVIV was present at a relative abundance of 0.12 indiv/min and MACU at 0.03 indiv/min.	*< 0.05 indiv/min and MACU absent for two consecutive surveys.*	*altered seasonality, increased sedimentation of slow habitats). (To be quantified with RHAM).*
Overhanging vegetation.	*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 indiv/min and BTRI at 0.72 indiv/min.*	*BVIV & BTRI absent during any survey or BVIV present with relative abundance < 0.05 indiv/min and BTRI < 0.5 indiv/min.*	*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*
Undercut banks.	*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 indiv/min and BEUT at 0.43 indiv/min.*	*BEUT absent during any survey or present at a relative abundance of < 0.20 indiv/min and MMAC absent for two consecutive surveys.*	*Significant change in undercut bank habitats (to be quantified with RHAM).*
Instream vegetation.	*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 indiv/min and BVIV at 0.12 indiv/min.*	*BVIV absent during any survey or with relative abundance < 0.05 indiv/min and TREN absent for two consecutive surveys.*	*Significant change in Instream vegetation habitats (to be quantified with RHAM).*

Table B57 EWR 6: EcoSpecs and TPCs: Macroinvertebrates

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, Heptageniidae).	*The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.*
No group to dominate the fauna i.e. be present in C abundance (> 100) over more than two consecutive surveys.	

Table B58 EWR 7: EcoSpecs and TPCs: Geomorphology

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) must be more than 90%.* • *GAI level IV in 2007 measured 100%.* **Sampling protocol:** *Sediment is to be sampled in the active channel downstream of the bridge (i.e. downstream of the EWR cross-section, this is immediately upstream of the bridge).*
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.* *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.*

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 exceed 61%.*	

Table B59 EWR 7: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Exotic species cover between 15 - 20%.*	*An increase in exotic species covers above 20%.*
Terrestrialisation.	*Terrestrial woody cover between 5 and 10%.*	*An increase in terrestrial woody species cover > 10%.*
	Terrestrial woody cover between 20 and 30%.	*An increase in terrestrial woody species cover > 30%.*
Indigenous Riparian Woody Cover.	*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%.	*An increase in riparian woody cover of more than 50% OR a decrease below 10%.*
	Riparian woody cover between 20 and 70%.	*A decrease in riparian woody species covers below 20% OR above 70%.*
Phragmites (reed) cover.	*Reed covers between 10% and 20%.*	*A decrease in reed cover below 20%.*
	Reed covers between 10% and 90%.	*An increase in reed cover above 80% or a decrease below 20%.*
	Reed covers between 40% and 50%.	*An increase in reed cover above 40%.*

Table B60 EWR 7: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During recent baseline (EWR) survey fish were sampled at 3.5 individuals per minute. This may be even higher during optimal sampling conditions.*	*Relative abundance of less than 2 individual per minute sampled at the site (during same season as baseline data with optimal sampling conditions).*	*N/A.*
Alien fish species.	*No alien fish species sampled at site during recent surveys.*	*Presence of any alien/introduced fish species at site during any survey.*	*N/A.*
FD Habitats.	*During recent baseline (EWR) survey CANO was present at site at a relative abundance of 0.15 individual/min and BMAR at a relative abundance of 1.56 indiv/min.*	*CANO and BMAR absent from site during any survey OR present at relative abundance < 0.1 indiv/min for CANO and < 1.2 indiv/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).*
FS habitats.			
Substrate.			
Flow dependant spp (flow alteration).	*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 indiv/min and BEUT at a relative abundance of 1.13 indiv/min.*	*CANO and BEUT absent from site during any survey OR present at relative abundance < 0.1 indiv/min for CANO and < 0.9 indiv/min for BEUT.*	
Water quality intolerance.			*Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).*
SD habitats.	*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 indiv/min and BMAR at a relative abundance of 1.56 indiv/min.*	*OMOS and BMAR absent from site during any survey OR BMAR present at relative abundance of < 1. 2 indiv/min.*	*Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).*
Water column.			*Reduction in suitability of water column (i.e. increased sedimentation of pools).*
SS habitats.			*Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).*
Overhanging vegetation.	*BTRI & BEUT will be most appropriate indicators of overhanging vegetation habitats at*	*BTRI and BEUT absent from site during any survey OR present at relative abundance < 0.40*	*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*

METRIC	ECOSPEC	TPC	HABITAT
	the site. During recent baseline (EWR) survey BTRI was present at site at a relative abundance of 0.67 indiv/min and BEUT at a relative abundance of 1.13 indiv/min.	*indiv/min for BTRI and < 0.9 indiv/min for BEUT.*	
Undercut banks.	*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 indiv/min*	*BEUT absent during any survey or present with relative abundance < 0.9 indiv/min.*	*Significant change in undercut bank habitats (to be quantified with RHAM).*
Instream vegetation.	*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).*

Table B61 EWR 7: EcoSpecs and TPCs: Macroinvertebrates

ECOSPECS: HABITAT	TPCs
Average depth >01m, 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, Heptageniidae).	*The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.*
No group to dominate the fauna i.e. be present in C abundance (> 100) over more than two consecutive surveys.	

Table B62 EWR 8: EcoSpecs and TPCs: Geomorphology

METRIC	ECOSPEC	TPC
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%.
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.*

Table B63 EWR 8 EcoSpecs and TPCs: Physico-chemical (Visual)

METRIC	ECOSPEC	TPC
Water odour type and extent	*None*	*Cattle: ≥ 3*
		Chemical pollution: ≥ 1
		Other sources: ≥ 2
Filamentous algae in water column	*1*	*>3*
Water colour and extent	*2, Brown*	*Green: ≥ 3.*
		All other colours: ≥ 1
Turbidity/clarity	*2*	*≥ 2*
Water surface indicator and extent	*None*	*All indicators: ≥ 2*
		Salt deposits: ≥ 1
Algal cover on hard surfaces	*1*	*> 4*

Table B64 EWR 8: EcoSpecs and TPCs: Riparian vegetation

METRIC	ECOSPEC	TPC
Exotic Invasion (perennial exotics).	*Exotic species cover between 5 - 10%.*	*An increase in exotic species covers above 10%.*

Terrestrialisation.	*The absence of terrestrial woody species.*	*An increase in terrestrial woody species cover > 5%.*
Phragmites (reed) cover.	*Reed covers above 30%.*	*A decrease in reed cover below 30%.*
	Reed covers between 20% and 80%.	*An increase in reed cover above 80% or a decrease below 20%.*

Table B65 EWR 8: EcoSpecs and TPCs: Fish

METRIC	ECOSPEC	TPC	HABITAT
Species richness.	*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).*
Relative abundance.	*During recent surveys fish were sampled at 13.1 indiv/min.*	*Relative abundance of less than 8.0 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently.*	
Alien fish species.	*No alien fish species sampled at site during recent surveys.*	*Presence of any alien/introduced fish species at site during any survey.*	*N/A.*
FD Habitats.	*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 indiv/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 indiv/min.)*	*BMAR absent during any survey (or with relative abundance < 0.18 indiv/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).*
FS habitats.			
Substrate.			
Flow dependant spp (flow alteration).			
Water quality intolerance.	*Under baseline survey LCYL were absent at site EWR 8 while LMOL was monitored at very low numbers (0.02 indiv/min.)*	**Both** *LMOL and LCYL absent during any survey.*	*Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).*
SD habitats.	*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 indiv/min, while OMOS was monitored at 3.69 indiv/min.*	*TREN and OMOS absent during any survey AND/OR TREN present with relative abundance < 0.10 indiv/min and OMOS < 2.0 indiv/min.*	*Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools) (to be quantified with RHAM).*
Water column.	*BMAR & OMOS will be most appropriate indicators of Water column habitats and expected to always be present at the site. Under baseline conditions BMAR was sampled at a relative abundance of 0.24 indiv/min electrofishing and OMOS was monitored at a relative abundance of 3.69 indiv/min.*	*BMAR and OMOS absent during any survey AND/OR BMAR present with relative abundance < 0.18 indiv/min and OMOS < 2.0 indiv/min.*	*Reduction in suitability of water column (i.e. increased sedimentation of pools).*
SS habitats.	*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 indiv/min, and BVIV was monitored at a relative abundance of 4.05 indiv/min.*	*TREN & BVIV absent during any survey AND/OR TREN present with relative abundance < 0.10 indiv/min and BVIV < 2.0 indiv/min.*	*Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats) (to be quantified with RHAM).*
Overhanging vegetation.			*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*
Instream vegetation.			*Significant change in overhanging vegetation habitats (to be quantified with RHAM).*
Undercut banks.	*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 indiv/min.*	*PPHI absent during any survey or present with relative abundance < 0.2 indiv/min.*	*Significant change in undercut bank habitats (to be quantified with RHAM).*

Table B66 EWR 8: EcoSpecs and TPCs: Macroinvertebrates

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).	*The presence of one or more taxon occurring in C abundance, i.e. > 100 individuals for two consecutive surveys.*
No group to dominate the fauna i.e. be present in C abundance (> 100) over more than two consecutive surveys.	

B1.3 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). This is applicable to Crocodile sub-catchment: EWR 1 and 2; Sabie-Sand sub-catchment: EWR 1, EWR 3 and EWR 8 where RHAM data for visual physico-chemical variables were available.

Table B67 Diatom EcoSpecs and TPCs based on a B EC

Physico-chemical metric	EcoSpecs	Class rank*	TPC
pH	*6 - 8 Circumneutral*	*3*	*≥2; ≤4*
Salinity	*Fresh brackish (100 - 500 µS/cm)*	*2*	*<2*
Nutrients	*Slightly elevated concentrations of organically bound nitrogen.*	*1*	*≤2*
Organics	*β-mesosaprobic: BOD_5 < 4mg/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 (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: Frustulia and Eunotia 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: Frustulia and Eunotia 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*	*Epithemia adnata (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*

RHAM Water Quality			Diatoms (R-DRAM)			
RHAM indicator	**Trigger/Water quality indicator**	**TPC**	**Considered metric/species**	**EcoSpec Class ranking**	**TPC[1]**	**TPC[2]**
	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.

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. This is applicable to Sabie-Sand sub-catchment: EWR 3, and 6 where RHAM data for visual physico-chemical variables were available.

Table B68 Diatom EcoSpecs and TPCs based on a C EC

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-ά-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: Frustulia and Eunotia 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: Frustulia and Eunotia 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*	*Epithemia adnata (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*