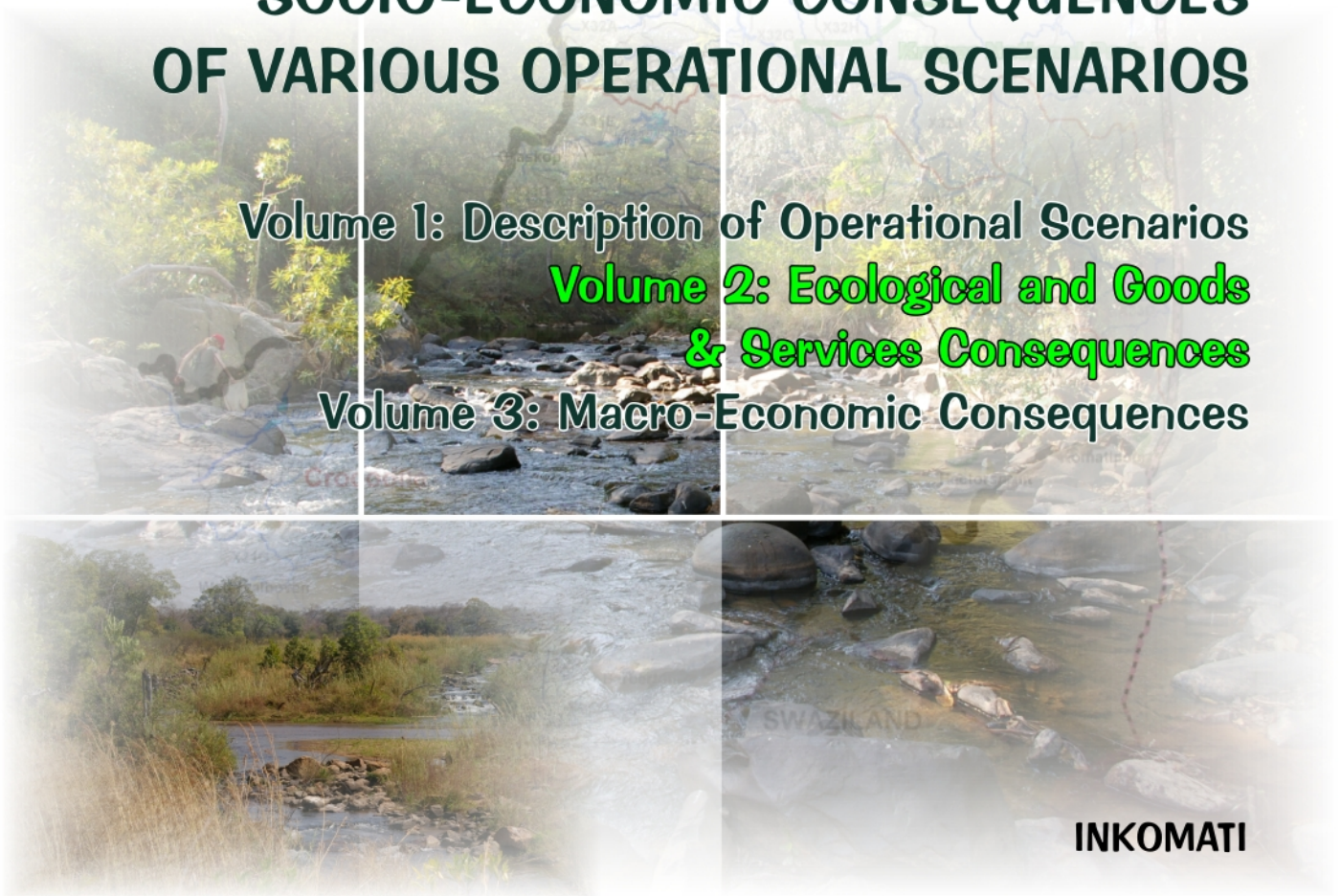
Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the INKOMATI WATER MANAGEMENT AREA, MPUMALANGA

PROJECT NO: WP 9133

ECOLOGICAL, GOODS & SERVICES AND SOCIO-ECONOMIC CONSEQUENCES OF VARIOUS OPERATIONAL SCENARIOS



Volume 1: Description of Operational Scenarios
Volume 2: Ecological and Goods & Services Consequences
Volume 3: Macro-Economic Consequences

INKOMATI

MARCH 2010

REPORT NO.: 26/8/3/10/12/011

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

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

SABIE AND CROCODILE RIVER SYSTEMS : OPERATIONAL SCENARIOS AND CONSEQUENCES REPORT: VOLUMES 1 – 3

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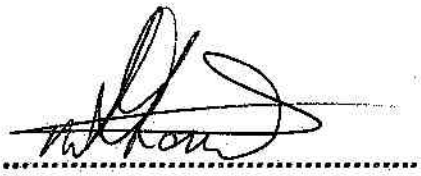

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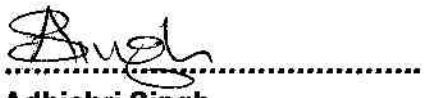

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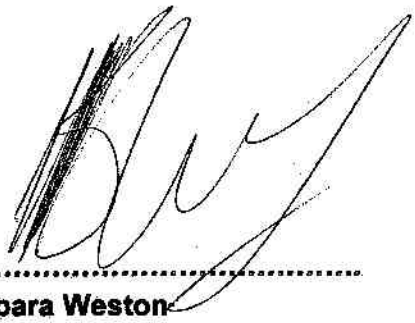


Barbara Weston
Study Manager

PREFACE

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 Montrose and Mountain View Dams. These studies require higher levels of confidence in the Reserve determination results as is currently available in certain of the catchments, such as the Sabie-Sand and Crocodile River catchments. This will assist the DWAF to make informed decisions regarding the authorisation of future water use and the magnitude of the impacts of the present and proposed developments.

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

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

STUDY AREA AND STUDY SITES

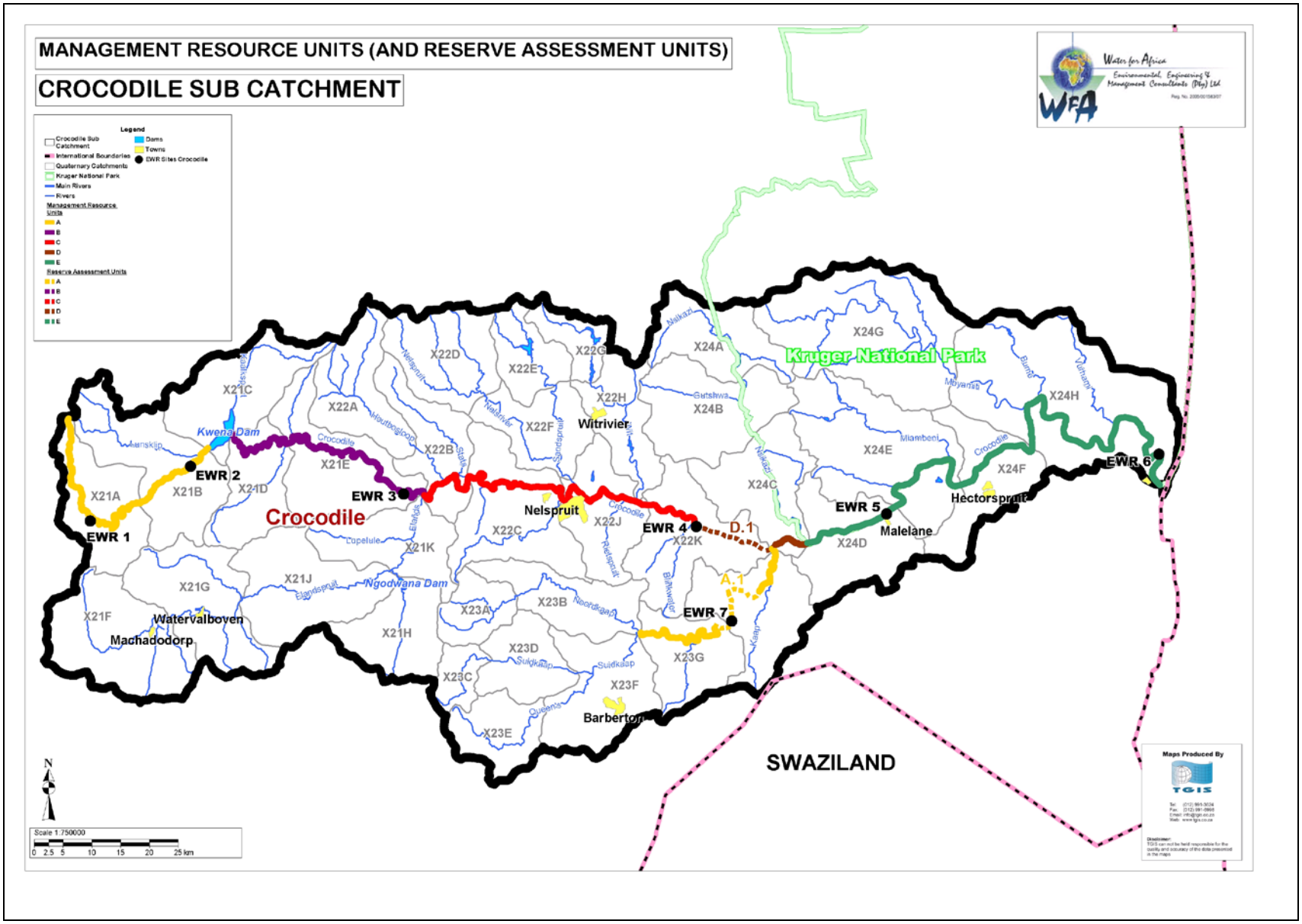
The Inkomati WMA is largely located within the Mpumalanga Province. It can be considered to consist of three largely independent catchments, the Komati, Crocodile (East) and Sabie–Sand River catchments. All these rivers drain the WMA and confluence to form the Incomati River in Mozambique which flows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

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

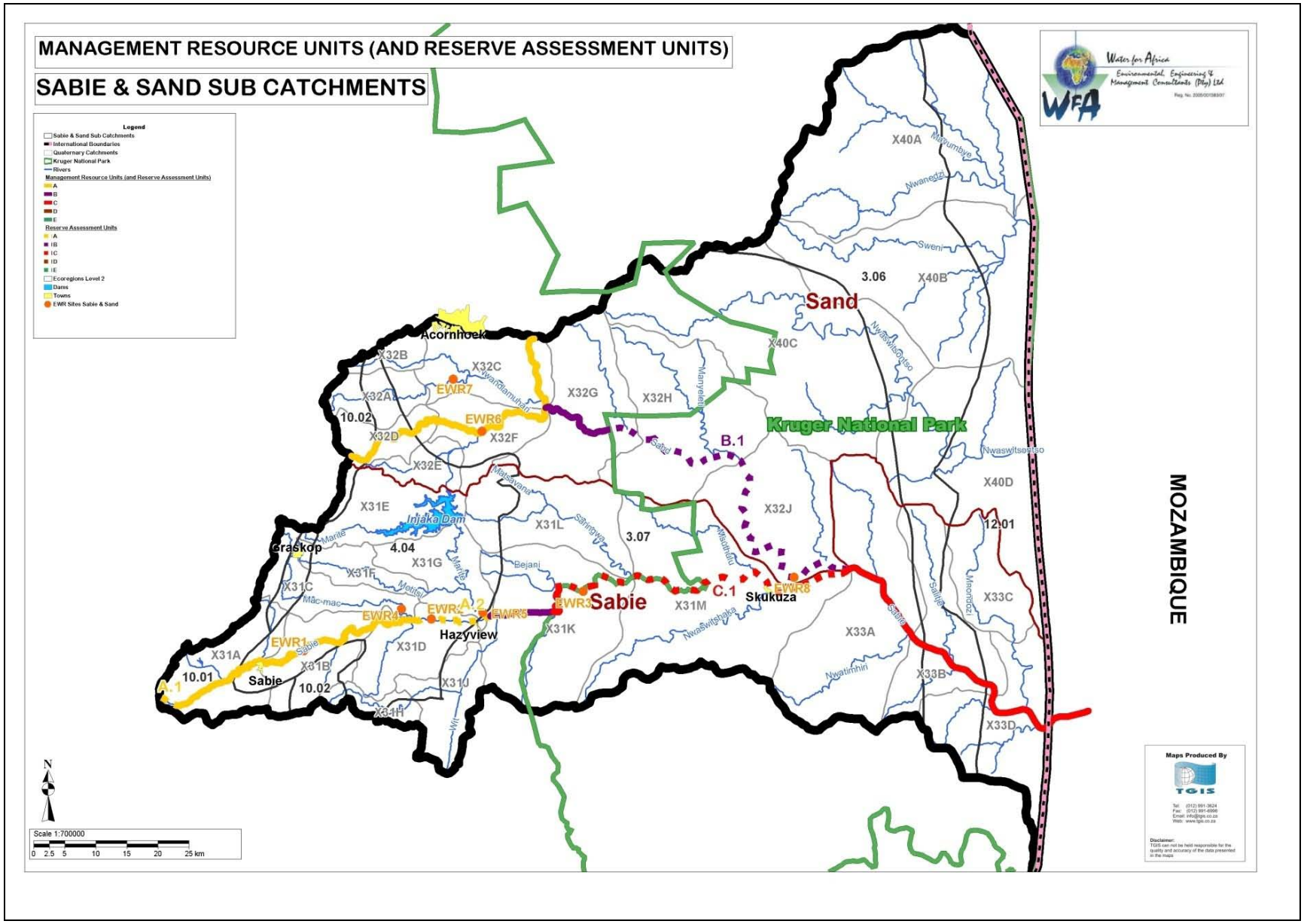
Locality of EWR sites for the Inkomati River System

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

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



Crocodile River catchment and locality of EWR sites



Sabie-Sand River catchment and locality of EWR sites

THIS REPORT

This report consists of three separate standalone volumes which each provide a summary of the methods followed and the results. To ensure that a logical process could be followed in any one of the reports, this combined executive summary was provided in each report. This provides the context of all the work undertaken for Step 5 of the Ecological Reserve study.

The report consists of three volumes as follows:

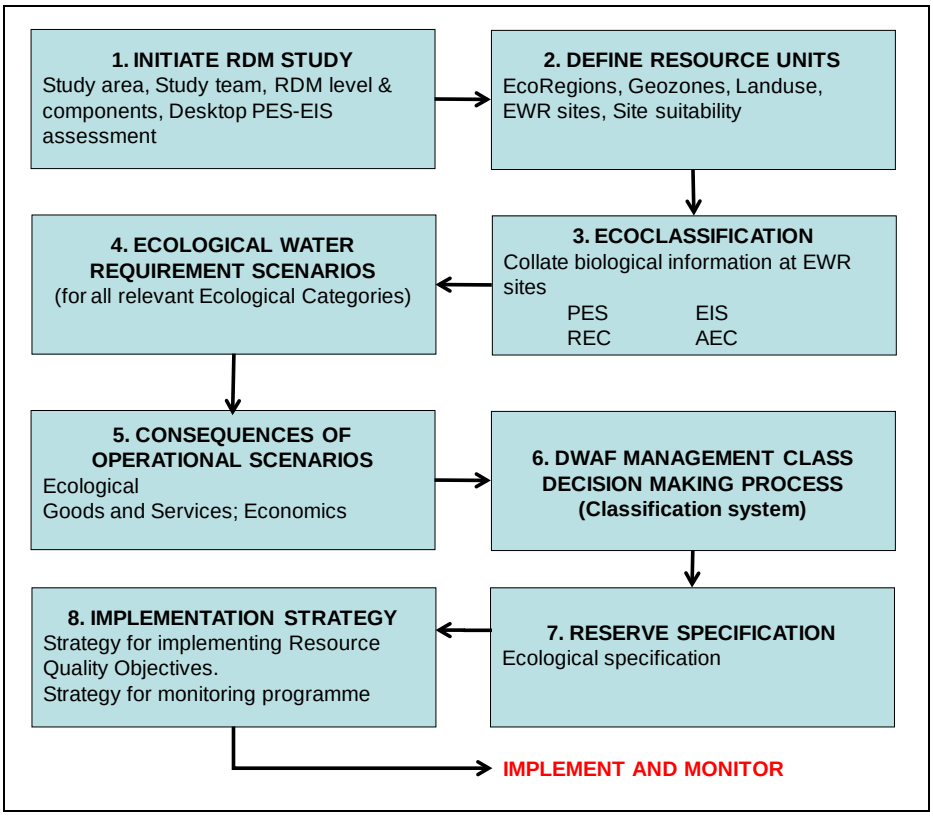
- Volume one: Description of the operational scenarios.
- Volume two: Ecological and G&S consequences of the operational scenarios.
- Volume three: Macro Economic consequences of the operational scenarios.

EVALUATION OF OPERATIONAL SCENARIOS

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 scenario other than the present which could be implemented in future.

The Comprehensive Ecological Reserve Methodology was followed within the 8 - step Ecological Reserve process (refer to figure below). This section summarizes step 5 of the Ecological Reserve process that was followed during this study.



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

Step 5 refers to the ecological consequences of operational scenarios. However, as part and parcel of the Ecological Reserve approach, this step has been extended since the early 2000s to include the Goods and Services (G&S) and macro economic consequences. In the absence of a Classification system, this was specifically to provide DWA with a greater understanding of the consequences of decisions to either protect or use the water resources in the Crocodile, Sabie and Sand River catchments.

The objective of this Reserve step is therefore to provide sufficient information to the decision maker regarding the operational scenarios and the consequences of these in terms of:

- Ecology
- Goods and Services (G&S)
- Socio Economics

This should then allow for informed decision-making regarding which Ecological Category and Reserve should be signed off.

INFORMATION REQUIRED PRIOR TO THIS STEP

Reserve Step 3: EcoClassification

EcoClassification determines the Present Ecological State (PES) and identifies the changes (from natural) that have taken place resulting in the PES. A Recommended Ecological Category (REC) based on the Ecological Importance and Sensitivity (EIS) is also identified as well as the issues that will have to be addressed to achieve this REC (if different from the PES).

A suite of models is used to determine the EcoClassification. This process has to be in place and finalised prior to step 5. Ecological consequences are described in terms of changes in Ecological Category from the PES, and a good understanding of the PES is therefore required. The models are used in a predictive fashion to estimate what the resulting EC will be for each operational scenario.

Reserve Step 4: EWR scenarios

The term EWR scenario refers to flow regimes set for a range of ECs. The resulting flow regimes, serve as a baseline against which to measure the consequences on the PES of the flow regimes associated with the various operational flow scenarios.

This information is also used during the design of the operational scenario phase to assess the implications of the Reserve and can guide the design of the operational scenarios.

Goods and Services

The consequences of operational scenarios on the G&S must be assessed. It is therefore required to identify the relevant G&S as well as to estimate a value of the G&S. This serves as the baseline and changes based on the different operational scenarios are measured against this. The focus is on G&S that will change due to changes in flow and the associated responses of the other physical drivers and biota.

Socio Economics

The economic impact of the proposed operational scenarios is measured against the deviation from the current economic activities. This entails that a detailed analysis of the current activities of water use are performed and expressed in terms of Gross Domestic Product (GDP), Employment

and impact on households and specifically on Low Income Households. The parameters are expressed in terms of direct, indirect and induced impacts.

If a specific scenario is by implication causing a curtailment in the volume of available water the impact of the lower volume is calculated and expressed. The curtailment of a specific activity takes place against a number of assumptions. It is assumed that domestic and industrial water will be provided within an active Water Conservation and Demand Management program. This does not apply for irrigation water and is it mostly the irrigation activities that are curtailed.

In the case of a volume curtailment it is accepted that the area is reduced. When decreasing "Assurance of Supply" the long term average production yield is lowered. In the case of curtailment, the low value crops are reduced first, followed by the higher value crops. In the final instance the macro economic impacts of the different scenarios are presented to assist in the final decision making process.

STEP 5: DETERMINING CONSEQUENCES TO OPERATIONAL SCENARIOS

Identifying and determining operational scenarios

The operational scenarios mostly focus on different flow scenarios. There are two types of operational flow scenarios:

a) Changes in the present operation in terms of flow.

b) Future development scenarios (which will result in different operational flow scenarios).

The Reserve team is dependent on the client supplying the operational scenarios. Usually, the Reserve team and the managing client body, in this case DWA and specifically the Project Management Team, will facilitate the process. Various meetings were held to present findings, discuss preliminary results, and to agree on a final range of the most likely and realistic scenarios to be provided for assessing consequences.

Part and parcel of this process is yield modelling. The flow time series at various points in the catchment were provided through a water resources systems model in terms of natural and present day flows. A monthly time step was used in all these simulations. Prior to identifying the operational scenarios, the EWR scenarios for different ECs was run through the yield model to identify whether the EWR scenarios could be met and, if not, how much could be met and where (in terms of seasons etc.) the problems lie.

This information can then provide guidance for identifying operational scenarios. Three hypothetical examples of the rationale and type for different scenarios are provided:

- If it is identified that the Reserve can mostly be met except during the dry season in very dry years, the EWR drought flows can be decreased by an estimated percentage and this will serve as one of the scenarios. The EWR specialists will then assess what the implications are of the decreased flows in terms of EC.
- Another example could be that a new irrigation development is being planned and an existing dam has to supply the water for this irrigation development. The yield modelling process will include this future irrigation development and then assess the resulting flows at each EWR site. The EWR specialist will again assess the consequences on EC.
- Future development scenarios could consist of a new dam and transfer scheme. These kinds of scenarios are complicated as each future development scenario consists of its own range of scenarios, which is dependent on how the system will be operated.

Once all the scenarios are identified, the output from the yield model is provided in the required format for consequences assessment. Volume 1 in this report series documents the operational scenarios that were modelled and the consequence of these scenarios on system yield.

Assessing consequences of operational scenarios

a) Ecological consequences

Detail is provided in Volume 2 regarding this process. In summary, the flow regime at each EWR site and for each scenario is provided as a flow duration table. This information is used either in this format, or converted to ecological stress. Where necessary, the response of the fluvial geomorphology, physico-chemical variables and biota, is modelled to assess the EC for each operational flow scenario.

b) Goods and Services

Detail is provided in Volume 2 regarding this process. In summary, the ecological specialists evaluate whether the identified Goods and Services will change in terms of order of magnitude for each operational scenario.

c) Socio-economics

Detail is provided in Volume 3 regarding this process. 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 changed due to each operational scenario as well as the EWR scenarios are determined.

ACRONYMS AND ABBREVIATIONS

AEC	Alternative Ecological Category
CD: RDM	Chief Directorate: Resource Directed Measures
CD:RDM	Chief Directorate: Resource Directed Measures
COMBUD	Computer Based Budgets
D:RQS	Directorate: Resource Quality Services
DWA	Department of Water Affairs (Name change 2009)
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
EZ	Economic Zone
FDI	Flow dependent macroinvertebrate
FFHA	Fish Flow Habitat Assessment
FRAI	Fish Response Assessment Index
FROC	Fish Frequency of Occurrence
FV	Future value
GDP	Gross Domestic Product
G&S	Goods and Services
GAI	Geomorphology Assessment Index
HFSR	Habitat Flow Stressor Response
LSR	Large semi-rheophilic fish
MAR	Mean Annual Runoff
MCM	Million Cubic Metres
MCM/annum	Million Cubic Metres per annum
MIRAI	Macroinvertebrate Assessment Index
MRU	Management Resource Unit
MVI	Marginal vegetation macroinvertebrate
PAI	Physico-chemical Assessment Index
PD	Present Day
PDH	Present Day Hydrology
PES	Present Ecological State
Quat	Quaternary catchment
REC	Recommended Ecological Category
SAM	Social Accounting Matrix
Sc	Scenario
SR	Small rheophilic fish
VEGRAI	Riparian Vegetation Response Assessment Index
WIM	Water Impact Model
WMA	Water Management Area

Department of Water Affairs

Chief Directorate: Resource Directed Measures

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

MARCH 2010

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DWA Project No: WP 9133
Report No: 26/8/3/10/12/011

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. 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 which consists of Volume 2 of a 3 part series of reports used to describe the operational scenarios that were evaluated and their ecological goods and services and macro-economic consequences.

THIS REPORT IS TO BE REFERENCED AS FOLLOWS:

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.

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Dr Kotze, Piet (Fish)
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EXECUTIVE SUMMARY

VOLUME 1: THE DESIGN OF OPERATIONAL SCENARIOS

CROCODILE SUB-SYSTEM GROUP 1: EWR DEMANDS EXCLUDED

Scenarios C1 to C6*: A combination of operating rules, restrictions, and/or curtailments applied*: 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 have been modelled, the river flow is very similar for many of the scenarios. Under Sc C3 and Sc C6 the water saved by the restrictions of irrigation resulted in increased yield of Kwena Dam and two additional scenarios, Sc C3.1 and C6.1 were modelled and the ecological consequences were determined. Under these scenarios the increased yield was released down the river to determine how much of the additional yield would supply the EWRs.

Scenario C7: ***New dam at Montrose:*** A new dam will be constructed at the Montrose site which is located just downstream of the confluence of the Crocodile and Elands Rivers. 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 drops 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 was 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:*** This scenario consisted of the Mountain View site which is located a few kilometres upstream of the confluence of the Kaap and Crocodile Rivers. The same assumptions as for Montrose Dam were made.

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.

Scenario C11: ***No cross-border flows:*** One of the main drivers of the low-flow under current operating conditions is the cross-border flows. As the lower Crocodile River has in the past flowed at very low flows, it was requested that the scenario of not supplying these minimum flows be modelled.

CROCODILE SUB-SYSTEM GROUP 2 SCENARIOS: EWR DEMANDS INCLUDED

The scenarios presented in this section pertain specifically to implementing the EWR for the Recommended Ecological Category (REC) and the Present Ecological State (PES) (basically EWR scenarios). Operating rules which entailed a range of restrictions and curtailments were developed to meet the EWR scenarios.

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 are 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.

THEREFORE, the PES EWR had to be seen as one scenario in 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 scenario (see above), 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.

Scenario C14: ***Meet the REC at EWR 6*****:** In order to meet the EWR for the REC, irrigators would need to be curtailed by 50%.

SABIE RIVER SUBSYSTEM

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.

SAND RIVER CATCHMENT

Four abstraction weirs (*viz*. Champagne, Dingleydale, New Forest, Edinburgh) in the Upper Sand exist but are not operating correctly. All the water (i.e.100%) is diverted and only the high flow spills continue downstream. There are also leaks from canals and the weirs that will trickle at places in the river. The Sand scenarios were based on the assumption that these four abstraction weirs would be rehabilitated, thus improving the flow downstream.

Scenarios consisting of combinations of weir improvement, curtailment and restrictions were simulated. The scenarios selected for evaluation are listed below (highlighted).

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**

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. This rule, referred to here as the Sellick rule (after Charles Sellick) only comes into effect when the river flow drops to a certain level.

SUMMARY OF RESULTS

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

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

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

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

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

VOLUME 2: 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 riverine EWR site and Management Resource Unit (MRU).

All information used during the EcoClassification step (the suite of EcoClassification models set up for different ECs) (DWAF, 2009a) and the Ecological Water Requirement (EWR) scenario step (DWA, 2010) is used as baseline for this assessment.

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

- The operational scenarios (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 identifies the direction of change (either positive or negative), and estimates the magnitude of the change in benefits and costs that may 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 is, 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 undergo 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.

ECOLOGICAL CONSEQUENCES RESULTS

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 E EC.
Red with X:	The results are below a E EC.

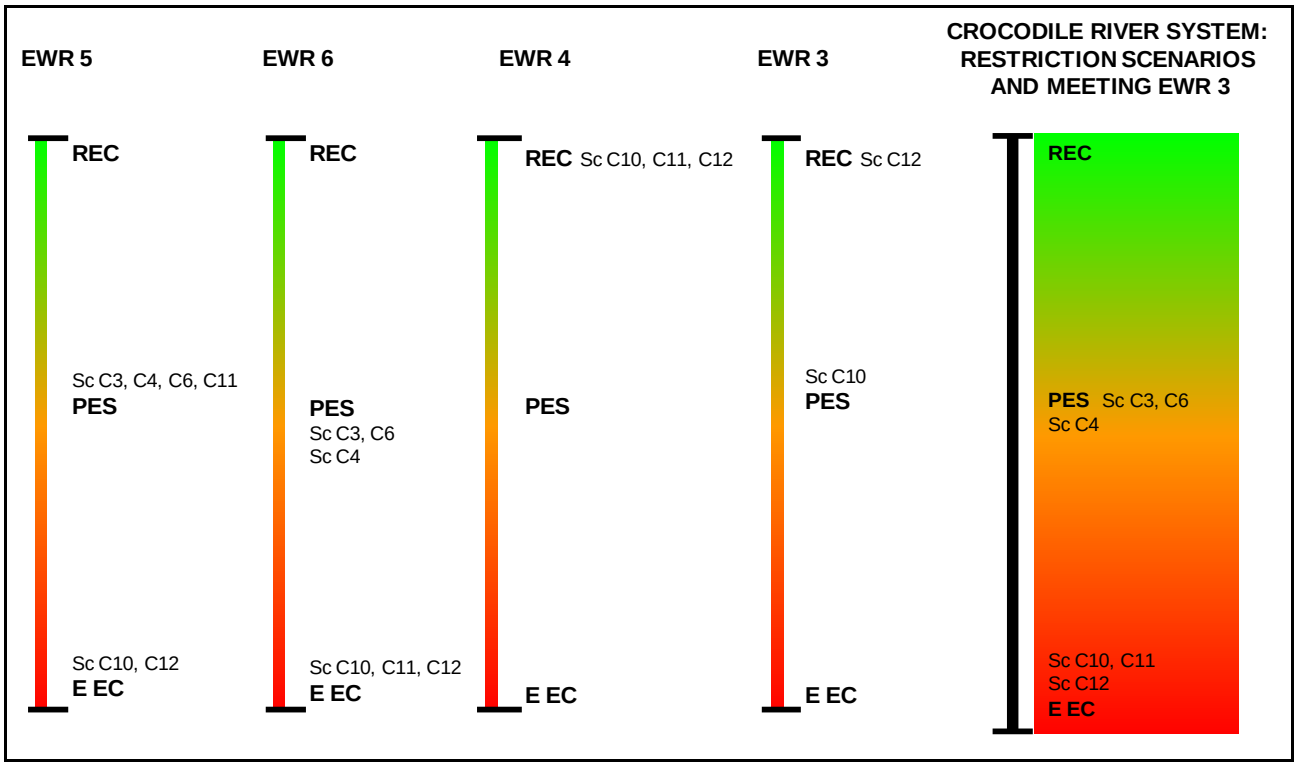
Crocodile Sub-system: Curtailment and restriction irrigation scenarios

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.

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

The results provided in the table 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. 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.

Within a system context none of the scenarios meet the REC at any of the EWR sites. The PES is 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 are not met and was ranked below the PES in the figure below. Scenario C10 – C12 resulted in a deterioration of the PES EcoStatus. The overall assessment is provided as the traffic diagram on the right.

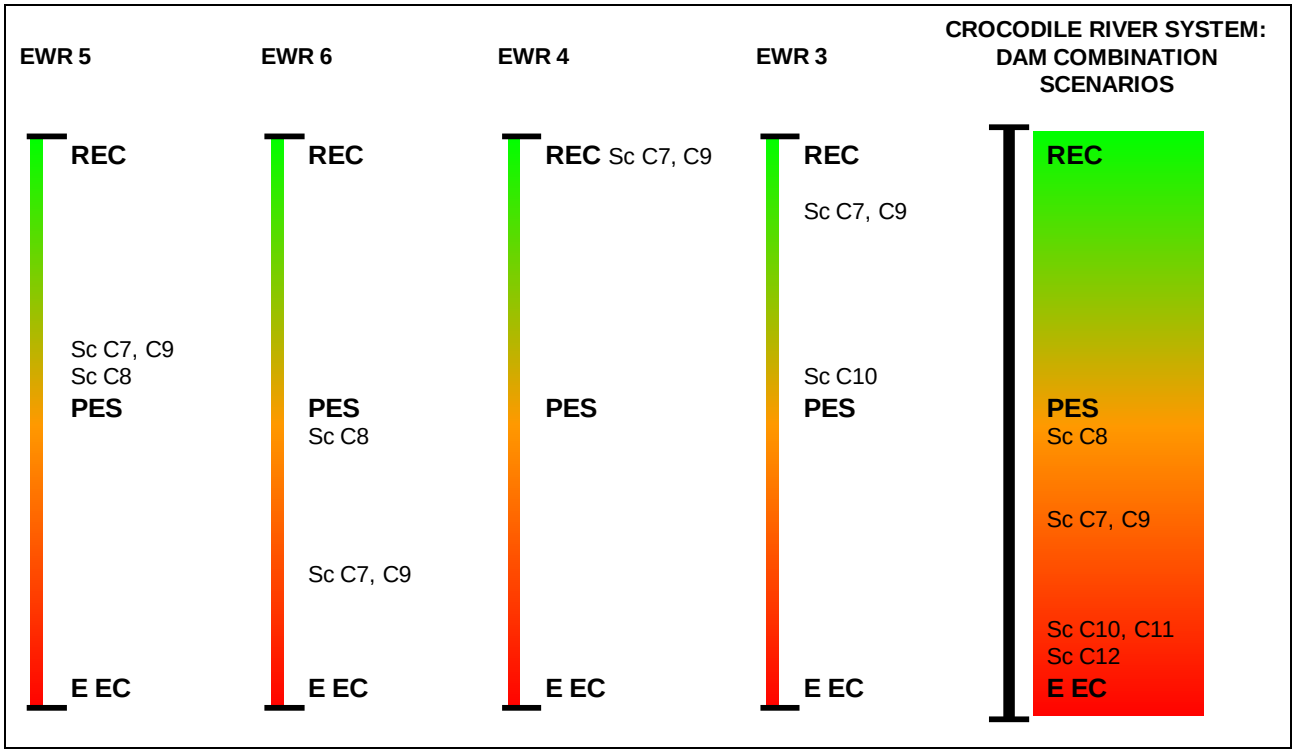


Crocodile Sub-system: Development (new dam) scenarios

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

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 maintains the PES EcoStatus but does not maintain the riparian vegetation and geomorphology PES. Scenario C8 was therefore ranked lower than the PES (figure below) 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.



Crocodile River: Additional scenarios evaluated at EWR 6

Two optimised scenarios were developed for additional screening, 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 the figure below.

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

REC Sc C6.1

Sc C3.1

PES
Sc C3,C 6
Sc C4

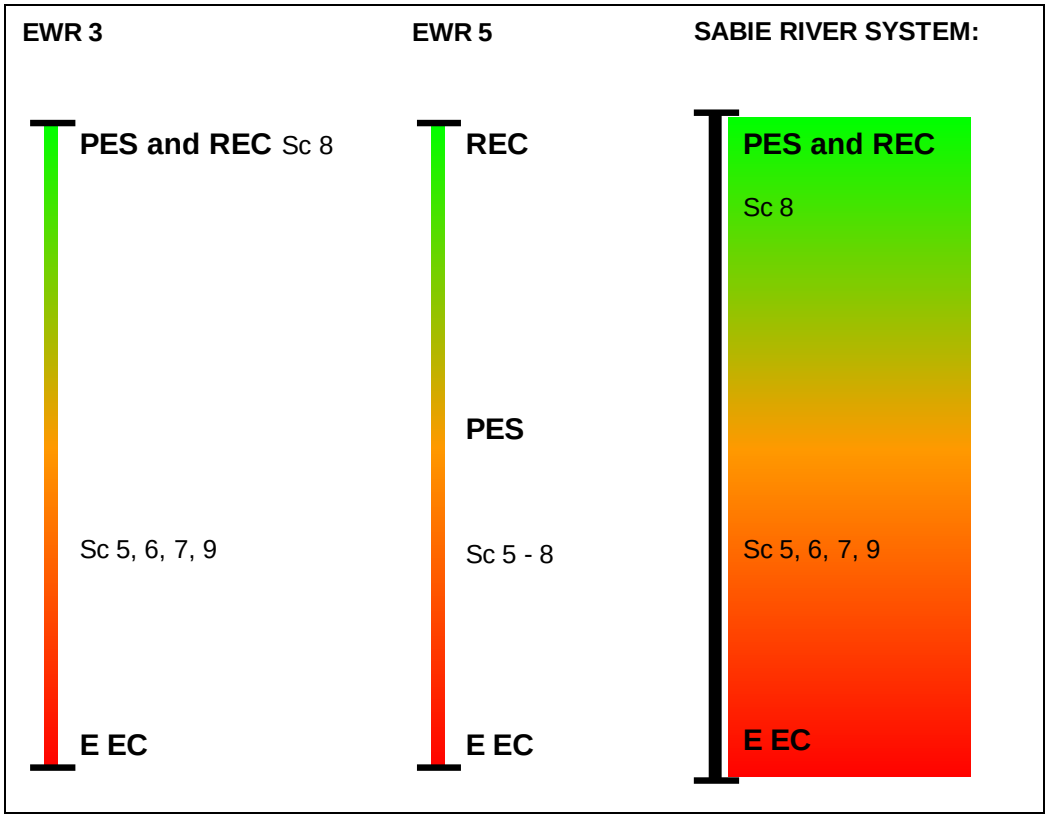
Sc C10, C11, C12
E EC

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	✓

Ecological consequences of the Sabie Sub-system

The table and figure below provides a summary of the results at each EWR site. Sc 8 achieves the objectives at EWR 3 in KNP but not at Marite (EWR 5). Therefore it is significantly better than the other scenarios which are at both sites lower than the PES.

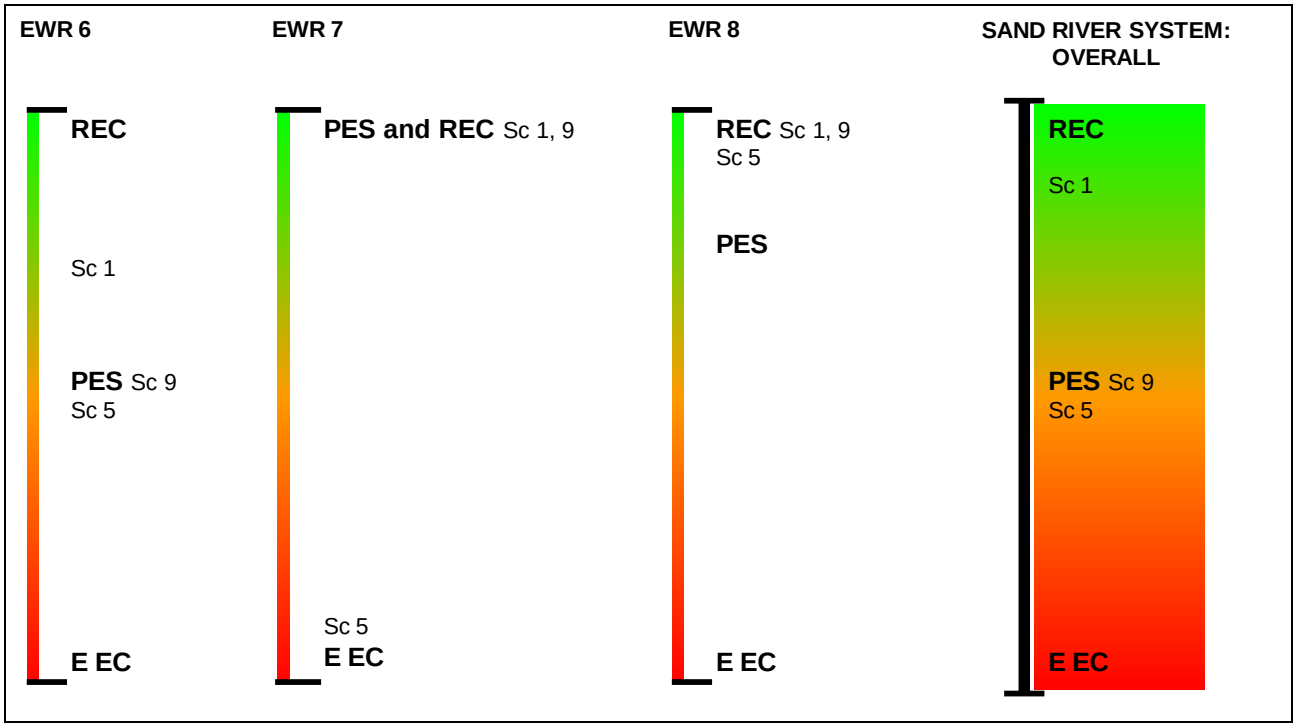
SABIE RIVER SYSTEM				
EWR SITE	Sc 5	Sc 6	Sc 7	Sc 8
EWR 3	X	X	X	✓
EWR 5	X	X	X	X
OVERALL	X	X	X	X



Ecological consequences of Sand sub-system

The table provides a summary of the results at each EWR site. Scenario 1 is an improvement of the PES at EWR 6 and meets the REC at EWR 7 and 8. It is a better scenario than Sc 9 which only meets the PES at EWR 6 and does not improve it as is the case with Sc 1. Scenario 5 is the worst scenario as it does not meet the PES/REC at EWR 7.

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



GOODS AND SERVICES SUMMARY OF RESULTS

The following represents a summary of scenarios 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.

Economic Zone	EWR Site	Scenarios							
Crocodile-East 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					

RECOMMENDATIONS

Crocodile Sub-system

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

Due to the socio economic impact of Sc C6.1 it is acknowledged that it is unlikely to be considered. Therefore Sc C3.1 is therefore a better option, although the potential socio-economic consideration can 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 results in the improvement of the PES, the risk associated with the PES not degrading further will 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.

Sabie Sand Sub-system

No operational scenarios were required for evaluation in the Sabie System. Theoretical scenarios that consist of different levels of irrigation restrictions to meet increasing irrigation requirements were investigation. These represent increased flows to various degrees at EWR 5 (Marite) and decreased flows at EWR 3 (Kidney). Scenario 8 is the only scenario that still meets the PES and REC at EWR 3 in the KNP. The Marite REC was not achieved. The present flow regime results in the same situation and it is 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 are 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 will be the best scenario as this scenario improves the PES at EWR 6 and meets the REC requirements at EWR 7 and 8. Scenario 1 is therefore recommended from the ecological and G&S viewpoint.

VOLUME 3: ECONOMIC CONSEQUENCES

INTRODUCTION

Changes in water volume have an effect on the economics of a catchment e.g. change in supply to farmers will affect activity per hectare and therefore affect the Gross Domestic product (GDP) and employment opportunities. Assurance also reflects long-term water availability which influences GDP and employment opportunities, but only for the harvesting cost. This implies that if assurance increases, job opportunities will increase during harvesting. Therefore, water volumes were transformed with the use of the WIM model to determine total GDP, total number of employment opportunities and the distribution towards the low income households in Zone 1. All the scenarios were based upon the Base (Current State).

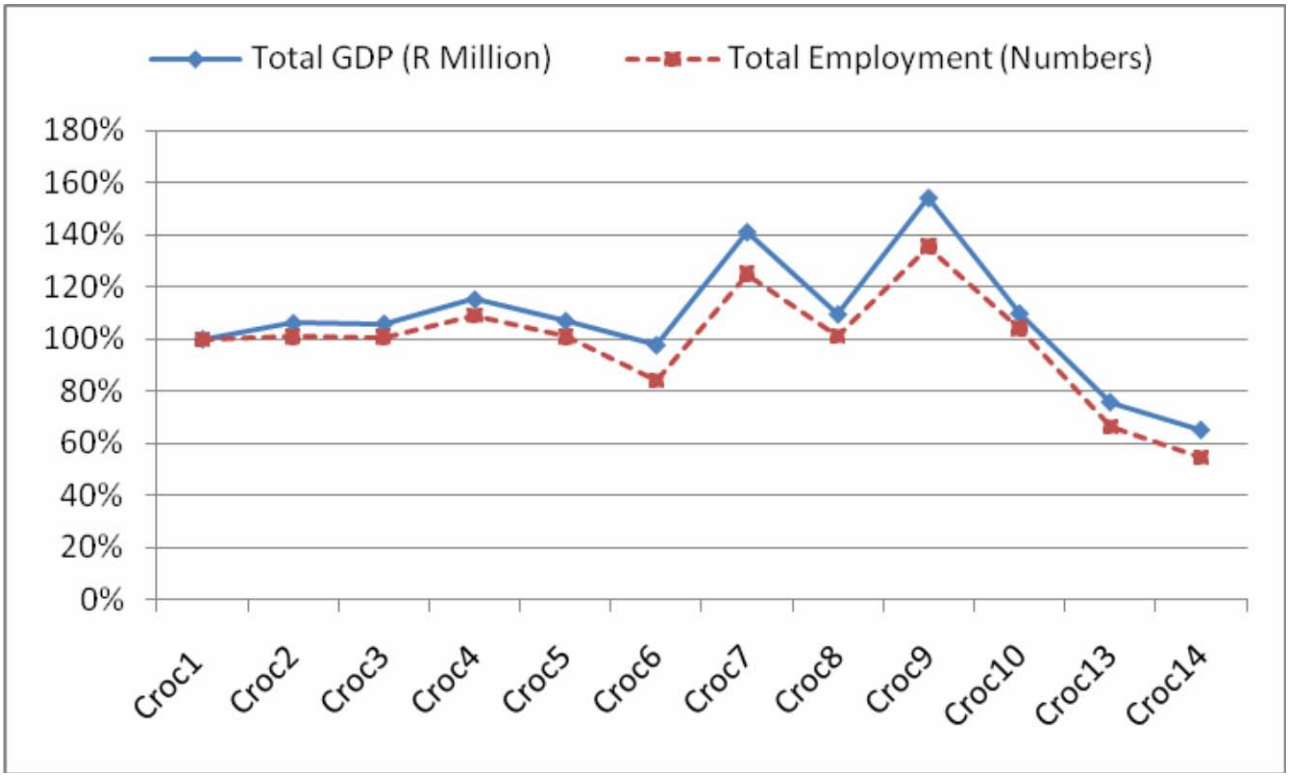
The Sabie scenarios were not further evaluated as all scenarios related to an improved assurance and supply to agriculture.

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.

CROCODILE RIVER CATCHMENT RESULTS

The figure below reflects that Sc C7 and C9 are the best economic impact performers when analysing the scenarios. These economic impacts are expressed in total GDP, total number of employment opportunities as well as the distribution towards Low Income Households. Low income households follow mostly the trend of GDP and are therefore not included in the graph.

When the scenarios involving dams and international flow are excluded, Scenario C4 reflects the best economic performance.

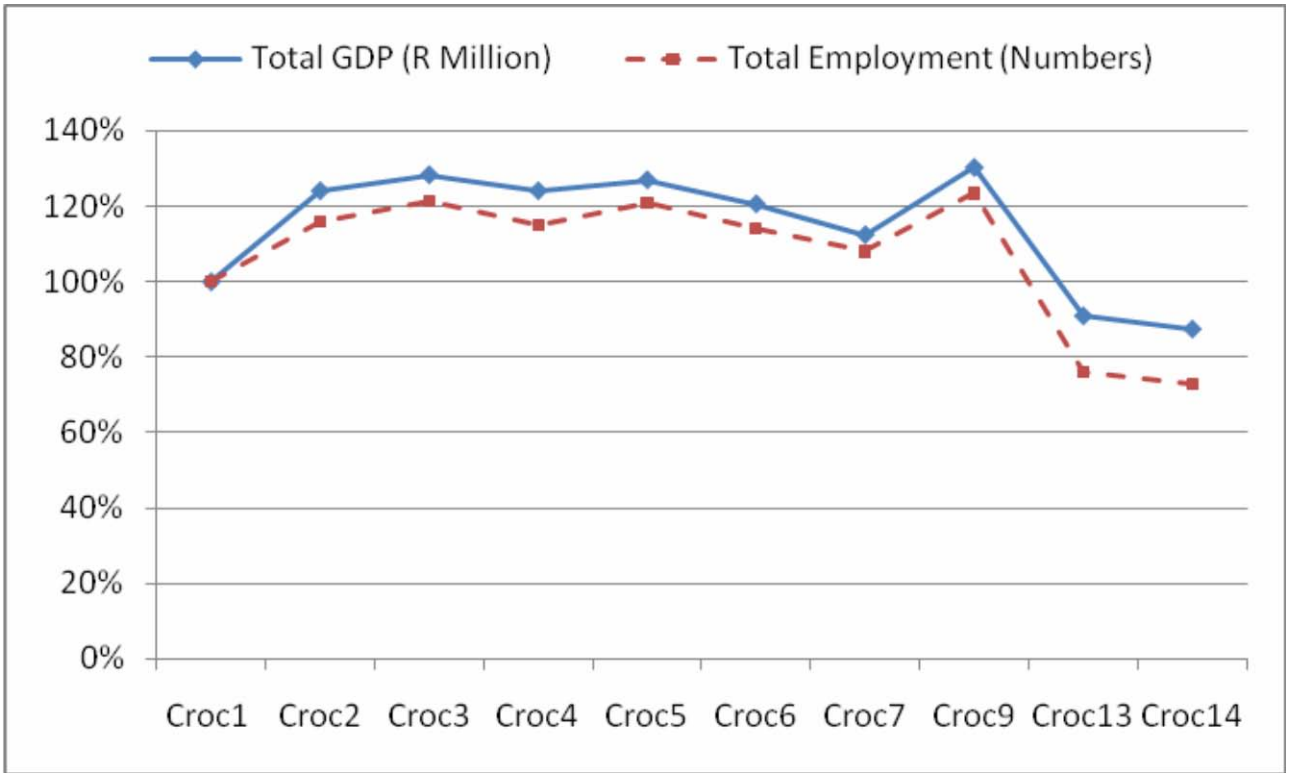


In summary, if the development scenarios (Sc C7 – C9) are excluded from the assessment, Sc C2 to 6 all give a positive deviation compared to Sc 1 (Present Day), with Sc 4 being the best of these scenarios in terms of GDP and total employment. Scenario C9 is the best scenario (most positive GDP impact) and total employment when analysing all the impacts.

It must be noted (refer to Volume 1): The Present Ecological State will be maintained by Sc C1, i.e. the way the system is presently being operated. Scenario C13 (PES), refers to an additional flow scenario which will also maintain the PES and consists of higher flow requirements than present day in certain months. This scenario will include a lower risk of failure of the PES and further degradation of the river to a lower category. The economic consequences associated with this PES EWR scenario must NOT be confused with the consequences of maintaining the river in its present state, as that is being achieved by Sc C1, or the baseline (present operation of the system).

KAAP RIVER CATCHMENT RESULTS

The macro economic impacts of the scenarios on Zone 2 are provided in the figure below. The results reflect that Sc C9 is the best economic impact performer. These economic impacts are expressed in total GDP, total number of employment opportunities as well as the distribution towards Low Income Households. If the development scenarios are excluded, Sc C3 is the most recommended scenario in terms of GDP and employment.



Based on the results all the scenarios have a positive deviation from the GDP, except for Sc C13. Scenario C3 is the best scenario if the development scenarios (Sc C7 – C9) are excluded.

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1 INTRODUCTION

1.1 PURPOSE OF THE REPORT

This report serves to document the results of the specialist meetings held from 22 – 24 June and 9 – 11 June 2009, providing ecological and Goods and Services (G&S) consequences of a range of operational scenarios based on the output from the yield model (discussed in Volume 1 of this report series).

1.2 ASSUMPTIONS AND LIMITATIONS

- The ecological and Goods and Services (G&S) consequences of the range of operational scenarios were only assessed for the riverine EWR sites.
- During preliminary screening of the operational scenarios it became clear that the operational scenarios would have no impact on EWR 1 and 2 in the Crocodile River System and EWR 1, 2 and 4 in the Sabie River system and therefore no assessment of ecological consequences were included.
- The interpretation of the ecological consequences was limited by the available hydrology. No daily hydrology was available and therefore the change in floods under the different scenarios could not be interpreted.

1.3 OUTLINE OF THE REPORT

The consequences of the operational scenarios, RDM Report 26/8/3/10/12/011, consists of a three volume report series which is outlined below:

- Volume one: Description of the Operational Scenarios.
- **Volume two (this report): Ecological and Goods and Services Consequences.**
- Volume three: Macro Economic Consequences.

The report structure of Volume two is provided below.

The consequences of the operational scenarios, RDM Report 26/8/3/10/12/011, consist of a three volume report series which is outlined below:

- **Volume one: (This report) Description of Operational Scenarios.**
- Volume two: Ecological and Goods and Services Consequences.
- Volume three: Macro Economic Consequences.

The report structure of Volume one is provided below.

Chapter 2: Ecological Consequences: Approach
This chapter provides the methods and approach followed for deriving ecological consequences for each Reserve component.

Chapter 3: Goods and Services: Method
This chapter provides the method followed for determining the consequences of the operational scenarios on Goods and Services.

Chapter 4: Preliminary screening of Scenarios
Background and a summary of the operational scenarios assessed at each EWR site are provided.

Chapter 5 - 9: Determination of Ecological consequences: Crocodile River System

This consists of the results of evaluating the effect of the various scenarios on the EC for the following EWR sites:

- EWR 3: Poplar creek (Crocodile river)
- EWR 4: Kanyamazane (Crocodile river)
- EWR 5: Malelane (Crocodile river)
- EWR 6 Nkongoma (Crocodile river)
- EWR 7: Honeybird (Kaap river)

Chapter 10: Conclusions: Crocodile River System

The results of the ecological consequences of the operational scenarios in the Crocodile River system are summarised.

Chapter 11 - 15: Determination of Ecological consequences: Sabie-Sand River System

This consists of the results of evaluating the effect of the various scenarios on the EC for the following EWR sites:

- EWR 3: Kidney (Sabie river)
- EWR 5: Marite (Marite river)
- EWR 6: Mutlumuvi (Mutlumuvi river)
- EWR 7: Thlulandziteka (Thlulandziteka river)
- EWR 8: Lower Sand (Sand river)

Chapter 16: Conclusions: Sabie-Sand River System

The results of the ecological consequences of the operational scenarios in the Sabie-Sand River system are summarised.

Chapter 17: Goods and Services: Consequences of Operational Scenarios

The outcome of the Goods and Services (G&S) evaluation per Economic Zone is provided as well as the consequences for each operational scenario.

Chapter 18: Conclusions and Recommendations: Ecological Consequences

Recommendations are made.

Chapter 19: References

2 ECOLOGICAL CONSEQUENCES: APPROACH

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 riverine EWR site and Management Resource Unit (MRU).

All information used during the EcoClassification step (the suite of EcoClassification models set up for different ECs) (DWA, 2009) and the Ecological Water Requirement (EWR) scenario step (DWA, 2010a,b) is used as baseline for this assessment.

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

- The operational scenarios (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.

Note: As only monthly modelling is available, the assessment of floods will always be of low confidence

- 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.

The following was then undertaken for the instream biota assessment:

- Each time series was converted into a stress duration table and provided on a graph for two months (the same months evaluated during the EWR workshop) that included the EWR scenarios, natural, and present day hydrology (PDH). For further explanation regarding the Habitat flow Stressor Response (HFSR) process and interpretation of the stress graphs, refer to DWA (2010a, b) and below.
- The requirements set for the low flow EWR scenarios for both fish and macroinvertebrates were copied onto these graphs.
- The operational scenarios were then compared to the EWRs set for various ECs. For example, if the operational scenario lied between the B EC and C EC for fish for a maintenance flow in the dry season, the operational scenario could either be a B, a B/C or a C.
- The information on the driver responses were also used to interpret the response to the operational scenarios.
- If it was not obvious what the resulting EC was, the stress and habitat implications for the operational scenario were investigated and the responses modelled in the Fish Response Assessment Index (FRAI) and Macro invertebrate response Assessment Index (MIRAI) to determine the EC.

The following was then undertaken to predict the resulting EcoStatus for each operational scenario:

- The VEGRAI, MIRAI and FRAI results (EC percentages and confidence evaluation) was provided for EcoStatus modelling.

The more detailed assessments for each component and guideline for interpretation of the stress graphs is provided below.

2.1 PHYSICO-CHEMICAL COMPONENT

The water quality specialist used the following information to assess water quality changes and consequences to operational scenarios:

- PAI and water quality information tables produced during the EcoClassification process (DWA, 2009).
- Information describing the present state for water quality at each site, including issues driving water quality.
- Flow-duration tables and graphs for natural, present day and each operational scenario.
- Flow time-series for natural, present day and each operational scenario. The flow information presented for the present state is therefore linked to the Present Ecological State (PES) for water quality, as defined during the EcoClassification process (DWA, 2009).
- Water quality modelling, if available: Modelling information provided concentration-time series for selected variables, and changes in flow that could be linked to changes in concentrations. This information is normally only available for variables that have a conservation relationship with flow, e.g. salts and other ions. However, metals are not generally analyzed as part of the DWA monitoring programme and Intermediate Reserve Methodology does not make provision for the initiation of monitoring.

The PAI model for the Present Ecological State (PES) was adjusted according to physico-chemical changes expected under each scenario. A description of these changes was provided to the instream biota specialists and additional changes were made in consultation with the project team. Final adjustments to the model were highlighted, and notes included. All PAI models and water quality tables are available electronically (DWA, 2010c). The ecological consequences of each scenario were documented (this report).

2.2 GEOMORPHOLOGY

- Monthly volumes and flow duration curves were used during the assessment.
- A qualitative description of the changes in geomorphology and riparian vegetation of each operational scenario per site was provided to the instream biota specialists.
- Floods: Total volumes of the EWR floods in each month were compared to the total volumes available under each scenario. Where possible guidance by the systems modeller was provided on whether the changes were likely to be in terms of small, moderate or large floods. The lack of daily hydrology hindered the interpretation of the consequences of changed floods under the different scenarios.
- The GAI/VEGRAI for the PES or Alternative Ecological Category (AEC) (whichever most appropriate) was adjusted and these adjustments to the different metrics were highlighted in the model and are available electronically.

2.3 RIPARIAN VEGETATION

- Flow duration curves of each scenario were compared to natural and present day flows to determine qualitative changes in seasonality, maintenance and drought dry and wet season flows, and high flows or floods (usually smaller floods). Before a quantitative analysis was done, a general description of change (based on the above comparisons) was noted.
- Using hydraulic profiles (look-up tables of the discharge:stage relationship, provided electronically (DWA, 2010c) with surveyed vegetation points on the profile (these were upper and lower limits of distribution for each species or guild), the levels of inundation, at both the upper and lower limits, of each species or guild was quantitatively defined for present day and natural (modelled) drought and maintenance flows, for both wet and dry seasons (which usually coincide with the summer growth period and the winter dormancy respectively, but depends on the type of system and the geographic location). The same was then done for each scenario and the results displayed in a comparison table.
- The above qualitative description of the changes in riparian vegetation (species or guilds), together with actual average changes in inundation levels for present day and each operational scenario per site was provided to the instream biota specialists to indicate changes in availability and quality of different instream habitats that were are provided by riparian vegetation.
- It is important to bear in mind that when the drought and maintenance flows are the foci for quantitative comparisons, an unrealistic result may occur since the remainder of the year is just as important, as are certain aspects of the flow regime e.g. changes in duration of zero flows, or prolonged reduction in summer (wet season) maintenance flows, or prolonged increases in winter (dry season) base flows, to name a few. These aspects were taken into account when during the description of the likely changes to riparian vegetation structure and distribution.
- Floods: Total volumes of the EWR floods in each month were compared to the total volumes available under each scenario. It was assumed that if seasonality had not changed, the flood occurrence in time would be in the usual wet season for that system. Where possible guidance by the systems modeller was provided on whether the changes were likely to be in terms of small, moderate or large floods. Flow duration curve comparisons were also used (as indicated above) to qualitatively assess changes (can be done for each month of the year). If changes to floods were likely to result in changes to riparian vegetation metrics, then this was also incorporated into the VEGRAI (see next point below).
- The VEGRAI for the PES or AEC (whichever most appropriate) was then adjusted based on the data and descriptions from the above comparisons. A VEGRAI was compiled for each scenario. Adjustments were made to applicable metrics in applicable zones (before and after values were recorded) with motivations for each adjustment. Confidence levels in metric assessment were also changed if applicable. These changes were highlighted in the model and are available electronically (DWA, 2010c). The new Ecological Category was recorded for each scenario and the ecological consequences were documented (this report).

2.4 INSTREAM BIOTA

The two months assessed during the EWR specialist meeting represented the lowest (September) and highest (February) monthly volumes. During the assessment of operational scenarios, additional months might also require assessment as the initial design of the operational scenarios

could result in other months being the higher or lowest flowing months. These months were then also assessed. .

2.4.1 Macroinvertebrates

- The descriptions of stress indices and recommendations for EWR generated during step 4 (determining Ecological Water Requirements) was used to evaluate the operational scenarios.
- The driver changes in physico-chemical variables, geomorphology and riparian vegetation (low flows and floods) were considered.
- The operational scenarios were assessed in terms of stress and the change from the required stress.
- With the information already described for each stress level, it was determined whether the changes in habitat stress would impact on species stress and whether these changes would sufficiently change specific metrics or the frequency of occurrence of taxa used in the MIRAI that would result in a category change.
- The MIRAI for the PES or AEC (whichever most appropriate) used during the EcoClassification determination, was adjusted and these adjustments to the different metrics were highlighted in the model.
- The resulting change in EC was described qualitatively (and provided in this report), and the models are provided as electronic data (DWA, 2010c).

2.4.2 Fish

- During the EWR determination, the Fish Flow Habitat Assessment (FFHA) model was used to determine the fish HFSR requirement.
- The same model was now used to assess the operational scenarios.
- The flow duration table for each operational scenario and at each EWR site was copied into the model.
- The model uses the determined stress index and provides an indication of the changes in the indicator fish species/guild in habitat and stress.
- The driver changes in physico-chemical variables, geomorphology and riparian vegetation (low flows and floods) were considered.
- All this information was then used to determine whether the changes in habitat stress would impact on species stress and whether these changes would sufficiently change specific metrics or the frequency of occurrence of fish species used in the FRAI that would result in a category change.
- The FRAI for the PES or AEC (whichever most appropriate) used during the EcoClassification determination, was adjusted and these adjustments to the different metrics were highlighted in the model.
- The resulting change in EC was described qualitatively (and provided in this report), and the models are provided in as electronic data (DWA, 2010c).

2.5 INTERPRETATION OF STRESS DURATION GRAPHS

Figure 2.1 is an example of a stress duration graph representing a typical scenario evaluation and illustrates the stress requirements and stress points required for different ECs set during the EWR scenario step. For further information of the Habitat Flow Stressor Response (HFSR) method see HFSR manual (IWRS2S, 2004) and DWA (2010a, b) of this study. The graph should be interpreted as follows:

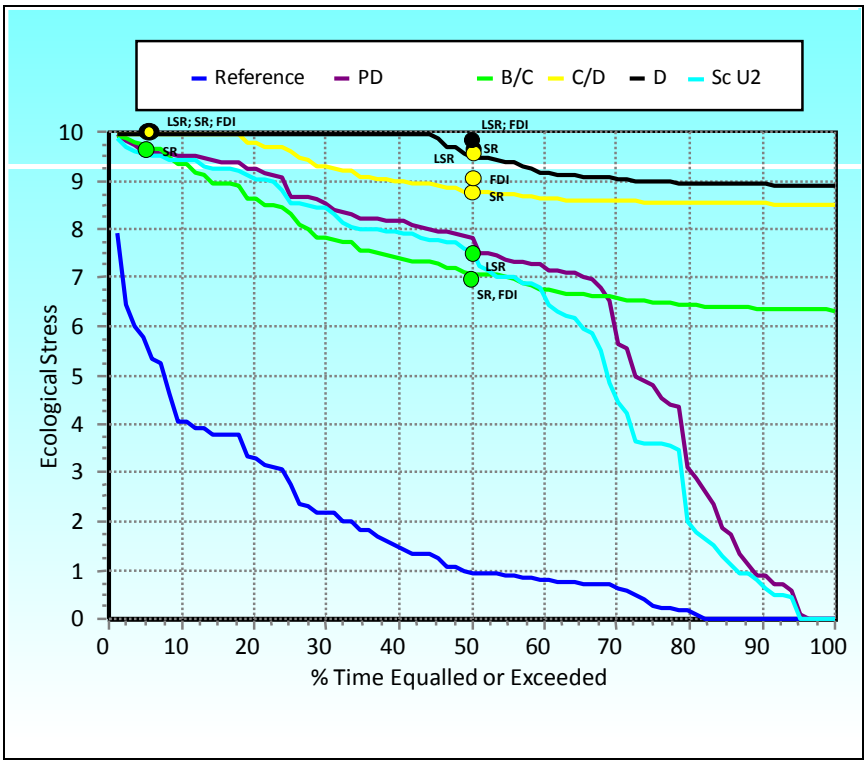


Figure 2–1 Example of a stress duration graph

Figure 2.1 illustrates the hypothetical stress requirements and stress points required for a C/D PES (yellow line), B/C REC (green line) and a D AEC (black line). The purple line illustrates Present Day flows while the blue line represents reference flows. The different coloured circles indicate the requirements of the instream biota as determined during the EWR scenario step (DWA, 2010a, b). Each circle is labeled as follows and indicates a different biotic component:
SR – Small rheophilic fish guild.
LSR – Large semi-rheophilic fish guild.
FDI – Flow dependent macroinvertebrates and/or MVI – marginal vegetation macroinvertebrates

The component with the lowest stress requirement (highest flow) will guide the shape of the line and the final stress requirement. Note that zero on the y axis (Ecological stress) refers to zero stress (optimum habitat conditions) and 10 refer to critical stress associated with zero flows.

The operational scenario, represented by the light blue line (Sc U2), is converted to stress and then included in the above graph for comparison with the stress requirements of different ECs.

The stress associated with Sc U2 lies closest to the B/C requirements for all the instream components. Specialists have to predict whether the scenario, which represents increased stress from the B/C requirement (10% to 58% on the x axis), still lies within the B/C range or whether it represents a lower category (i.e. a C or C/D).

The process, as described in Section 2.4 is followed to determine the EC and then the EcoStatus associated with each scenario is determined.

2.6 COMPARISONS OF THE IMPACT OF THE DIFFERENT SCENARIOS

A table is provided which compares the impact of each scenario per site against the PES and Recommended Ecological Category (REC). The resulting EC for each component is provided as well as the EcoStatus. An example is provided in Table 2.1.

Table 2.1 EWR 1: Predicted ECs for each operational scenario

Driver Components	PES	REC	Sc 7	Sc 10	Sc 12
WATER QUALITY	C	B/C	C	C	C
GEOMORPHOLOGY	C	C	C/D	C	C
Response Components	**PES**	**REC**	**Sc 7**	**Sc 10**	**Sc 12**
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

The above table is then summarised according to whether the scenarios meet the REC or not, and if not, to what degree. The coding below is used and an example is provided in Table 2.2. This coding is alos provided as an A3 fold out page at the end of the document. One can therefore open the page and use it to interpret the results.

✓ 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[1]).
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.

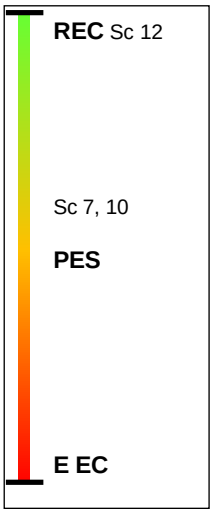
[1] Refer to DWA (2009) for more information on non-flow related impacts.

Table 2.2 An example of the operational scenario consequences summary for an EWR site

EWR SITE	SC 7	SC 10	SC 12
EWR 3	X	X	✓

The above example illustrates that Sc 12 meets the REC, for all components. Scenario 7 and Sc 10 is an improvement of the PES but does not meet the REC requirement.

The results of Table 2.2 are then illustrated on a scale from good (REC) to 'bad' (an E EC). In this case the REC is an improvement of the PES and the PES is therefore placed in the middle of the scale (Figure 2.2). The scale indicates the degree of improvement the scenarios are from the PES. This is for illustration purposes and comparing all the scenarios at each site in a system context. As the scale can be subjective, a typical explanation as provided below should accompany the figure.



Scenario 12 meets the REC requirement. Scenario 7 and 10 is an improvement of the PES but does not meet the REC requirement. Three components have improved by half a category and the EcoStatus has improved within the current EC.

Figure 2–2 Illustration of the degree to which a REC is met

2.7 ELECTRONIC DATA SUPPLEMENTING THIS REPORT

The adjusted component assessment models for the respective scenarios of each site are provided electronically as well as the adjusted EcoStatus models (DWA, 2010c). This will include the Present Day, Natural, EWR and Operational scenario flow duration curves that were used in this study.

3 GOODS AND SERVICES: METHOD

3.1 ANALYSIS OF THE CATCHMENT

According to 2001 population figures for the Croc East, Sabie and 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.

From the prior research undertaken during the baseline study (DWA, 2010d) key G&S were estimated (as per Table 3.3). Table 3.1 sets out the likely importance of utilisation by quaternary. These were then verified with the relevant specialists who had been involved in the ecological dimensions of the Komati, Crocodile (East) and Sabie-Sand River catchment systems. Where relevant, impacts associated with scenarios at the defined economic zones were estimated.

Table 3.1 Resource dependence of G&S by quaternary catchment

Quat	Number of People Dependant	Significance of G&S	Source, level and comments
X21A	0	0	Commercial forestry and mixed low density, site visit
X21B	0	0	Commercial forestry and mixed low density, site visit
X21C	0	0	Commercial forestry and mixed low density, site visit
X21D	0	0	Commercial forestry and mixed low density, site visit
X21E	0	0	Commercial forestry and mixed low density, site visit
X21F	2	1	Machadadorp, low density commercial farm, site visit
X21G	0	0	Emgwenya, forestry, low density mixed farm
X21H	0	0	Forestry, low density commercial
X21J	0	0	Tulluch Moor NR Forestry, mixed agriculture, mill
X21K	0	0	Forestry, Ngodwana Starvation Creek NR
X22A	0	0	Makoboulaan NR, forestry
X22B	0	0	Forestry, mixed commercial irrigation
X22C	0	0	Forestry, mixed agriculture - HL Hall, Residential - Nelspruit
X22D	0	0	Site visit: All forestry
X22E	0	0	Forestry
X22F	1	1	Forestry, mixed farming, residential- Rock Drift
X22G	0	0	Site visit, all forestry
X22H	0	0	Forestry Witrivier, mixed farming
X22J	3	2	Nelspruit- farming
X22K	3	2	Dense Settlement, KaNyamazane, mixed farming
X23A	0	0	Forestry
X23B	0	0	Forestry, mixed farm, some sugar cane
X23C	0	0	Forestry
X23D	0	0	Forestry, mixed farming
X23E	0	0	Forestry
X23F	1	1	Barberton, some forestry, mixed farming
X23G	0	0	Mixed farming, Sheba mine
X23H	2	2	Kaapmuiden, residential, mixed farming
X24A	4	4	Kruger 50%, subsistence and Settlement 50%
X24B	4	4	Kruger 25%, subsistence and settlement 75%

Quat	Number of People Dependant	Significance of G&S	Source, level and comments
X24C	5	3	Kruger 25%, subsistence and settlement 75% - KaNyamazane
X24D	0	0	Kruger 33%, sugar cane commercial 75%
X24E	0	0	Kruger 75%, sugar cane commercial 25% TSB
X24F	0	0	Kruger 33%, sugar cane commercial 75%
X24G	0	0	KNP 100%
X24H	0	0	Kruger 75%, sugar cane commercial 25%
X31A	2	1	Forestry, town of Sabie
X31B	0	0	Forestry
X31C	0	0	Forestry
X31D	0	0	Small holdings, tourism, mixed farming irrigation, forestry
X31E	2	4	Forestry and lower reaches subsistence and settlement
X31F	0	0	Forestry
X31G	2	4	Forestry and lower reaches subsistence and settlement
X31H	0	0	Forestry
X31J	2	4	Forestry and lower reaches subsistence and settlement
X31K	4	4	KNP 50%, settlement 50%
X31L	4	4	Closer rural settlement and subsistence
X31M	2	4	KNP 75%, settlement 25%
X32A	2	4	Upper forestry then dense rural settlement and subsistence
X32B	4	4	Upper forestry then dense rural settlement and subsistence
X32C	4	4	Dense rural settlement and subsistence
X32D	3	4	Upper forestry then dense rural settlement and subsistence
X32E	3	4	Upper forestry then dense rural settlement and subsistence
X32F	4	4	Dense rural settlement and subsistence
X32G	4	4	Dense rural settlement and subsistence some KNP
X32H	4	4	KNP 50%, settlement 50% Hluvukani Thulani
X32J	0	0	Mala Mala KNP 100%
X33A	0	0	KNP 100%
X33B	0	0	KNP 100%
X33C	0	0	KNP 100%
X33D	0	0	KNP 100%
X40A	0	0	KNP 100%
X40B	0	0	KNP 100%
X40C	2	4	KNP 75%, settlement 25% Welverdiend
X40D	0	0	KNP 100%

3.2 ECONOMIC ZONES AND SCENARIOS

For analytical purposes, the Crocodile East sub-catchment was further divided into seven economic zones (EZ) and the Sabie-Sands area was sub-divided into three economic zones (refer to DWA, 2010d) for more detail.

The operational scenarios are described in detail in Volume 1 of this report series and summarised in Section 4 of this report.

The combination of economic zones with scenarios had a potential myriad of impact combinations. However some scenarios generated impacts on the goods and services that were similar enough to be grouped together. Further the range of scenarios considered covered only portions of the economic zones. A summary of scenarios considered by economic zone is set out in Table 3.2 below.

Table 3.2 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

3.3 METHODS

The methods followed were according to DWAF (2004) and is essentially scenario based. 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 may have been 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 Komati, Crocodile (East) and Sabie–Sand River catchment systems.
- The biophysical specialists then identified the potential change that each of the key G&S may undergo in each of the scenario clusters. 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.
- 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 (Chapter 4) 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 3.1.

Table 3.3 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		

4 PRELIMINARY SCREENING OF SCENARIOS

Detailed information regarding operational scenarios is documented in Volume 1 (Description of operational scenarios) of this report series. For the purposes of this report the operational scenarios are summarized.

4.1 CROCODILE RIVER SYSTEM

It was determined that scenarios C3 – C4 and C6 – C12 would impact on the Crocodile System at EWR 3 - 7 to varying degrees. Table 4.1 provides a summarised description of the scenario, as well as reason for evaluating the specific scenario at the respective EWR sites.

Table 4.1 Summarised description of scenarios and reasoning for analysis at EWR sites

Scenario	Description	Reasoning	Impacted site/s
Sc C3, C4, C6	***A combination of operating rules, restrictions, and/or curtailments applied.***		
	The scenarios related mainly to the option of either introducing curtailments to water users (by means of compulsory licensing) or implementing harsher restrictions in the Crocodile River.		EWR 5 EWR 6
Sc C7	***New dam at Montrose***		
	In this scenario it is assumed that a new dam will be constructed at the Montrose site which is located just downstream of the confluence of the Crocodile and Elands Rivers. The Montrose Dam will replace the Kwena Dam as being the main regulator of flow in the Crocodile River. Kwena Dam will supplement the Montrose Dam by making releases when the storage in Montrose Dam drops to below 10% of its full supply capacity. The water abstracted from the Montrose Dam (i.e. yield) is supplied directly from the dam and not released into the Crocodile River to supplement downstream users. EWR 3 was also included in the assessment to determine the impacts upstream of Montrose Dam as this site would only receive water from Kwena Dam when releases are made to supplement Montrose Dam.		EWR 3 - 6
Sc C8	***New dam at Mountain View***		
	It was assumed when modelling this scenario that a new dam is to be constructed at the Mountain View site which is located a few kilometres upstream of the confluence of the Kaap and Crocodile Rivers. The water abstracted from the Mountain View Dam (i.e. yield) is supplied directly from the dam and not released into the Crocodile River to supplement downstream users. No restriction is imposed on the yield i.e. it is the historic firm yield of the dam.		EWR 5 - 7
Sc C9	***New dams at Montrose and Mountain View***		
	Combination of the above two dams. The same rules applied.		EWR 3 - 7
Sc C10, C12	***Reduced releases from Kwena Dam to meet the 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. This scenario implies decreased releases from Kwena Dam in the dry season and increased releases in the wet season to meet requirements of EWR 3. Sc C10 aims to meet the PES scenario and Sc C12 the REC. This will impact on all the downstream sites and therefore EWR 4 – 6 were evaluated to test and determine the implications of this scenario at these sites.		EWR 3 - 6
Sc C11	**No cross-border flows**		
	This scenario represents the current day operation of demand/releases but excludes the minimum flows for cross-border flows. This scenario will mostly affect sites downstream of EWR 4, i.e. within the major sugar cane irrigation area. Only EWR 5 and 6 were evaluated.		EWR 5 EWR 6

Preliminary screening of scenarios consisted of visually comparing the stress duration graphs for each scenario (Sc) as well as the flow duration graphs. If two scenarios were very similar, it was assumed that the consequences would be the same or, the resolution of knowledge on biophysical responses would be such, that a distinction could not be made. This assessment was undertaken

by the EWR co-ordinator prior to the assessment and was, where necessary confirmed by the specialists during the specialist meeting. The results of the preliminary screening of scenarios are provided in Table 4.2. 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 4.2 Scenarios evaluated at EWR 3 – EWR5 in the Crocodile River 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			

4.2 SABIE RIVER SYSTEM

4.2.1 Description of Operational Scenarios (Sc 1, 5 – 8): Increased irrigation, i.e. increased releases from Inyaka Dam

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 (MCM/a). In addition, varying levels of water restriction were imposed on users. 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.

4.3 SAND RIVER SYSTEM

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.

5 EWR 3: POPLAR CREEK (CROCODILE RIVER) - ECOLOGICAL CONSEQUENCES

Scenarios C7, C9, C10 and C12 were evaluated and are discussed in Section 5.1 to 5.3.

5.1 IMPACT OF SCENARIO C7 AND C9

Scenario C7 includes Montrose Dam in the Crocodile River, downstream of the Elands confluence. An evaluation of this scenario was included to illustrate the affects upstream of Montrose Dam as Kwena Dam will only release water to top up Montrose Dam when there are insufficient flows. The only flows EWR 3 will receive are therefore these top up flows and any incremental flows from tributaries downstream of Kwena Dam. Scenario C9 is a combination of the Montrose Dam in the Crocodile River and the Mountain View Dam few kilometres upstream of the confluence of the Kaap and Crocodile Rivers. The stress and flow duration graphs indicated that Sc C7 and C9 were sufficiently similar to be addressed as one.

Figure 5-1 illustrates the stress requirements and stress points required for a B/C PES (green line) and B REC (purple line). The red line illustrates Present Day flows (at times lying under the green line – wet season) while the blue line represents reference flows. Flows are currently higher than natural in the dry season due to releases from Kwena Dam. Compared to PD, both Sc C7 and C9 result in higher stress during dry season especially during drought periods due to lower flows. During wet season stress decreases compared to PD conditions due to improved wet season base flows. The scenarios however result in the removal of small and medium floods.

DRY SEASON **WET SEASON**

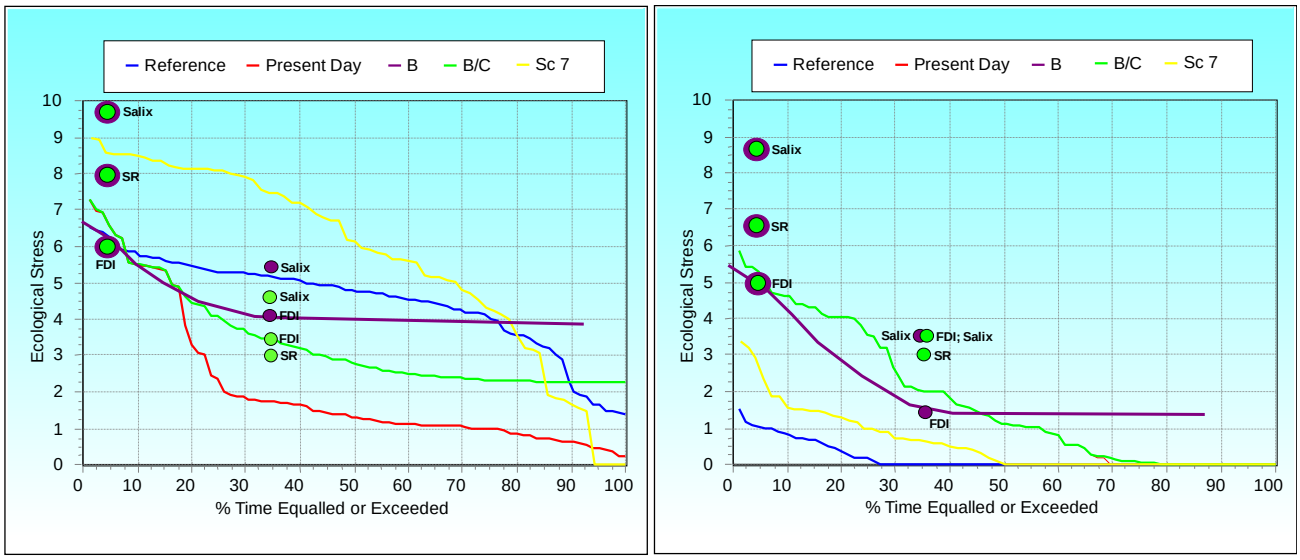


Figure 5–1 Stress duration for EWR 3: Dry and Wet season, Sc C7

5.2 ECOLOGICAL CONSEQUENCES: SCENARIO C7

5.2.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc C7	
PHYSICO-CHEMICAL				
C	B/C	C/D	C	Substantially lower flows in the dry season and improved wet season flows as compared to PD will change temperature, oxygen, toxic and nutrient levels in the dry season. Overall conditions remain within a C category, despite a change during the dry season (74.73% to 65.27%).
GEOMORPHOLOGY				
C	C	C	C/D	The decreased dry season base flows will reduce low flow season scour, bank cutting and turbidity, all of which have been artificially increased due to elevated flows. This will enable a move towards the reference condition. Wet season base flows are increased, but small and moderate floods are essentially removed. This will reduce habitat diversity though infilling of channel with sands, leading to a loss of gravel and bedrock habitats. Slight reduction in PES. Although most floods are removed, all sediment is trapped in Kwena Dam and therefore fewer floods slow the rate of incision of the bed and banks of the reach.

5.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc C7	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B/C	Indicator species: *Salix mucronata*. Inundation of lowest limit in the marginal zone changes from 20 – 30 cm under PD flows (maintenance) to 12 – 17 cm. These reduced winter flows will provide establishment opportunities for *S. mucronata* and will promote a healthier population structure. More naturalised flows will also promote non-woody colonisation which may promote bank restabilisation.	Inundation of lowest limit in the marginal zone changes from 17 – 25 cm (less than dry season) under PD flows (maintenance) to 20 - 30 cm. A more naturalised flow regime, will promote *S. mucronata* establishment on the lower zone which may become important for reducing bank erosion which is taking place.
Exotic invasion and selected vegetation removal are also overriding impacts at this site (non-flow related impacts), neither of which will improve from improved flow and therefore the REC is not achieved.					
FISH					
B	B	C	A/B	Maintenance flows are lower than PD flows and equal or slightly higher than natural flows for dry season months (May to Oct). In general the fish stress is much lower than those set to maintain the PES/REC, which should therefore support even better habitat conditions and therefore improved biotic integrity based on fish (SR can be expected to fall in a category A)*.	Flows are higher than PD for wet season months Nov to Apr. Habitat suitability for SR guilds will improve from the PES of D to an A/B.
An improvement in the overall conditions for fish will result in an A/B EC. The fish assemblage is presently in a relatively good condition (category B) and is expected to respond further positively to the improved seasonality. The primary impacts on the fish assemblage will be associated with non-flow impacts (introduced fish species and migration barriers).					
MACROINVERTEBRATES					
C	B	C/D	C	Seasonality is improved; the water quality and substrate remain similar to PD. Less marginal vegetation habitat available in the dry season leading to a decrease in the abundance and frequency of occurrence (FROC) in the vegetation dwelling taxa. Some taxa preferring slower flows and living on the water surface are likely to be regained. The MIRAI score remains in a C category but changes from 74.5% to 76.9%.	
ECOSTATUS					
B/C	C	C/D	B/C	The improvement of the fish component leads to an improvement in the instream condition. Although the geomorphology has slightly deteriorated, the improvement in vegetation results in a B/C EcoStatus which is better than the PES.	

* The Fish Flow habitat Assessment (FFHA) graph seems to indicate increased stress, because of scenario flows moving closer to natural and PD flows are higher than natural as a result of Kwena Dam releases).

5.3 IMPACT OF SCENARIO C10

Scenario C10 represents decreased releases from Kwena Dam to meet the PES ecological requirements at EWR 3 in the dry season and increased releases to meet these requirements in

the wet season. This will impact on all the downstream sites. Scenario C10 is represented by the black line in Figure 5-2 and is very similar to the B/C (PES) requirements in the dry season. Compared to PD flows, conditions under Sc C10 are similar during dry season drought, however stress is increased during maintenance conditions. Note that the PD wet season curve is lying below the B/C curve.

DRY SEASON **WET SEASON**

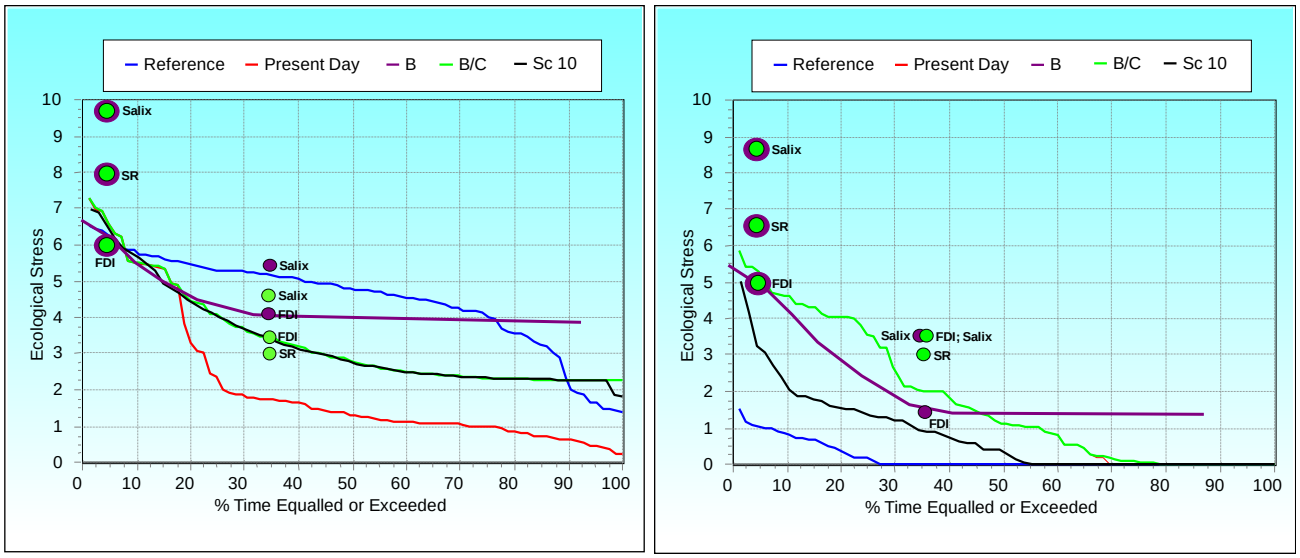


Figure 5–2 Stress duration for EWR 3: Dry and Wet season, Sc 10

5.4 ECOLOGICAL CONSEQUENCES: SCENARIO 10

5.4.1 Driver components

EC				COMMENT
PES	REC	AEC↘	Sc C10	
PHYSICO-CHEMICAL				
C	B/C	C/D	C	Lower flows in the dry season compared to PD will change temperature, oxygen, toxic and nutrient levels. However, note that compared to natural, PD flows are higher than natural. Higher flows in the wet season will change present conditions (temperature, oxygen, turbidity, toxics) to a B category in wet season. Overall conditions remain within a C category, although conditions improve from present during the wet season (74.73% to 84.91%) and deteriorate slightly during the dry season (74.73% to 65.27%).
GEOMORPHOLOGY				
C	C	C	C	The decreased dry season base flows will reduce low flow season scour, bank cutting and turbidity, all of which have been artificially increased due to elevated flows. This will enable a move towards the reference condition. Increased wet season base flows and small floods will increase wet season scour of the bed. Since sediment is trapped in the upstream dam, scour will cause widening and deepening of the channel and armouring of the bed. More natural flow patterns will be restored to the site, but due to the sediment trapping impacts of the Kwena Dam, restoration of the flows will not achieve much improvement of the geomorphology. This is because the clean water releases from the dam will continue to scour the bed and banks of the reach. Dry season turbidity should decrease and marginal zones may partially stabilise, creating in-channel conditions more similar to reference.

5.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↘	Sc C10	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B/C	Indicator species: *S. mucronata*. Inundation of lowest limit in the marginal zone changes from 20 – 30 cm under PD flows (maintenance) to 18 - 20 cm. These reduced winter flows will have a similar effect to Sc 7, but the reduction in flows is less (closer to PD but more different to natural).	Inundation of lowest limit in the marginal zone changes from 17 – 25 cm (less than dry season) under PD flows (maintenance) to 20 - 30 cm. A more naturalised flow regime, will promote *S. mucronata* establishment on the lower zone which may become important for reducing bank erosion which is taking place. Exotic invasion and selected vegetation removal are also overriding impacts at this site, neither of which will improve from improved flow. Improved flooding will promote riparian woody species, but unfortunately this applies to woody exotics growing at the site (*Gleditsia* spp. mainly).
FISH					
B	B	C	A/B	The same as for Sc C7 but with slightly more stress in the dry season due to reduced flows. FRAI: A/B EC (91%).	
MACROINVERTEBRATES					
C	B	C/D	C	The dry season flows are similar to those requested for the invertebrates to be in a C category, while the wet season flows are slightly better than those requested for invertebrates to remain in a C category. The slightly improved wet season is likely to result in an improvement in the macroinvertebrates living in the marginal vegetation. The macroinvertebrates will remain in a C category but change from 74.5 % to 76%.	
ECOSTATUS					
B/C	C	C/D	B/C	The improvement in fish and macroinvertebrates leads to an improved of the instream state (B) and the EcoStatus is a slight improvement of the PES within the B/C EC.	

5.5 IMPACT OF SCENARIO C12

Figure 5-3 illustrates Sc C12 (yellow line) and represents decreased releases from Kwena Dam to meet the ecological requirements of the REC at EWR 3 in the dry season and increased releases to meet these requirements in the wet season and is very similar to Sc C10, but with further improved (more) dry season flows. This will impact on all the downstream sites. As with Sc C10 conditions are similar to PD during drought with increased stress during maintenance periods while there is an increase in small floods during the wet season. Note that the PD wet season curve is lying below the B/C curve.

DRY SEASON **WET SEASON**

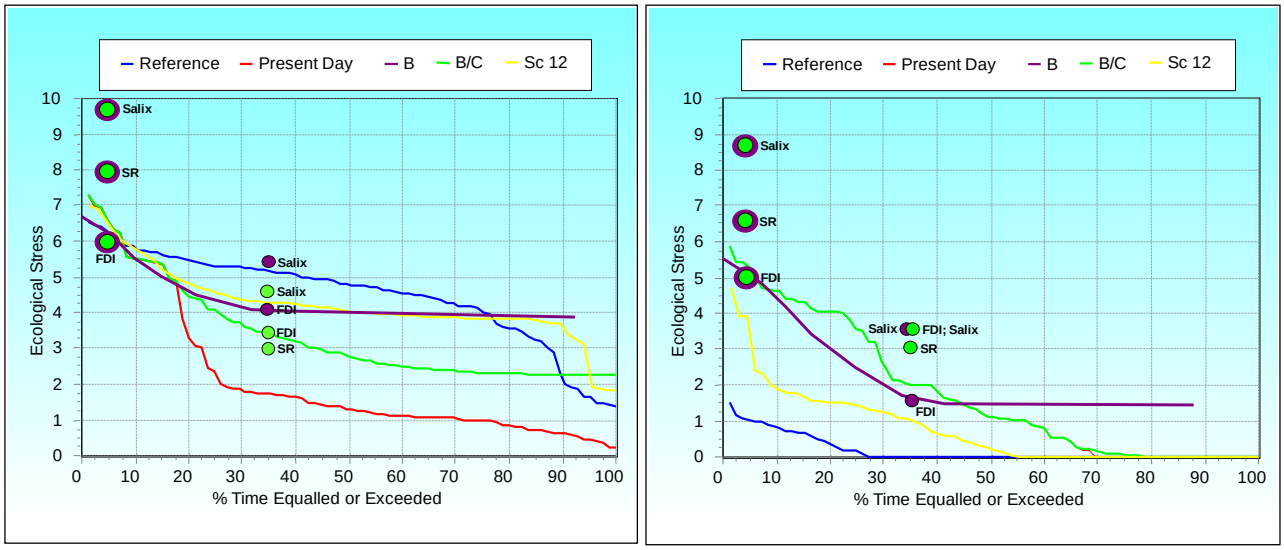


Figure 5–3 Stress duration for EWR 3: Dry and Wet season, Sc C12

5.6 ECOLOGICAL CONSEQUENCES: SCENARIO C12

5.6.1 Driver components

EC				COMMENT
PES	REC	AEC↘	Sc C12	
PHYSICO-CHEMICAL				
C	B/C	C/D	C	Substantially lower flows in the dry season as compared to PD will change temperature, oxygen, toxic and nutrient levels. Note that the seasonal distribution will be more natural though. Higher flows in the wet season will change present conditions (temperature, oxygen, turbidity, toxics) to a B category. Overall conditions remain within a C category, although conditions improve from the PES during the wet season (74.73% to 84.91%) and deteriorate slightly during the dry season (74.73% to 65.27%).
GEOMORPHOLOGY				
C	C	C	C	The decreased dry season base flows will reduce low flow season scour, bank cutting and turbidity; all of which have been artificially increased due to elevated flows. This will enable a move towards the reference condition. Increased wet season base flows and small floods will increase wet season scour of the bed. Since sediment is trapped in the upstream dam, scour will cause widening and deepening of the channel and armouring of the bed. These scenarios restore more natural flow patterns to the site, but due to the sediment trapping impacts of the upstream dam, restoration of the flows will not achieve much improvement of the geomorphology. This is because the clean-water releases from the dam will continue to scour the bed and banks of the reach. Dry season turbidity should decrease and marginal zones may partially stabilise, creating in-channel conditions more similar to reference.

5.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↘	Sc C12	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B/C	Similar to Sc C7: with inundation of lowest limit in the marginal zone changing from 20 – 30 cm under PD flows (maintenance) to 15 – 18 cm for *S. mucronata*. These reduced winter flows will provide establishment opportunities for *S. mucronata* and will promote a healthier population structure. More naturalised flows will also promote non-woody colonisation which may promote bank restabilisation.	Similar to Sc C10 but with slightly more inundation of 25 – 35 cm.
FISH					
B	B	C	A/B	The same as Sc C7 but with slightly more stress in the dry season due to reduced flows. FRAI: A/B EC (91%).	
MACROINVERTEBRATES					
C	B	C/D	B	This scenario is similar to the flows required for the macroinvertebrates to improve to a B category. No MIRAI was run for this scenario. The MIRAI % for this category remains 84.1% as determined for the REC.	
ECOSTATUS					
B/C	B	C/D	B	The improvement of all the response components along with water quality results in this scenario achieving the REC requirements of a B.	

5.7 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 3 are provided in Table 5.1.

Table 5.1 Ecological consequences of operational flow scenarios at EWR 3

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. The degree to which each scenario at EWR 3 meets the REC is summarised in Figure 5-4 below.

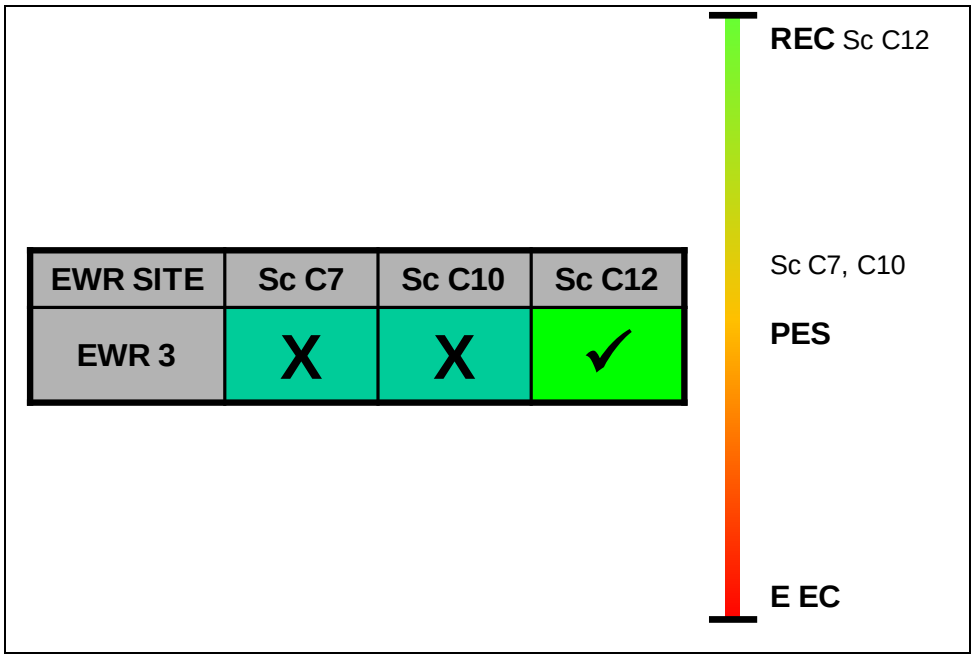


Figure 5–4 Summary of the impacts of operational flow scenarios at EWR 3

6 EWR 4: KANYAMAZANE (CROCODILE RIVER) - ECOLOGICAL CONSEQUENCES

Scenarios C7, C9, C10, C11 and C12 were evaluated and are discussed in Section 6.1 to 6.3.

6.1 IMPACT OF SCENARIO C7 AND C9

The stress and flow duration graphs indicated that Sc C7 and C9 were similar in the dry season. Figure 6-1 illustrates the stress requirements and stress points required for a B REC[2] (purple line) and C/D AEC (green line). Scenario C7 and Sc C9 are represented by the yellow and black lines respectively. Both scenarios are similar to PD in the dry season with decreased stress during drought periods (0 – 10%). However in wet season flows are very different to PD due to the new proposed Montrose Dam and resulting in increased stress for the duration of the wet season.

DRY SEASON **WET SEASON**

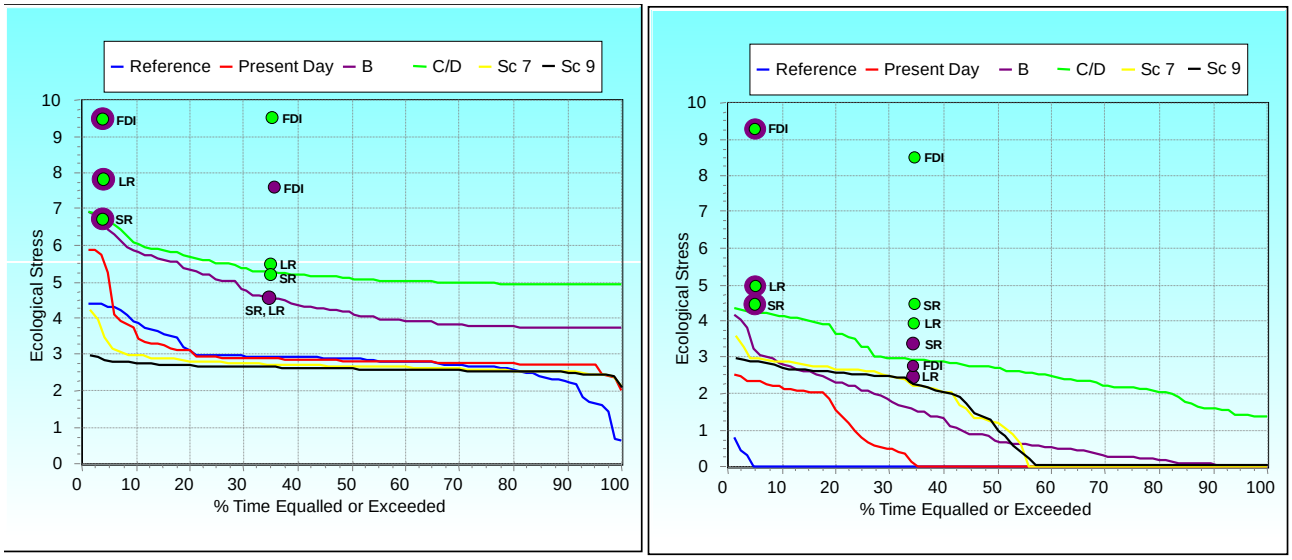


Figure 6–1 Stress duration for EWR 4: Dry and Wet season, Sc C7 and Sc C9

6.2 ECOLOGICAL CONSEQUENCES: SCENARIO C7 AND C9

6.2.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc C7	
PHYSICO-CHEMICAL				
C	B	C	C	Increased base flows will sustain moderate water quality as there are reduced high flows due to Montrose Dam and fewer flushing flows. Although higher turbidity levels are expected, and slightly increased toxics may be present due to fewer flushing flows, the water quality state should stay in a C category (76.73% – 72.73%).
GEOMORPHOLOGY				
B/C	B	C	C	The increased dry season base flows may increase low flow season bed scour and maintain turbidity but otherwise are unlikely to have any significant geomorphological impact at the site. Decreased wet season base flows and small floods will reduce scour of the bed. Further narrowing of the channel, infilling of pools and reduction of gravel areas are likely. The resultant river channel morphology and in-channel processes and available habitat will be moderately worse than the current condition, resulting in a decrease from the PES of B/C

[2] During the determination of EWR scenarios (DWA, 2009) it became evident that the PES and REC low flow requirements were similar. The fish component drove the requirements and was already in a B category. The macroinvertebrates required improvement from a C to a B, but the B category requirements were still less than the fish B requirements. Therefore the low flow requirements were the same for both the PES and REC EcoStatus.

EC				COMMENT
PES	REC	AEC↓	Sc C7	
				to a C. Overall, further infilling of pools and narrowing of the channel is likely.

6.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc C7	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	C	Currently there is no inundation of the lowest limit (20 – 25 cm above water level) in the marginal zone of the indicator *Ludwigia octovalvis.* This improves slightly during scenario flows to 18 – 20 cm above water level (base flows), but inundation still does not occur. Inundation only occurs for 1 to 10 % of the time in May and Jun respectively (1 – 6 cm inundation) and not for the remainder of the dry season. The situation is similar under PD flows. *Berulla* spp., *C. dives* and *Persecaria* spp. remain inundated throughout the dry season at their lowest limit (20 - 30 cm below water level) under PD conditions, which provides good instream habitat for fauna. This level of inundation increases under scenario flows to 25 – 30 cm, which will provide slightly more instream habitat overall. Similarly *P. mauritianus* is inundated by 5 – 10 cm of water under PD flows and this improves to 9 – 14 cm under scenario flows.	Wet season base flows result in *L. octovalvis* ranging from 10 cm above water level (still no inundation) to being 14 cm below water level (inundation in Feb) under PD flows. Under scenario flows however, no inundation occurs (10 – 20 cm above water level throughout wet season at 30%). Inundation of *Berulla* spp., *C. dives* and *Persecaria* spp. ranges from 40 – 60 cm under PD flows and is reduced to 25 – 35 cm under scenario flows. Similarly *P. mauritianus* is inundated by 20 – 35 cm of water under PD flows and this is reduced to 12 – 20 cm under scenario flows.
With additional available habitat in the marginal and lower zone, riparian vegetation cover and abundance will improve in the dry season. During the wet season woody density will be slightly reduced due to higher flows and non-woody expansion favoured, but the major impacts at this site are non-flow related (exotic invasion and vegetation removal).					
FISH					
B	B	C	A/B	In dry season the flows are higher than natural and REC, present hydrology and PES for an extended period. Habitat suitability for the dry season under Sc 9 will thus be very good (AEC) for SR and LSR guilds during most of dry season months. The stress curves for this site indicate very low or no stress situation during the dry season.	For the entire flow duration, flows are lower than natural flows and PD, but higher than PES (REC) for an extended period. Habitats suitability for the wet season under will thus be very good (B EC) for SR and moderate (C EC) for LSR during most of wet season months.
There are overall good flows in both dry and wet periods, often similar or slightly higher than natural (dry season) and an improvement in PD as well as requested PES (REC) flows. Therefore the fish can be expected to improve to an A/B (FRAI = 87.6%).					
MACROINVERTEBRATES					
C	B	C/D	B/C	The dry season is similar to PD but with less severe droughts and the marginal vegetation habitat improves as well. This results in the return of some of the more flow sensitive and vegetation dwelling taxa and improved abundances and FROC of others. The macroinvertebrates improves from a present C category (MIRAI of 75.9%) to a B/C category with a MIRAI score of 78.9%.	
ECOSTATUS					
B/C	C	C/D	B	The instream biota has improved from the PES and the instream state is similar to the REC requirements. However riparian vegetation has not improved to the same degree. This is because increased flows alone will not improve the vegetation EC unless it is accompanied by addressing the non-flow related problems (exotic vegetation and vegetation removal). In this case the assumption was that the alien vegetation issue would be addressed and the EcoStatus was modified to represent this situation.	

6.3 IMPACT OF SCENARIO C10 AND C12

In order to meet the PES and REC requirements at EWR 3, Sc C10 and C12 represent different degrees of decreased releases from Kwena Dam in the dry season and increased releases in the wet season These two scenarios were assessed to determine the impact of these releases on EWR 4. During the scenario assessment the ecological consequences of Sc C10 and Sc C12 were very similar and therefore the results of these scenarios are provided together and represented by Sc C10. In Figure 6-2, Sc C10 is represented by the light blue line and Sc C12 by

the yellow line. Both scenarios reflect less stress during drought conditions in the dry season and are generally similar to the B requirement. During the wet season both scenarios indicate improved flows and are better than the B requirement. Compared to PD, both Sc C10 and C12 result in increased stress for most of the dry season, while stress decreases in the wet season and small floods improve.

DRY SEASON **WET SEASON**

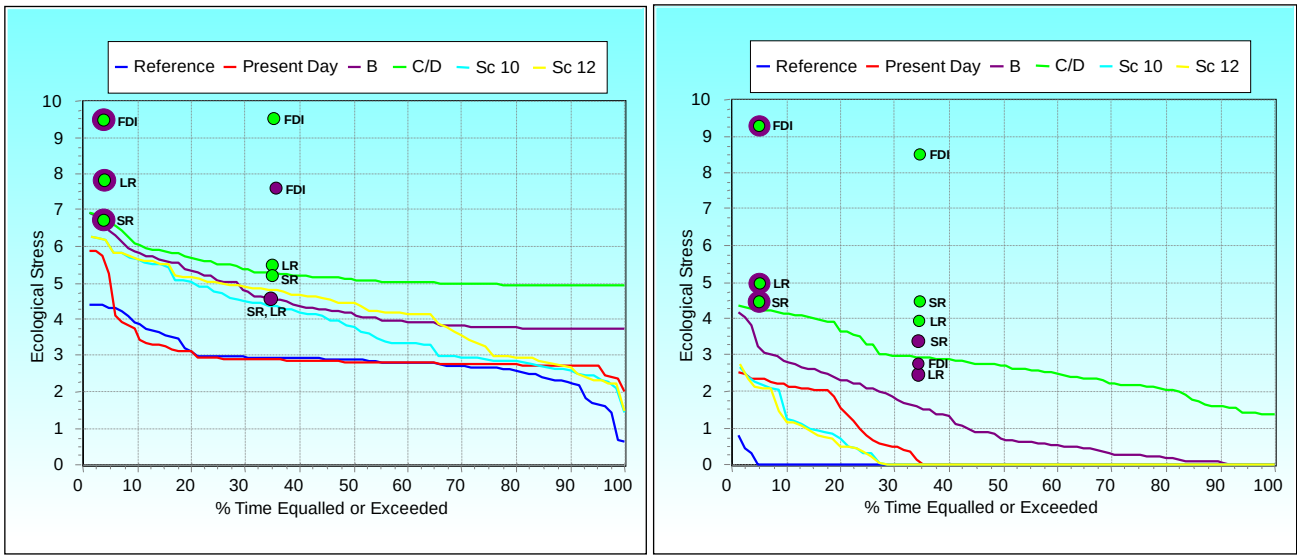


Figure 6–2 Stress duration for EWR 4: Dry and Wet season, Sc C10 and Sc C12

6.4 ECOLOGICAL CONSEQUENCES: SCENARIO C10 AND C12

6.4.1 Driver components

EC				COMMENT
PES	REC	AEC↘	Sc C10	
PHYSICO-CHEMICAL				
C	B	C	C	Due to the developed nature of the catchment, flows lower than PD is expected to impact on most water quality parameters. Due to the nature of the stretch, only small impacts on temperature and oxygen are expected. Slightly improved high flows occur during wet season. The water quality state should stay in a C category, although the category will change from 76.73% to 64.36%.
GEOMORPHOLOGY				
B/C	B	C	C	The very decreased dry season base flows may reduce turbidity and seasonal scour, but otherwise unlikely to have any significant geomorphological impact at the site. Increased wet season base flows and small floods will increase scour of the bed, ameliorating some of the channel narrowing. Reduced large floods may reduce pool depths. In-channel conditions will improve due to increased wet season base flows, but this will be offset by impacts of the reduction in the peak (Feb and Mar) large floods.

6.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↘	Sc C10	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	C	*Berulla* spp., *C. dives* and *Persecaria* spp. remain inundated throughout the dry season at their lowest limit (20 - 30 cm below water level) under PD maintenance conditions. This level of inundation is reduced under scenario flows to less than 10 cm with inundation removed in some areas. *P. mauritianus* is inundated by 5 – 10 cm of water under PD flows but under scenario flows, no inundation occurs (5 – 20 cm above water level).	Inundation of *Berulla* spp., *C. dives* and *Persecaria* spp. ranges from 40 – 60 cm under PD flows to 30 – 70 cm under scenario flows. *P. mauritianus* is inundated by 20 – 35 cm of water under PD flows and this is improved to 15 – 50 cm under scenario flows. High flow variability is increased. Elevated wet season flows and variability is likely to remove some of the exotic species (which is high at this site) and reduce terrestrialisation. This will facilitate improved riparian vegetation cover and abundance and will improve species composition.
FISH					
B	B	C	B	Trends are similar to Sc C11, with low and high flows slightly lower but similar to PES flows. This resulted in a slight improved PES FRAI score of 86.5% (B).	
MACROINVERTEBRATES					
C	B	C/D	B	The droughts are less severe, otherwise it is similar to the modelled B REC which is less flow than present day but more than what the macroinvertebrates require for a B category. The improved vegetation habitat is likely to result in the return of Helodidae and Pleidae resulting in a B category with a MIRAI score of 85.5%.	
ECOSTATUS					
B/C	C	C/D	B	The instream biota has improved to the REC as well as the instream EC, however riparian vegetation has not improved to the same degree. This is because increased flows alone will not improve the vegetation EC unless it is accompanied by addressing the non-flow related problems (exotic vegetation). In this case the assumption is that the alien vegetation issue will be addressed and the EcoStatus was modified to represent this situation.	

6.5 IMPACT OF SCENARIO C11

Scenario C11 is represented by the orange line in Figure 6-3. This scenario represents increased wet season base flows and decreased dry season base flows. Dry season base flows are currently artificially high, so this scenario restores some of the natural seasonality. Moderate floods in Feb and March are slightly decreased compared to PD. Scenario C11 is very similar to PD for both seasons.

DRY SEASON **WET SEASON**

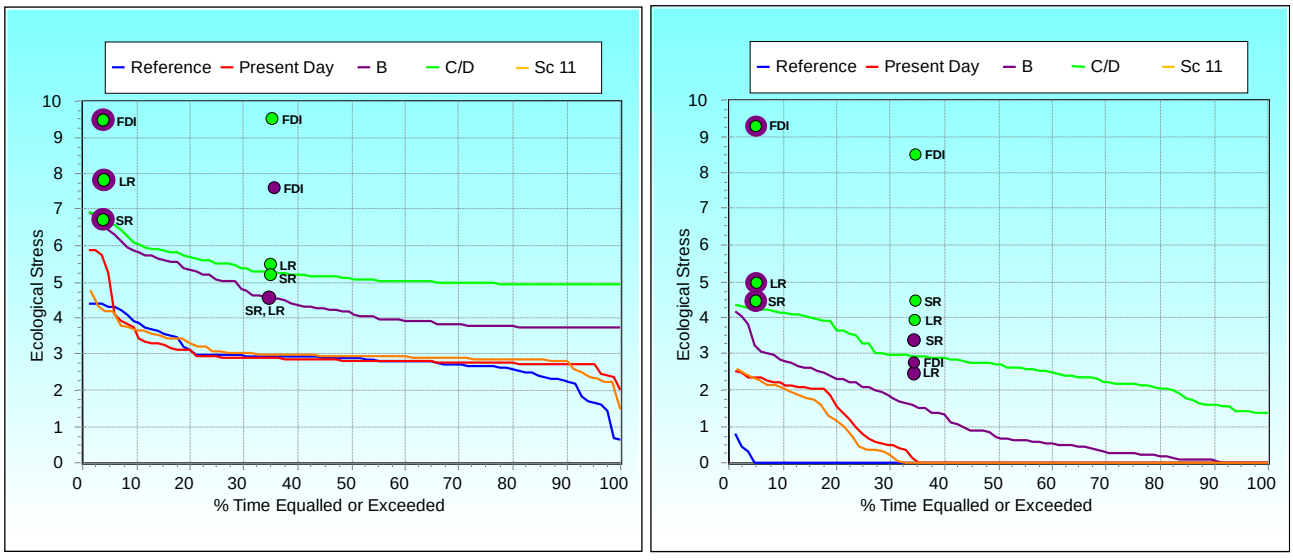


Figure 6–3 Stress duration for EWR 4: Dry and Wet season, Sc C11

6.6 ECOLOGICAL CONSEQUENCES: SCENARIO C11

6.6.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc C11	
PHYSICO-CHEMICAL				
C	B	C	C	Flows are slightly reduced from PD during the dry season with slightly improved high flows. The water quality state should stay unchanged, i.e. 76.73%.
GEOMORPHOLOGY				
B/C	B	C	B/C	The decreased dry season base flows may reduce turbidity, but otherwise the scenario is unlikely to have any significant geomorphological impact at the site. Increased wet season base flows and small floods will increase scour of the bed, ameliorating some of the channel narrowing. Reduced large floods may reduce pool depths. In-channel conditions will improve due to increased wet season base flows, but this will be offset by impacts of the reduction in the peak (Feb and Mar) large floods. Base flows are closest to natural under this scenario.

6.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc C11	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	C	*Berulla* spp., *C. dives* and *Persecaria* spp. remain inundated throughout the dry season at their lowest limit (20 - 30 cm below water level) under PD maintenance conditions. This level of inundation is reduced under scenario flows to 18 – 28 cm, an insignificant change, but more importantly these species always have some inundation (even at 99%) throughout the dry (and wet) season, while drying out does occur under PD flows. This means that overall there will be more instream habitat that currently, and these species will also respond by increasing cover and abundance. Similarly *P. mauritianus* is inundated by 5 – 10 cm of water under PD flows but this is reduced to 2 – 8 cm under scenario flows. Overall base flows are better though and instream reeds will increase, inundation only ceases for 5% of the time.	Inundation of *Berulla* spp., *C. dives* and *Persecaria* spp. ranges from 40 – 60 cm under PD flows to 40 – 65 cm under scenario flows. *P. mauritianus* is inundated by 20 – 35 cm of water under PD flows and this is improved to 25 – 50 cm under scenario flows. Better base flows will improve recruitment opportunities for marginal and lower zone woody species (*B. salicina* and *C. erythrophyllum*) as well.
As non-flow related impacts are so high at this site (exotic invasion and vegetation removal mainly) it doesn't improve as much as it would otherwise.					
FISH					
B	B	C	A	In dry season the flows are just lower than the natural flows, for an extended period similar or higher than present hydrology, and higher than PES and REC. Habitat suitability for the dry season will thus be very good (A) for SR and LSR during most of dry season months. The stress curves for this site indicate relatively low, just higher than natural and similar to present day stress levels for SR and LSR.	For the entire wet season flow duration, the flows are lower than natural, but higher than present hydrology, the PES (REC) and AEC. Habitat suitability for this period will thus be very good (A/B) for SR and good (B) for LSR during most of wet season months (higher than present day flows).
Overall good flows occur in both dry and wet periods, which are lower than natural, similar to PD flow but generally better than PES requested flows. Therefore the fish can be expected to improve from a B (84.2%) to an A/B EC. (87.4% - adjusted FRAI score used).					
MACROINVERTEBRATES					
C	B	C/D	B	Same response as Sc C10 and C12. MIRAI: B EC of 85.4%.	
ECOSTATUS					
B/C	C	C/D	B	Same as for Sc C10 and C12.	

6.7 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 4 are provided in Table 6.1.

Table 6.1 Ecological consequences of operational flow scenarios at EWR 4

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. The degree to which each scenario at EWR 4 meets the REC is summarised in Figure 6-4.

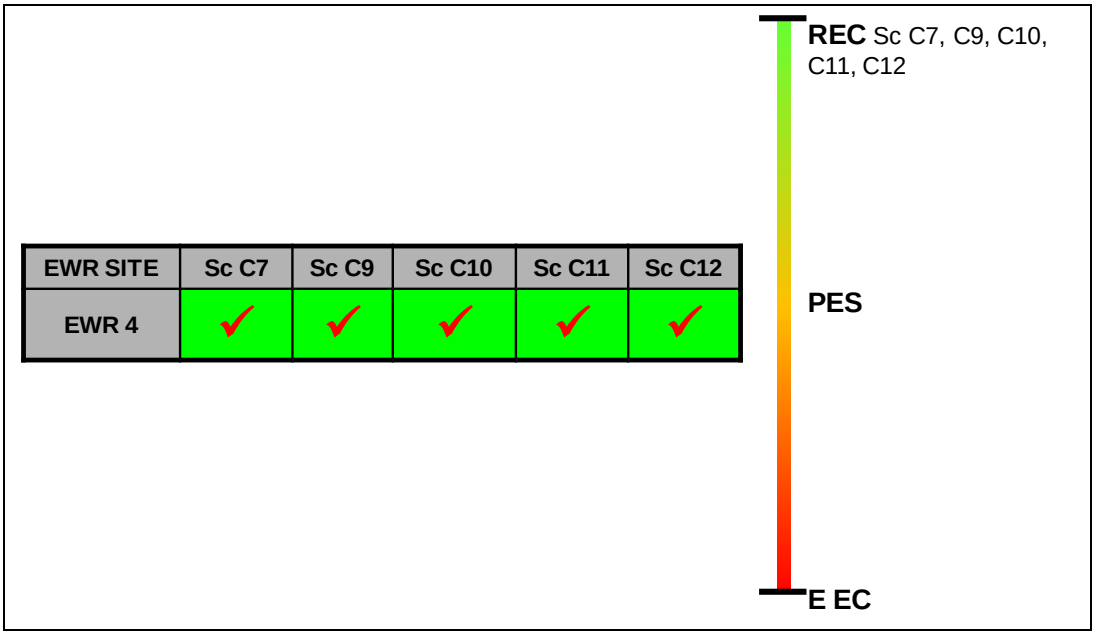


Figure 6–4 Summary of the impacts of operational flow scenarios at EWR 4

7 EWR 5: MALELANE (CROCODILE RIVER) - ECOLOGICAL CONSEQUENCES

Scenarios C3, C4 and C6 - C12 were evaluated and are discussed in Section 7.1 to 7.4.

7.1 IMPACT OF SCENARIO C3, C6 AND C11

The stress and flow duration graphs indicated that Sc C3, C6 and C11 were similar and therefore results of these three scenarios are provided together. These scenarios are based on different irrigation curtailments and restrictions in the Crocodile River. Figure 7-1 illustrates the stress requirements and stress points required for a B REC (purple line), C PES (green line) and D AEC (yellow line). Scenario c3 is represented by the orange line, Sc c6 by the light blue and Sc c11 by the black line. These scenarios all represent reductions in dry season base flows and increased base flows in the wet season from PD to varying degrees.

DRY SEASON **WET SEASON**

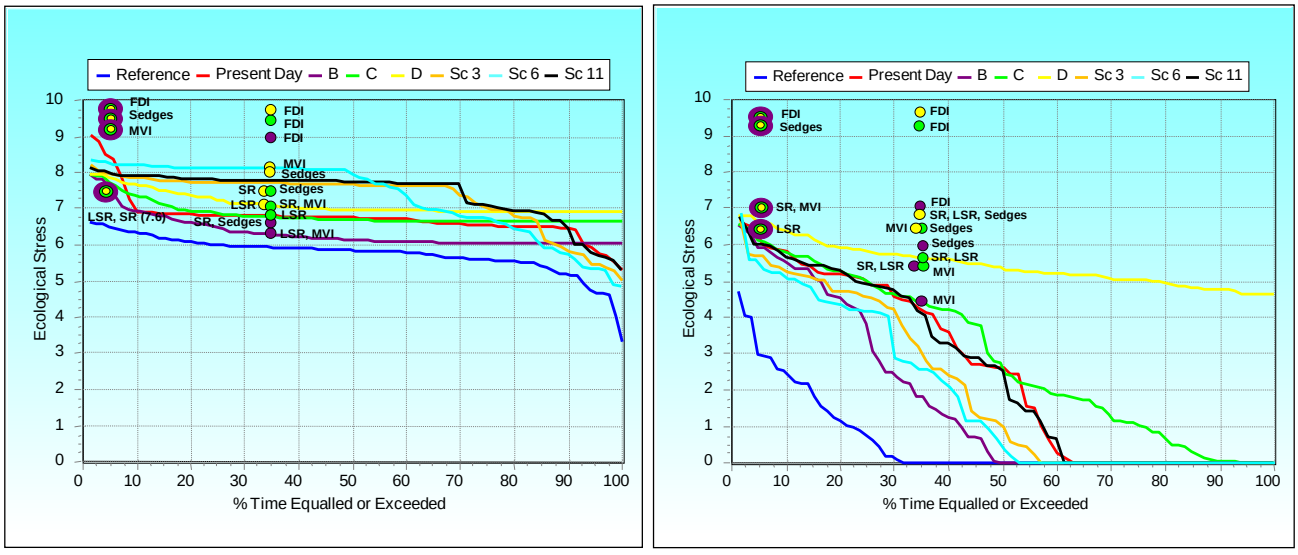


Figure 7–1 Stress duration for EWR 5: Dry and Wet season, Sc CC3, C6 and Sc C11

7.2 ECOLOGICAL CONSEQUENCES: SCENARIO C3, C6 AND C11

7.2.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc C3	
PHYSICO-CHEMICAL				
C	B	D	C	Flows drop slightly lower than PD during dry season while higher flows than PD in the wet season should improve salts, nutrients and temperature slightly. Although there is some fluctuation from PD during the wet season, the scenarios are not expected to change the water quality state from a C category, although the score changes from 67.2% to 71.8%.
GEOMORPHOLOGY				
C/D	C	D	C	Reduced low flows during the dry season, relative to present day, will have little perceptible impact. Increased wet season base flows and small floods will increase scour; reverse some of the channel narrowing and vegetation encroachment (caused by decades of stabilised flows). Incision and channel narrowing has occurred at the site in response to stabilised flows. Increased wet season flows and reinstated wet season small floods will improve the EC through increased channel scour and channel maintenance. The resultant more dynamic channel will be closer to the reference condition.

7.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc C3	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B/C	Flows are similar to present day, and higher than what was specified for the PES. This means that in the peak of the dry season, inundation of *Phragmites mauritianus* at its lower range (marginal zone) increases from 0 to 1 to 6 cm. Similarly, the inundated root zone of *Persecaria* spp. increases in depth from 24 to 31 cm. This additional inundation will favour riparian vegetation vigour and will provide additional instream habitat for aquatic fauna. No change to the PES occurs when using the VEGRAI, which remains a C. This is because the additional flow is not sufficient to cause the marginal zone to recede (one of the impacts was reduced flows that resulted in the marginal encroaching), and is likely to improve vegetation density without migration.	Inundation of *P. mauritianus* during wet season base flows increases markedly from what is required for the PES. Inundation at the lower limit of its range increases from 9 cm to 44 – 57 cm. This will result in a higher proportion of the population being inundated and will improve density, vigour and reproduction on a whole. Inundation depths may result in the marginal zone receding, but the extent will be small. This would however be an improvement to the EC of the marginal and lower zones with the EC changing from 76.3% (C) to 77.5% (B/C). Similarly, *Persecaria* spp., *Cyperus* spp. and *Juncus* spp. are also markedly more inundated and although their distribution along the river is patchier than reeds, the edge of the marginal zone where these species occur is likely to recede. Flood requirements are met by these scenarios.
FISH					
C	B	D	C	The flow falls below natural, present hydrology, the PES, REC as well as AEC. Habitat suitability will be mostly poor to very poor for the SR and LSR guild during all dry season months. A significant deterioration in the PES can therefore be expected in dry season (SR can be expected to fall in a D and LSR in E EC).	For the entire flow duration, there are significantly lower flows than natural, but significantly higher than present hydrology, the PES, REC and AEC requirements. Habitats suitability will be moderate to optimal for all life stages and requirements of SR and LSR guild, with the SR guild in an A/B EC.
The overall condition for fish is expected to remain in the same EC of C, being slightly lower (66.9%) than the PES (75.2%). Flows under Sc C6 are better in the summer and similar in the winter compared to Sc C3 while Sc C11 dry season flows are similar to Sc C3, and wet season flows are slightly lower. However these scenarios result in the same PES.					
MACROINVERTEBRATES					
C	B	D	C	The water quality and marginal vegetation habitat remains similar to the present day situation. The only change is a slight improvement in the wet season. This will lead to a number of taxa (Coenagrionidae, Lymnaeidae, Planorbidae, Hydrophilidae and Leptoceridae) occurring at slightly higher frequencies and Coenagrionidae and Physidae occurring at slightly higher abundances. This leads to a very slight improvement in the macroinvertebrate community from a MIRAI of 76.9% to 77% still in a C category.	
ECOSTATUS					
C	B	D	C	These scenarios result in a slight improvement of the PES due to the improvement in riparian vegetation and geomorphology.	

7.3 IMPACT OF SCENARIO C4

Scenario C4 is also based on different irrigation curtailments and restrictions changes in the Crocodile River and is represented by the black line in Figure 7-2. This scenario represents higher stress than the D requirements in the dry season, while wet season stress lies between the B and C requirement. In relation to PD, dry season drought stress is less under scenario C4 while maintenance conditions will be more stressed. During wet season stress is less during drought than under PD and there is an increase in moderate floods.

DRY SEASON **WET SEASON**

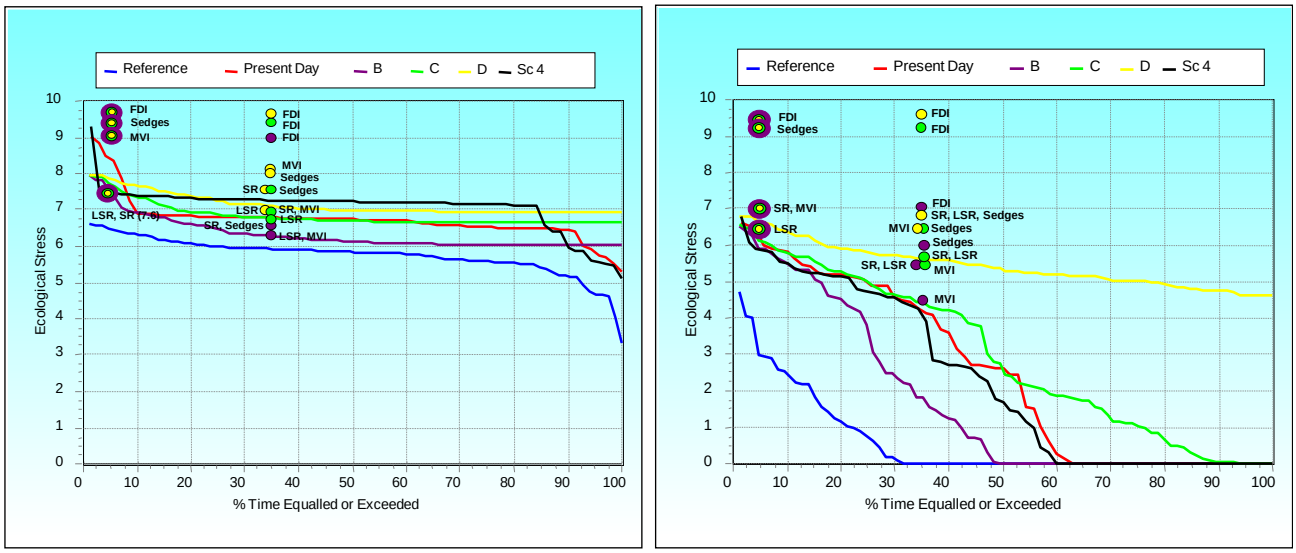


Figure 7–2 Stress duration for EWR 5: Dry and Wet season, Sc C4

7.4 ECOLOGICAL CONSEQUENCES: SCENARIO C4

7.4.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc C4	
PHYSICO-CHEMICAL				
C	B	D	C	Same response as Sc C3. Water quality remains in a C EC, 71.8%.
GEOMORPHOLOGY				
C/D	C	D	C	Same response as Sc C3. There is an improvement to a C EC.

7.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc C4	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B/C	Same response as Sc C3. VEGRAI of a B/C (77.5%).	
FISH					
C	B	D	C	Same response as Sc C3	
Sc C4 will have less flow (increased stress) than natural, the PES, REC and AEC flows and result in deterioration in habitat conditions for fish during the dry season. The opposite is true for the wet season where flows, and thus habitat suitability for fish, will be better and result in a significant improvement in EC from the PES. Different life stage requirements will not be met during the dry season but during the wet season flows will be good to optimal for all life stages. Overall condition of fish is therefore expected to remain in the same EC as the PES (66.1%).					
MACROINVERTEBRATES					
C	B	D	C	Scenarios C4, C7, C8, and C9 are all similar to either the present day or PES requirements for macroinvertebrates, and the scenarios have no significant impact. Therefore the EC remains the same as for the PES (76.9%).	
ECOSTATUS					
C	B	D	C	There is a slight improvement of the PES within the same category due to the improvement in riparian vegetation and geomorphology.	

7.5 IMPACT OF SCENARIO C7 AND C9

The stress and flow duration graphs indicated that Sc C7 and C9 were sufficiently similar to be addressed as one. Figure 7-3 illustrates Sc C7 (black line) and Sc C9 (light blue line). Both scenarios are similar to PD in the dry season with more flows during drought periods (0 – 10%), similar to the C requirements. However in wet season flows are very different to PD due to the new Montrose Dam and decreased spills and at times are less than the D requirements.

DRY SEASON **WET SEASON**

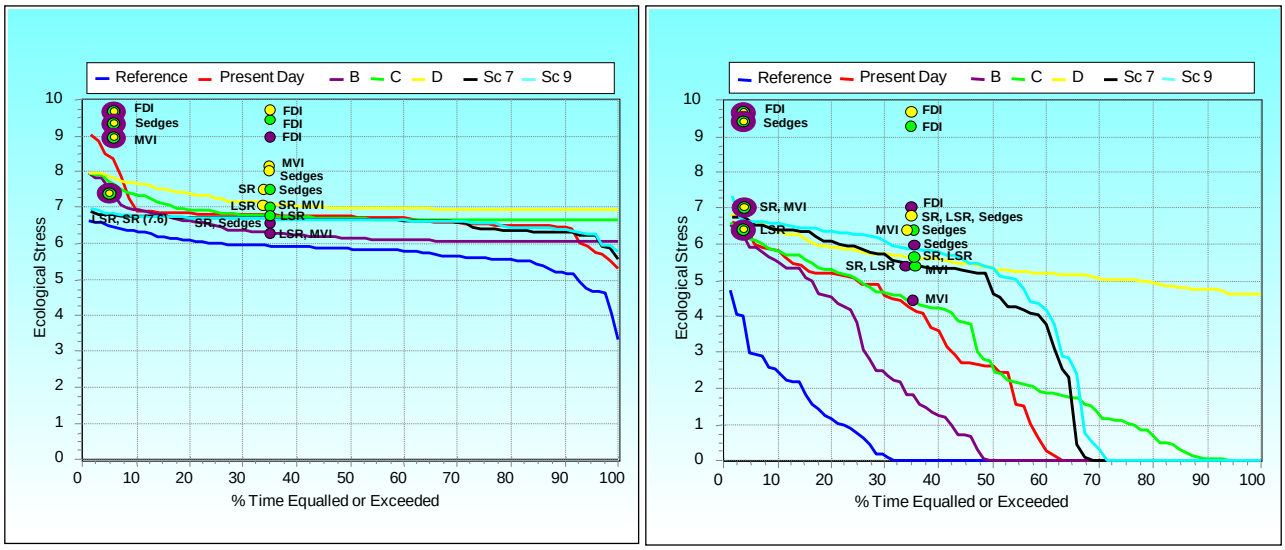


Figure 7–3 Stress duration for EWR 5: Dry and Wet season, Sc C7 and C9

7.6 ECOLOGICAL CONSEQUENCES: SCENARIO C7 AND C9

7.6.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc C7	
PHYSICO-CHEMICAL				
C	B	D	C	Dry season flows is similar to PD and although there is some fluctuation from PD during the wet season, the scenarios are not expected to change the water quality state.
GEOMORPHOLOGY				
C/D	C	D	D	Dry season flows is similar to PD and no changes are therefore expected during this period. There are very large reductions in floods and base flows during the wet season and it is expected that there will be a further increase in incision, channel narrowing and deepening of the channel. Incision and channel narrowing has occurred at the site in response to stabilised flows. Under Sc C7, this trend will be accelerated. Loss of sand bars and shallow sandy areas of the channel are likely as these become stabilised by vegetation and the active channel narrows and deepens.

7.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc C7	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	C	Dry season flows are almost identical to PD, and higher than what was specified for the PES. This means that in the peak of the dry season, inundation depths of all three dominant marginal and lower riparian species (*Phragmites, Persecaria* and *Cyperus*	The overall flow volumes will decrease significantly but the flow is more consistent and reliable. However, in the peak of the wet season, inundation depths of all three dominant marginal and lower riparian species (*Phragmites, Persecaria* and *Cyperus* spp.) will be

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc C7	DRY SEASON	WET SEASON
				spp.) will remain unchanged, and no change to the PES occurs when using the VEGRAI.	significantly reduced. *Persecaria* inundation depths will be decreased by over 30% in comparison to PD conditions. However, this perennial species is a strong re-seeder and stoloniferous, and is likely to rapidly migrate with the receding marginal zone. The surface area of available habitat may be somewhat reduced, but the population size and health of this species is unlikely to be significantly affected. *Phragmites* inundation depths will be decreased to less than half of those of PD conditions. *Cyperus* inundation depths will also be decreased to less than half of those of PD conditions. Both of these are fairly long-lived geophytes with strongly developed rhizomes that play an important role in sediment binding. These species are unlikely to migrate rapidly with the receding marginal zone and it is likely that the surface area of available habitat will be significantly reduced. Furthermore, reduced inundation frequency and duration is likely to lead to reduced plant vigour and thus reduced vegetative growth and reproductive success in terms of both rhizome growth and seed production. Reduced vigour of reedbeds and a concomitant reduction in the sediment binding effect of rhizomes and roots. Terrestrialisation and invasion by alien plants are also likely to increase within the marginal and particularly the lower riparian zone.
The vegetation will deteriorate within the C EC.					
FISH					
C	B	D	B/C	Maintenance flows are below natural and REC, but generally above PD, PES, as well as AEC requirements. Habitat suitability will be mostly considerably better for SR and LSR guilds during all dry season months compared to the PES. A significant improvement in the PES can therefore be expected in the dry season (the SR guild will improve to a A/B EC and the LSR guild remains in a C EC).	Slightly lower than PD flows occur and there is an increase in flow after the dry period (lag/retention period – 1 month). The flows are generally lower than natural, PD, similar than REC, but higher than PES, and AEC requirements. Habitats suitability is moderate for all life stages and requirements of SR and LSR guilds with the SR guild in an A/B EC. Delayed early season freshets might influence spawning activities negatively.
Improved low flows, and resulting improved habitat conditions, especially for SR fish during the dry season. On the other hand, reduced flows during high flow periods (compared to natural and the REC) will be experienced, but without perceived impact. Different life stage requirements will be met during all seasons but during the early wet season, flows might be sub-optimal for some life stages due to the lag/retention period. Overall the condition for fish is expected to improve from a C (75.2%) to a B/C (81.3%).					
MACROINVERTEBRATES					
C	B	D	C	Same response as Sc C4. The EC remains the same as for the PES (76.9%).	
ECOSTATUS					
C	B	D	C	The improvement in the fish results in an improvement of the PES instream state to a B/C. However there is a deterioration in geomorphology and riparian vegetation (within the PES EC) and therefore the EcoStatus improves within the PES EC.	

7.7 IMPACT OF SCENARIO C8

Scenario 8 modelling includes the proposed Mountain View Dam on the Kaap River. The results of the scenarios are similar to Sc C4 except for dry season drought periods occurring 0 – 10% of the time when stress will be much higher under Sc C8 represented by the orange line in Figure 7-4. During dry season drought conditions while Sc C 8 results in more stress compared to PD, while stress is slightly more during maintenance conditions. During the wet season, flows are also very similar to Sc C4 and lie between the C and D requirements and results in more stress than under PD.

DRY SEASON **WET SEASON**

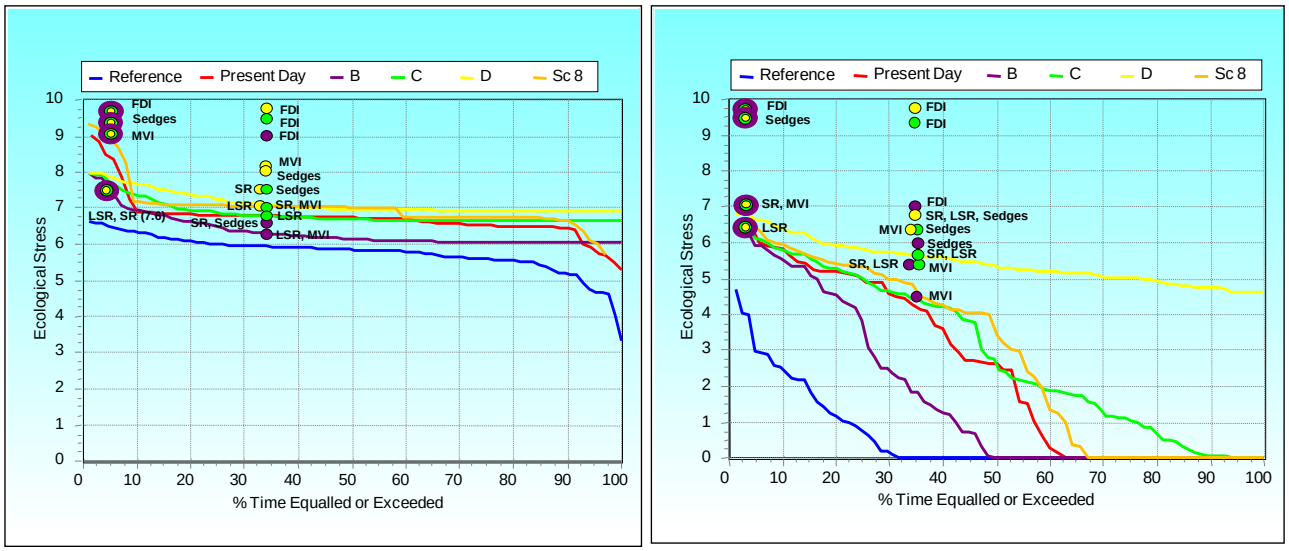


Figure 7–4 Stress duration for EWR 5: Dry and Wet season, Sc C8

7.8 ECOLOGICAL CONSEQUENCES: SCENARIO C8

7.8.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc C8	
PHYSICO-CHEMICAL				
C	B	D	C	Same response as Sc C7 and C9. No change is expected in the water quality state.
GEOMORPHOLOGY				
C/D	C	D	C	Same response as Sc C3. There is an improvement to a C EC.

7.8.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc C8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B/C	Same response as Sc C3. VEGRAI of a B/C (77.5%).	
FISH					
C	B	D	C	Same response as Sc C4. Condition of fish is expected to remain in the same EC as the PES (66.1%).	
MACROINVERTEBRATES					
C	B	D	C	Same response as Sc C4. The EC remains the same as for the PES (76.9%).	
ECOSTATUS					
C	B	D	C	Same result as Sc C4.	

7.9 IMPACT OF SCENARIO C10 AND C12

To meet the PES and REC requirements at EWR 3, Sc C10 and C12 represent different degrees of decreased releases from Kwena Dam in the dry season and increased releases in the wet season. The ecological consequences of Sc C10 and Sc C12 were very similar and therefore the results of these scenarios are provided together and represented by Sc C10. In Figure 7-5, Sc

C10 is represented by the light blue line and Sc C12 by the black line. Both scenarios reflect increased drought conditions in the dry season compared to PD and are generally similar to the B requirement. During the wet season both scenarios indicate improved flows and are better than the B requirement.

DRY SEASON **WET SEASON**

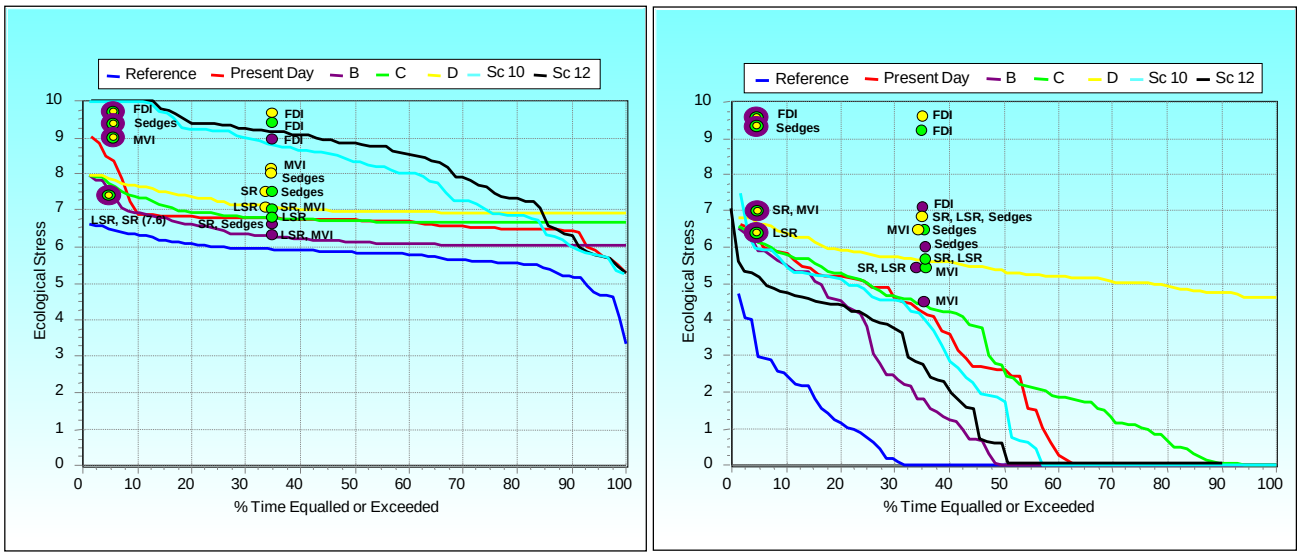


Figure 7–5 Stress duration for EWR 5: Dry and Wet season, Sc C10 and Sc C12

7.10 ECOLOGICAL CONSEQUENCES: SCENARIO C10 AND C12

7.10.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc C10	
PHYSICO-CHEMICAL				
C	B	D	D	Flows drop significantly during the dry season, with concomitant impacts on salts, nutrients, DO, temperature and toxics. Higher flows than PD in the wet season should improve salts, nutrients, temperature and oxygen slightly. The improved flows during the wet season would not be enough to compensate for the impacts related to reduced and zero flows during the dry season. The water quality state is expected to change from a C to D category, i.e. 67.2% to 49.28%.
GEOMORPHOLOGY				
C/D	C	D	D	Extreme reductions, and periods of no flow, in the dry season will destabilise the active channel through loss of stabilising marginal vegetation. During the wet season there is a limited reduction in base flows, but a wider, flatter channel is expected due to loss of stabilising marginal vegetation (due to dry season zero flows). This will reduce in-channel habitat diversity. Incision and channel narrowing has occurred at the site in response to stabilised flows and under this scenario, the loss of marginal vegetation due to reduced dry season flows will destabilise the channel. Over time this may create a system more like the Letaba River - wide, sandy, unconfined and highly mobile sandy bed with little stabilising marginal vegetation. To a small extent this dynamic morphology is tending towards Reference (dynamic, wider channel), but the change to seasonal flow is completely unnatural.

7.10.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc C10	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	D	Inundation of all marginal zone reeds and sedges is reduced to the point where no inundation occurs at the lower limit in the marginal zone. Periods of zero flow are markedly increased. The *Persecaria* spp. population remains inundated, but this is reduced by about 50% from 31 cm inundation in PD conditions to 17 cm at the aquatic edge of the marginal zone. This will severely reduce instream faunal habitat and increase water stress of vegetation during winter. Capillary movement of water in sandy alluvial conditions is likely to be sufficient to ensure survival along the marginal zone, but vegetation cover and abundance will be severely reduced.	Increased zero flows even during wet season base flows occurs. Cover and abundance will similarly be reduced and reproduction is likely to cease.
The EC changes from 76.3% to 57.1% (D), which is similar to the AEC.					
FISH					
C	B	D	D	The flows fall below natural, present hydrology, PES, REC as well as the AEC. Habitat suitability will be mostly poor to very poor for SR and LSR guild during all dry season months. A significant deterioration in the PES can therefore be expected (SR and LSR guild can be expected to fall in an E EC).	For the entire flow duration, there are lower flows than natural, but significantly higher than present hydrology, PES, REC and AEC requirements. Habitats suitability is moderate to optimal for all life stages and requirements of SR and LSR guild (SR guild will improve to an A/B EC).
Overall condition for fish will change for the FRAI from a C (75.2%) to a D (53%). The deterioration in EC is particularly as a result of zero flow conditions during dry season that will result in loss of rheophilic species, while species with preference for overhanging vegetation (barbs) will also be impacted negatively. Although conditions will be good during the wet season, it is expected that these fish guilds may not recover.					
MACROINVERTEBRATES					
C	B	D	D	These scenarios were most similar to the D category and were therefore compared to the D MIRAI of 56.59%. . The worse and extended drought in the dry season and the worse dry season, leads to a loss of approximately 50% of the vegetation and a deterioration in water quality. This may result in a loss of the following taxa: Coenagrionidae, Atyidae, Leptophlebiidae, Elmidae, Pleidae as well as 1sp each of Baetidae and Hydropsychidae. The following taxa are likely to occur at a decreased frequency: Dytiscidae, Hydroptilidae, Physidae, Planorbidae, Leptoceridae, Simuliidae, Naucoridae, Hydrophilidae and Libellulidae. The macroinvertebrates decrease to a D/E (41.3%).	
ECOSTATUS					
C	B	D	D	These scenarios have a severe impact on the site resulting in deterioration in all components. The EcoStatus is a D.	

7.11 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 5 are provided in Table 7.1.

Table 7.1 Ecological consequences of operational flow scenarios at EWR 5

Driver Components	PES	REC	Sc C3, C6, C11	Sc C4, C8	Sc C7, C9	Sc C10, C12
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 the instream both improve. The degree to which each scenario at EWR 4 meets the REC is summarised in Figure 7-6.

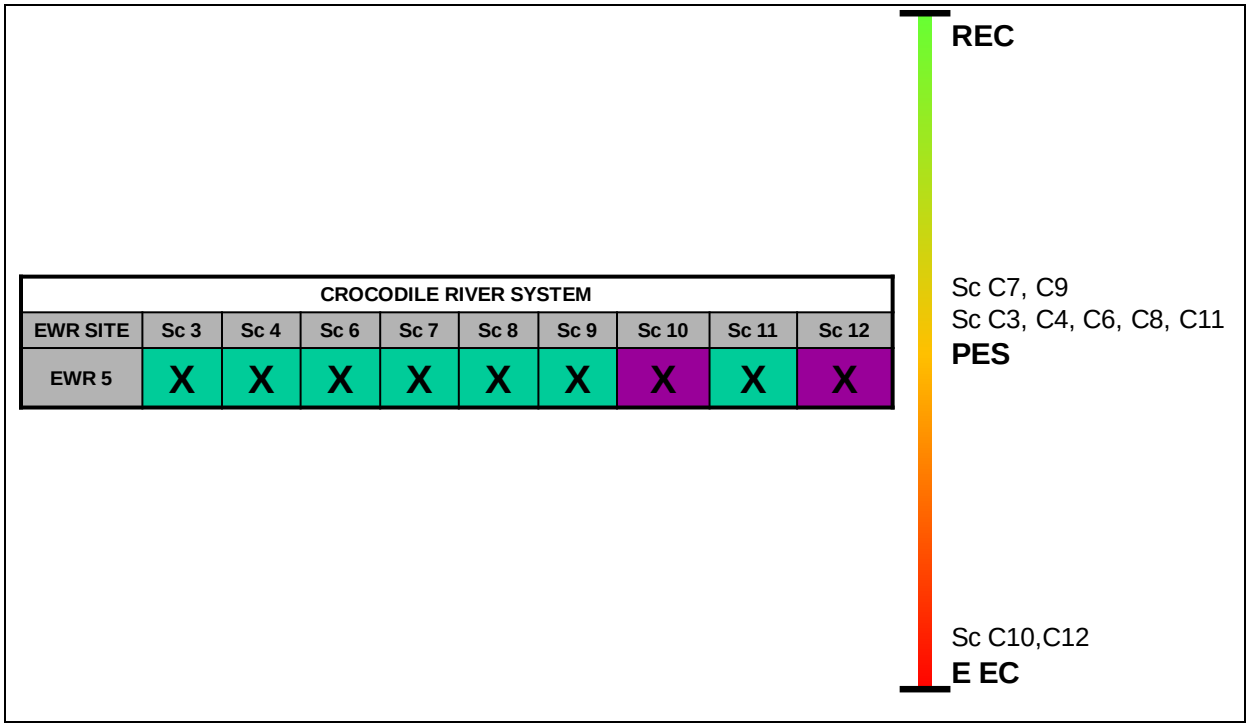


Figure 7–6 Summary of the impacts of operational flow scenarios at EWR 5

8 EWR 6 NKONGOMA (CROCODILE RIVER): ECOLOGICAL CONSEQUENCES

Scenarios C3, C4, C6, C8 and C11 were assessed and the ecological consequences are discussed below.

8.1 IMPACT OF SCENARIO C3

Scenario C3 is based on different irrigation curtailments and restrictions changes in the Crocodile River and is represented in Figure 8-1 by the light blue line. Figure 8-1 also illustrates the stress requirements and stress points required for a B REC (purple line), C PES (green line) and D AEC (yellow line). During the dry season Sc C3 is similar to the D requirements and PD and during the wet season Sc C3 is similar to the PES requirements with less stress than under PD although base flows are reduced during drought conditions the stress during this time will be less than PD but more than the PES requirements.

DRY SEASON **WET SEASON**

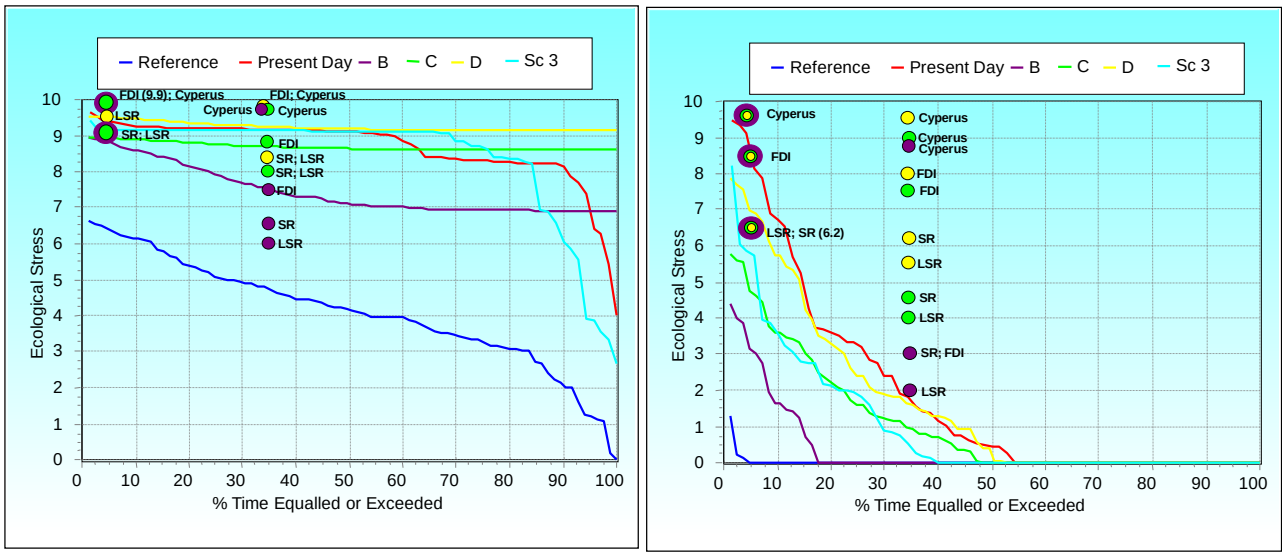


Figure 8–1 Stress duration for EWR 6: Dry and Wet season, Sc C3

8.2 ECOLOGICAL CONSEQUENCES: SCENARIO C3

8.2.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc C3	
PHYSICO-CHEMICAL				
C	B	D	C	Water quality conditions deteriorate as flows drop during two months in the dry season. There are higher flows than PD hydrology during the wet season. Overall conditions remain within a C category, although a deterioration to a C/D EC in the dry season will occur (i.e. 67.48% to 60.54%).
GEOMORPHOLOGY				
C	C	C/D	C	No perceptible change to geomorphology is anticipated during the dry season. The very slight increases in the wet season base flows will marginally improve instream condition but will not result in a higher EC. Infilling of the pools and narrowing of the channel are not likely to be significantly reversed by the small increases in base flow, but may cause slight improvements in available gravels within the active channel. No change in the overall EC is expected.

8.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc C3	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B/C	*P. mauritianus* remains inundated at its lower limit (up to 30 to 40 cm) during dry season maintenance. This is not different from PD. Other minority vegetation components such as *Ludwigia, Persecaria* and *C. marginatus* remain inundated at their lower limits to 2 - 3 cm. This again, is not different from PD, but the contribution to instream habitat is highly patchy and localized.	*P. mauritianus* remains inundated at its lower limit (up to 70 to 90 cm) during wet season maintenance. This is on average 20 cm more than PD maintenance, and therefore there is more instream habitat for macroinvertebrates and fish. Similarly, inundation in the marginal of *Ludwigia, Persecaria* and *C. marginatus* improves from 20 – 40 cm on average to 40 – 50 cm.
The additional, but tolerable inundation during the wet season will provide additional instream habitat, and provide opportunity for *Ludwigia, Persecaria* and *C. marginatus* to colonize additional sandy patches that were not previously available. The vegetation will improve to a B/C (79.7%).					
FISH					
C	B	D	D	The general trends in flows and fish stress is very similar to Sc 4, with conditions for fish being slightly better under Sc C3, with an estimated FRAI score of 50.2% (D EC).	
MACROINVERTEBRATES					
C	B	D	C	There is a slight improvement in the amount of reeds available to macroinvertebrates as well as a slight improvement in water quality. More scouring and a wider channel will result. These changes in the macroinvertebrate habitat results in a slight increase in the frequency of occurrence of the following taxa: Veliidae, Leptophlebiidae, Elmidae, Dytiscidae and Leptoceridae. These changes in frequency of occurrence results in a slight improvement of the macroinvertebrates from a present day MIRAI score of 72.9% to 74.3% (C category).	
ECOSTATUS					
C	B	D	C	Although there is deterioration in the fish the scenario results in a C EC, indicating that the PES EcoStatus will be met.	

8.3 IMPACT OF SCENARIO C4

Scenario C4 is based on different irrigation curtailments and restrictions changes in the Crocodile River and is represented in Figure 8-2 by the black line. Sc C4 is very similar to the D requirements and PD during dry and wet season, with wet season conditions being less stressed than PD.

DRY SEASON **WET SEASON**

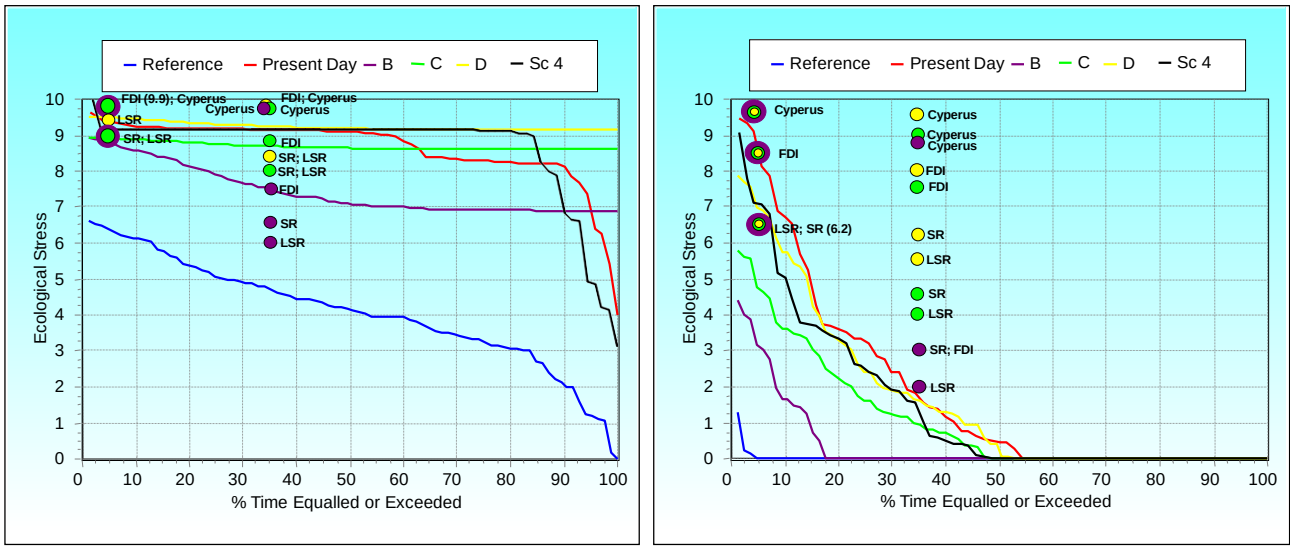


Figure 8–2 Stress duration for EWR 6: Dry and Wet season, Sc C4

8.4 ECOLOGICAL CONSEQUENCES: SCENARIO C4

8.4.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc C4	
PHYSICO-CHEMICAL				
C	B	D	D	During dry season very low flows during most of the dry season will impact greatly on water quality. Increases in toxics, temperatures and a drop in oxygen level will impact directly on biota, while increases in filamentous algae will impact on habitat availability. Lower flows than PD is evident during wet season. Dry season: Water quality state will deteriorate from a C category (67.8%) to a D category (51.44%). Wet season: Water quality state will remain in a C category. Overall category is deterioration from a C to a High D category.
GEOMORPHOLOGY				
C	C	C/D	C	Same response as Sc C3. No change is expected in the PES.

8.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc C4	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B/C	Scenario C4 is similar to Sc C3 with slightly less inundation, but still improvement from PD. Higher wet season flows will also improve survival probabilities and fecundity of *Breonadia salicina,* especially on lower zone bedrock. The vegetation will improve to a B/C (79.7%).	
FISH					
C	B	D	D/E	Flows fall below natural, present hydrology, the PES, REC as well as AEC. Habitat suitability will be mostly poor to very poor for SR and LSR guilds during all dry season months. A significant deterioration in the PES can therefore be expected in dry season (SR can be expected to fall in a F and LSR in E/F EC under this scenario).	Flows fluctuate above and below the present hydrology, PES and REC requirements. Habitat suitability for all life stages of the LSR guild will decrease (PES from D/E down to E EC) and moderate requirements for SR (PES from F up to E EC).
Less flow (increased stress) than natural, PES, REC and AEC flows will result in deterioration in habitat conditions for fish during the dry season. Fluctuations in wet flows will result in mixed reactions, impacting on the recovery of the site after poor low flow conditions. The FRAI have been impacted and deteriorate from a 74.7% integrity score (C) to 41.5% (D/E).					
MACROINVERTEBRATES					
C	B	D	C	There is slightly more scouring of the bed and a slightly wider channel compared to present day. The water quality is likely to deteriorate to a high D category. These changes lead to a loss of one Baetidae sp and a decrease in the FROC of the following taxa: Veliidae, Leptophlebiidae, Elmidae, Tricorythidae, Dytiscidae and Leptoceridae leading to a deterioration within the present EC from 74.9% to 69.6%.	
ECOSTATUS					
C	B	D	C	Scenario C4 will maintain the PES, although the fish deteriorates to an unacceptable condition.	

8.5 IMPACT OF SCENARIO C6

Sc C6 is based on different irrigation curtailments and restrictions changes in the Crocodile River and is represented in Figure 8-3 by the black line. Sc C6 is very similar to the D requirements and PD during dry and wet season. During the dry season Sc C6 provides slightly improved (from the D EC) base flows and improved wet season flows which are between the B and C requirement and better than PD.

DRY SEASON **WET SEASON**

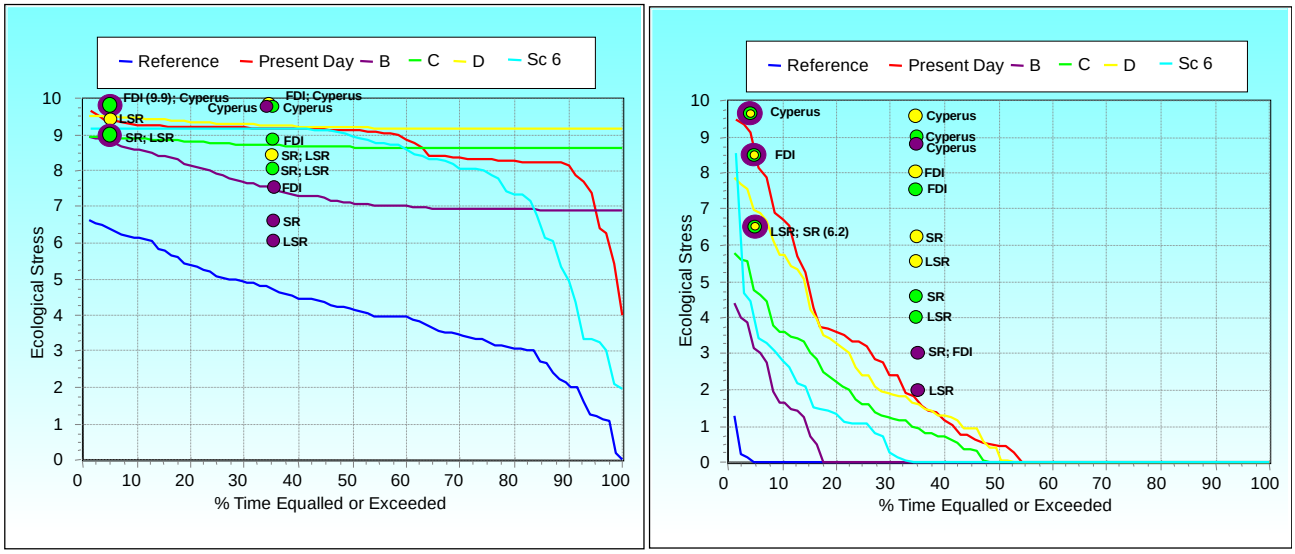


Figure 8–3 Stress duration for EWR 6: Dry and Wet season, Sc C6

8.6 ECOLOGICAL CONSEQUENCES: SCENARIO C6

8.6.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc C6	
PHYSICO-CHEMICAL				
C	B	D	C	During the dry season flows are slightly higher than PD hydrology. During the wet season flows are significantly higher than PD hydrology, particularly for Sc C6. Overall conditions improve within the category from 67.8% to 75.14%.
GEOMORPHOLOGY				
C	C	C/D	C	No perceptible change to geomorphology is anticipated during the dry season. Large increases in the wet season base flows and small floods should scour the channel and ameliorate some of the channel infilling as well as infilling of the pools and narrowing of the channel. This should deepen the pools and widen the channel. Some slight improvement in available gravels within the active channel could be expected.

8.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc C6	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B	There is a slight increase in flow volumes over PD, and the flows are more consistent. Dry season inundation levels are practically identical to present day. Therefore, in the peak of the dry season, inundation depths of the two dominant marginal and lower riparian species (*P. mauritianus* and *C. marginatus*) will remain unchanged, and no change to the PES occurs when using the VEGRAI, which remains a C.	There is a 70% increase in flow volumes for the 30 percentile at the peak of the wet Season (Feb). This translates into significantly greater inundation depths (13 cm increase in inundation depth) and duration of inundation for the *P. mauritianus* and *C. marginatus* over PD. It is therefore expected that the surface area of available habitat for these species (and other marginal and lower riparian species) will increase significantly, as will the vigour and reproductive success (both sexual and vegetative) of these species. Other lower riparian zone species such as *B. salicina* and *Ficus capreifolia* will also benefit significantly in terms of available habitat and reproductive success. It is also likely that species richness (α-diversity) will increase within the marginal and lower riparian zones. Terrestrialisation and alien plant invasion within the lower riparian zone are also likely to decrease.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc C6	DRY SEASON	WET SEASON
An improvement to the PES to a B EC.					
FISH					
C	B	D	D	The general trends in flows and fish stress is very similar to Sc 4, with an estimated FRAI score of 52.6% (D EC).	
MACROINVERTEBRATES					
C	D	B	C	Same response as Sc C3. There is an improvement within the PES.	
ECOSTATUS					
C	D	B	C	Same response as Sc C3 although there is a greater improvement in vegetation.	

8.7 IMPACT OF SCENARIO C7 AND C9

The stress and flow duration graphs indicated that Sc C7 and C9 were sufficiently similar to be addressed as one In Figure 8-4. Scenario C7 is represented by the black line and Sc C9 by the light blue line. During dry season these two scenarios lie between the C and D requirements and is similar to PD and during the wet season they represent large scale reductions in flow i.e. less than PD.

DRY SEASON **WET SEASON**

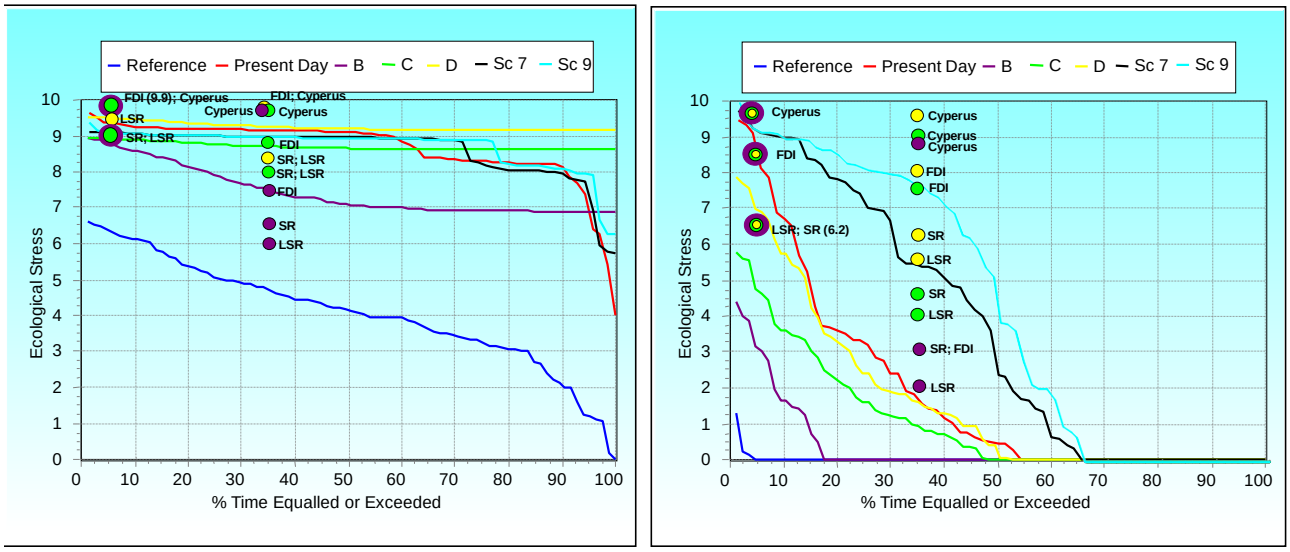


Figure 8–4 Stress duration for EWR 6: Dry and Wet season, Sc C7 and Sc C9

8.8 ECOLOGICAL CONSEQUENCES: SCENARIO C7 AND C9

8.8.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc C7	
PHYSICO-CHEMICAL				
C	B	D	C	During the dry season flows are slightly better than the PD hydrology used to determine physico-chemical status. During the wet season, flows are lower than PD. Reduced flushing flows will impact on nutrients, toxics and turbidity. Although the impact of reduced flushing flows in the wet season will result in an impact, the water quality state will not change from a C category (i.e. 67.48% to 63.24%).
GEOMORPHOLOGY				

EC				COMMENT
PES	REC	AEC→	Sc C7	
C	C	C/D	C/D	he decreases in the wet season base flows will result in further reduction in sediment movement and infilling of pools during wet season. The reduced small floods and lower wet season base flows will reduce sediment movement and exacerbate the infilling of the pools in this reach. This will reduce instream habitat availability and is likely to reduce habitat diversity.

8.8.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc C7	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	D	Similar to Sc C3 in the dry season, with little change to vegetation or instream habitat. Average inundation of *Ludwigia, Persecaria* and *C. marginatus* increases slightly from 2 - 3 cm to 4 to 5 cm. Even though the change is small, survival of marginal zone obligates like *Ludwigia* and *Persecaria* will improve during critical winter months.	Base flows and small floods are reduced. Inundation of *P. mauritianus* declines at its lowest limit from 50 – 80 cm to 50 – 60 cm. Similarly, inundation in the marginal of *Ludwigia, Persecaria* and *C. marginatus* decreases from 20 – 40 cm (on average to 40 – 50 cm) to 15 to 30 cm. Since these species are patchy, this may be significant reduction of habitat for instream fauna, and since sandy substrate is limited at this site, migration or recolonization may not be effective. Recruitment opportunities on all zones will be markedly reduced for woody riparian species which will cause population structures to deteriorate even farther. Non-woody cover and abundance will also reduce as water stress in critical growing season limits primary production as well as fecundity.
FISH					
C	B	D	C	Flows fall below natural and REC, but varies when compared with present hydrology, PES (relatively similar). Habitat suitability will be mostly poor (E/F) for SR and LSR guilds during most dry season months, but similar to the PES.	For the entire flow duration, there are significant lower flows than natural and REC, with variation regarding present hydrology, PES, and AEC requirements. Habitats suitability will be poor (F) for certain life stages and requirements of SR and LSR guilds.
This scenario is overall very similar to the PES, in both dry and wet periods. Therefore the fish will not change significantly and the FRAI will follow the PES trend (FRAI not adjusted).					
MACROINVERTEBRATES					
C	B	D	D	There is a slight reduction in the amount of marginal vegetation habitat for the macroinvertebrates as well as a slight deterioration in the water quality. Available habitat at the site is likely to be smothered a bit by sand accumulation. These changes in habitat are likely to lead to the loss of Simuliidae, Hydropsychidae, Elmidae, Leptoceridae and Libellulidae and a decreased frequency of occurrence of Turbellaria, Belostomatidae, Pleidae, Coenagrionidae and Hydrophilidae compared to the D category scenario. The macroinvertebrates deteriorate to a D category of 51.6%.	
ECOSTATUS					
C	B	D	D	The reduced flows during the wet season results in a deterioration of the biota. The instream component deteriorates to a D and this along with the deterioration in riparian vegetation and geomorphology results in a D EcoStatus which is lower than the PES requirements.	

8.9 IMPACT OF SCENARIO C8

Scenario C8 modelling includes the proposed Mountain View Dam on the Kaap River. Sc C8 is illustrated in Figure 8-5 and represents the light blue line. In the dry season this scenario is very similar to Sc C7 and Sc C9 and PD, however during the wet season the base flows are reduced to a lesser extent and less than PD.

DRY SEASON **WET SEASON**

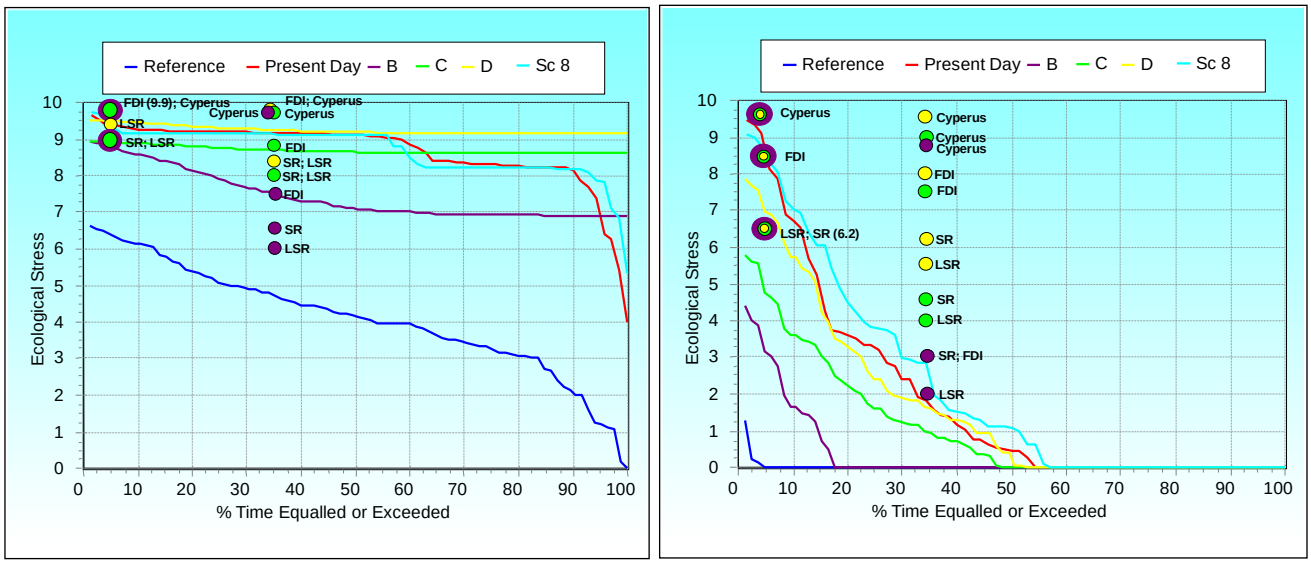


Figure 8–5 Stress duration for EWR 6: Dry and Wet season, Sc c8

8.10 ECOLOGICAL CONSEQUENCES: SCENARIO C8

8.10.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc C8	
PHYSICO-CHEMICAL				
C	B	D	C	Dry and wet season are similar to PD and therefore no change in the water quality state is expected.
GEOMORPHOLOGY				
C	C	C/D	C/D	Same response as Sc C7.

8.10.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc C8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	C/D	Similar to Sc C7 with slightly lower flows in April and May. However the response is the same as with Sc C7 which is deterioration to a C/D EC.	
FISH					
C	B	D	C	Same response as Sc C7, with fish remaining in a C EC.	
MACROINVERTEBRATES					
C	B	D	C	This scenario is similar to present day and therefore the macroinvertebrates remain in a C.	
ECOSTATUS					
C	B	D	C	The reduced base flows during the wet season under Sc C8 do not impact as severely on the biota as Sc C7. The biotic and instream components remain in a C EC and therefore the EC is is similar to the PES and will meet the PES requirements.	

8.11 IMPACT OF SCENARIO C10, C11 AND C12

In order to meet the PES and REC requirements at EWR 3.Scenario C10 and C12 represent different degrees of decreased releases from Kwena Dam in the dry season and increased

releases in the wet season Sc C11 includes current day demands and releases, but cross-border flows are not included. The stress and flow duration graphs indicated that Sc C10, C11 and C12 were sufficiently similar to be addressed as one. Figure 8-6 illustrates Sc C10 (light blue line), Sc C11 (black line) and Sc C12 (orange line) and during dry season these scenarios represent drastically reduced base flows for more than 50% of the time while wet season flows are similar to PD under Sc C11 and slightly improved under Sc C10 and Sc C12.

DRY SEASON **WET SEASON**

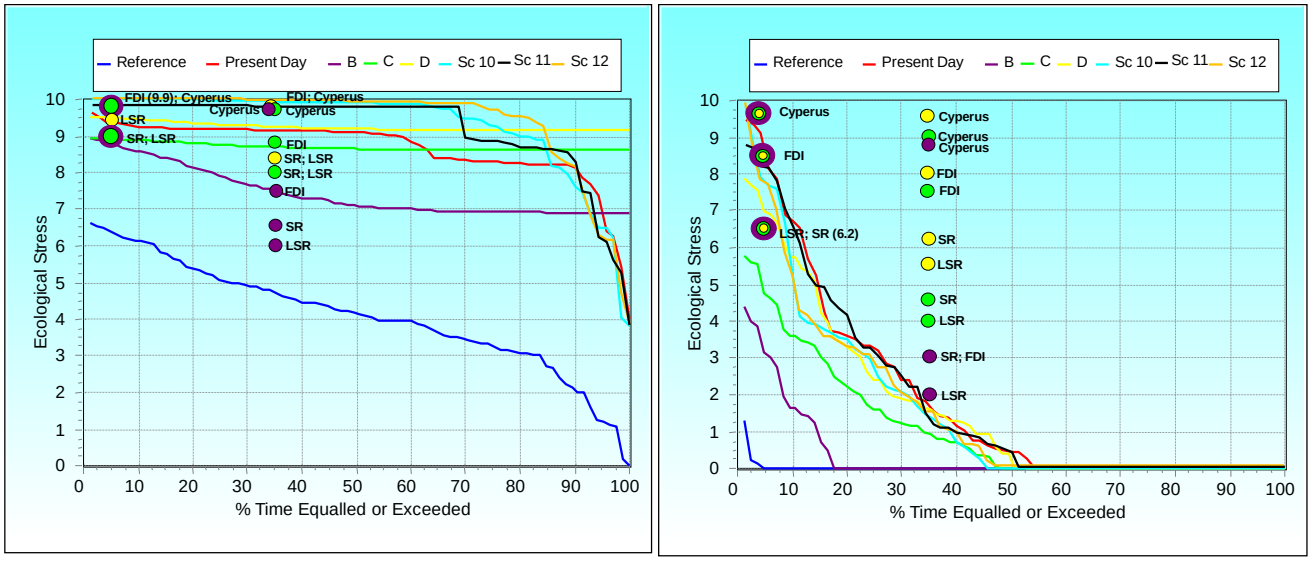


Figure 8–6 Stress duration for EWR 6: Dry and Wet season, Sc C10, Sc C11 and Sc C12

8.12 ECOLOGICAL CONSEQUENCES: SCENARIO C10, C11, AND C12

8.12.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc C10	
PHYSICO-CHEMICAL				
C	B	D	D/E	Very low flows during most of the dry season will cause extreme water quality problems. Increases in toxics and temperature, and a drop in oxygen level with impact directly on biota, while increases in filamentous algae will impact on habitat availability. Wet season flows are similar to PD hydrology. Overall conditions are expected to drop to a D/E category, i.e. 67.8% to 39.28%, despite wet season flows being similar to PD.
GEOMORPHOLOGY				
C	C	C/D	C	Lower dry season flows will not have a large geomorphological impact. Fines will settle more than currently, but this is not unusual for the dry season. The slightly increased wet season base flows will marginally improve instream conditions and result in slightly deeper channels and pools. Incision and channel narrowing has occurred at the site in response to stabilised flows. The reduced dry season and slightly increased wet season flows will increase sediment scour and result in a small improvement in condition of the in-channel habitats.

8.12.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc C10	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	D/E	There is severe reduction (80%) in flow volumes for the 30 percentile at the peak of the wet dry season (Oct) when compared to PD. This translates into a very significant decrease in inundation depths (26 cm) for *P. mauritianus* (from 38 to 12 cm) and *C. marginatus* (from 4 cm to 2 cm above the inundated zone) when compared to PD. The vigour and reproductive success (both sexual and vegetative) of both these species and other marginal and lower riparian zone species is likely to decrease significantly. Furthermore, the available surface area of suitable habitat will also decrease significantly, and migration of the marginal species will in many cases not be possible as a result of large areas of the channel which comprise bedrock. The recharge of sediment bars will in many cases no longer occur as they are perched on bedrock. This desiccation of sediment bars will affect not only *Phragmites* and *Cyperus* but also *F. capreifolia, B. salicina* and other marginal and lower riparian zone species. A significant decrease in species richness as well as increased terrestrialisation and alien plant invasion are expected.	There is a small (10%) increase in flow volumes for the 30 percentile at the peak of the wet Season (Feb) when compared to PD. This small flow increase translates into a very slight increase (3 cm) in inundation depths for *P. mauritianus* (from 76 to 79 cm) and *C marginatus* (from 42 to 45 cm) when compared to PD. It is therefore expected that no significant changes to habitat quality and quantity will occur for *Phragmites*, *Cyperus* and other marginal and lower riparian zone species.
A deterioration of the PES (from C to D/E) occurs when using the VEGRAI.					
FISH					
C	B	D	D	Significant fewer flows (increased stress) than natural, PES, REC and AEC flows will result in deterioration in habitat conditions for fish during the dry season. During the wet season flows, and thus habitat suitability for fish, will be varied compared to PES, REC and PD (For LSR the trend is similar to the REC). Different life stage requirements will not be met during the dry season but during the wet season flows will be good to optimal for all life stages due to acceptable maintenance flows. Overall condition for fish will however change for the FRAI from a C (74.7%) to a D (48.5%) as a result of the poor conditions during the dry season.	
MACROINVERTEBRATES					
C	B	D	D	The water quality is likely to deteriorate to a D/E category with increased temperatures and decreased dissolved oxygen concentrations. The increased nutrients coupled to the lower flows are likely to cause a proliferation in the amount of filamentous algae, thus seriously reducing the amount of habitat available to the macroinvertebrates. The changes in habitat and water quality are likely to lead to the loss of Simuliidae, Hydropsychidae, 1 sp of Baetidae, Elmidae and Libellulidae. The FROC of Muscidae is likely to increase while the FROC of Ceratopogonidae, Turbellaria, Hydroptilidae, Leptoceridae and Gomphidae are likely to increase. These conditions might also lead to a dominance of the exotic Thiaridae already present at the site. The MIRAI score will probably deteriorate from the present state of 74.9% (C category) to DE category of 39.3%.	
ECOSTATUS					
C	B	D	D	The sever conditions during the dry season impact on the biota resulting in a D EC for the instream component. This coupled with the deterioration in water quality and riparian vegetation will lead to an overall deterioration in the EcoStatus to a D.	

8.13 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 6 are provided in Table 8.1.

Table 8.1 Ecological consequences of operational flow scenarios at EWR 6

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. The degree to which each scenario at EWR 6 meets the REC is summarised in Figure 8-7 below.

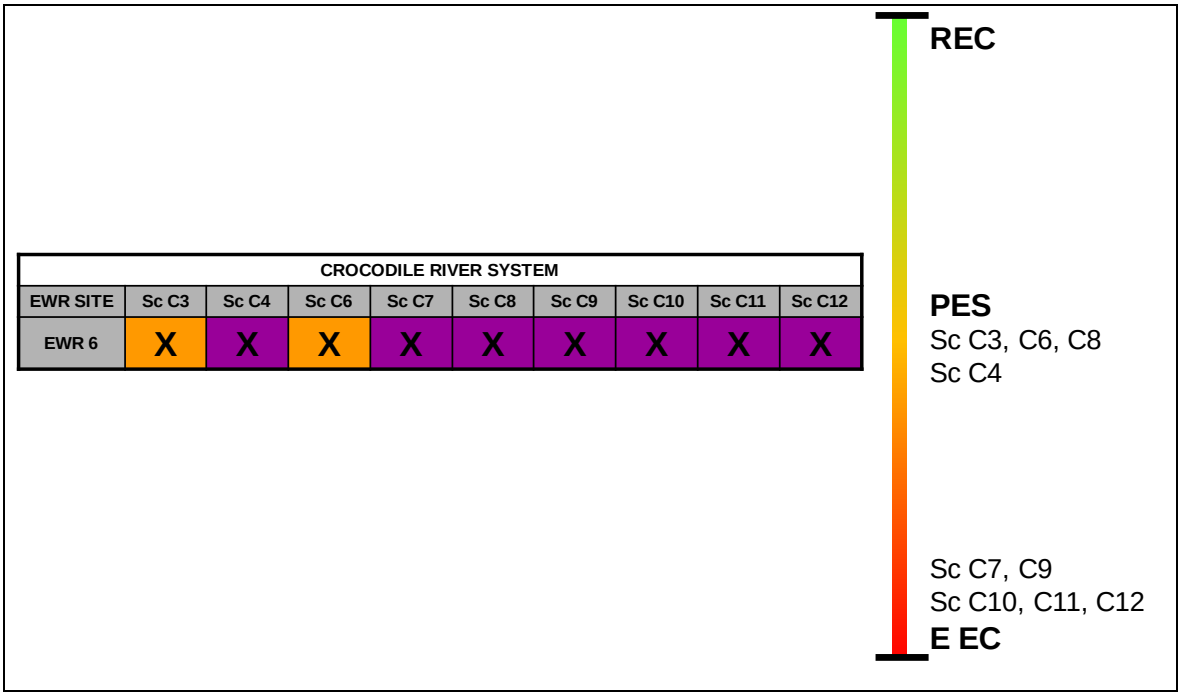


Figure 8–7 Summary of the impacts of operational flow scenarios at EWR 6

9 EWR 7: HONEYBIRD (KAAP RIVER) - ECOLOGICAL CONSEQUENCES

9.1 IMPACT OF SCENARIO C8

The stress and flow duration graphs indicated that Sc C8 and C9 were sufficiently similar to be addressed as one. Scenario C8 includes the proposed Mountain View Dam on the Kaap River and is situated just downstream of EWR 7. The modelling includes the removal of the yield from the dam at a flat rate. Figure 8-1 illustrates the stress requirements and stress points required for a B REC (purple line), C PES (green line) and D AEC (yellow line) and Sc C8 is represented by the black line. During the dry season zero flow conditions occur for more than 90% of the time while wet season zero flows occurs for approximately 75% of the time.

DRY SEASON **WET SEASON**

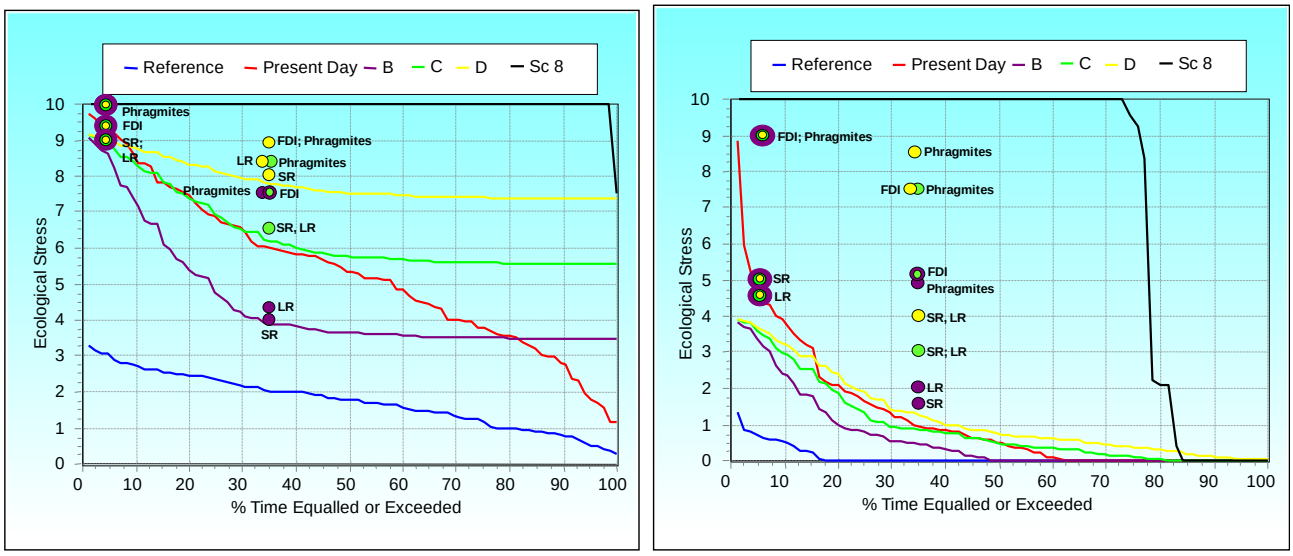


Figure 9–1 Stress duration for EWR 7: Dry and Wet season, Sc C8

9.2 ECOLOGICAL CONSEQUENCES: SCENARIO C8

9.2.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc C8	
PHYSICO-CHEMICAL				
C	B	D	E	There are only intermittent spills during the wet season, so very few flushing flows will occur. Impacts on water quality would be extreme, particularly on temperature and oxygen levels in pools downstream of the dam. If thresholds on temperature and oxygen are imposed, the category would drop to an E category. If thresholds are not imposed, the water quality state would drop into a D category.
GEOMORPHOLOGY				
B	B	C	D	No flows in the dry season will lead to total loss of instream habitats. Only occasional small flows in the wet season will be present, resulting in accumulation of fines; absence of scouring of the cobbles and gravels; armouring of the bed; encroachment by vegetation (riparian and terrestrial) and stablilisation of bars and terraces. The resultant river channel morphology and in-channel processes and available habitat will be significantly different from the current condition. This will drop the EC by two Ecological Categories (from the current B to a low D).

9.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc C8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C/D	B/C	D	E/F	There is very severe reduction (100%) in flow volumes for the 30 percentile at the peak of the dry season (Oct) when compared to PD. This severe flow reduction translates into a very significant decrease in inundation depths for *P. mauritianus* (from 18 cm below water level to 14 cm above the PD inundation zone) and *Salix mucronata* (from 44 cm to 76 cm above the inundated zone) when compared to PD. The vigour and reproductive success (both sexual and vegetative) of both these species and other marginal and lower riparian zone species is likely to decrease very significantly and loss of *S. mucronata* may be total. Furthermore, the available surface area of suitable habitat will also decrease significantly, and migration of the marginal species will in many cases not be possible as a result of large areas of the channel which comprise bedrock. Furthermore, recharge of sediment bars will in many cases no longer occur as they are perched on bedrock. This desiccation of sediment bars will affect not only *Phragmites* and *S. mucronata* but also *Syzigium cordatum, Ficus sycamorous* and, *Ischaemum fasiculatum* and other marginal and lower riparian zone species.	There is very severe reduction (100%) in flow volumes for the 30 percentile at the peak of the dry season (Oct) when compared to PD, and there is therefore no flow. This absence of flow translates into a very significant decrease in inundation depths for *P. mauritianus* (from 41 cm below water level to 14 cm above the PD inundation zone) and *S. mucronata* (from 21 cm to 76 cm above the PD inundated zone). These severe drought conditions will occur during the peak growing and reproductive season. The vigour and reproductive success (both sexual and vegetative) of both *Phragmites* and *Salix*, as well as other marginal and lower riparian zone species is likely to decrease very significantly and loss of *S. mucronata* is likely to be total. Furthermore, the available surface area of suitable habitat will also decrease drastically, and migration of the marginal species will in many cases not be possible as a result of large areas of the channel which comprise bedrock. Furthermore, recharge of sediment bars will in many cases no longer occur as they are perched on bedrock. This desiccation of sediment bars will affect not only *Phragmites* and *S. mucronata* but also *B. salicina, S. cordatum, F. sycamorous* and, *I. fasiculatum* and other marginal and lower riparian zone species.
During the dry season a significant decrease in species richness within the marginal and lower zones is expected. Alien invasion is likely to increase very significantly in the lower zone. During the wet season significant decrease in species richness within the marginal and lower zones is expected. Alien invasion is likely to increase very significantly in the lower zone. *Arundo donax* infestations have already severely degraded the lower zone at this site, and this species to likely to benefit from reduced base flows and flooding frequency. A deterioration of the PES (from C/D to E/F) occurs when using the VEGRAI.					
FISH					
C	B	D	E	Flows will be significantly lower than natural, PD, PES, REC and AEC flows. Habitat suitability will be poor to very poor and have a critical impact on the condition of the fish assemblage. The FFHA model indicates that the SR and LSR guilds will fall in a category F during this scenario	Flows will be significantly lower than Natural, PD, PES, REC and AEC flows. Habitat suitability will be poor to very poor and have a critical impact on the condition of the fish assemblage. The FFHA model indicates that the SR and LSR guilds will fall in a category F.
This scenario will result in critical stress on fish due to reduced habitat suitability (poor to very poor) during most months. The high occurrence of zero flows, even in wet season, will especially have devastating effect on the fish assemblages. The FRAI indicated that the PES will fall from a category C (76%) to a category E (24.4%).					
MACROINVERTEBRATES					
C	B	D	F	There is no flow at the site for virtually the whole of the dry season and most of the wet season. This means that it is likely that only hot stagnant, saline pools will remain. It is likely to result in the loss of all flow and water quality sensitive taxa with only highly tolerant taxa surviving in the pools. The macroinvertebrates will deteriorate from the present B status of an 83.6% MIRAI score to a F category with a MIRAI score of 16.1%	
ECOSTATUS					
C	B	D	E/F	The long periods of zero flow will have devastating impact on the site. All biotic components deteriorate to an E – F category. Water quality is also severely impacted resulting in an EcoStatus of E/F which is unacceptable.	

9.3 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 7 are provided in Table 9.1.

Table 9.1 Summary of ecological consequences of flow scenarios at EWR 7

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. The degree to which each scenario at EWR 7 meets the REC is summarised in Figure 8-2 below.

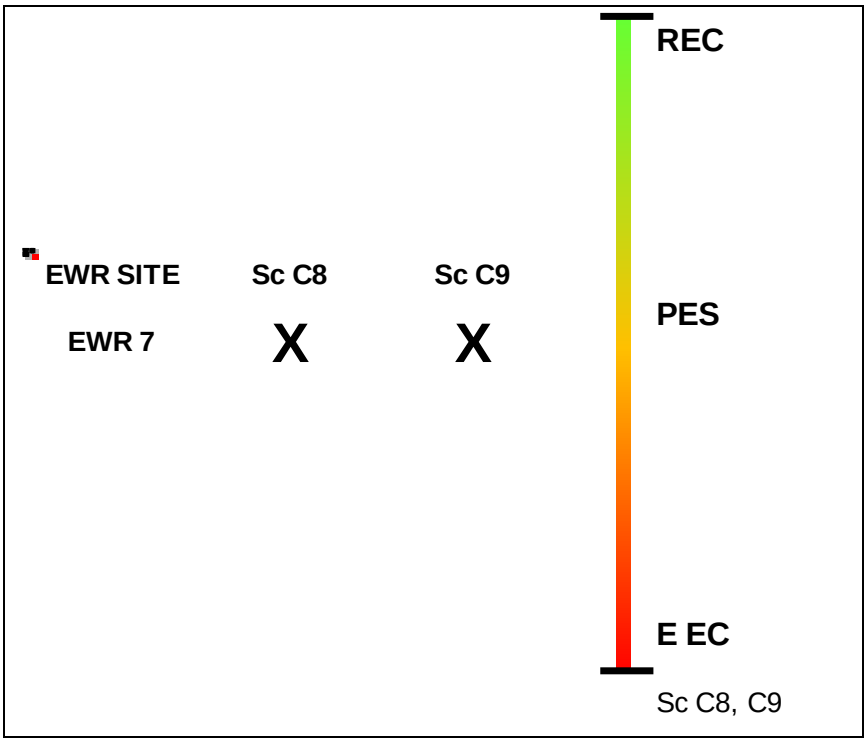


Figure 9–2 Summary of the impacts of operational flow scenarios at EWR 7

10 CONCLUSIONS: CROCODILE RIVER SYSTEM

10.1 SUMMARY OF RESULTS

10.1.1 Ecological consequences of irrigation restriction scenarios (including decreasing flows to supply EWR 3)

Table 10.1 provides a summary of the results at each EWR site. The key to the table is on the fold-out A3 page (Section 2.6). An overall assessment was undertaken to compare the scenarios that consist of different levels of irrigation restrictions as well as Sc C10 and C12 that represents decreased flow requirements to meet the PES and REC EWR at EWR 3.

The overall evaluation usually reflects the site evaluation 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.

Table 10.1 Summary of the consequences of the operational scenarios (Sc C3, C4, C6, C10 - C 12) at each EWR site

EWR SITE	Sc C3	Sc C4	Sc C6	Sc C10	Sc C11	Sc C12
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

Within a system context none of the scenarios meet the REC at any of the EWR sites. The PES is 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 are not met and was ranked below the PES in Figure 10-1. Scenario C10 – C12 resulted in a deterioration of the PES EcoStatus.

The results provided in Table 10.1 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 10-1). 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. For example, a scenario where the REC is achieved for two components, e.g. fish and vegetation, would be better and ranked higher on the scale than where only one component has met the REC.

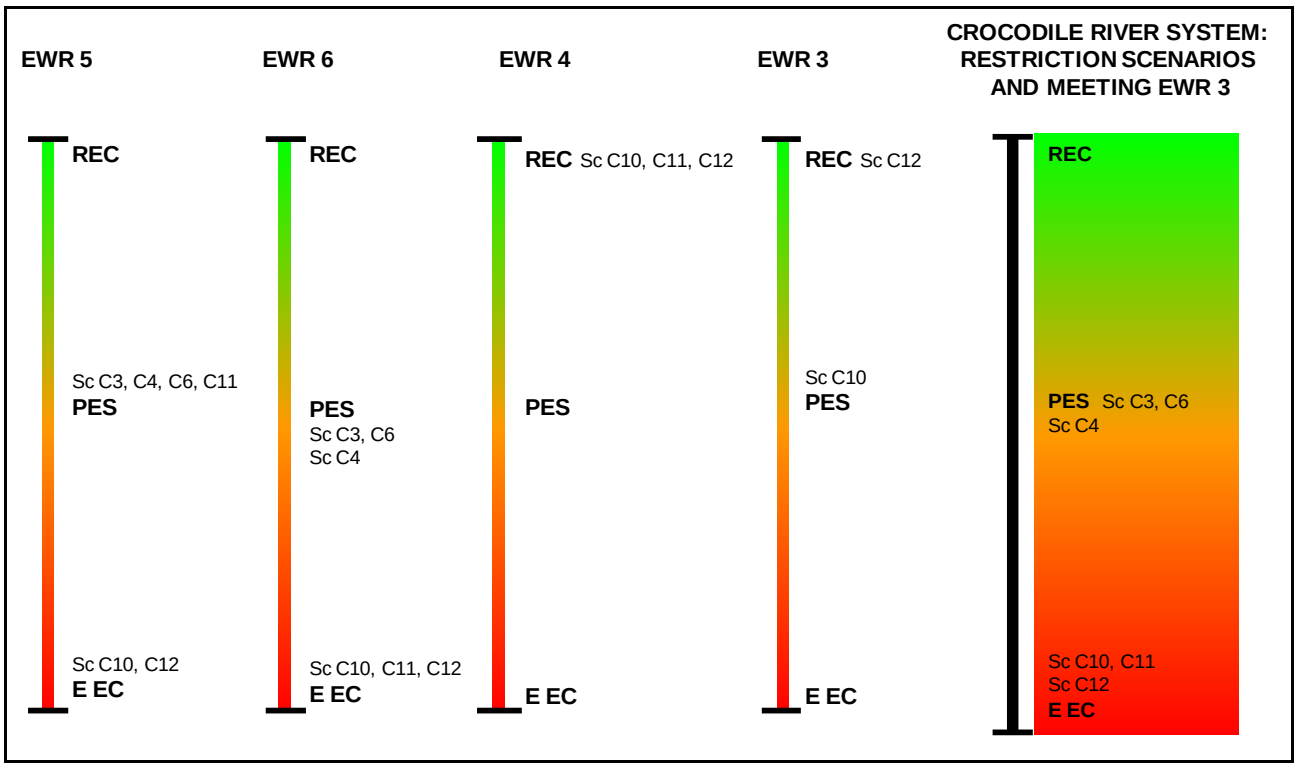


Figure 10–1 Ranking of operational scenarios per EWR site and a summarised ranking in terms of a traffic diagram

10.1.2 Ecological consequences of development (new dam) scenarios

These scenarios were not evaluated in detail as each dam and combination will require a whole range of different operating rules for useful comparison. These simplified and probably unlikely operating scenarios are compared in Table 10.2 and Figure 10-2. For further explanation, refer to Section 10.1.1 above.

Table 10.2 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 maintains the PES EcoStatus but does not maintain the riparian vegetation and geomorphology PES. Scenario C8 was therefore ranked lower than the PES (Figure 10-2) 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.

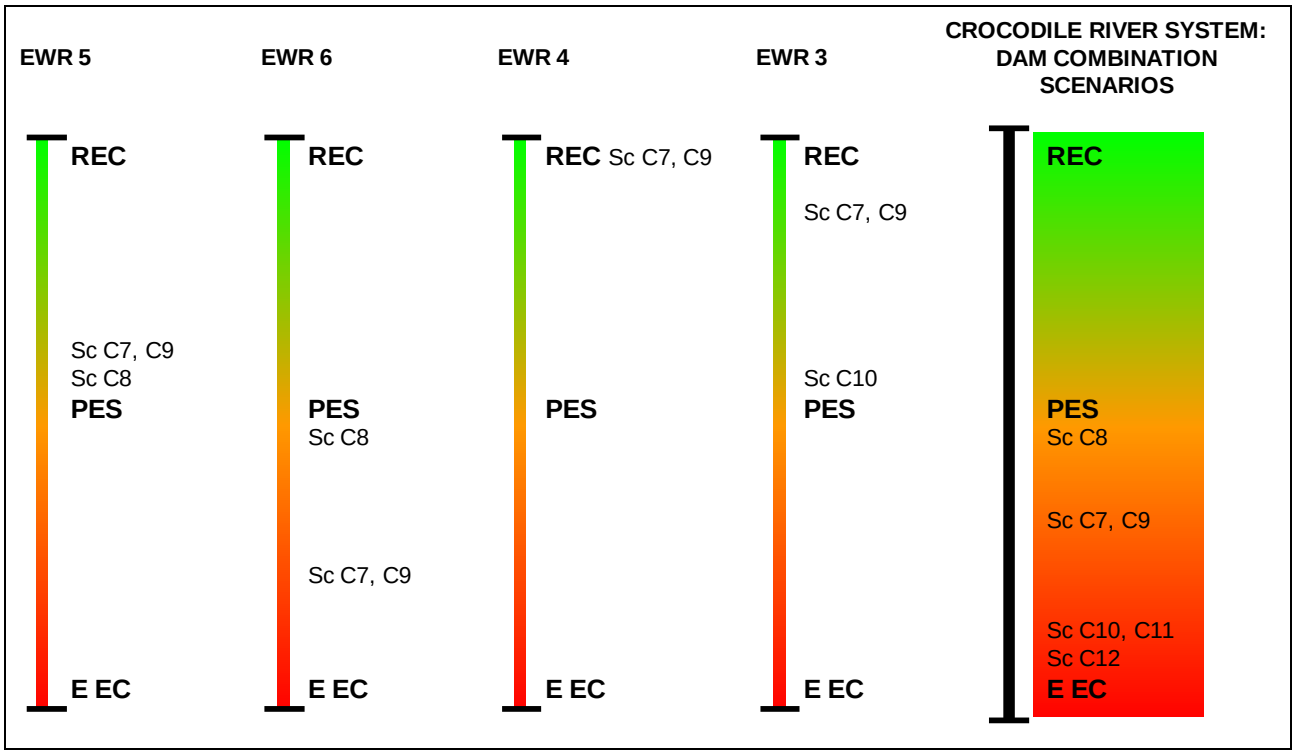


Figure 10–2 Ranking of future (dam) development scenarios

10.2 ADDITIONAL SCENARIOS EVALUATED AT EWR 6

Two optimised scenarios were developed for additional screening, Sc C3.1 and Sc C6.1. Both were evaluated at EWR 6 as the key site. These scenarios are described in Volume 1 of this report series. The ecological consequences of Sc C3.1 and C6.1 at EWR 6 are provided in Table 10.3.

Table 10.3 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
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

Scenario C6.1 achieves the REC and Sc C3.1 improved the PES (Table 10.3). The degree to which Sc C3.1 and C6.1 met the REC at EWR 6 is summarised in Figure 10-3 below.

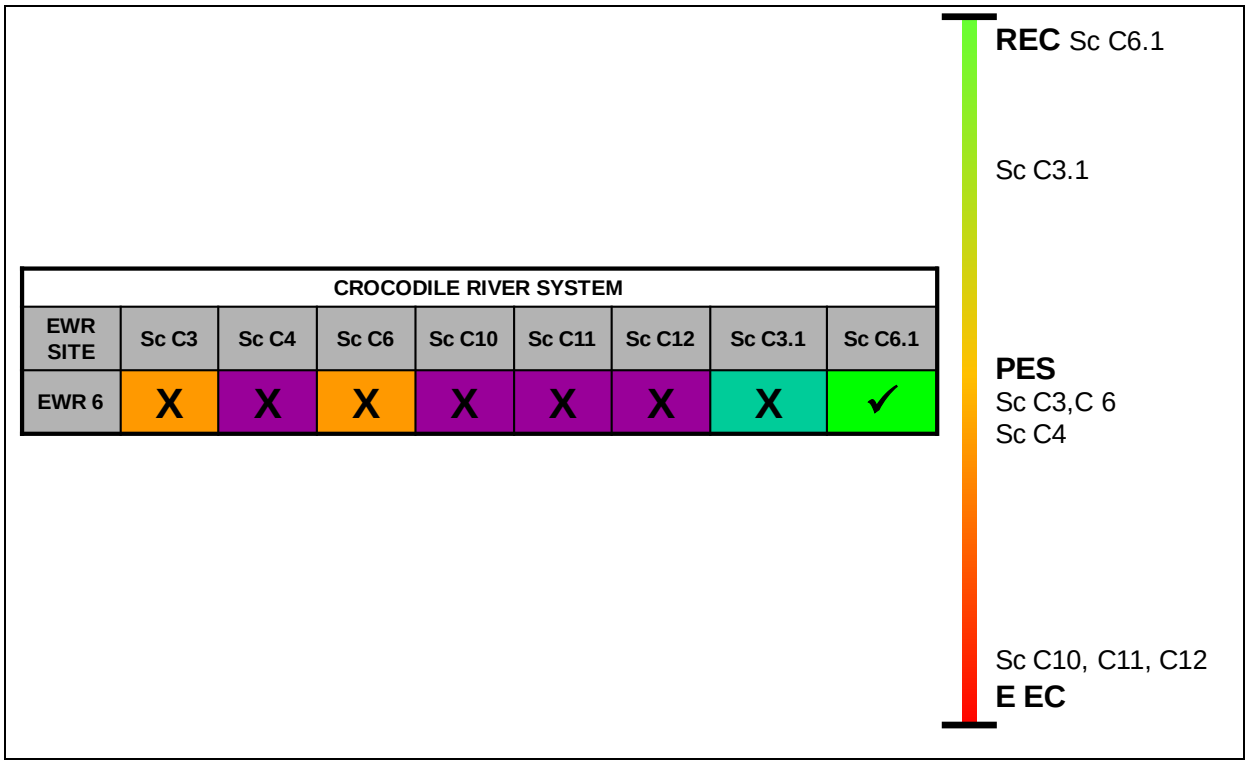


Figure 10–3 Summary of the impacts of Sc C3.1 and Sc C6.1 at EWR 6

11 EWR 3: KIDNEY (SABIE RIVER) - ECOLOGICAL CONSEQUENCES

All the scenarios include increased releases from Inyaka Dam for irrigation. This results increased flows at EWR 5 and decreased flows at EWR 3. Flows however, appear to be similar or higher than PD for almost all the scenarios in October (key dry month). Due to the pattern of irrigation used in the yield model, the flows of some scenarios are significantly lower however in July (Droughts) and August (Maintenance). It was therefore important that these months were also considered as the key stress months. Therefore Jul, Aug and Oct were assessed but the stress duration graphs for October only were provided.

11.1 IMPACT OF SCENARIO 5

Figure 11-1 illustrates the stress requirements and stress points required for a B/C PES (green line) and A/B REC (purple line). The red line illustrates Present Day flows while the blue line represents reference flows. Sc 5 (yellow line) represents slightly improved flows from PD in the dry season and less flow than PD in the wet season, with most of the stress requirements lying between the PES and REC.

DRY SEASON **WET SEASON**

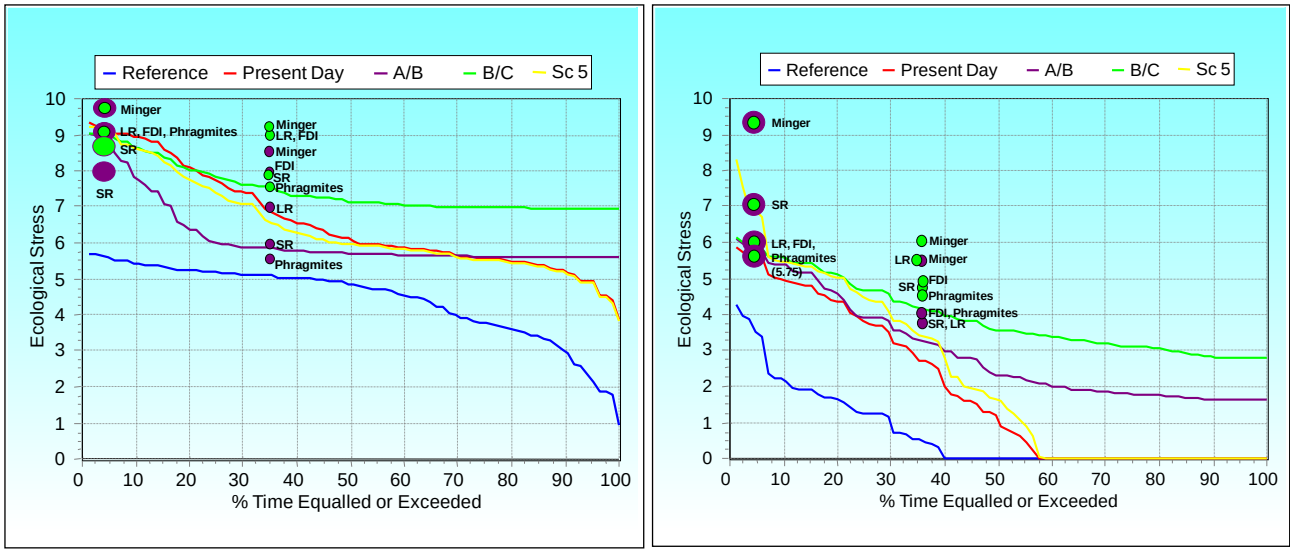


Figure 11–1 Stress duration for EWR 3: Dry and Wet season, Sc 5

11.2 ECOLOGICAL CONSEQUENCES: SCENARIO 5

11.2.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc 5	
PHYSICO-CHEMICAL				
B	B	C	B	Decreased flows during July, together with an anticipated increase in urban activities, may cause a small increase in nutrients. No significant change expected during the wet season. Increased irrigation and restrictions between EWR 3 and 5 will result in less of the additional flow releases from Inyaka Dam reaching EWR 5.
GEOMORPHOLOGY				
B	B	C	B/C	The large reductions in low flows will cause some increased in-channel fines. These conditions could reduce the number of active channels which would reduce habitat availability and diversity. However this is not expected to cause gross morphological change as the site is highly resistant to change. During wet season there will be a small reduction in Class III floods (60 - 80 m^3/s) and large reduction in the size/frequency of Class I (25 m^3/s)

EC				COMMENT
PES	REC	AEC→	Sc 5	
				floods. However this is not expected to have a major impact on channel processes or morphology because the effective discharges are represented by far larger floods which are largely unchanged, and the site is highly resistant to morphological change (because of the bedrock controls). A minor change from a B to a B/C is expected.

11.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 5	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
A/B	A/B	B/C	B	Most scenarios have higher flows than present day in Oct, but in Jun, Jul and sometimes Aug flows are lower. Differences between scenario flows and what was specified for the PES differ more noticeably for maintenance base flows (30%), but less so under drought conditions (5%).	A slight reduction in smaller class floods, which are important for recruitment opportunities on the marginal and lower zones. The chance of reduced small floods is not likely to alter the EC of this site. It will merely retard a natural trend towards increased woody vegetation in the marginal and lower zones. The upper zone has historically been predominantly terrestrial and will remain in this state.
Dry season flow conditions are likely to add to survival stress of vegetation components, especially since the seasonality of lowest flows is brought forward in the season. This will not adversely affect recruitment opportunities or fecundity since the timing is still within the winter months, but some mortality of existing juveniles is expected. A slight reduction in marginal and lower zone vegetation cover and abundance reduces the PES to B (86.8%).					
FISH					
B	B	C	B	Compared to the natural hydrology, there will be less flow available all months of the year with a resultant overall decrease in EC. The FFHA model indicates that the SR indicator guild will decrease an EC from the PES for the month of Jul and Aug, emphasizing the decreased habitat suitability that can be expected during this month. There is however no change in the PES (B EC - 82.8%).	
MACROINVERTEBRATES					
B	B	C	C	During Jul and Aug droughts, low and very low flows result in a loss of depth and velocity, and significant loss of critical flow habitat. Cobble areas are reduced in extent due to loss of flow and increased sedimentation, and marginal vegetation reduced in extent as a habitat due to exposure of stems and shoots. These changes will lead to a decrease in presence and abundance of sensitive indicator taxa, with their critical life stages potentially non-viable, and those of some of the less sensitive taxa at risk. During the wet season drought period, small reductions in depth and velocity will have the effect of reducing abundances of those macroinvertebrates with a preference for moderate and high velocities, and for marginal vegetation.	
ECOSTATUS					
A/B	A/B	B/C	B	There is deterioration in geomorphology, macroinvertebrates and riparian vegetation. Due to the impact on these components the instream EC deteriorated with a half a category and the ecological objectives at this site are not met.	

11.3 IMPACT OF SCENARIO 6

Scenario 6 is represented by the black line in Figure 11-2. Dry season flows are virtually similar to PD while wet season flows are decreased drastically during the drought period (up to 5% exceedence).

DRY SEASON **WET SEASON**

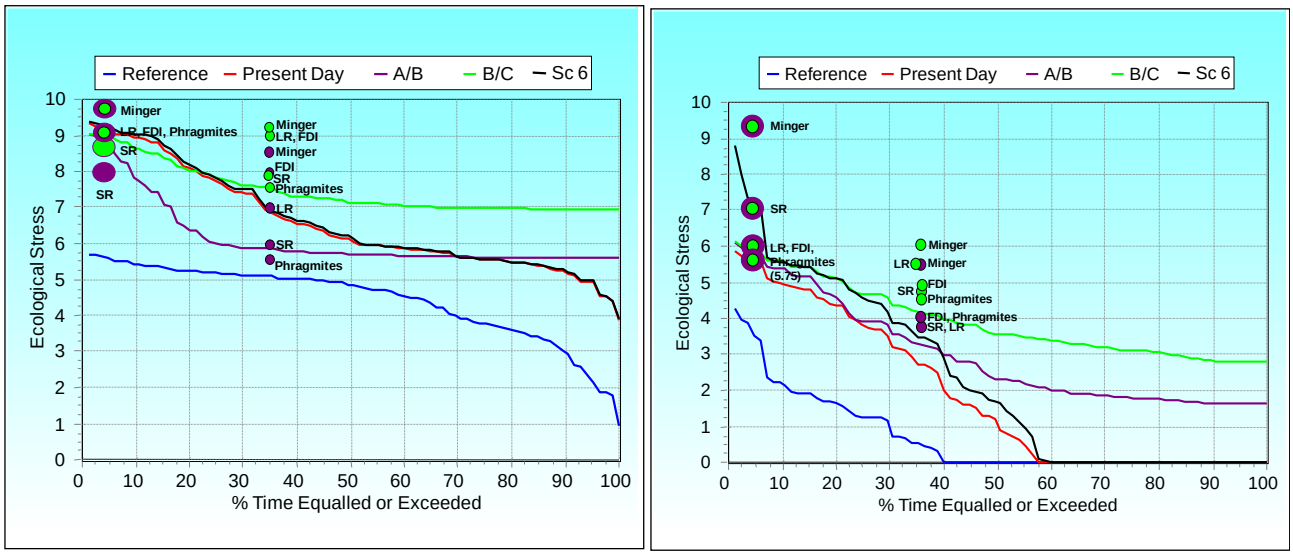


Figure 11–2 Stress duration for EWR 3: Dry and Wet season, Sc 6

11.4 ECOLOGICAL CONSEQUENCES: SCENARIO 6

11.4.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc 6	
PHYSICO-CHEMICAL				
B	B	C	C	Scenario 6 has substantially lower flows over the Nov – Jan, and lower flows over winter, i.e. Jun to Aug, with concomitant impacts on water quality. Lower flows during the dry season will result in an increase in nutrient levels and fluctuations in temperature and oxygen levels. A slight increase in toxicant levels may be expected due to an anticipated increase in urban activities and lower dilution flows. During wet season lower flows will be experienced under this scenario.
GEOMORPHOLOGY				
B	B	C	B/C	Same as for Sc 5.

11.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 6	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
A/B	A/B	B/C	B	Refer to Sc 5.	
FISH					
B	B	C	B/C	Based on the month of Oct flows and stress will be very similar to the present hydrology and no change in the present EC is expected.	The wet season month (Feb) will have lower flows than natural and present hydrology (FFHA category for SR and LR in the wet season, based on hydrology will decrease from C under present hydrology to D under Scenario 6). The flows for Scenario 6 however still fall within the ranges of drought (5%) and maintenance (35%) flows recommended to maintain the PES during the wet season (Feb).
There will be less flow available all months of the year under Scenario 6, with a resultant overall decrease in EC. The Jul flows indicated that under drought conditions all fast habitats will be lost, which can be expected to have a significant impact on the SR guild at this site. The velocity should however be just adequate to allow survival of the SR guild in these critical habitats, although they will be highly stressed. SR should be able to recover once conditions improve again after the drought. The overall impact on abundance and cover during these periods may result in a decrease in the PES from a B (85.6%) to a B/C (79.7%).					
MACROINVERTEBRATES					

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 6	DRY SEASON	WET SEASON
B	B	C	C	Refer to Scenario 5.	
ECOSTATUS					
A/B	A/B	B/C	B	There is a deterioration in all the components resulting in a B EcoStatus. The PES and REC is therefore not being met.	

11.5 IMPACT OF SCENARIO 7

Scenario 7 is represented by the light blue line in Figure 11-3. Dry season flows are an improvement from the PD. Wet season drought stress is more than all the requirements set but for the rest of the time Sc 7 lies between the REC and AEC.

DRY SEASON **WET SEASON**

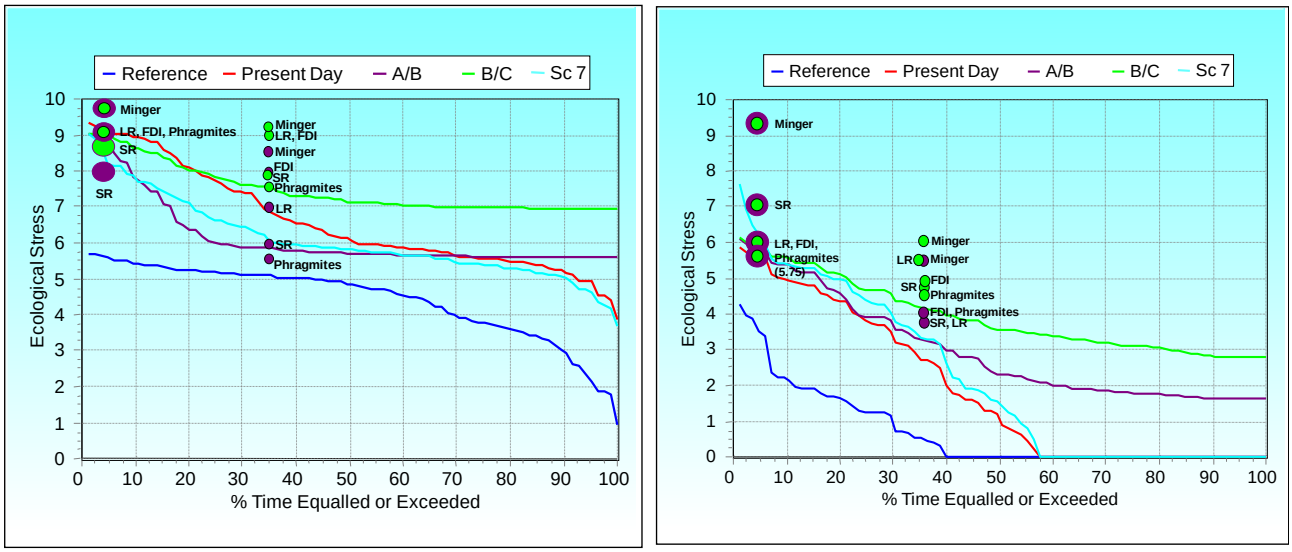


Figure 11–3 Stress duration for EWR 3: Dry and Wet season, Sc 7

11.6 ECOLOGICAL CONSEQUENCES: SCENARIO 7

11.6.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc 7	
PHYSICO-CHEMICAL				
B	B	C	B	Refer to Sc 5.
GEOMORPHOLOGY				
B	B	C	B	Lower flows occur and therefore a minor increase in fines in the channel during the dry season can be expected. No large morphological change is expected at the site due to the steep, fast flowing confined nature of the active channels (transport potential >> sediment supply). During wet season there will be a small reduction in Class III floods (60 - 80 m^3/s) and large reduction in the size/frequency of Class I (25 m^3/s) floods. However this is not expected to have a major impact on channel processes or morphology because the effective discharges are represented by far larger floods which are largely unchanged, and the site is highly resistant to morphological change (because of the bedrock controls). The sandy (braided and pool-rapid) reaches between large bedrock anastomosing reaches may be more negatively affected due to increased sediment storage and reduction in channel size and depth. However, little gross morphological change is expected since the effective discharges remain largely unimpacted.

11.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↘	Sc 7	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
A/B	A/B	B/C	A/B	The impacts are similar to Sc 5 although not as severe and the EC remains in an A/B.	
FISH					
B	B	C	B	Flows and stress under Scenario 7 will be very similar to the present hydrology and little change in the present EC is expected.	Lower flows than natural and present hydrology, but will be very similar to the flows recommended to maintain the PES, and should therefore not result in any significant changes from the PES.
MACROINVERTEBRATES					
B	B	C	C	During dry season the flow varies slightly within the dry months with some decrease in Jul droughts and a slight increase for the months of Aug and Oct droughts, but does not show much variation in flow as the maximum depth, velocity and wetted perimeters remains more or less the same. The resulting overall slight increase in flow will probably affect the abundances of cobble dwelling macroinvertebrates. In wet season there is an indication of a slight decline in flow during the drought of wet season. During these times there is an indication of a decrease in hydraulic parameters but very minimal. Flow seems to recover again during maintenance with flow, depths, velocities and wetted perimeters being the same as the PES conditions	
ECOSTATUS					
A/B	A/B	B/C	B	There is a deterioration in macroinvertebrates that results in the deterioration of the instream EC with a half a category.	

11.7 IMPACT OF SCENARIO 8

Scenario 8, represented by the orange line in Figure 11-4 provides less stress than the REC requirements and PD in dry season while stress is similar to the REC requirements and PD during wet season for most of the time.

DRY SEASON **WET SEASON**

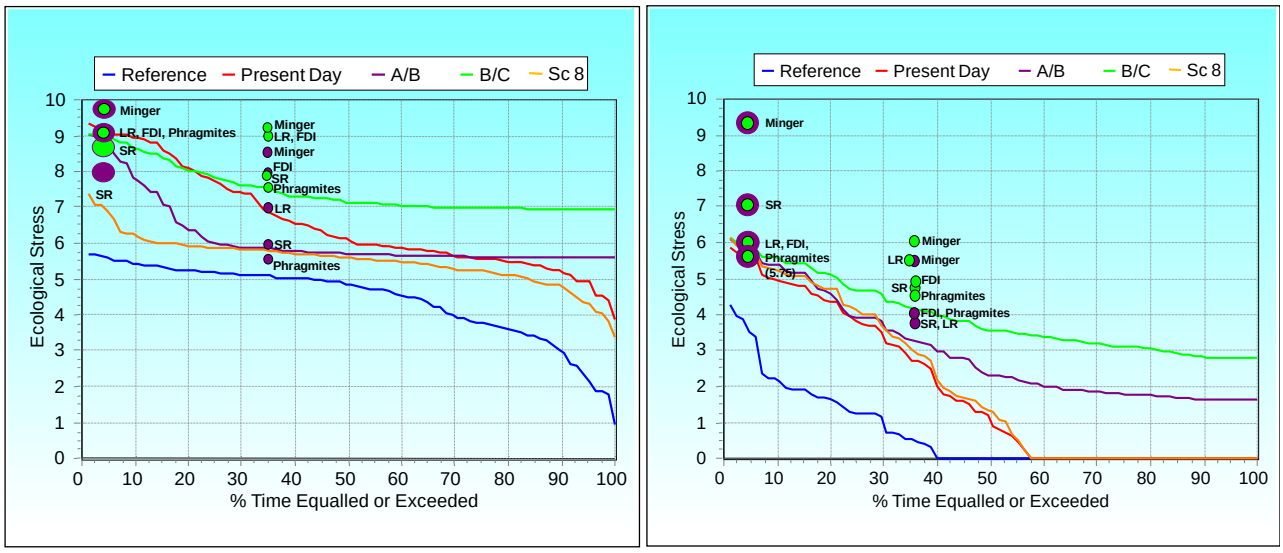


Figure 11–4 Stress duration for EWR 3: Dry and Wet season, Sc 8

11.8 ECOLOGICAL CONSEQUENCES: SCENARIO 8

11.8.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc 8	
PHYSICO-CHEMICAL				
B	B	C	B	Refer to Scenario 5.
GEOMORPHOLOGY				
B	B	C	B	No change from the PD is expected and therefore the EC is the same as for the PES.

11.8.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
A/B	A/B	B/C	A/B	The impacts are similar to Sc 5 although not as severe and the EC remains in an A/B.	
FISH					
B	B	C	B	During the dry season (Jul), the maintenance flows and stress will be similar to the present hydrology and no change in the present EC is expected. A reduction of drought flows from the recommended 1.4 m^3/s to maintain the PES to 0.8 m^3/s under Sc 8 is of some concern. The fast flowing habitats during this period however seem to still be adequate to maintain the integrity of the small rheophilic fish species for the period and a decrease in the EC should not occur.	The wet season will have lower flows than natural and present hydrology, but will be very similar to the flows recommended to maintain the PES, and should therefore not result in any significant changes from the PES.
MACROINVERTEBRATES					
B	B	C	B	During dry season drought periods, the macroinvertebrate stress is between 6 and 7, which signifies no change from the B EC in Oct but a slight change in Jul and Aug (lowest flow months) in terms of the disappearance of some very fast flow biotopes. This may impact slightly on the viability and abundance of sensitive indicator taxa. During wet season maintenance the macroinvertebrate stress is 3, compared to the macroinvertebrate stress of 4 under PES conditions which signifies an improvement. This improvement relates to a slight increase in stream width, depth and velocity which results in more fast and very fast biotopes and less very slow and slow biotopes. An increase in the fast flow habitat may favour certain sensitive indicator taxa, but not to such an extent to increase the B EC.	
ECOSTATUS					
A/B	A/B	B/C	A/B	The scenario does not impact on any of the components and therefore the EcoStatus for the PES and REC is maintained.	

11.9 IMPACT OF SCENARIO 9

Scenario 9 is represented by the yellow line in Figure 11-5. During dry season Sc 9 lies mostly between the A/B and B/C requirements while wet season stress increases during drought periods and similar to PD for the rest of the time.

DRY SEASON **WET SEASON**

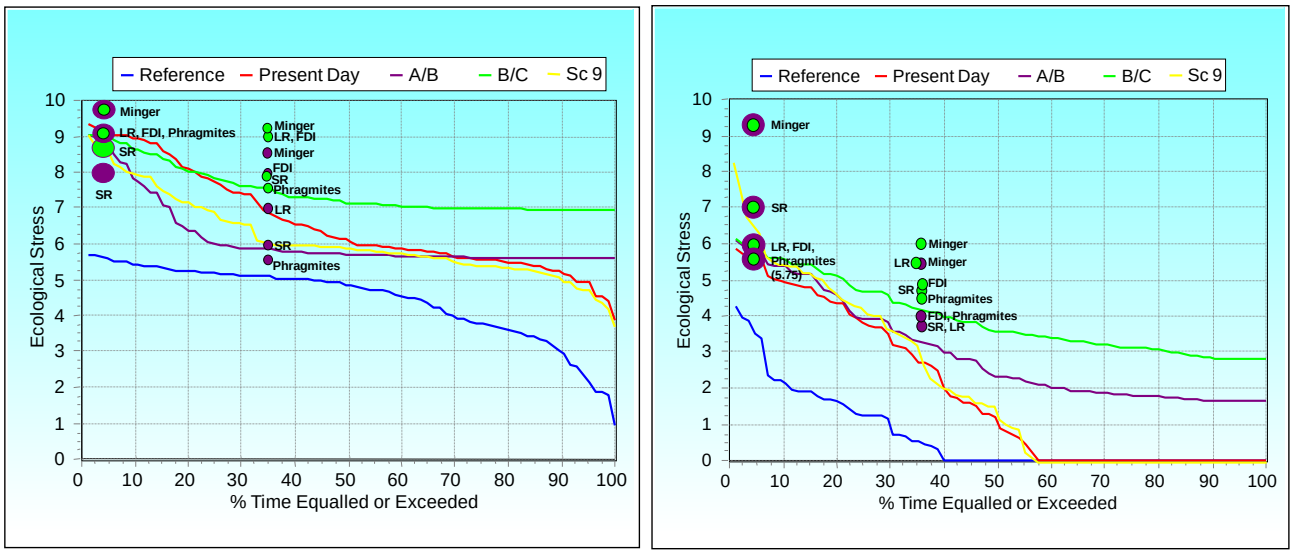


Figure 11–5 Stress duration for EWR 3: Dry and Wet season, Sc 9

11.10 ECOLOGICAL CONSEQUENCES: SCENARIO 9

11.10.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc 9	
PHYSICO-CHEMICAL				
B	B	C	B	No significant change from the PES is expected.
GEOMORPHOLOGY				
B	B	C	B	Refer to Sc 7.

11.10.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc 9	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
A/B	A/B	B/C	B	Refer to Sc 5.	
FISH					
B	B	C	B/C	There will be some increased stress in some months which can be expected to reduce breeding success, nursery habitats and overall abundance of especially rheophilic species. The PES reduces from a B (85.6%) to a B/C (81.7%) category.	
MACROINVERTEBRATES					
B	B	C	B/C	The decrease in habitat during the dry season is likely to affect the cobble dwelling taxa with decreased abundances and FROC of those taxa preferring fast and very fast flows over coarse substrates (VFCS) (e.g. Hydropsychidae, Simuliidae, Perlidae, Elmidae and Heptageniidae). Some of the more sensitive vegetation-dwelling taxa such as Pyralidae and Helodidae may be lost from the system. There is an absence of VFCS in the wet season in the most severe drought conditions (2% exceedence) that might affect those very sensitive taxa preferring very fast velocities. These conditions are likely to occur only very infrequently and for relatively short periods which will still allow those highly sensitive taxa to remain in the system.	
ECOSTATUS					
A/B	A/B	B/C	B	Fish and macroinvertebrates are impacted under this scenario resulting in a deteriorated instream condition and an overall EcoStatus of a B which does not meet the ecological requirements of the site.	

11.11 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 3 are provided in Table 11.1.

Table 11.1 Ecological consequences of operational flow scenarios at EWR 3

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 a A/B EcoStatus. The rest of the scenarios all result in a B EcoStatus which is lower than the PES and REC requirements. The degree to which each scenario at EWR 3 meets the PES and REC is summarised in Figure 11-4 below.

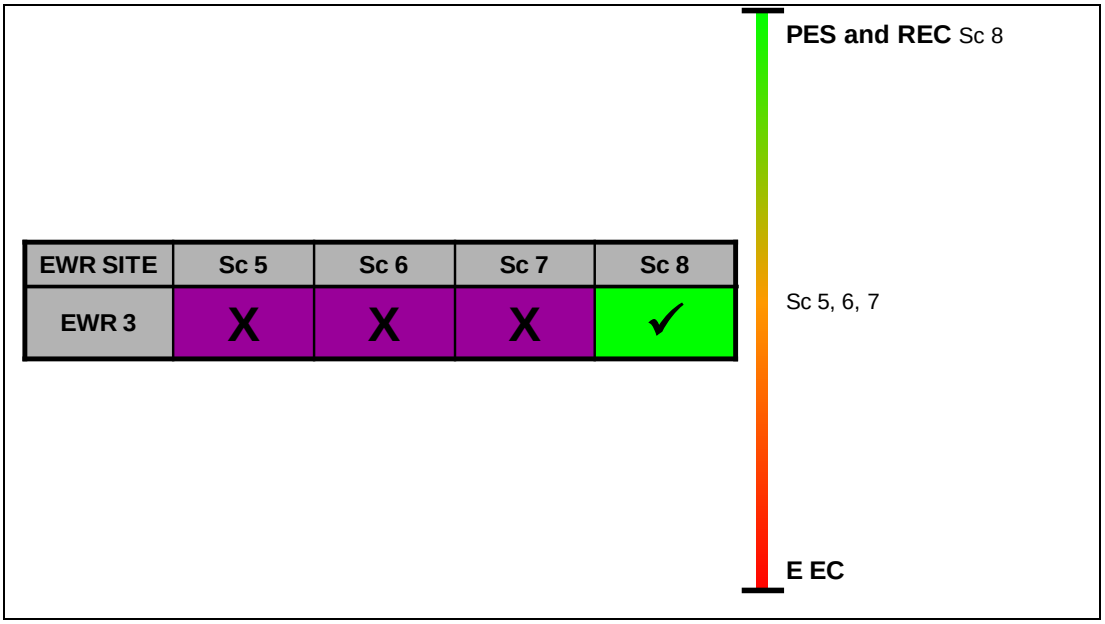


Figure 11–6 Summary of the impacts of operational flow scenarios at EWR 3

12 EWR 5: MARITE (MARITE RIVER) - ECOLOGICAL CONSEQUENCES

All the scenarios include increased releases from Inyaka Dam which will have the following consequences:

- Base flow releases which are currently high will be higher than natural and constant.
- Less floods will occur as Inyaka Dam levels will be lower than present, i.e. less spills..

Main issues considered during the scenario evaluation were:

- The impact of constant base flow.
- The impact of base flows higher than natural.
- The impact of lack of seasonal diversity.
- The impact of seasonal abnormalities (Oct and Sept drought flows etc. are much higher than the other months).
- The impact of decreased floods.

12.1 IMPACT OF SCENARIO 5 - 8

The stress and flow duration graphs indicated that Sc 5, 6, 7 and 8 are sufficiently similar to be addressed as one. Figure 12-1 illustrates the stress requirements and stress points required for a B REC (purple line), B/C PES (green line) and C/D REC (yellow line). The red line illustrates Present Day flows while the blue line represents reference flows. Scenario 5 (black line) is lying beneath Sc 6 (light blue line) while Sc 7 (orange line) represents Sc 8 as well.

DRY SEASON **WET SEASON**

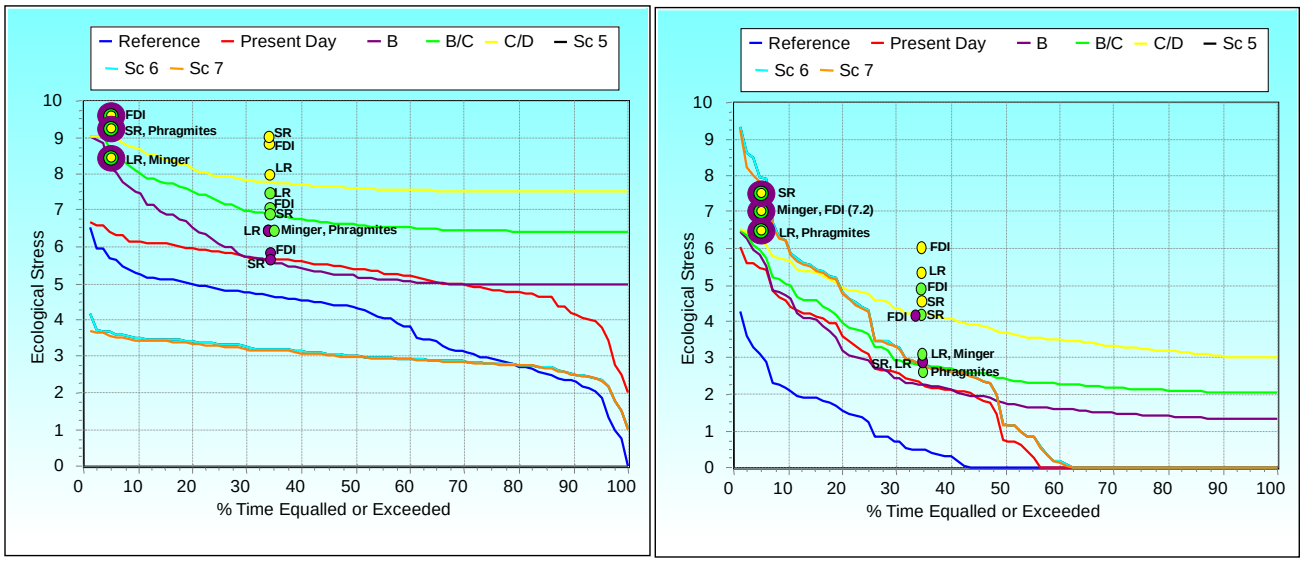


Figure 12–1 Stress duration for EWR 5: Dry and Wet season, Sc 5 – 8

Under these scenarios there is a significant reduction in floods. Figure 12.2 illustrates the spills (monthly) at Inyaka Dam under the scenarios (blue line) compared to the daily observed flows. The figure demonstrates that during a period of 20 years, there will only be three spills from Inyaka Dam.

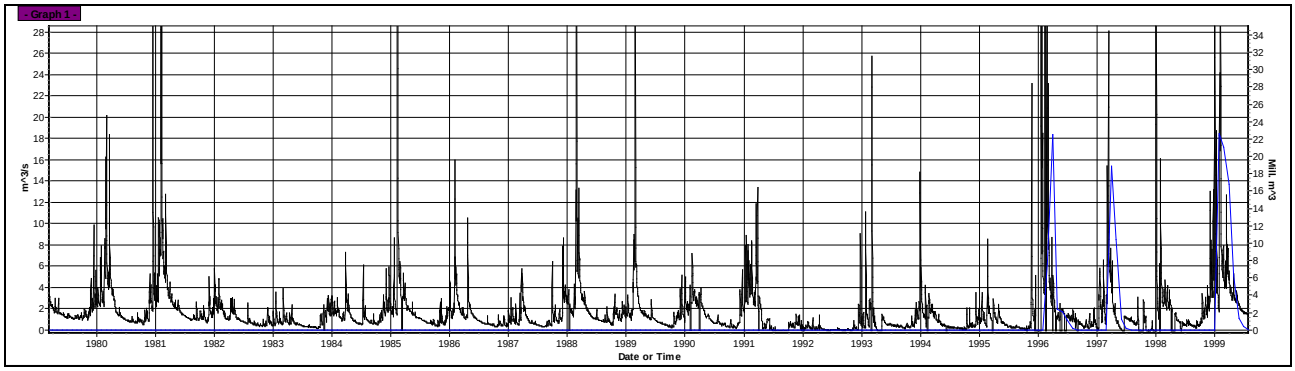


Figure 12–2 Monthly spills of Nyaka Dam under scenarios 5 - 8

12.2 ECOLOGICAL CONSEQUENCES: SCENARIO 5 - 8

12.2.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc 5-8	
PHYSICO-CHEMICAL				
B	B	C	B	Higher base flows than present will flush out any build-up of nutrients during the dry season. Lower flows and no spills coming from Inyaka Dam during the wet season may impact on oxygen and temperature levels. Flows are lower for about 6 months of the year, but substantially elevated in Aug - Oct. Although higher base flows provide dilution capacity, fewer spills from Inyaka Dam will have a small impact on the instream water quality habitat.
GEOMORPHOLOGY				
C	C	D	D	Elevated dry season flows will promote channel narrowing and possible limited incision during dry season. There will be significantly decreased floods (due to constant draw-down of the dam to supply irrigation farmers). No channel widening can occur in the absence of floods, which will result in limited bed scour resulting in accumulation of sands. The channel will narrow (encroachment is no longer reset by frequent floods) and probably slightly shallow due to accumulated sands. The effective discharge flow class (the annual and intra-annual floods responsible for most of the sediment transport) now occur far less frequently, so sediment transport is reduced, but sediment input it still high from the granitic, semi-arid catchment. Channel morphology at the site and within the reach is relatively resistant to change due to bedrock controls.

12.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc 5-8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
B/C	B	C/D	C/D	The change to dry season flows resulted in a slight change in the VEGRAI score because elevated flows in the dry season (Sep and Oct mainly) will improve reed cover and abundance in the marginal zone. This reduces the EC from 80.4% to 79%, but remains a B/C. This is because the additional water improves vegetation survival and vigour in the marginal and to a lesser extent the lower zone (especially lower portions). Reduction of floods is drastic, however, with Class I to V floods being absent altogether for up to 8 to 12 years at a time. Loss of Class III to V floods will severely reduce survival of riparian vegetation on the lower and upper zones and remove recruitment opportunities. Recruitment will therefore be dependent on rainfall events. Riparian vegetation cover and abundance will thus reduce and be lost to terrestrial vegetation over time, but existing adults will persist. Loss of Class I and II floods means the marginal zone and lower portions of the lower zone will not get inundated. Both reeds and woody riparian vegetation are likely to increase in density in the absence of flooding disturbance, and marginal zone is likely to be reduced to a vigorous band along the base flow level (the band being a mix of reeds (sand) and marginal zone trees (bedrock). Overall the EC drops from PES of 80.4% (B/C) to 59.3% (C/D).	
FISH					
B/C	B	C/D	C	Although the flows in the wet season are less than natural, the critical habitats of the indicator taxa will still be available, albeit in slightly reduced abundance. Some increase stress may result in a slight reduction in FROC of some of the fish species with preference for the fast habitats. The stress exerted during the wet season will result in a slight decrease in EC (from PES of 77.9% - B/C) to a C – 73%. This is primarily attributed to the reduced habitat suitability and availability for fish with a preference for fast habitats, which will be reduced. The impact of reduced seasonal variability and decreased flooding regime may contribute to the decreased EC.	

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc 5-8	DRY SEASON	WET SEASON
MACROINVERTEBRATES					
B/C	B	C	C	During the dry season inundation of vegetation increases and depth of inundation will increase. The additional area for attachment (reeds) is likely to encourage simuliids, and certain baetid and hydropsychid species. Depending on the degree of dominance, this may cause a reduction in cobble-dwelling taxa (e.g. Heptageniidae, Psephenidae, and Perlidae). Potential compromise of juvenile taxa during a critical hatching period, due to high velocities (although there will be some vegetation cover in the inner marginal vegetation zone). This could threaten summer recruitment of the macroinvertebrate community. During drought periods in the wet season, the low discharge is associated with reduced depths and low velocities, as well as a loss in connectivity. Water quality deteriorates as a result of high temperature, and low oxygen. Significant loss of flow habitat and inundated vegetation. During these periods it is likely that the more sensitive elements of the community, as well as a portion of the midsummer juvenile taxa will be reduced in abundance or eliminated altogether (depending on drought duration). The loss of floods will have the long-term effect of embedding substrates. This will result in a net increase in sedimentation of cobble and boulder habitat, and a loss of surface area for cobble-dwelling macroinvertebrates. The cumulative effect of the dry season and wet season changes is reflected in the C EC (71%).	
ECOSTATUS					
B/C	B	C/D	C	There is a deterioration in all components except physico-chemical variables. This results in a deterioration in the instream conditions and the EcoStatus.	

12.3 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 5 are provided in Table 12.1.

Table 12.1 Ecological consequences of operational flow scenarios at EWR 5

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. The degree to which each scenario at EWR 5 meets the PES and REC is summarised in Figure 12-3 below.

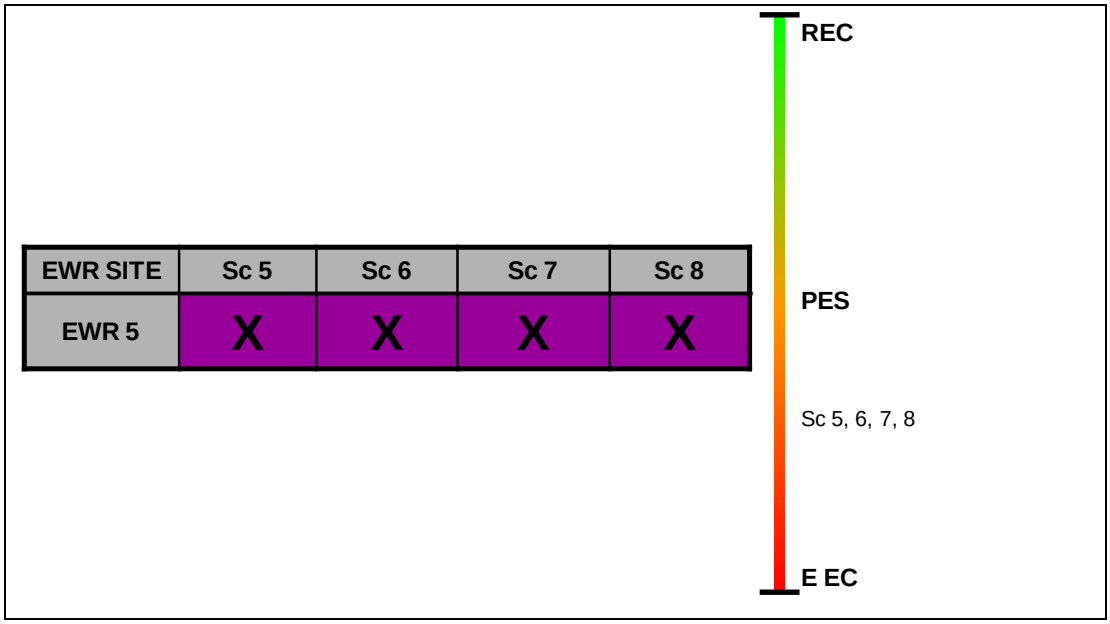


Figure 12–3 Summary of the impacts of operational flow scenarios at EWR 5

13 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER) - ECOLOGICAL CONSEQUENCES

The Sand River scenarios were based on the assumption that the four abstraction weirs in the Upper Sand would be rehabilitated, thus improving the flow downstream (refer to Volume 1 in this report series). Scenario 1 (referred to the Sellick rule) therefore is based on a portion of this water being allowed to flow past abstraction points down the river. Scenario 5 and 9 consists of simulated flows that include combinations of weir improvement, and different levels of curtailment and restrictions.

NOTE: The hydrology provided for the Sand River catchment was extremely unreliable due to the lack of gauges and information on the system. Only one gauge in the lower Sand River was functional and the operation of local small weirs, dams and irrigation canals was also not clear. This resulted in the hydrology being changed based on some anecdotal information, and some of it after the EWR workshop, resulting in many EWRs having to be re-evaluated. The assessment of scenarios is based on the adjusted hydrology.

13.1 IMPACT OF SCENARIO 1

Figure 13-1 illustrates the stress requirements and stress points required for a C PES (yellow line), B REC (green line) and C/D AEC (black line). The red line illustrates Present Day flows while the blue line represents reference flows and the purple line the new modelled Present Day flows. Sc 1 (light blue line) is lying between the PES and AEC requirements for most of the time with decreased stress during dry season drought but overall representing improved flows from the new PD. During the wet season the stress is more than the C/D requirements for up to 28% of the time after which it is very similar to the new modelled PD.

DRY SEASON **WET SEASON**

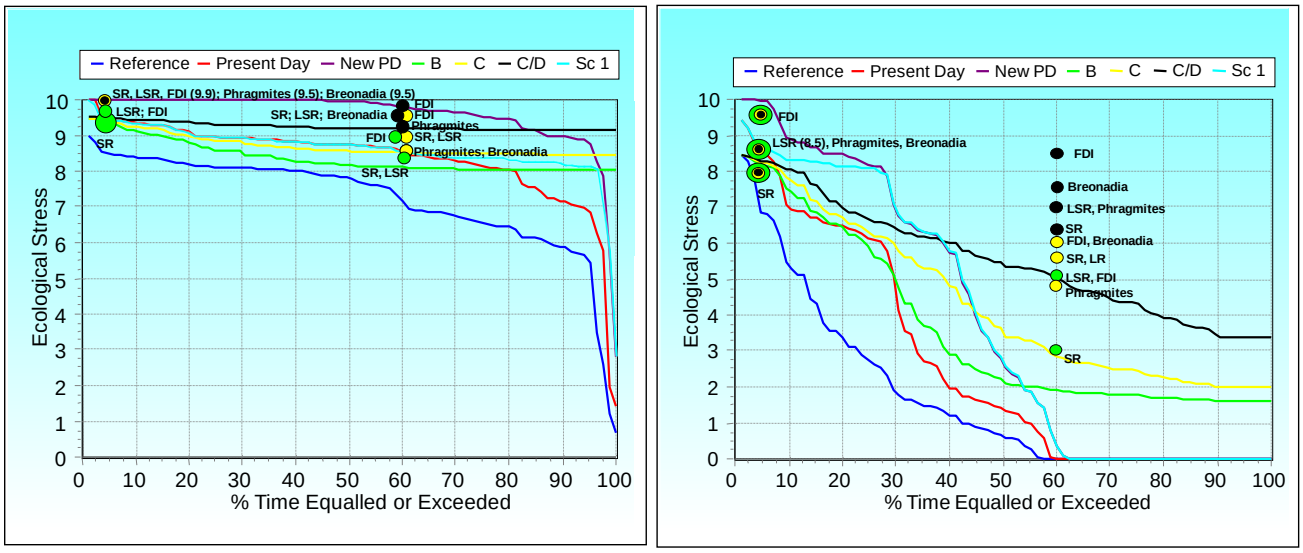


Figure 13–1 Stress duration for EWR 6: Dry and Wet season, Sc 1

13.2 ECOLOGICAL CONSEQUENCES: SCENARIO 1

13.2.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc 1	
PHYSICO-CHEMICAL				
B/C	B	C/D	B/C	No significant change is expected.
GEOMORPHOLOGY				
C	C	D	C	Base flows are strongly elevated during dry season, creating a larger, wider and deeper channel. During wet season there is no change in floods from PD conditions, but base flows are strongly elevated. These flows will result in improved marginal vegetation and marginal zone (the low flow actives the channel bank) stability as well as scouring of fines from the bed. This will have no impact on the overall geomorphology condition since the site is bedrock controlled.

13.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 1	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	C	No change from the PES	
FISH					
C	B	D	B/C	Compared to the PD hydrology, there will be more flow available all months of the year, with a resultant overall increase in EC from a C (69,2%) to B/C (78,5%).	
MACROINVERTEBRATES					
B/C	B	C	B	During drought conditions flows are more than the PES requirements and similar to the REC requirements. Maintenance flows are improved from the PES and REC requirements and the habitat will maintain current FDI taxa.	Drought conditions are less than the requirements set for the PES and REC, however during maintenance the flows are better than the PES and REC requirements. The increase in depth, discharge and velocities favours an overall improvement in macroinvertebrate habitat condition and abundance.
Increase in habitat will favour an increase in both presence and abundance of FDIs and MVIs for the majority of the wet season. An improvement in the macroinvertebrate PES from a B/C to a B is expected.					
ECOSTATUS					
C	B	C/D	B/C	The improvement in base flows benefit fish and macroinvertebrates resulting in an improvement of the PES for these components and a resulting EcoStatus improvement to a B/C	

13.3 IMPACT OF SCENARIO 5

Scenario 5 is represented by the orange line in Figure 13-2. Zero flow conditions prevail for approximately 15% of the time during dry season drought while stress is less than the C/D requirements up to 60% of the time after which the flows improve. Wet season drought stress is higher than any of the requirements set. Between 10% and 28% stress is similar to the C/D requirements and then steadily improves.

DRY SEASON **WET SEASON**

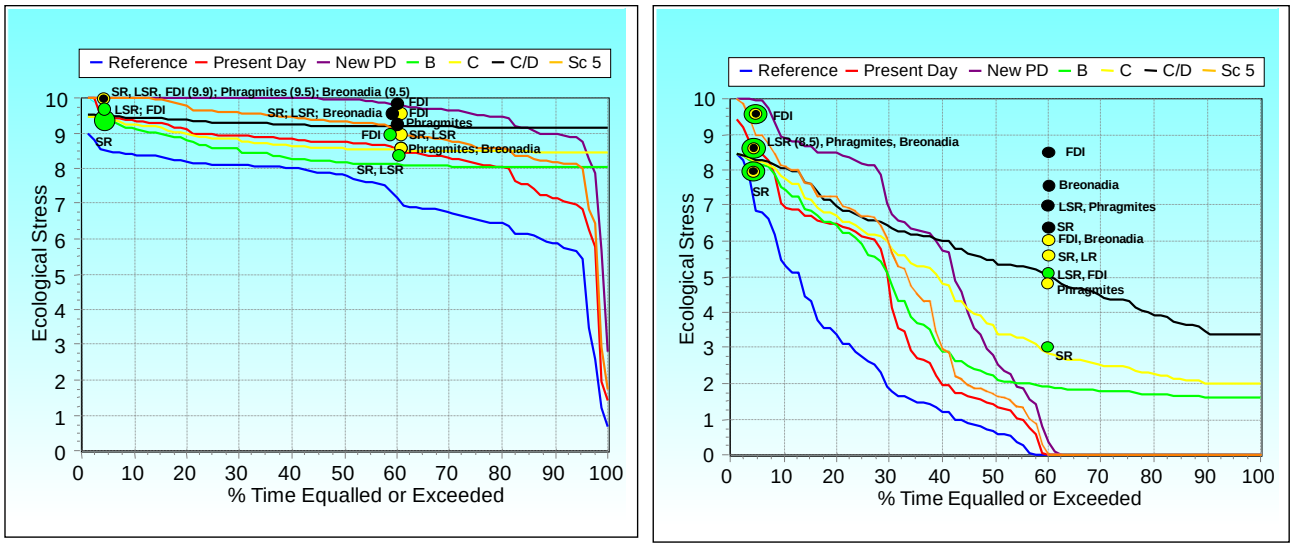


Figure 13–2 Stress duration for EWR 6: Dry and Wet season, Sc 5

13.4 ECOLOGICAL CONSEQUENCES: SCENARIO 5

13.4.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc 5	
PHYSICO-CHEMICAL				
B/C	B	C/D	C	Flows are significantly reduced compared to other scenarios in July – December, with concomitant impacts on temperature and oxygen levels in the dry season. Lower dilution flows will also result in slightly elevated salts and higher nutrient levels. Water quality will deteriorate to a C EC.
GEOMORPHOLOGY				
C	C	D	C	The scenario will have no impact on the overall geomorphology condition since the site is bedrock controlled.

13.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 5	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	C	*Phragmites mauritianus* remains slightly inundated on average, at dry season maintenance in all scenarios, but is likely to encroach on the active channel for Scenario 5. The change is small however, and EC changes from 75.5% (C) to 72.4 (C).	
FISH					
C	B	D	C	This situation will maintain the SR guild at this site. The overall impact on abundance and cover during these periods will result in a change in the overall PES (FRAI) of the site. The increase and duration in wet season flows will enhance fish migration, breeding and habitat integrity, while the improved low flows during the dry season (compared to the present day situation) will maintain their numbers and ensure that most of these fish survive in the shorter no flow period. This will improve the fish within the same EC (69.2% (PES) to 74.0% (Sc 5).	
MACROINVERTEBRATES					
B/C	B	C	C	The extended drought period may result in the loss of the more sensitive taxa. The reeds may encroach on the channel, and be inundated at shallower depths. This might also impact on the abundance of the marginal vegetation macroinvertebrates.	The water quality is likely to deteriorate to a C EC with deterioration in dissolved oxygen, temperature and nutrients. This might lead to a proliferation of algae impacting on the benthic habitat.
These changes results in the macroinvertebrates changing from a B/C category (MIRAI: 77.7%) to a C category (MIRAI: 72.9%).					
ECOSTATUS					

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 5	DRY SEASON	WET SEASON
C	B	C/D	C	The drop in invertebrates EC result in an Instream EC drop. The overall EcoStatus of a C is still maintained.	

13.5 IMPACT OF SCENARIO 9

Scenario 7 is represented by the light blue line in Figure 13-3. Dry season flows are an improvement from the PD. Wet season drought stress are more than all the requirements set but for the rest of the time Sc 7 stress lies between the REC and AEC.

DRY SEASON **WET SEASON**

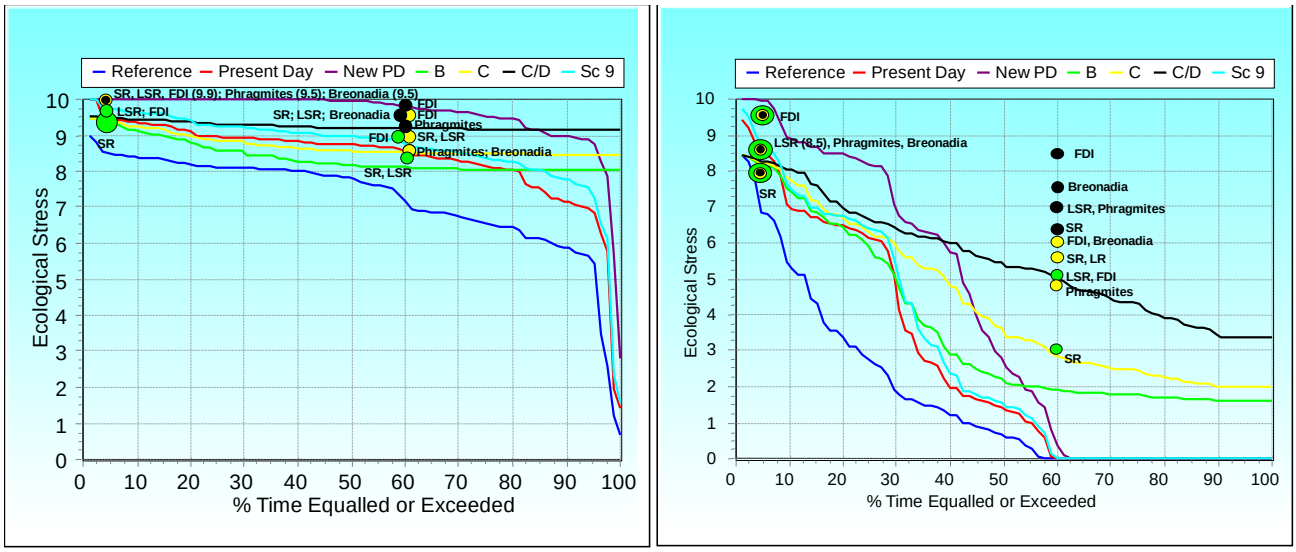


Figure 13–3 Stress duration for EWR 6: Dry and Wet season, Sc 9

13.6 ECOLOGICAL CONSEQUENCES: SCENARIO 9

13.6.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc 9	
PHYSICO-CHEMICAL				
B/C	B	C/D	B/C	Although increased flows occur during the wet and dry season, this is not significant enough to change the PES EC.
GEOMORPHOLOGY				
C	C	D	C	Bedrock controlled channel, therefore no change.

13.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc 9	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	C	Scenario 9 has slightly reduced flows than those specified in the PES, but does not result in a change to the PES.	
FISH					
C	B	D	C	An overall slight improvement can be expected as a result of the generally improved flows (compared to PD and recommended flows for maintenance of PES). This will primarily be attributed to improved cover for some species (vegetation and water column). The fish PES will remain in its current EC of a C, with a slight improvement within this EC (FRAI score increasing from 69% to 73.3%).	
MACROINVERTEBRATES					
B/C	B	C	B/C	During dry season zero flow periods are improved which results in improved velocities and the introduction of slow flow habitat.	Although flows are slightly less during drought conditions maintenance flows lie between the PES and REC requirements for 30% of the time and should sustain the macroinvertebrate community providing similar habitat than under PES conditions.
The macroinvertebrate condition improves from 77.7% to 80.1% which means it is still within the PES.					
ECOSTATUS					
C	B	C/D	C	All the components are similar to the PES with fish and macroinvertebrates slightly improving within the respective EC. Therefore Sc 9 meets the requirements of the PES but not the REC.	

13.7 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 6 are provided in Table 13.1.

Table 13.1 Ecological consequences of operational flow scenarios at EWR 6

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. The degree to which each scenario at EWR 6 meets the PES and REC is summarised in Figure 13-4 below.

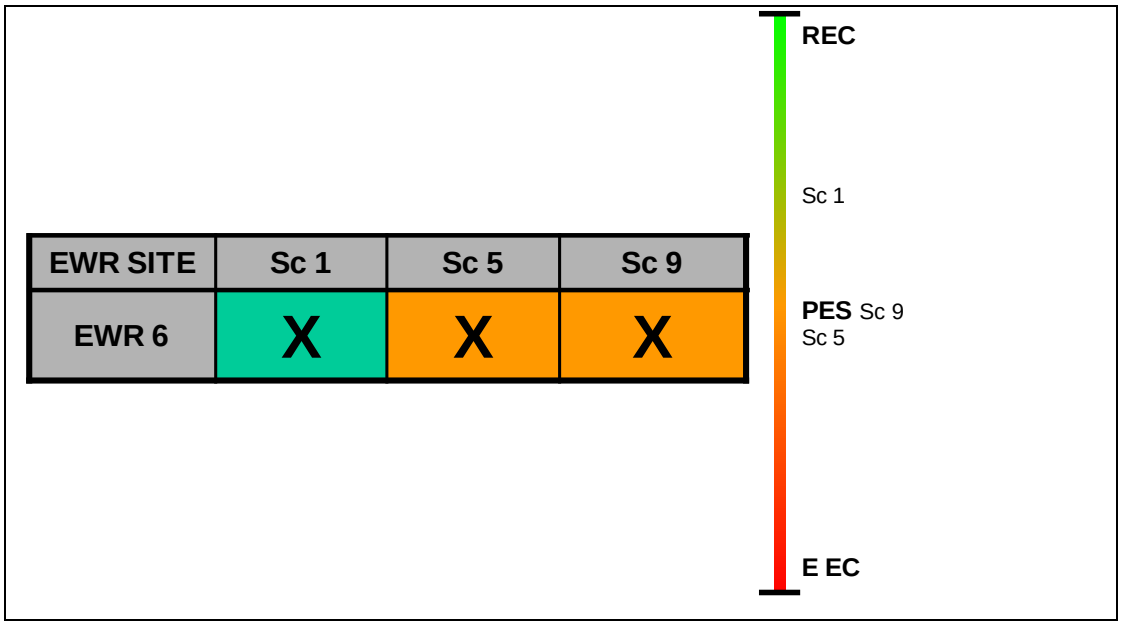


Figure 13–4 Summary of the impacts of operational flow scenarios at EWR 6

14 EWR 7: THLULANDZITEKA (THLULANDZITEKA RIVER) - ECOLOGICAL CONSEQUENCES

Refer to Chapter 13 for more detail regarding the scenarios.

14.1 IMPACT OF SCENARIO 1

Figure 14-1 illustrates the stress requirements and stress points required for a C PES (yellow line), B REC (green line) and D AEC (black line). The red line illustrates Present Day flows while the blue line represents reference flows and the purple line the new modelled Present Day flows. Sc 1 (light blue line) results in less stress than the PES, REC and AEC during dry and wet season.

DRY SEASON **WET SEASON**

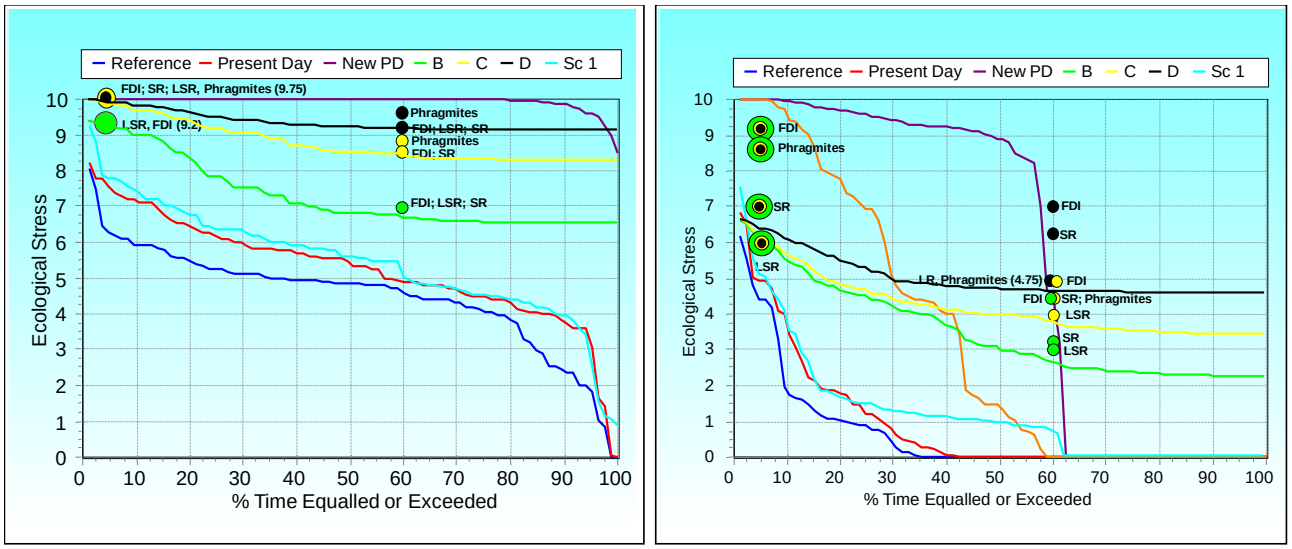


Figure 14–1 Stress duration for EWR 7: Dry and Wet season, Sc 1

14.2 ECOLOGICAL CONSEQUENCES: SCENARIO 1

14.2.1 Driver components

EC				COMMENT
PES & REC	AEC↑	AEC↓	Sc 1	
PHYSICO-CHEMICAL				
C	B	D	B/C	All flows are improved, resulting in an improvement in nutrient levels and instream temperature and oxygen conditions. Water quality state is therefore expected to improve to at least the AEC ↑ .
GEOMORPHOLOGY				
C/D	C	D	C	Base flows are strongly elevated during dry season and there is no change in floods from PD in the wet season. The channel would be larger, wider and deeper, and fines will be scoured from the active channel bed. Increased base flows will improve marginal vegetation and marginal zone (the low flow active channel bank) stability and scour fines from the bed. No change in gross morphology or EC is expected since the site is bedrock controlled. The main impact on geomorphology is the upstream catchment erosion, so the increased low flows will ameliorate this and the AEC ↑ will be achieved

14.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES & REC	AEC↑	AEC→	Sc 1	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B	The scenario is higher than the AEC ↑ requirement and it is expected that it will achieve the B EC.	
FISH					
C	B	D	B	This situation will improve the SR guild at this site. The overall impact on abundance and cover during these periods will result in a change in the overall PES. The increase and duration in all flows will enhance the overall fish integrity (compared to the present day situation) as the current low flows and no flow situations are alleviated. This improvement will result in a to a Category B (85.4%) (previously category C (65.4%)).	
MACROINVERTEBRATES					
B/C	B	C/D	B	During dry season drought conditions the flow requirements of the B EcoStatus are met. Improvement in MVI habitat and increased velocities will favour an increase in abundances of FDIs and MVIs from the B state. The B EcoStatus requirements are also met during maintenance periods and conditions favour an increase in abundance of the more sensitive FDI taxa. Maintenance wet season flows meet the B EcoStatus requirement as well and conditions are likely improved due to the increase in depth of inundation, and in flow habitat.	
ECOSTATUS					
C	B	D	B	All the biological responses achieve the AEC ↑ and the EcoStatus is therefore a B.	

14.3 IMPACT OF SCENARIO 5

Scenario 5 is represented by the orange line in Figure 14-2. During dry season periods of zero flows occurs up to 70% of the time, while during wet season this occurs for approximately 8% of the time. Stress during wet season is higher than the AEC requirement for 40% of the time.

The following is important to note. If the yield model results are indicating that the Sc 5 will not change from present day, then obviously the PES will be maintained. It means that irrespective of the uncertainty around the PD hydrology, the conceptual understanding is that the scenario has not changed or is not worse than PD hydrology.

The evaluation below compares Sc 5 to the PES flows and ignores the relationship with the new PD.

DRY SEASON **WET SEASON**

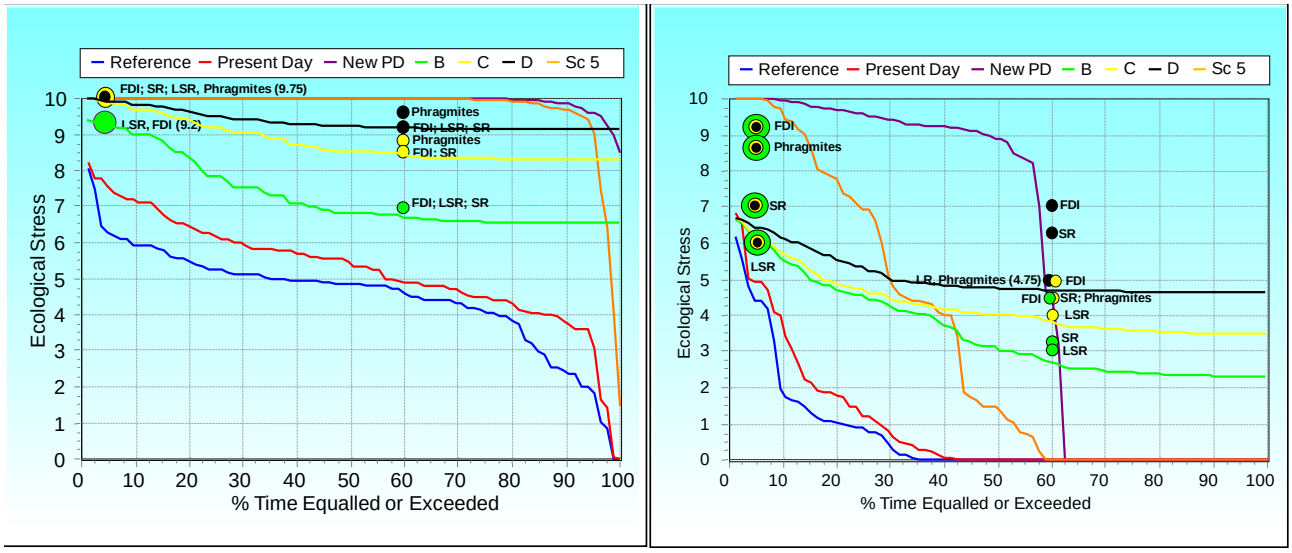


Figure 14–2 Stress duration for EWR 7: Dry and Wet season, Sc 5

14.4 ECOLOGICAL CONSEQUENCES: SCENARIO 5

14.4.1 Driver components

EC				COMMENT
PES & REC	AEC ←	AEC→	Sc 5	
PHYSICO-CHEMICAL				
C	B	D	D	During dry season substantially lower flows will result in elevations in salts and nutrients, and poorer temperature and oxygen conditions. Lower flows during the wet season will exacerbate fair-marginal water quality conditions. No flow for 70% of the time during the dry season, and 8% of the time in the wet season will result in a change of water quality category from a C to a D.
GEOMORPHOLOGY				
C/D	C	D	C/D	Due to the stable nature of the site, the decreased flows will not change the EC from the PES.

14.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES & REC	AEC ←	AEC→	Sc 5	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	D	Scenario 5 has high probability of extended periods of no flow, with drought conditions occurring even for 30% of the time (dry season maintenance). Severely reduced flows (especially in dry season, but even in wet season) will reduce reeds ability to counter non-flow related impacts (trampling and burning) thus reducing cover and density. The EC will drop to a D	
FISH					
C	B	D	D	Due to the long zero flow periods in the dry season and decreased flows in the wet season the SR guild will be impacted and the fish PES will decrease from a C (65.4%) to a D (42.5%) EC.	
MACROINVERTEBRATES					
B/C	B	C/D	D	The extended no flow conditions for >70% results in no suitable habitat available for any of the FDIs and no to extremely limited habitat for MVIs.	
ECOSTATUS					
C	B	D	D	The long period of zero flow conditions impact severely on water quality and the biota. This results in deteriorated instream condition and the EcoStatus drops to a D. This scenario does not meet the PES/REC requirements.	

14.5 IMPACT OF SCENARIO 9

Stress under Sc 9 (orange line in Figure 14-3) is similar to the B requirements up to 45% of the time and steadily improves. Wet season drought stress is similar to the PES and REC requirements and is better than the REC requirements for the rest of the time.

DRY SEASON **WET SEASON**

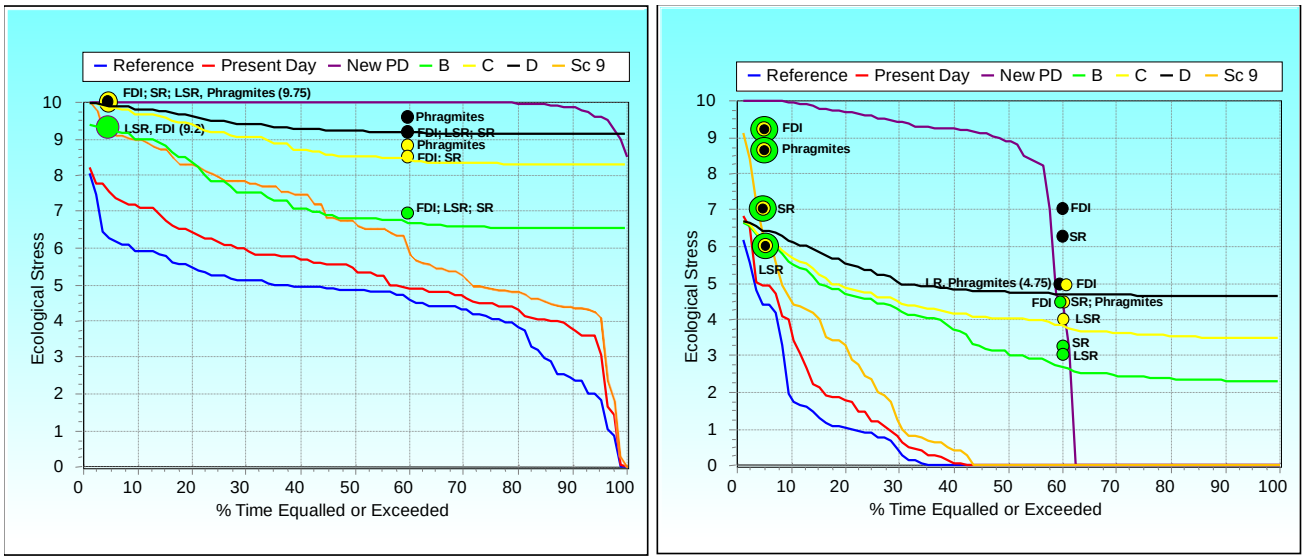


Figure 14–3 Stress duration for EWR 7: Dry and Wet season, Sc 9

14.6 ECOLOGICAL CONSEQUENCES: SCENARIO 9

14.6.1 Driver components

EC				COMMENT
PES & REC	AEC ←	AEC→	Sc 9	
PHYSICO-CHEMICAL				
C	B	D	B/C	Similar to Sc 1.
GEOMORPHOLOGY				
C/D	C	D	C	Similar to Sc 1.

14.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES & REC	AEC ←	AEC→	Sc 9	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	D	B	Similar to Sc 1.	
FISH					
C	B	D	B	Similar to Sc 1	
MACROINVERTEBRATES					
B/C	B	C/D	B	Drought and maintenance flows improve and this equates to a slight improvement in habitat conditions for FDI and MVI taxa. These conditions are likely to improve the macroinvertebrate condition from the present B/C category (MIRAI: 78.19%) to a B category (MIRAI: 82.66%).	
ECOSTATUS					
C	B	D	B	Same as Sc 1	

14.7 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 7 are provided in Table 14.1.

Table 14.1 Ecological consequences of operational flow scenarios at EWR 7

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

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 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.

The degree to which each scenario at EWR 7 meets the PES and REC is summarised in Figure 14-4 below.

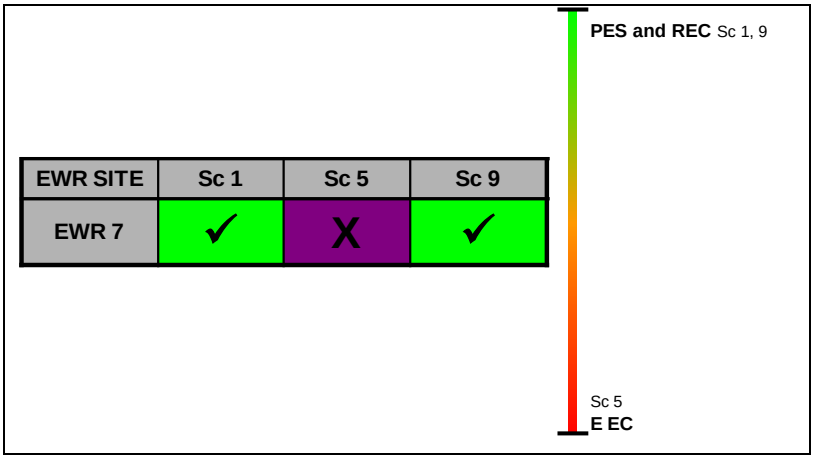


Figure 14–4 Summary of the impacts of operational flow scenarios at EWR 7

15 EWR 8: LOWER SAND (SAND RIVER) - ECOLOGICAL CONSEQUENCES

Scenarios 1, 5 and 9 were evaluated and are discussed in Section 15.1 to 15.3. Refer to Section 13 for more detail.

15.1 IMPACT OF SCENARIO 1

Figure 15-1 illustrates the stress requirements and stress points required for a B PES and REC (purple line) and C AEC (green line). The red line illustrates Present Day flows while the blue line represents reference flows and the yellow line the new modelled Present Day flows. Scenario 1 (black line) is very similar to the PES and REC requirements and improves from 55% onwards. During the wet season flows are an improvement of the PD flows.

DRY SEASON **WET SEASON**

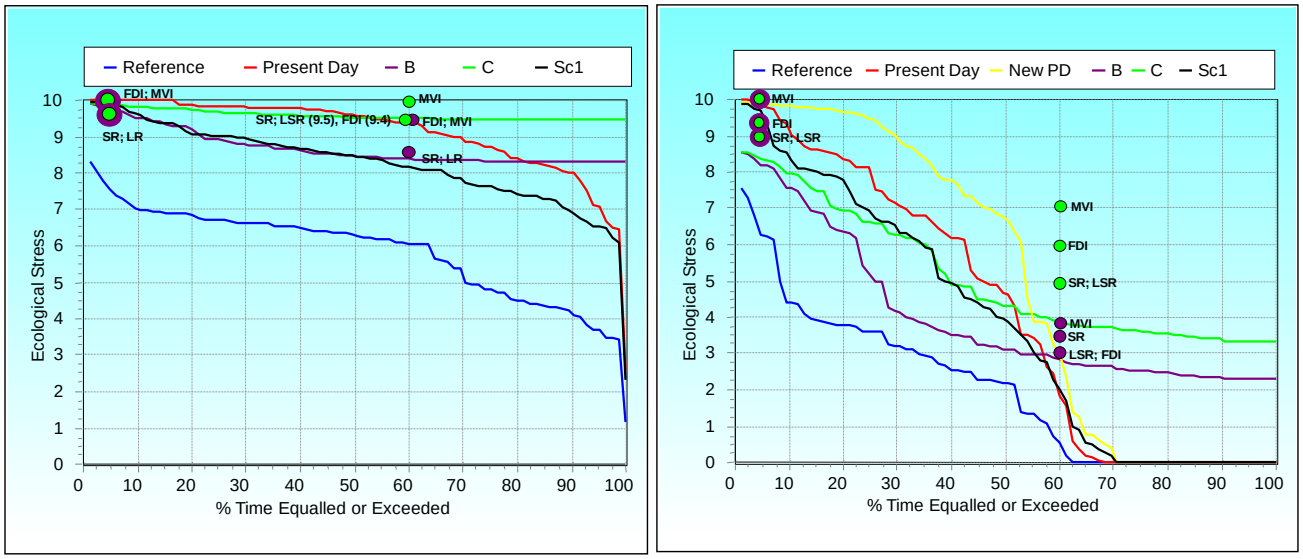


Figure 15–1 Stress duration for EWR 8: Dry and Wet season, Sc 1

15.2 ECOLOGICAL CONSEQUENCES: SCENARIO 1

15.2.1 Driver components

EC				COMMENT
PES	REC	AEC↓	Sc 1	
PHYSICO-CHEMICAL				
B	B	C	A/B	Higher flows in the dry season will result in an anticipated improvement in nutrient levels and instream temperatures. All scenarios show an increase in water for most of the year, with a concomitant improvement in water quality.
GEOMORPHOLOGY				
C	C	C	C	Base flows are strongly elevated during the dry season. The channel would be larger, wider and deeper. There are no changes in floods from Present Day conditions during the wet season, but again base flows are strongly elevated. Increased base flows will improve marginal vegetation and marginal zone (the low flow active channel bank) stability, creating a more stable channel which will be more easily scoured (deepened).

15.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↘	Sc 1	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
B	B	B/C	B	Drought stress for all scenarios is less severe than what was indicated to maintain the PES, and is the same as present day, thus all scenarios will equally favour riparian vegetation at the 5% duration. Both dry and wet season maintenance flows are higher than present day. The effect will be that reed beds and woody marginal and lower zone vegetation will have more water available. Reeds will have less physiological stress and will be more vigorous, density could increase, but reedbeds on the whole will not change river morphology. The channel will remain open and reeds will not encroach on the main channel. A VEGRAI has not been run for this site because improved flow (even close to natural) will not remove reeds thus taking the site towards an historical reference condition. The presence of reeds in the system will likely become the new accepted condition.	
FISH					
B	B	C	B	Based on Oct, flows will be higher than the present hydrology but similar to the flows recommended to maintain the PES, and this scenario should therefore not result in a change in the PES.	The FFH category for SR and LSR guilds will increase from F under present hydrology to C EC. The flows for maintenance and drought periods of the wet season is however very similar to those recommended for maintenance of the overall fish PES in a category B, and it is therefore expected that the PES will not change.
MACROINVERTEBRATES					
C	B	C/D	B	The Scenario supplies significantly decreased stress than the requested B stress for a B REC. The macroinvertebrates will therefore improve to a B.	
ECOSTATUS					
B	B	C	B	To achieve the REC, only macroinvertebrates had to improve to a B EC and that has been achieved.	

15.3 IMPACT OF SCENARIO 5

Scenario 5 is represented by the light blue line in Figure 13-2. Flows during dry season are very similar to PD conditions while flows in the wet season are higher than PD.

DRY SEASON **WET SEASON**

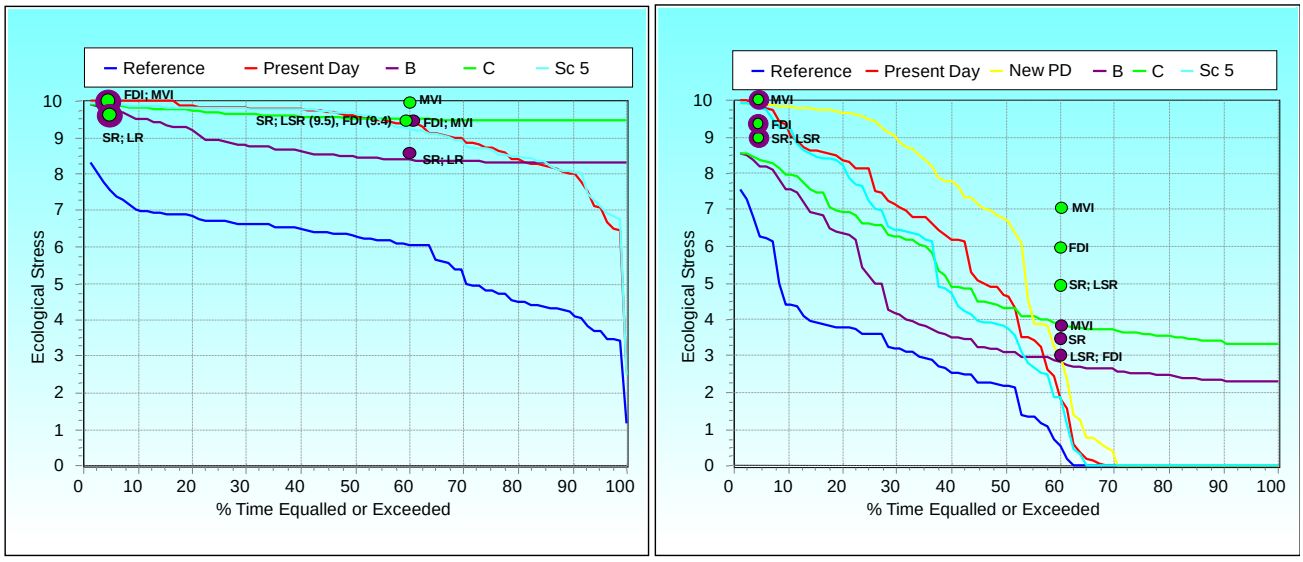


Figure 15–2 Stress duration for EWR 8: Dry and Wet season, Sc 5

15.4 ECOLOGICAL CONSEQUENCES: SCENARIO 5

15.4.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc 5	
PHYSICO-CHEMICAL				
B	B	C	B	Same as for Sc 1.
GEOMORPHOLOGY				
C	C	C	C	Similar to Sc 1.

15.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 5	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
B	B	B/C	B	Same as for Sc 1.	
FISH					
B	B	C	B	Same as for Sc 1.	
MACROINVERTEBRATES					
C	B	C/D	B	Same as for Sc 1.	
ECOSTATUS					
B	B	C	B	Same as for Sc 1.	

15.5 IMPACT OF SCENARIO 9

Flows under Sc 9 (orange line in Figure 15-3) during the dry season the stress is very similar to the B requirement and improve from 40% exceedence. During wet season the stress lie between the B and C requirements and improve after 53% exceedence.

DRY SEASON **WET SEASON**

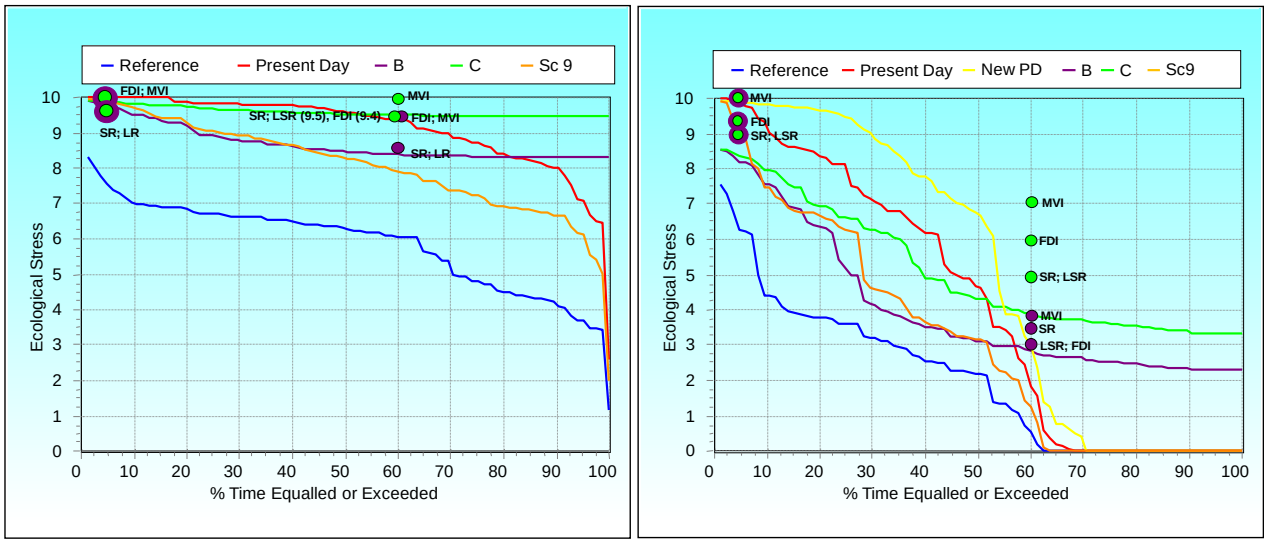


Figure 15–3 Stress duration for EWR 8: Dry and Wet season, Sc 9

15.6 ECOLOGICAL CONSEQUENCES: SCENARIO 9

15.6.1 Driver components

EC				COMMENT
PES	REC	AEC→	Sc 9	
PHYSICO-CHEMICAL				
B	B	C	B	Same as for Sc 1.
GEOMORPHOLOGY				
C	C	C	C	Same as for Sc 1.

15.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 9	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
B	B	B/C	B	Same as for Sc 1.	
FISH					
B	B	C	B	The flows during the wet season (Feb), will be improved substantially. During Jul flows under Sc 9 indicated that drought conditions (95% flow duration) fast habitats will be better than the PES and similar to present day flows. This situation will maintain the SR guild at this site. The overall impact on abundance and cover during these periods will not result in a change in the overall PES (FRAI) of the site. Although the increase in wet season flows will enhance fish migration, breeding and habitat integrity, the very low flows during the dry season (similar to the present day situation) will diminish their numbers and reset the situation to the current PES of a category B (85.9%).	
MACROINVERTEBRATES					
C	B	C/D	B	Same as for Sc 1	
ECOSTATUS					
B	B	C	B	See Sc 5.	

15.7 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 8 are provided in Table 15.1.

Table 15.1 Ecological consequences of operational flow scenarios at EWR 8

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

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. The degree to which each scenario at EWR 8 meets the PES and REC is summarised in Figure 15-4 below. The PES is in this case not in the middle of the scale as it is the same as the REC in terms of EcoStatus, but requires improvement in one of the components.

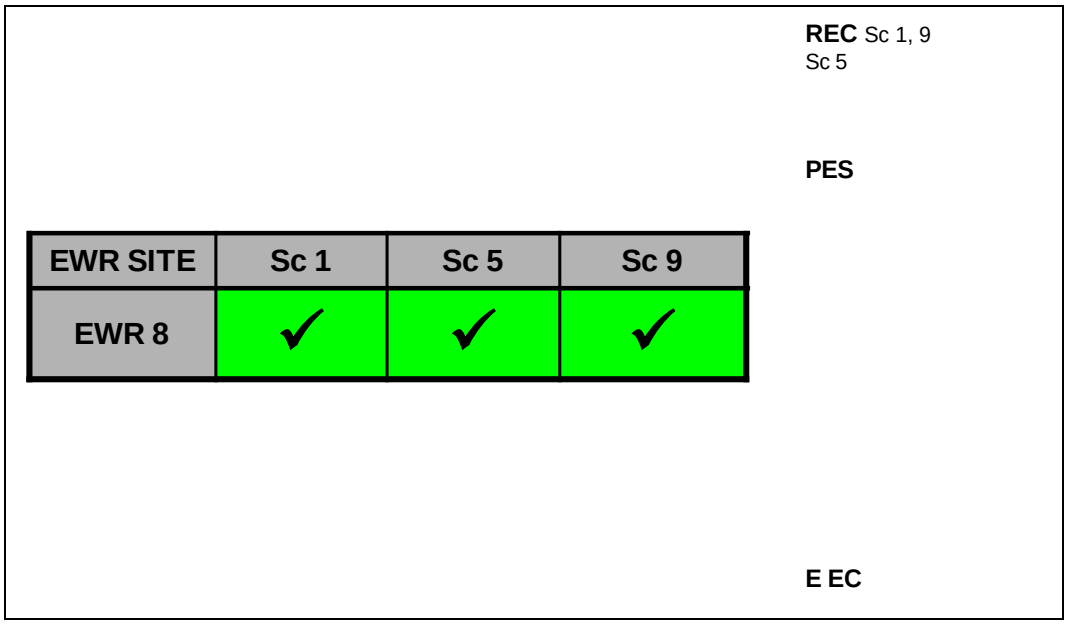


Figure 15–4 Summary of the impacts of operational flow scenarios at EWR 8

16 CONCLUSIONS: SABIE-SAND RIVER SYSTEM

16.1 SUMMARY OF RESULTS: SABIE RIVER SYSTEM

16.1.1 Ecological consequences of operational scenarios (Sc 5 – 9)

Table 16.1 provides a summary of the ecological consequences at each EWR site in the Sabie River system. The key to the table is on the fold-out A3 page (Section 2.6). 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.

The overall evaluation usually reflects the site evaluation 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.

Table 16.1 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 meets the PES/REC at EWR 3 in KNP but not at EWR 5 (Marite). Therefore it is significantly better than the other scenarios which are lower than the PES at both sites. The results provided in Table 16.1 are ranked and illustrated on a scale from good (REC) to 'bad' (an E EC) where in this case the PES and REC have both been placed at the top as the PES = REC for EWR 3 which is the key site in the system (Figure 16-2).

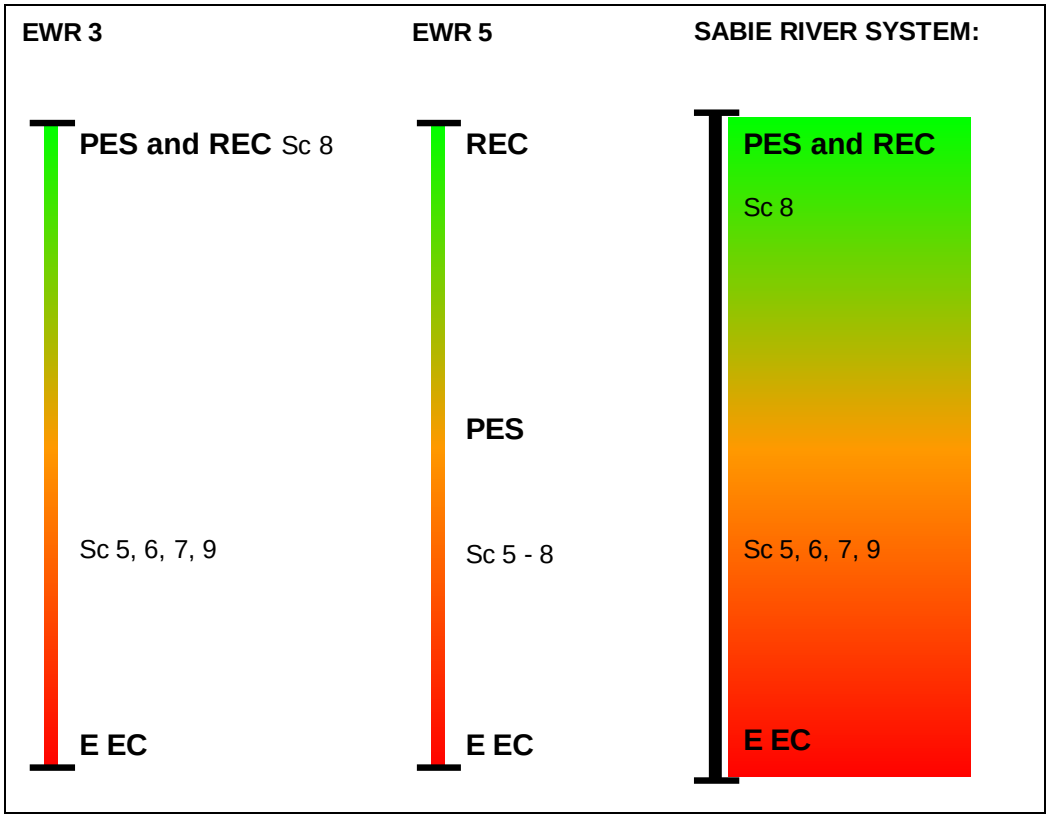


Figure 16–1 Ranking of operational scenarios per EWR site and a summarised ranking in terms of a traffic diagram

16.2 SUMMARY OF RESULTS: SAND RIVER SYSTEM

16.2.1 Ecological consequences of operational scenarios (Sc 1, 5 and 9)

Table 16.2 provides a summary of the ecological consequences at each EWR site in the Sand River system. For more information see Section 10.1.1. An overall assessment was undertaken to compare the scenarios that consist of combinations of weir improvement, curtailment and restrictions.

Table 16.2 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 is an improvement of the PES at EWR 6 and meets the REC at EWR 7 and 8. It is a better scenario than Sc 9 which only meets the PES at EWR 6 and does not improve it as is the case with Sc 1. Scenario 5 is the worst scenario as it does not meet the PES/REC at EWR 7.

The results provided in Table 16.2 are ranked and illustrated on a scale from good (REC) to 'bad' (an E EC) (Figure 16-2). Note that the PES and REC have both been placed at the top together at EWR 7 as the PES = the REC.

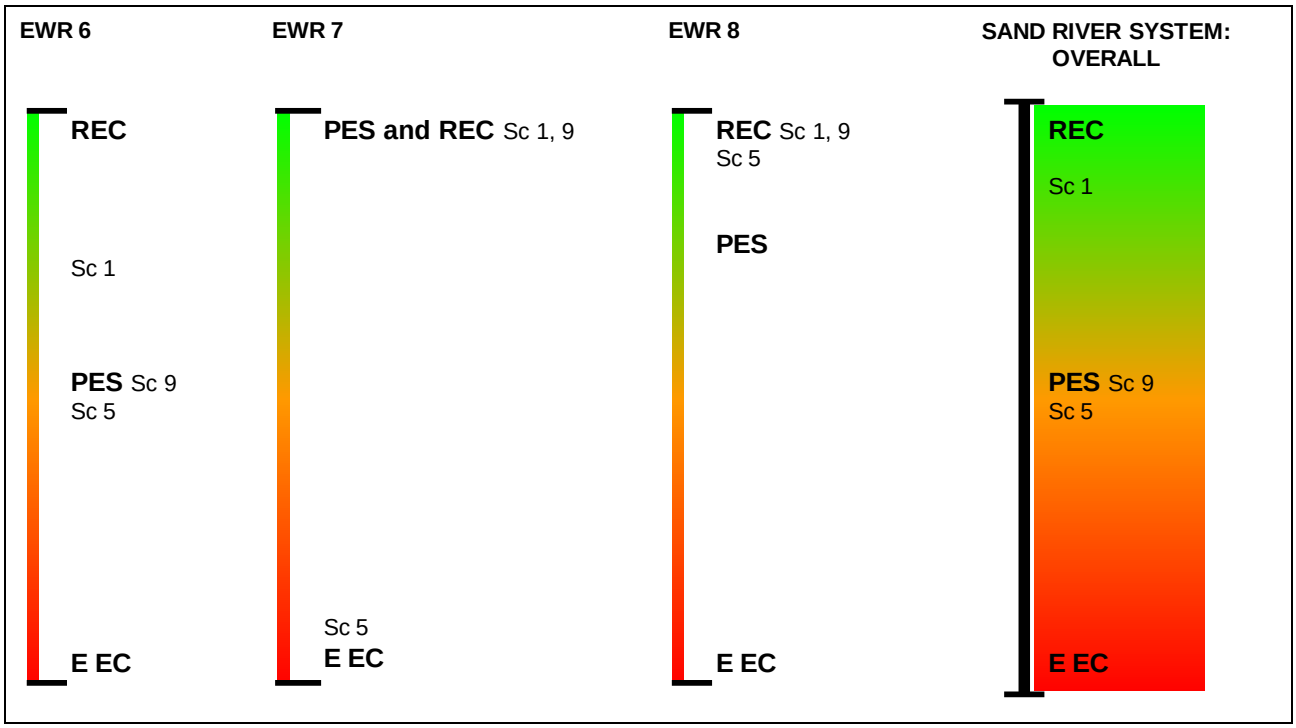


Figure 16–2 Ranking of operational scenarios per EWR site and a summarised ranking in terms of a traffic diagram

17 GOODS AND SERVICES: CONSEQUENCES OF OPERATIONAL SCENARIOS

The impact of the different scenarios is discussed below in terms of the different economic zones of the Crocodile and Sabie-Sand River systems. Detailed information on the economic zones are provided in DWA (2010d).

17.1 LOWER KWENA ECONOMIC ZONE

For the Lower Kwena the utilisation of G&S was ranked as low. There are few communities that are dependent on the basket of G&S that are available as the formal market dominates 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. Overall the presence of fish (mostly tilapia and barbs) was deemed to be improved by about 10%. Important riparian vegetation was deemed to improve by a similar positive amount although some of these, particularly wattle and blue gum are invasive aliens. The ability of the system to protect itself through regulating water quality as well as through bank protection was also deemed to react positively under all scenarios. Results are provided in Table 17.1[3] below.

Table 17.1 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

[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.

G&S as benefits								
Resources	**Common name**	**Scientific**	**Importance**	**Utilisation**	**Sc 3**	**Sc 7**	**Sc 10**	**Sc 12**
Disservices as costs								
Pathogens treatments			Very Low	Low	1	1	1	1
Pathogens productivity loss			Very Low	Low	1	1	1	1

17.2 MIDDLE CROCODILE ECONOMIC ZONE

The utilisation of G&S was ranked as high to medium high. A number of communities are dependent on the basket of G&S that are available. They co-exist in linkages to the formal market that dominates portions of the catchment. Overall all scenarios had a positive impact on the availability of G&S. However Sc 7 and 9 had mixed results. While abundance of fish species were regarded as increasing across all scenarios (by about 10%) the more water thirsty riparian vegetation was sent decline by about 20% under the same scenarios. As these tend to be the alien invasive this is potentially a positive environmental aspect. However reliance, by people, on these species for aspects such as construction material and firewood does mean that their relatively lower abundance has some negative consequences. Indigenous species were deemed to react positively under al scenarios. The ability of the system to protect itself through regulating water quality as well as through bank protection was also deemed to react neutrally or marginally negatively under scenarios. In summary the Sc 10 was deemed to be overall most positive followed by Sc 11 and 12. Scenario 7 and 9 were deemed to bring about somewhat less positive results on availability of G&S. Results are provided in Table 17.2 below.

Table 17.2 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
	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

G&S as benefits									
Resources	**Common name**	**Scientific name**	**Importance**	**Utilisation**	**Sc 7**	**Sc 9**	**Sc 10**	**Sc 11**	**Sc 12**
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

17.3 KAAP ECONOMIC ZONE

The utilisation of G&S was ranked as low although there are pockets of G&S dependence. The only scenarios evaluated were 8 and 9. These have a dramatic negative impact on the G&S. All fish stocks were regarded as virtually collapsing to about 10% of present abundance. The riparian vegetation, with the exception of some alien invasive species was seen to be potentially collapsing by about 40% to 60%. 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 17.3 below.

Table 17.3 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 Sp*	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

17.4 LOWER CROCODILE ECONOMIC ZONE

This is largely the land associated with the Kruger National Park (KNP) although parts of the KaNyamazane community are also present. As such, G&S as they relate to the aesthetic aspects of the park and impact on tourism are important. Direct utilisation by certain members of the

greater KaNyamazane community is also important. Scenarios 3, 6, 7 and 9 were considered as a single scenario as they have very similar impact. Scenarios 10 and 12 were also combined. Scenarios 4 and 8 were considered on their own. The only scenario that has a neutral to marginally positive result on the availability of G&S is Sc 8. For the rest the impact is negative. Of these the most negative appear to be Sc 10 and 12 followed by Sc 4. Scenarios 3, 6, 7 and 9 while still negative perform slightly better. All (bar Sc 8) have negative impacts on the availability of fish species with declines in some vulnerable groups estimated to be as much as 40%. For the riparian vegetation the prediction is not quite as direct. Under Sc 10 and 12 most species would be negatively affected but under the remaining scenarios the hardier species may in fact be found to be slightly more abundant. Water quality will decline under most scenarios but most noticeably under Sc 10 and 12. Water quality functioning will remain largely stable under Sc 3, 6, 7 and 9 as well as 8. The ability of the river to regulate itself with regard to flood protection and erosion and protect will decline under Sc 10 and 12 as well as 8. Overall the best scenario appears to be Sc 8. Results are provided in Table 17.4 below.

Table 17.4 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

17.5 MARITSANE/INYAKA ECONOMIC ZONE

The utilisation of G&S was ranked as medium. A number of communities are dependent on the basket of G&S that are available. They co-exist in linkages to the formal market that dominates portions of the catchment. Only Sc 5 was considered. The fish were predicted not to react to the scenario but overall riparian vegetation was deemed to decline in abundance by about 20%. The exception would be the *Phragmites* that line the river bed. Water quality properties would remain largely unchanged but perhaps may react slightly negatively. Wetland cultivation may increase but the ability of the system to regulate flow would be negatively impeded. Overall the scenario is neutral to marginally negative for the basket of G&S. Results are provided in Table 17.5 below.

Table 17.5 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

17.6 SAND ECONOMIC ZONE

The utilisation of G&S was ranked as high to medium high. A number of communities are dependent on the G&S available. They co-exist in linkages to the formal market that dominates portions of the catchment. 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 has more mixed results. It has 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. As such Sc 5 is overall negative on the abundance and quality of G&S while Sc 1 and 9 are positive. Results are provided in Table 17.6 below.

Table 17.6 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 Sp	Important	High	1.1	1.1
Reeds	Reeds	Phragmites	Moderate	High	1.3	1.3
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

17.7 SUMMARY AND CONCLUSIONS

Table 17.7 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 17.7 Summary of predicted impact of scenarios on G&S in the Crocodile and Sabie-Sand River catchment

Economic Zone	EWR Site	Scenarios							
Crocodile-East 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					

18 RECOMMENDATIONS

18.1 CROCODILE RIVER SYSTEM

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

Due to the socio economic impact of Sc C6.1 it is acknowledged that it is unlikely to be considered. Therefore Sc C3.1 is therefore a better option, although the potential socio-economic consideration can 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 results in the improvement of the PES, the risk associated with the PES not degrading further will 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.

18.2 SABIE-SAND RIVER SYSTEM

No operational scenarios were required for evaluation in the Sabie System. Theoretical scenarios that consist of different levels of irrigation restrictions to meet increasing irrigation requirements were investigation. These represent increased flows to various degrees at EWR 5 (Marite) and decreased flows at EWR 3 (Kidney). Scenario 8 is the only scenario that still meets the PES and REC at EWR 3 in the KNP. The Marite REC was not achieved. The present flow regime results in the same situation and it is 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 are 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 will be the best scenario as this scenario improves the PES at EWR 6 and meets the REC requirements at EWR 7 and 8. Scenario 1 is therefore recommended from the ecological and G&S viewpoint.

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