REPORT NO: RDM/WMA11/00/CON/CLA/0614

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

PROJECT NUMBER: WP 10679

VOLUME 1: SUPPORTING INFORMATION ON THE DETERMINATION OF WATER RESOURCE CLASSES - RIVER ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

SEPTEMBER 2014

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

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REFERENCE

This report is to be referred to in bibliographies as:

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2	*Report Number: RDM/WMA11/00/CON/CLA/0113*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Status Quo assessment, IUA and Biophysical Node delineation and identification.**
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6	*Report Number: RDM/WMA11/00/CON/CLA/0212*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **BHNR**
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8.2	*Report Number: RDM/WMA11/00/CON/CLA/0714*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 2: Supporting Information on the Determination of Water Resource Classes - Estuary Ecological Consequences of Operational Scenarios**
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11	*Report Number: RDM/WMA11/00/CON/CLA/0415*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Main Report**

DEPARTMENT OF WATER AND SANITATION

CHIEF DIRECTORATE: RESOURCE DIRECTED MEASURES

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

VOLUME 1: SUPPORTING INFORMATION ON THE DETERMINATION OF WATER RESOURCE CLASSES – RIVER ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

Approved for RFA by:

…………………………………….. *……………………………………..*

Delana Louw *Date*

Project Manager

DEPARTMENT OF WATER AND SANITATION (DWS)

Approved for DWS by:

…………………………………….. *……………………………………..*

Date

Chief Director: Water Ecosystems

AUTHORS

The information in this report was authored by the multi-disciplinary group of specialists involved. Contributions were provided as follows:

- *Delana Louw: EWR coordinator and scenario process*
- *Dr Andrew Birkhead: Ecohydraulics and Ecohydrology*
- *Dr Andrew Deacon: Macro-invertebrates*
- *Shael Koekemoer: Report compilation*
- *Dr Pieter Kotze: Fish*
- *James Mackenzie: Riparian vegetation*
- *Mr Mark Rountree: Geomorphology*
- *Dr Patsy Scherman: Water quality*

REPORT SCHEDULE

Version	Date
First draft	*September 2014*
Final draft	*October 2014*

EXECUTIVE SUMMARY

BACKGROUND

The Mvoti to Umzimkulu WMA encompasses a total catchment area of approximately 27,000 km^2 and occurs largely within Kwazulu-Natal. A small portion of the Mtamvuna River and the upper and lower segments of the Umzimkulu River straddle the Eastern Cape, close to the Mzimvubu and Keiskamma Water Management Area (WMA) in the south (DWA, 2011). The Chief Directorate: Resource Directed Measures of the Department of Water Affairs initiated a study during 2012 for the provision of professional services to undertake the Comprehensive Reserve, classify all significant water resources and determine the Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area. The integrated steps for the study are provided below.

Step	Description
1	*Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s) (completed).*
2	*Initiation of stakeholder process and catchment visioning (on-going).*
3	*Quantify the Ecological Water Requirements and changes in non-water quality ecosystem goods, services and attributes*
4	**Identification and evaluation of scenarios within the integrated water resource management process.**
5	*Develop draft Water Resource Classes and test with stakeholders.*
6	*Develop draft RQOs and numerical limits.*
7	*Gazette and implement the class configuration and RQOs.*

*This report forms **part** of the outcomes of Step 4 (red above) within the integrated approach (DWA, 2012). The objective of this task was to provide the scenario analysis, assumptions and results and document the consequences of the scenarios for the various components under Task D4 which are provided as seven report volumes under Report 8. All the report volumes apart from 8.7 are supporting information that feeds into Report 8.7. This report will integrate all this information to derive Water Resource Classes for the various scenarios.*

The purpose of this report is to describe and document the river ecological consequences of the operational scenarios at the key biophysical nodes (Ecological Water Requirement (EWR) sites) by evaluating and determining the impact on the Ecological Category (EC). Note that as described above, this report (volume 1) only provides supporting information for Report 8.7.

STUDY AREA

The Mvoti to Umzimkulu WMA encompasses a total catchment area of approximately 27,000 km^2 and occurs largely within Kwazulu-Natal. A small portion of the Mtamvuna River and the upper and lower segments of the Umzimkulu River straddle the Eastern Cape, close to the Mzimvubu and Keiskamma WMA in the south (DWA, 2011).

The WMA extends from the town of Zinkwazi, in the north to Port Edward and on the south along the KwaZulu-Natal coastline and envelopes the inland towns of Underberg and Greytown up until the Drakensberg escarpment. The WMA spans across the primary catchment "U" and incorporates the secondary drainage areas of T40 (Mtamvuna River in Port Shepstone) and T52 (Umzimkulu River). Ninety quaternary catchments constitute the water management area and the *major rivers draining this WMA include the Mvoti, uMngeni, Mkomazi, Umzimkulu and Mtamvuna (DWA, 2011).*

EWR SITES AFFECTED BY OPERATIONAL SCENARIOS

The impact of operational scenarios in a river system is assessed at EWR sites located within the river systems. Eight EWR sites were identified which could possibly be impacted by the operational scenarios. These EWR sites are located in the Lovu, Mvoti, Heinespruit, uMngeni and Mkomazi river systems. Various other scenarios were modelled that impact the estuaries and the consequences will be discussed in detail in Volume 2 of this report series (report 8.2). Details of the EWR sites are provided in Table 1.2 and discussed in detail in DWA (2013). Their location within the study area is provided in Section 1.4 of the report.

EWR sites (Intermediate level) selected in the study area

EWR site name	SQ[1]	River	Latitude	Longitude	Eco Region (Level II)	Geomorphic Zone	Alt (m)	MRU[2]	Quat[3]
Lo_R_EWR1	*U70C-04859*	*Lovu*	*-30.09997*	*30.73603*	*17.01*	*Lower Foothills*	*44*	*Lovu D*	*U70D*
Mv_I_EWR1	*U40B-03770*	*Heinespruit*	*-29.13054*	*30.64002*	*16.02*	*Lower Foothills*	*929*	*MRU Heyns A*	*U40B*
Mv_I_EWR2	*U40H-04064*	*Mvoti*	*-29.26398*	*31.03513*	*17.03*	*Lower Foothills*	*203*	*MRU Mvoti C*	*U40H*
Mg_I_EWR2	*U20E-04243*	*uMngeni*	*-29.46184*	*30.29832*	*16.03*	*Upper Foothills*	*725*	*MRU Mgeni B*	*U20E*
Mg_I_EWR5	*U20L-04435*	*uMngeni*	*-29.64521*	*30.74556*	*17.03*	*Upper Foothills*	*177*	*MRU Mgeni D*	*U20L*
Mk_I_EWR1	*U10E-04380*	*Mkomazi*	*-29.74338*	*29.91165*	*16.03*	*Lower Foothills*	*916*	*MRU Mkomazi B*	*U20F*
Mk_I_EWR2	*U10J-04679*	*Mkomazi*	*-29.921*	*30.08448*	*16.02*	*Upper Foothills*	*537*	*MRU Mkomazi C*	*U20J*
Mk_I_EWR3	*U10M-04746*	*Mkomazi*	*-30.132*	*30.66245*	*17.01*	*Lower Foothills*	*50*	*MRU Mkomazi D*	*U10M*

1 Sub Quaternary reach *2 Management Resource Unit* *3 Quaternary catchment*

SCENARIO ECOLOGICAL CONSEQUENCES: LOVU RIVER

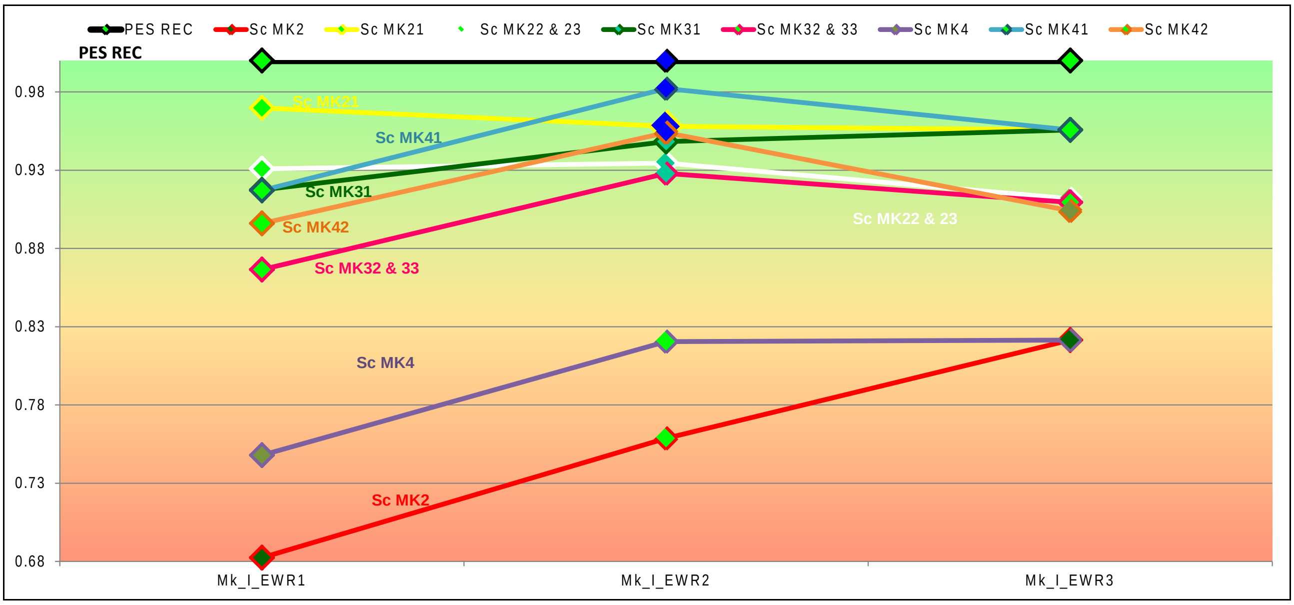
The results illustrate that all the scenarios meet the ecological objectives with Sc LO4 resulting in an improvement in the PES and REC. All scenarios are therefore acceptable from an ecological viewpoint.

SCENARIO ECOLOGICAL CONSEQUENCES: MKOMAZI CATCHMENT

The ranking of the scenarios at each site in terms of how successful the scenarios are in meeting the REC is provided in the figure below. The ranking shows that Sc MK2 and 4 are the lowest in the ranking order at all sites and significantly lower than the other scenarios. This is because Sc MK2 and 4 includes Smithfield Dam with no EWRs. All the rest of the scenarios still maintain the EcoStatus of a C at Mk_I_EWR1 but do not achieve the REC (PES). The major problem at Mk_I_EWR 1 is that the site is close to the dam and therefore only received the water being released from the dam or spills. As the river acts as a conduit to convey water from the dam down the system, the main reasons for not achieving the REC (PES) is the increased (above natural) and unseasonal base flows as well as the decrease in floods.

As one moves further downstream of the dam, the impacts become less pronounced. At Mk_I_EWR 2, tributary inflows mitigate some of the impacts of the unseasonal flows and the lack *of floods. However the main users are downstream of Mk_I_EWR 2, and therefore the impacts are still felt to some degree. Sc MK 21, 41 and 42 still maintain the EcoStatus of a B with Sc MK41 being the better scenario.*

At Mk_I_EWR3 Sc MK21, 41 and 31 maintains the C EcoStatus and are the best scenarios, although it also does not achieve all the ecological objectives.



Mkomazi River: Ranking of scenarios at each EWR site

The process to determine an integrated ranking of the different scenarios is described below. The first step was to determine the relative importance of the different EWR sites. The site weight (following table) indicates that Mk_I_ EWR 3 carries the highest weight due to the longer river distance which the scenario consequences are relevant for. The importance of Mk_I_EWR 2 is slightly lower due to the shorter distance it represents, which is offset in the higher ecological importance and presence in a protected area. Mk_I_EWR 1 will have a much lower weight, largely because the scenario consequences are only applicable to 14 km of the total length of river.

The weights are provided below. The weight is based on the conversion of the PES and EIS to numerical values to determine the normalised weight.

Weights allocated to EWR sites relative to each other

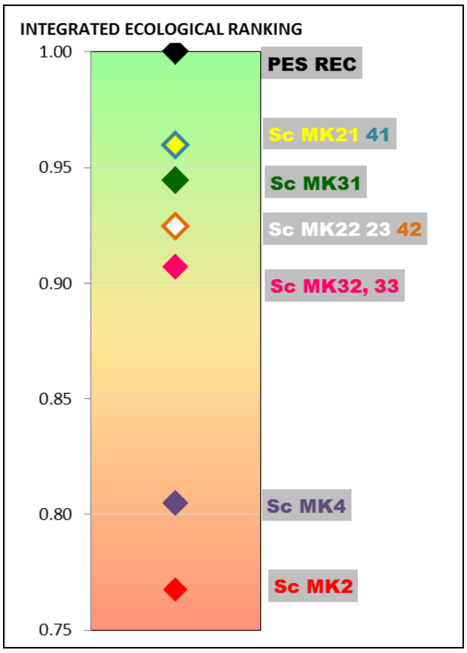
EWR site	PES	EIS	Locality in protected areas (0 - 5)	Distance	Normalised Weight
EWR 1	C	*Moderate*	*1*	*0.08*	**0.22**
EWR 2	B	*High*	*3*	*0.32*	**0.37**
EWR 3	C	*Moderate*	*1*	*0.6*	**0.41**

The weight is applied to the ranking value for each scenario at each EWR site and this provides an integrated score and ranking for the operational scenarios of the Mkomazi system. The ranking of '1' refers to the REC and the rest of the ranking illustrate the degree to which the scenarios meet the REC. The results are provided below after the weights have been taken into account.

Ranking value for each scenario resulting in an integrated score and ranking

EWR	PES	REC	Sc MK2	Sc MK21	Sc MK22	Sc MK23	Sc MK31	Sc MK32	Sc MK33	Sc MK4	Sc MK41	Sc MK42
Mk_I_EWR1	*0.22*	*0.22*	*0.15*	*0.21*	*0.21*	*0.21*	*0.20*	*0.19*	*0.19*	*0.17*	*0.20*	*0.20*
Mk_I_EWR2	*0.37*	*0.37*	*0.28*	*0.35*	*0.35*	*0.35*	*0.35*	*0.34*	*0.34*	*0.30*	*0.36*	*0.35*
Mk_I_EWR3	*0.41*	*0.41*	*0.34*	*0.39*	*0.37*	*0.37*	*0.39*	*0.37*	*0.37*	*0.34*	*0.39*	*0.37*
	1.00	*1.00*	*0.77*	*0.96*	*0.92*	*0.92*	*0.94*	*0.91*	*0.91*	*0.80*	*0.96*	*0.92*

The above results are plotted on a traffic diagram to illustrate the integrated ecological ranking.



Integrated ecological ranking of the scenarios on the Mkomazi River system

Sc MK 21 and 41 are the best options as they are the closest to meeting the ecological objectives. Both these scenarios include the total EWR flows and the impacts are mostly due to the impacts on the dam itself, such as the barrier effect, impact on larger frequency of floods and largely due to the increased (above natural) base flows.

SCENARIO ECOLOGICAL CONSEQUENCES: MVOTI CATCHMENT

Scenario MV41 which includes the dam and releases the full EWR will meet the ecological objectives. Sc MV42 and 43 are very similar, still maintain the REC EcoStatus but overall do not comply with all the objectives. Scenario MV3 is the least acceptable as it drops a category overall (D EC) and for most of the components.

SCENARIO ECOLOGICAL CONSEQUENCES: uMNGENI CATCHMENT

All scenarios meet the ecological objectives and improve the situation.

TABLE OF CONTENT

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TERMINOLOGY AND ACRONYMS

CD: RDM	*Chief Directorate: Resource Directed Measures*
DWA	*Department Water Affairs (Name change from DWAF applicable after April 2009)*
DWAF	*Department Water Affairs and Forestry*
DWS	*Department Water and Sanitation (Name change from DWA applicable after May 2014)*
EC	*Ecological Category*
EWR	*Ecological Water Requirements*
FRAI	*Fish Response Assessment Index*
FROC	*Frequency of Occurrence*
GAI	*Geomorphology Assessment Index*
GSM	*Gravel, Sand, Mud*
HFSR-RM	*Habitat Flow Stressor Response - Reserve Model*
MIRAI	*Macroinvertebrate Response Assessment Index*
MRU	*Management Resource Unit*
OCD	*Off-channel Dam*
PAI	*Physico-chemical Driver Assessment Index*
PD	*Present Day*
PES	*Present Ecological State*
Quat	*Quaternary reach*
REC	*Recommended Ecological Category*
RQO	*Resource Quality Objective*
Sc	*Scenario*
SQ	*Sub Quaternary reach*
SIC	*Stones-in-Current*
VEGRAI	*Riparian Vegetation Response Assessment Index*
WMA	*Water Management Area*
WWTW	*Waste Water Treatment Work*

1 INTRODUCTION

1.1 BACKGROUND

There is an urgency to ensure that water resources in the Mvoti to Umzimkulu Water Management Area (WMA) are able to sustain their level of uses and be maintained at their desired states. The determination of the Water Resource Classes of the significant water resources in Mvoti to Umzimkulu WMA will ensure that the desired condition of the water resources, and conversely, the degree to which they can be utilised is maintained and adequately managed within the economic, social and ecological goals of the water users (DWA, 2011). The Chief Directorate: Resource Directed Measures (CD: RDM) of the Department of Water and Sanitation (DWS) initiated a study during 2012 for the provision of professional services to undertake the Comprehensive Reserve, classify all significant water resources and determine the Resource Quality Objectives (RQOs) in the Mvoti to Umzimkulu WMA.

1.2 STUDY AREA

The Mvoti to Umzimkulu WMA encompasses a total catchment area of approximately 27,000 km^2 and occurs largely within Kwazulu-Natal. A small portion of the Mtamvuna River and the upper and lower segments of the Umzimkulu River straddle the Eastern Cape, close to the Mzimvubu and Keiskamma WMA in the south (DWA, 2011).

The WMA extends from the town of Zinkwazi, in the north to Port Edward and on the south along the KwaZulu-Natal coastline and envelopes the inland towns of Underberg and Greytown up until the Drakensberg escarpment. The WMA spans across the primary catchment "U" and incorporates the secondary drainage areas of T40 (Mtamvuna River in Port Shepstone) and T52 (Umzimkulu River). Ninety quaternary catchments constitute the water management area and the major rivers draining this WMA include the Mvoti, uMngeni, Mkomazi, Umzimkulu and Mtamvuna (DWA, 2011).

Two large river systems, the Umzimkulu and Mkomazi rise in the Drakensberg. Two medium-sized river systems the uMngeni and Mvoti rise in the Natal Midlands and have been largely modified by human activities, mainly intensive agriculture, forestry and urban settlements. Several smaller river systems (e.g. Mzumbe, Mdloti, Tongaat, Fafa, and Lovu Rivers) also exist within the WMA (DWAF, 2004). Several parallel rivers arise in the escarpment and discharges into the Indian Ocean and the water courses in the study area display a prominent southeasterly flow direction (DWA, 2011). The WMA is very rugged and very steep slopes characterise the river valleys in the inland areas for all rivers and moderate slopes are found but comprise only 3% of the area of the WMA (DWAF, 2004).

1.3 INTEGRATED STEPS APPLIED IN THIS STUDY

The integrated steps for the National Water Classification System, the Reserve and RQOs are supplied in Table 1.1.

Table 1.1 Integrated study steps

Step	Description
1	*Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s) (completed).*
2	*Initiation of stakeholder process and catchment visioning (on-going).*
3	*Quantify the Ecological Water Requirements and changes in non-water quality ecosystem goods, services and attributes*
4	**Identification and evaluation of scenarios within the integrated water resource management process.**
5	*Develop draft Water Resource Classes and test with stakeholders.*
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This report forms ***part*** *of the outcomes of Step 4 (red above) within the integrated approach (DWA, 2012). The objective of this task was to provide the scenario analysis, assumptions and results and document the consequences of the scenarios for the various components under Task D4 which are provided as seven report volumes under Report 8 (Table 1.2). All the report volumes apart from 8.7 are supporting information that feeds into Report 8.7. This report will integrate all this information to derive Water Resource Classes for the various scenarios.*

Table 1.2 The different report volumes which document the consequences of the scenarios for the various components

8	Operational Scenario and Management Class report volumes Report title
8.1	*Volume 1: Supporting Information on the Determination of Water Resource Classes – River Ecological Consequences of Operational Scenarios.*
8.2	*Volume 2: Supporting Information on the Determination of Water Resource Classes - Estuary Ecological Consequences of Operational Scenarios*
8.3	*Volume 3: Supporting Information on the Determination of Water Resource Classes – Estuary specialist appendices (available electronically only)*
8.4	*Volume 4: Supporting Information on the Determination of Water Resource Classes - Economic consequences of Operational Scenarios*
8.5	*Volume 5: Supporting Information on the Determination of Water Resource Classes - EGSA consequences of Operational Scenarios*
8.6	*Volume 6: Supporting Information on the Determination of Water Resource Classes - Water quality consequences of Operational Scenarios*
8.7	*Volume 7: Recommended Water Resource Classes.*

The purpose of this report is to describe and document the river ecological consequences of the operational scenarios at the key biophysical nodes (Ecological Water Requirement (EWR) sites) by evaluating and determining the impact on the Ecological Category (EC). Note that as described above, this report (volume 1) only provides supporting information for Report 8.7.

1.4 EWR SITES AFFECTED BY OPERATIONAL SCENARIOS

The impact of operational scenarios in a river system is assessed at EWR sites located within the river systems. Eight EWR sites were identified which could possibly be impacted by the operational scenarios. These EWR sites are located in the Lovu, Mvoti, Heinespruit, uMngeni and

Mkomazi river systems. Various other scenarios were modelled that impact the estuaries and the consequences will be discussed in detail in Volume 2 of this report series (report 8.2). Details of the EWR sites are provided in Table 1.3 and discussed in detail in DWA (2013). Their location within the study area is provided in Figures 1.1 to Figure 1.3.

Table 1.3 EWR sites (Intermediate level) selected in the study area

EWR site name	SQ[1]	River	Latitude	Longitude	Eco Region (Level II)	Geomorphic Zone	Alt (m)	MRU[2]	Quat[3]
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1 Sub Quaternary reach *2 Management Resource Unit* *3 Quaternary catchment*

1.5 OUTLINE OF REPORT

The report structure is outlined below.

Chapter 1: Introduction
This Chapter provides general background to the project Task.

Chapter 2: Approach: Determining the Ecological Consequences of Operational scenarios
This Chapter outlines the general approach to determining ecological consequences of operational scenarios

Chapter 3 – 9: Ecological Consequences
Detailed consequences of the operational scenarios on the various ecological components are provided.

Chapter 10: Conclusions
The ecological consequences of the operational scenarios are summarised.

Chapter 10: References

Chapter 11: Appendix A: Inundation levels of riparian vegetation indicators under different flow regimes
Information is provided in Table format.

Chapter 12: Appendix B: Report Comments

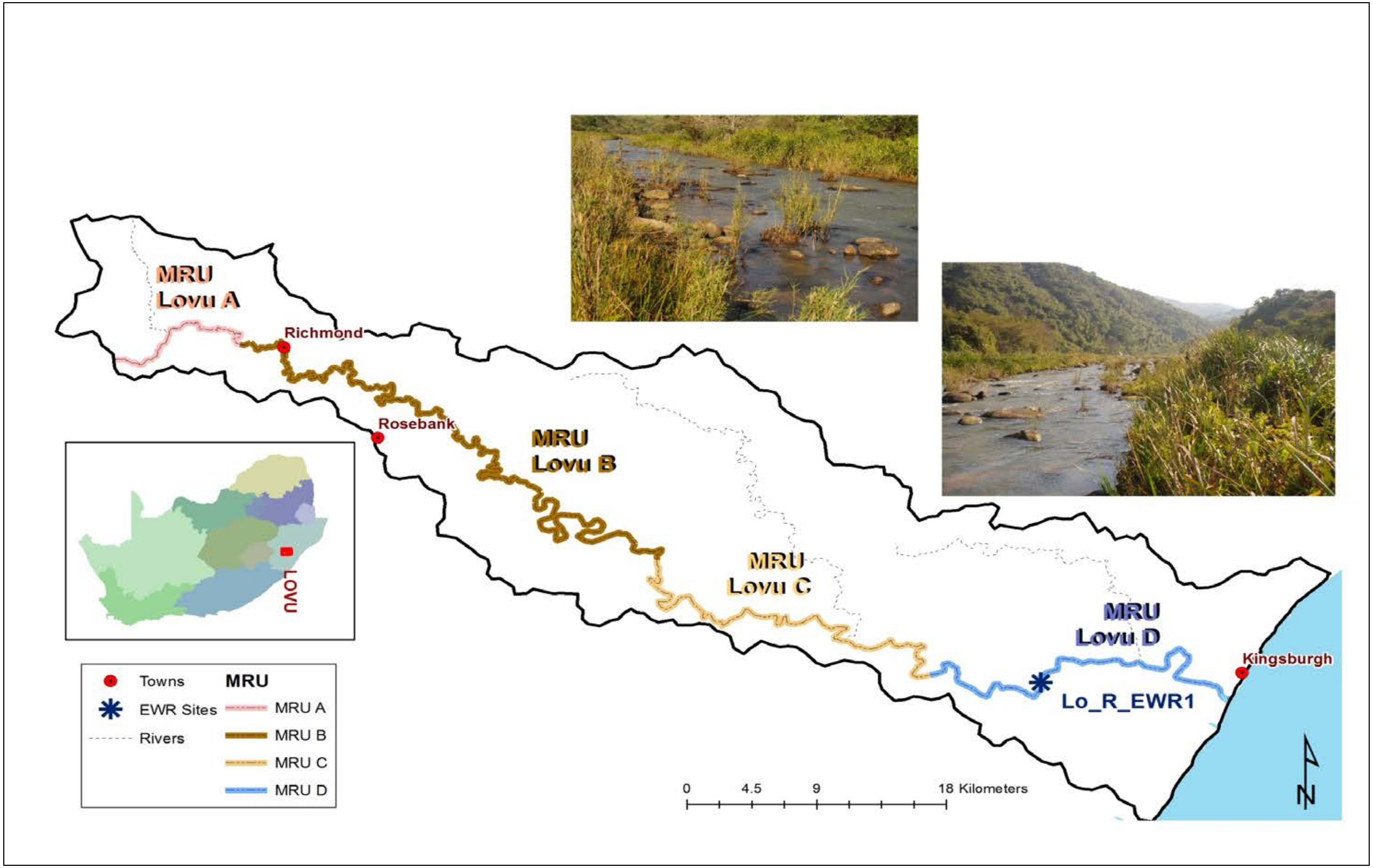


Figure 1.1 Lo_R_EWR1 (Lovu River) locality and photographs

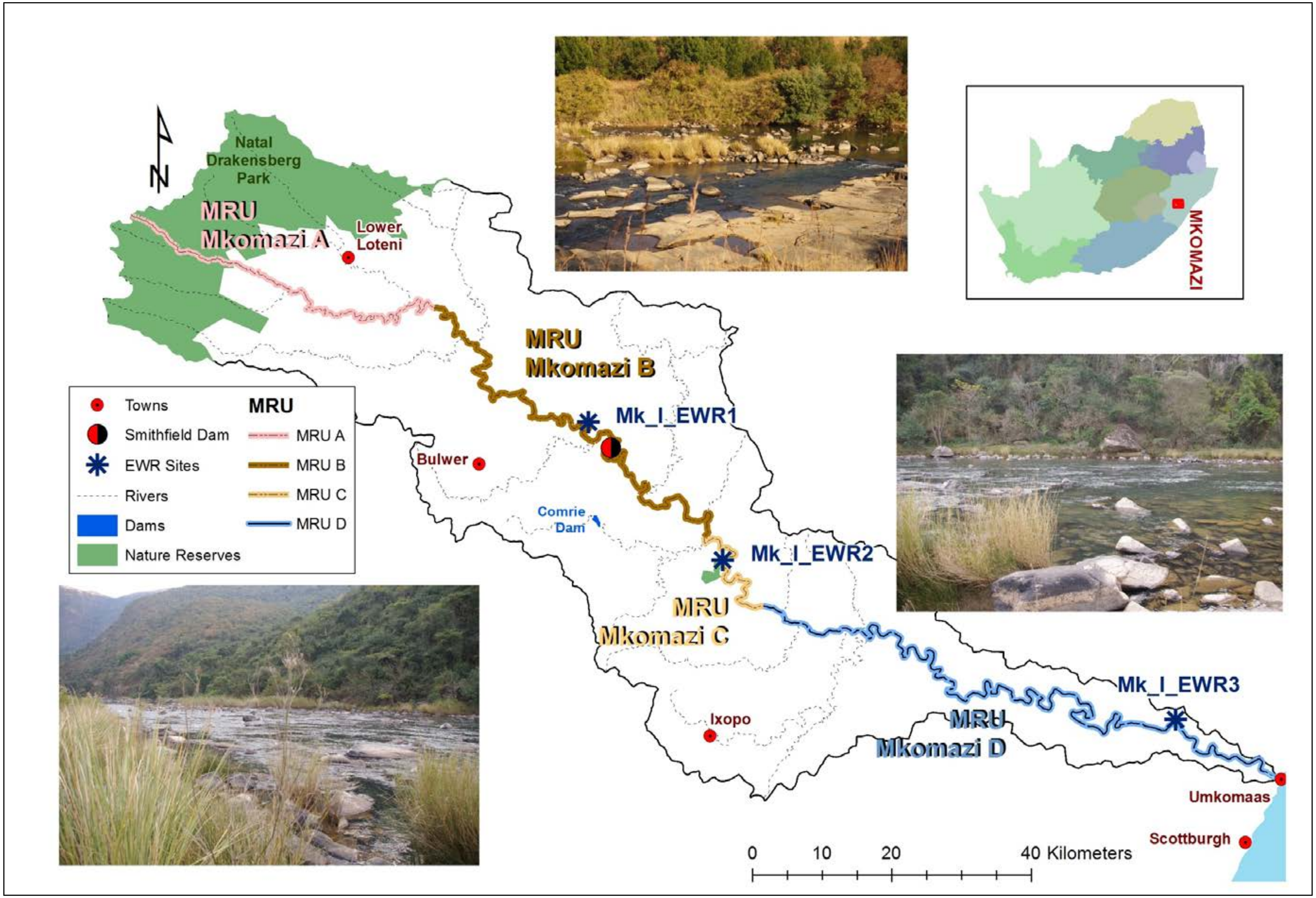


Figure 1.2 Mk_I_EWR1, Mk_I_EWR2 and Mk_I_EWR3 (Mkomazi River) locality and photographs

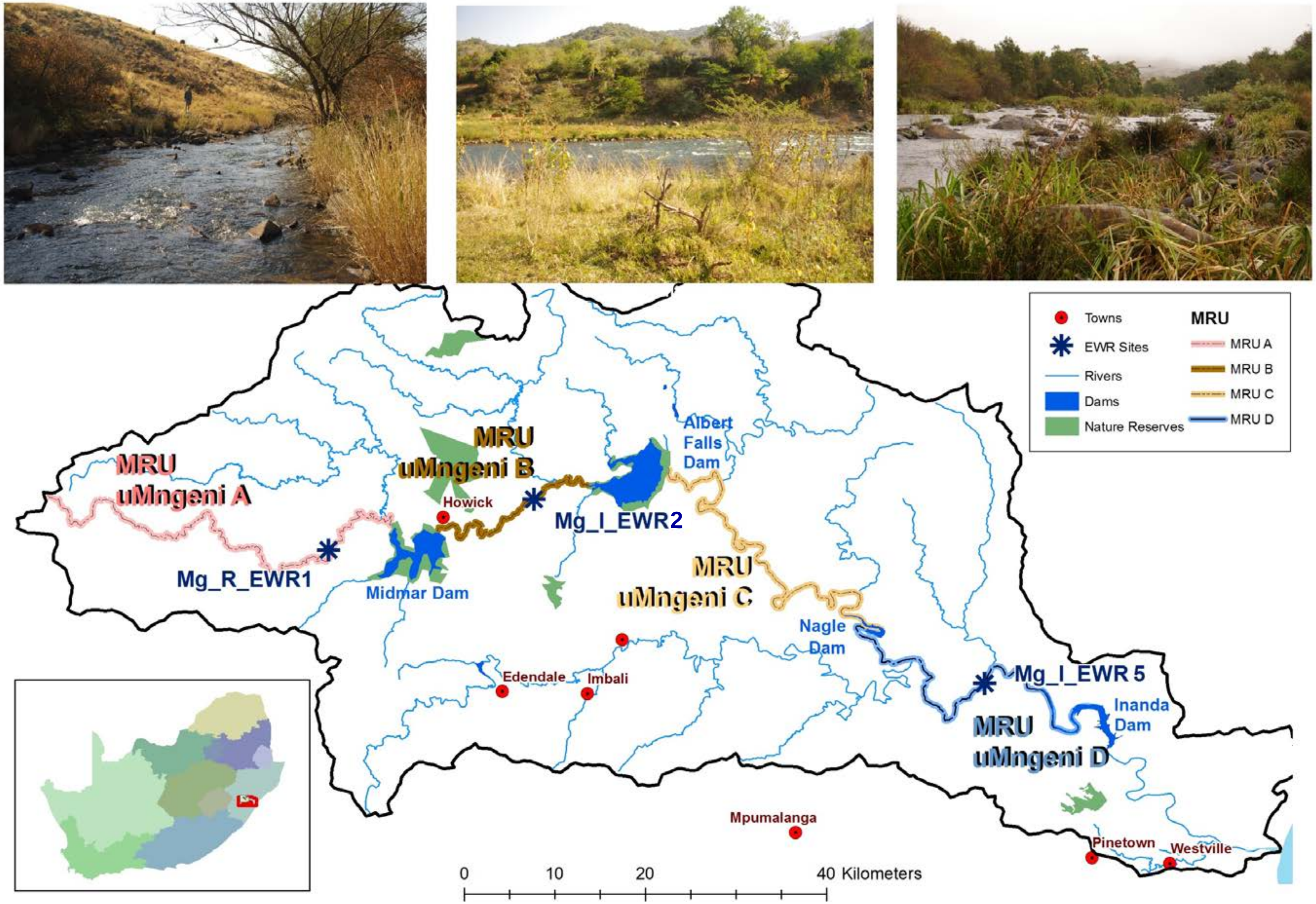


Figure 1.3 MG_I_EWR2 and MG_I_EWR5 (uMngeni River) locality and photographs

2 APPROACH: DETERMINING THE ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

2.1 AVAILABLE DATA

Information from step 3, i.e. quantifying the Ecological Water Requirements (EWR) was used as baseline for this assessment (DWA, 2014; DWS, 2014). The suite of EcoStatus models used during this task was:

- *Physico-chemical Driver Assessment Index (PAI): Kleynhans et al. (2005).*
- *Geomorphological Driver Assessment Index (GAI): Rountree and du Preez (in prep).*
- *Fish Response Assessment Index (FRAI): Kleynhans (2007).*
- *Macro Invertebrate Response Assessment Index (MIRAI): Thirion (2007).*
- *Riparian Vegetation Response Assessment Index (VEGRAI): Kleynhans et al. (2007).*

A summary of the Present Ecological State (PES) results for the various EWR sites that are affected by the operational scenarios (Sc) are provided in Table 2.1.

Table 2.1 Summary of the EcoClassification results of the EWR sites affected by operational scenarios (from DWA, 2014; DWS, 2014)

Component	Lovu River	Mkomazi River			uMngeni		Heinespruit	Mvoti River
	EWR1	EWR1	EWR2	EWR3	EWR2	EWR5	EWR1	EWR2
Physico chemical	B/C	A/B	A/B	A/B	C/D	C/D	C	C
Geomorphology	B	A/B	B	B	D	C/D	B	C
Fish	B/C	B	B	B	E*(D)	D	C	B/C
Macro-invertebrates	B/C	B/C	B	B	C	C/D	C	B/C
Riparian vegetation	B/C	C	B	D	C	D	B/C	C/D
EcoStatus	B/C	C	B	C	C	D	C	C

** Fish needs to improve to a D EC.*

2.2 PROCESS TO DETERMINE ECOLOGICAL CONSEQUENCES

The process is divided into chronological steps to determine the ecological consequences of the scenarios:

- *The operational scenarios 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 the consequences and resulting EC of the operational scenario at the EWR sites.*
- *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 VEGRAI model to predict the EC for the operational scenario.*

- *Note: As only monthly modelling was available, the assessment of floods within scenarios will always be of lower confidence.*

This information formed the basis for the instream assessment to determine the responses to these driver changes for each scenario:

- *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 scenario determination) that included the EWR scenarios, natural, and present day (PD) hydrology.*
- *The operational scenarios were then compared to the EWRs set for various ECs. For example, if the operational scenario lies between the B EC and C EC for fish for a 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 FRAI and MIRAI to determine the EC.*
- *The VEGRAI, MIRAI and FRAI results (EC percentages and confidence evaluation) was used to determine the EcoStatus.*

The approach to determine ecological consequences of the instream components are provided below.

2.2.1 Fish

The estimated change in the fish assemblage under each scenario was assessed based on the expected change in various aspects of importance (drivers/stressors), i.e. flow, habitat, water quality, migration and presence of alien fish species. These variables (metrics) were then used to change the present Frequency of Occurrence (FROC) (Kleynhans and Louw, 2007) a fish species in the FRAI by a relative percentage that reflects the extent of variation from present [range from 0% (no change from present) to +100% (100% improvement from present) OR -100% (100% deterioration from present)]. These changes were then further weighted for each species based on the relative intolerance/preference of each species to aspects/habitat features related to the specific variable (e.g. eels would for instance be more impacted by migratory impacts than potadromous species, a rheophilic species would be more intolerant to alterations in flow than a limnophilic species, etc.)

Flow: *The estimated change in maintenance and drought flows during wet and dry seasons, as well as potential change in seasonality was assessed using the 'Habitat Flow Stressor Response - Reserve Model' (HFSR-RM)[1]. The flow change percentage was weighted for each species using the "flow requirement intolerance rating".*

Substrate: *Geomorphological change (based on the outcomes of the GAI and specialist input from the geomorphologist) was used to determine the estimated percentage change in substrate quality and availability for fish. This change was weighted for each species using its specific "preference rating for substrate as cover".*

1 The application of the Revised Desktop Reserve Model (RDRM) (Hughes et al., 2011) for an Intermediate Ecological Reserve Method will be referred to as the 'Habitat Flow Stressor Response - Reserve Model' (HFSR-RM) as the model has been adjusted for specific application in a non-desktop situation.

Vegetation: *The change in the marginal vegetation was estimated based on the marginal zone section of the VEGRAI and vegetation specialist input. The marginal zone percentage change was weighted using the "preference rating for overhanging vegetation as cover for each fish species".*

Water quality: *The change in water quality under each scenario was based on input from the PAI and water quality specialist and the expected percentage change in water quality was weighted for each species based on their "requirement for unmodified water quality intolerance rating". The change in* **migratory aspects** *and presence of* **alien fish species** *was also altered in the relevant section of the FRAI model based on the expected change under the scenario.*

The **overall** *change, considering all these aspects, were then reflected by the change in FRAI score (%). This approach ensured that the change under each scenario will be relative to the actual change in the various drivers/stressors for the fish, and also considering the specific requirements and intolerance of each fish species to different aspects in its environment.*

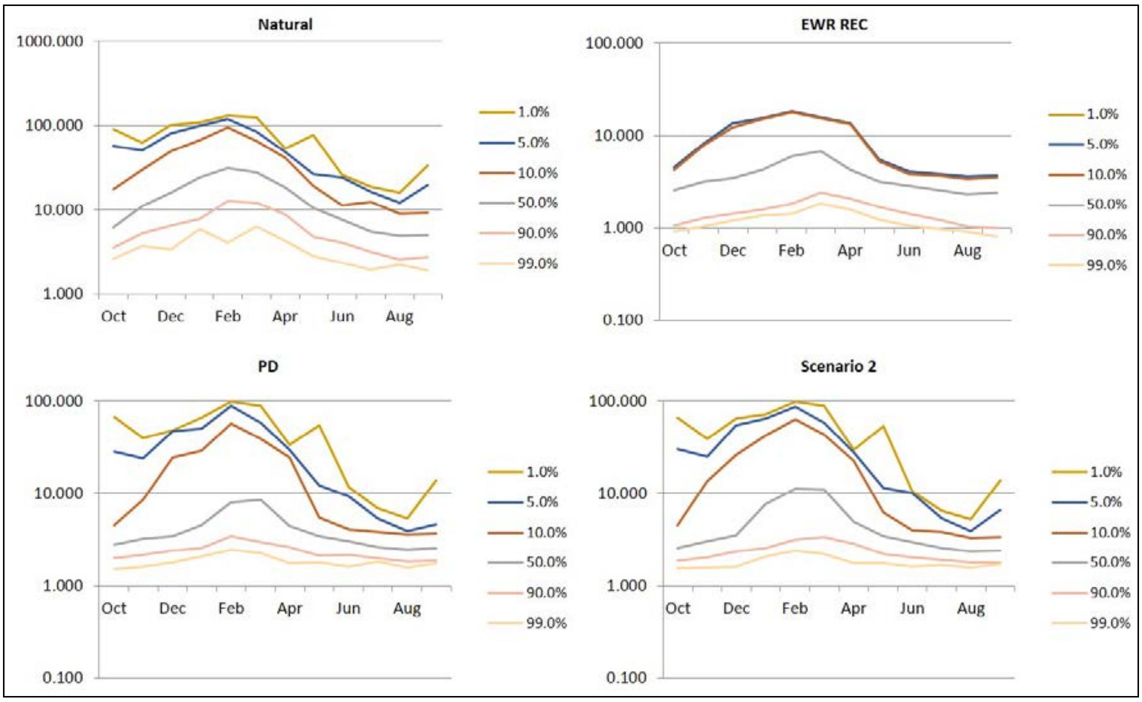
2.2.2 Macro-invertebrates

A similar approach than used for fish was also applied for the macro-invertebrate component. The same sources of information as described above was used to assess the proportion of change (5) from present under each scenario for aspects relating to flow modification, habitat, water quality and connectivity and seasonality. Flow modification, connectivity and seasonality change was again based on a detailed assessment of the change in flow (primarily using the HFSR-RM as support. Habitat changes were based on the geomorphological and riparian (marginal zone) vegetation input from the GAI and VEGRAI models and relevant specialist input. Water quality change was based on the PAI and water quality specialist input. The percentage changes was then used to alter the relevant metric in the MIRAI to calculate the altered MIRAI score and category expected under each scenario.

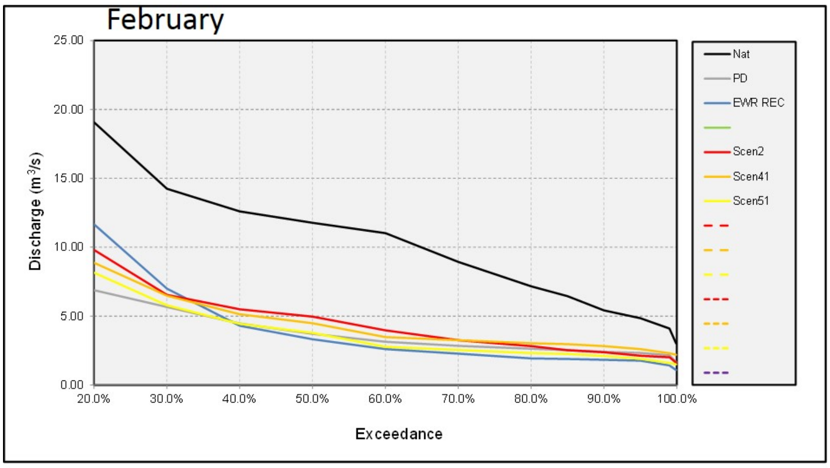
2.2.3 Riparian vegetation

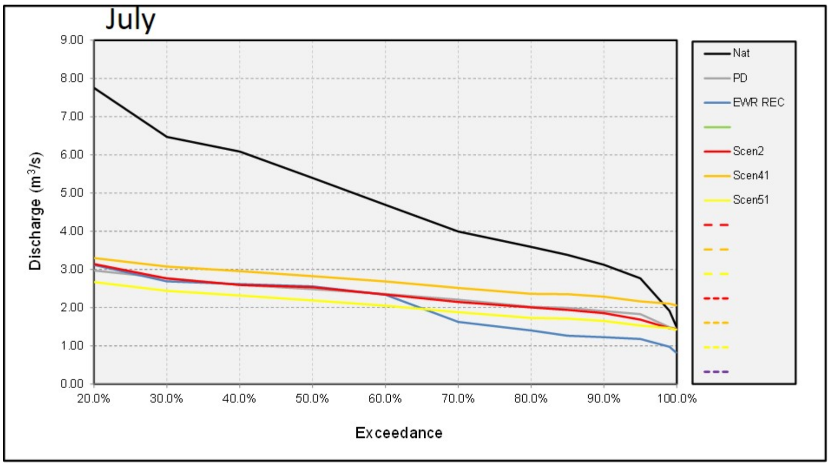
The following steps comprise the process employed to assess the ecological consequences of various scenario flow regimes on riparian vegetation:

1. *An overall qualitative description of differences between the applicable scenario and natural, present day and EWR flows is provided utilising log charts of monthly flow at the following percentiles: 1%, 5%, 10%, 50%, 90% and 99%. Differences in quantity of water (overall, high flows and low flows) are noted as well as changes to the seasonal distribution of flows. General statements regarding the response of riparian vegetation are then made based on these qualitative overviews. An example is provided below:*



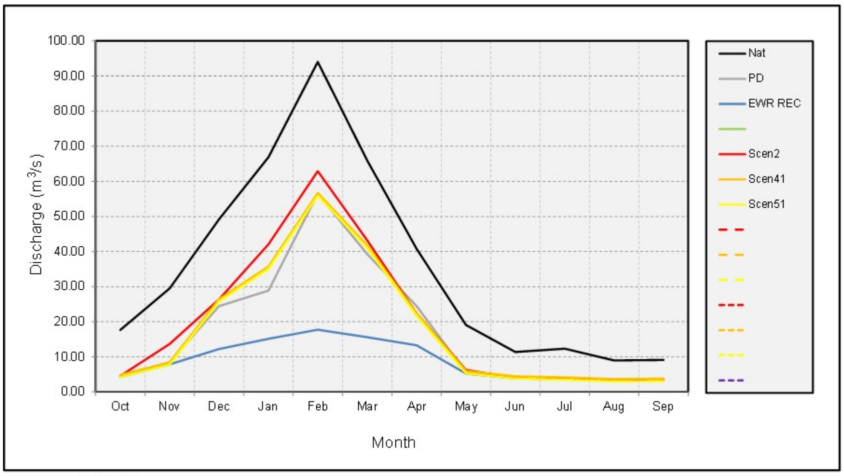
2. *A month-by-month comparison of the flow duration curves of the applicable scenario to natural, PD and EWR flows is conducted. General statements are made concerning the probable response of riparian vegetation (usually indicator or guild specific) taking specific cognisance of seasonal and phenological requirements of vegetation. The example below shows a comparison between February and July.*



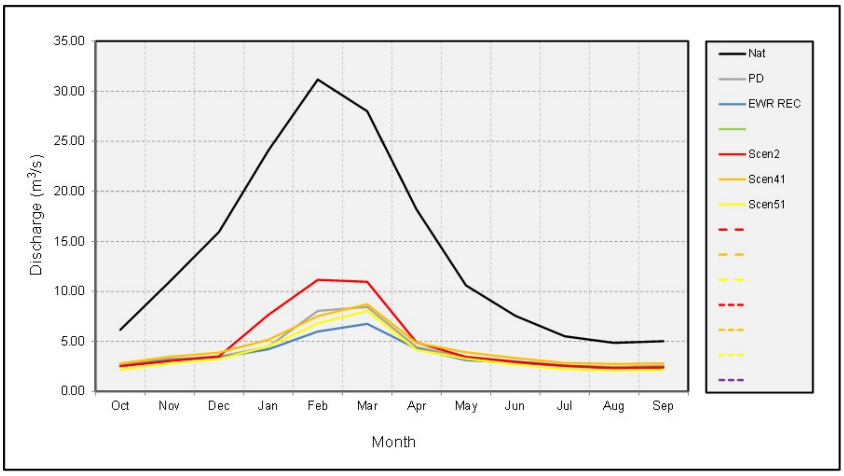


3. *A similar comparison is conducted at select percentiles (10%, 20%, 40%, 50%, 60%, 80% and 90%) showing the average annual distribution of flows at each percentile. The example below shows a comparison between the 50% and the 10%.*

10%



50%



4. *Stream permanency has been shown to be important for the persistence of riparian vegetation in perennial rivers (Lite and Stromberg, 2007; modified, Leenhouts et al.; 2005). Once stream permanency declines below 10% population density will decline and once stream permanency declines below 20% many species will likely disappear or be replaced by other hardy drought tolerant or terrestrial species. Each scenario is assessed for stream permanency (expressed as the % of an average year where flow does not cease) and compared to values for natural, PD and EWR flows. Scenarios are also checked against natural flows to ascertain whether flow ever exceeds natural. Such an increase in inundation may also elicit vegetation responses such as zone shrinkage and changes to species composition.*
5. *The flooding range for each riparian indicator is then used for a site-specific comparison of the scenario in order to determine to what extent the inundation or activation of each indicator changes and whether indicator drought tolerance is exceeded. This comparison is usually done for both the highest and lowest flow month and at percentiles representative of base flows (usually around 50%) and high flows (usually around 10 - 20%). Knowledge of indicator specific drought tolerance, maximum rooting depth and inundation requirements is used to assess whether changes will result in a response from the indicator. Likely responses of all indicators are then considered within respective sub-zone (such as marginal and lower zones) and changes made within VEGRAI (Kleynhans et al., 2007) to*

translate a vegetative response into a change in ecological state (EC). The example below shows comparison at the 50% for February and August.

February (wet season)		Indicator Species (lower and upper elevation above channel bed (m))											
		Cyperus dives		*Nasturtium officinale*		*Juncus effasus*		*Setaria sphacelata*		*Ludwigia octovalvis*		*Syzygium cordatum*	
Scenario	Discharge @ 50%	0.53	0.87	0.54	0.77	0.63	0.87	0.66	n/a	0.85	1.24	0.8	n/a
Nat	31.17	-0.61	-0.27	-0.6	-0.37	-0.51	-0.27	-0.48		-0.29	0.1	-0.34	
PD	8.06	-0.21	0.13	-0.2	0.03	-0.11	0.13	-0.08		0.11	0.5	0.06	
EWR	5.99	-0.17	0.17	-0.16	0.07	-0.07	0.17	-0.04		0.15	0.54	0.1	
Scen2	11.15	-0.29	0.05	-0.28	-0.05	-0.19	0.05	-0.16		0.03	0.42	-0.02	
Scen41	7.53	-0.21	0.13	-0.2	0.03	-0.11	0.13	-0.08		0.11	0.5	0.06	
Scen42	7.53	-0.21	0.13	-0.2	0.03	-0.11	0.13	-0.08		0.11	0.5	0.06	
Scen51	6.81	-0.19	0.15	-0.18	0.05	-0.09	0.15	-0.06		0.13	0.52	0.08	
Scen52	6.81	-0.19	0.15	-0.18	0.05	-0.09	0.15	-0.06		0.13	0.52	0.08	
August (dry season)		**Indicator Species (lower and upper elevation above channel bed (m))**											
		Cyperus dives		*Nasturtium officinale*		*Juncus effasus*		*Setaria sphacelata*		*Ludwigia octovalvis*		*Syzygium cordatum*	
Scenario	Discharge @ 50%	0.53	0.87	0.54	0.77	0.63	0.87	0.66	n/a	0.85	1.24	0.8	n/a
Nat	4.86	-0.13	0.21	-0.12	0.11	-0.03	0.21	0		0.19	0.58	0.14	
PD	2.44	-0.03	0.31	-0.02	0.21	0.07	0.31	0.1		0.29	0.68	0.24	
EWR	2.29	-0.03	0.31	-0.02	0.21	0.07	0.31	0.1		0.29	0.68	0.24	
Scen2	2.36	-0.03	0.31	-0.02	0.21	0.07	0.31	0.1		0.29	0.68	0.24	
Scen41	2.75	-0.05	0.29	-0.04	0.19	0.05	0.29	0.08		0.27	0.66	0.22	
Scen42	2.75	-0.05	0.29	-0.04	0.19	0.05	0.29	0.08		0.27	0.66	0.22	
Scen51	2.10	-0.01	0.33	0	0.23	0.09	0.33	0.12		0.31	0.7	0.26	
Scen52	2.10	-0.01	0.33	0	0.23	0.09	0.33	0.12		0.31	0.7	0.26	

6. *The final check is to determine whether flood requirements that were specified for the EWR are met and if not to what extent this is likely to affect riparian vegetation. Where applicable data from a spills analysis (if this is available) is assessed as well.*

2.3 PROCESS TO DETERMINE THE RANKING OF SCENARIOS PER EWR SITE

Once the change in ecological state was determined for each of the scenarios at a site, the scenarios had to be ranked from better to worse. Note that at this stage the ranking was ONLY considering the change in ecological state. The ranking illustrated the degree to which a scenario meets the Recommended Ecological Category (REC) (or one can describe it as the degree to which the ecological objectives which are represented by the REC are met). The scoring of one to zero is defined as follows:

- *1: REC is met for all components[2].*
- *0: REC is not met at any component and each component would be evaluated individually as zero.*

The concept per component and overall is the same. The following illustration is for one component, i.e. fish. Therefore, if the REC for fish is 62% and the scenario results in the fish being at 62%, then the resulting score would be a 1 (or 100% successful in meeting the REC for fish). If the resulting scenario results in fish being at 48%, then the score would be 0.77 (or 77% successful in meeting the fish REC).

Each component score is then averaged to obtain an overall score for the scenario. Once all the scores for each scenario have been calculated, these can then be ranked and plotted on a traffic diagram illustrating the degree to which the EcoStatus is met.

[2] *Components: Drivers (physico-chemical, geomorphology) and responses (fish, macro-invertebrates, and riparian vegetation).*

2.4 EVALUATED SCENARIOS

The scenarios that were evaluated to assess ecological consequences at the various EWR sites are summarised in a matrix (Table 2.2 – 2.5). Detail regarding the scenarios and the yield modelling is supplied in Report 7 – Water Resource Analysis Report.

To simplify, the scenarios below will be referred to by number and the letters will be left out. Note that Sc 1 in all cases represents present day (PD) hydrology and will not be evaluated as a scenario.

Table 2.2 Scenarios for ecological consequences determination: Lovu River

Scenario	Scenario Variables			EWR Drivers
	Update water demands	Ultimate development demands and return flows (2040)	Reduced abstraction and afforested areas	Lo_R_EWR1
LO1	*Yes*	*No*	*No*	*Yes*
LO2	*Yes*	*Yes*	*No*	*Yes*
LO3	*Yes*	*Yes*	*Yes (25%)*	*Yes*
LO4	*Yes*	*Yes*	*Yes (50%)*	*Yes*

Table 2.3 Scenarios for ecological consequences determination: Mkomazi River

Scenarios	Scenario Variables					EWR Drivers		
	Update water demands	Ultimate development demands and return flows (2040)	EWR	Mkomazi Water Project (MWP) (Smithfield Dam)	Ngwadini Off-channel Dam (OCD)	Mk_I_EWR1	Mk_I_EWR2	Mk_I_EWR3
MK1	*Yes*	*No*	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*
MK2	*Yes*	*Yes*	*No*	*Yes*	*Yes (no support)*	*Yes*	*Yes*	*Yes*
MK21	*Yes*	*Yes*	*REC tot[1] (EWR 2)*	*Yes*	*Yes (no support)*	*Yes*	*Yes*	*Yes*
MK22	*Yes*	*Yes*	*REC low (EWR 2)*	*Yes*	*Yes (no support)*	*Yes*	*Yes*	*Yes*
MK23	*Yes*	*Yes*	*REC low[2]+ (EWR 2)*	*Yes*	*Yes (no support)*	*Yes*	*Yes*	*Yes*
MK31	*Yes*	*Yes*	*REC tot (EWR 3)*	*Yes*	*Yes (no support)*	*Yes*	*Yes*	*Yes*
MK32	*Yes*	*Yes*	*REC low (EWR 3)*	*Yes*	*Yes (no support)*	*Yes*	*Yes*	*Yes*
MK33	*Yes*	*Yes*	*REC low+ (EWR 3)*	*Yes*	*Yes (no support)*	*Yes*	*Yes*	*Yes*
MK4	*Yes*	*Yes*	*No*	*Yes*	*Yes (with support)*	*Yes*	*Yes*	*Yes*
MK41	*Yes*	*Yes*	*REC tot (EWR 2)*	*Yes*	*Yes (with support)*	*Yes*	*Yes*	*Yes*
MK42	*Yes*	*Yes*	*REC low (EWR 2)*	*Yes*	*Yes (with support)*	*Yes*	*Yes*	*Yes*

1 Total REC requirements.
2 Based on total flows for January, February, March and low flows for remaining months.

Table 2.4 Scenarios for ecological consequences determination: Mvoti River

	Scenario Variables	EWR

						Drivers	
	Update water demands	**Ultimate development demands and return flows (2040)**	**EWR**	**Isithundu Dam**	**Imvutshane Dam**	**Mv_I_EWR1**	**Mv_I_EWR2**
MV1	*Yes*	*No*	*No*	*No*	*No*	*Yes*	*Yes*
MV3	*Yes*	*Yes*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
MV41	*Yes*	*Yes*	*REC tot (EWR 2)*	*Yes*	*Yes*	*No*	*Yes*
MV42	*Yes*	*Yes*	*REC low (EWR 2)*	*Yes*	*Yes*	*No*	*Yes*
MV43	*Yes*	*Yes*	*REC low[1]+ (EWR 2)*	*Yes*	*Yes*	*No*	*Yes*

1 Based on total flows for Jan - Mar and low flows for remaining months.

Note that there were no impacts on the Heinespruit (Mv_1_EWR1) and impacts on the scenarios at this site were not evaluated.

Table 2.5 Scenarios for ecological consequences determination: uMngeni River

Scenarios	Scenario Variables								EWR Drivers	
	Update water demands	Demands and return flows (2023)	Ultimate development demands and return flows (2040)	EWR	MMTS2	MWP	Darvill Re-use	Ethekwini Re-use	Mg_I_EWR2	Mg_I_EWR5
UM1	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*Yes*
UM2	*No*	*Yes*	*No*	*No*	*Yes*	*No*	*No*	*No*	*Yes*	*Yes*
UM41	*Yes*	*No*	*Yes*	*No*	*Yes*	*Yes*	*No*	*No*	*Yes*	*Yes*
UM42	*Yes*	*No*	*Yes*	*No*	*Yes*	*Yes*	*No*	*No*	*Yes*	*Yes*
UM51	*Yes*	*No*	*Yes*	*No*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
UM52	*Yes*	*No*	*Yes*	*No*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

3 LOVU CATCHMENT (U70) – ECOLOGICAL CONSEQUENCES AT LO_R_EWR1: LOVU RIVER

Scenario LO3 and LO4 were evaluated at LO_R_EWR1. Scenario LO2 was very similar to Sc LO1 with slightly (marginally) lower flows and overall similar to Sc LO1.

3.1 CHANGES IN FLOW REGIME

A summary of the effects of the operational scenarios is provided below:

- *Sc LO3: Relative to the PD (73 Mm^3) it represents flow increases (77 Mm^3) which is achieved by reducing forestry in the catchment by 25% and reduced abstraction.*
- *Sc LO4: Relative to the PD (73 Mm^3) it represents flow increases (84 Mm^3) which is achieved by reducing forestry in the catchment by 50% and reduced abstraction.*

The ultimate demands are increased abstractions for Richmond which is balanced against increased return flows. But the scenarios are driven by reduced abstraction and afforested areas, and therefore the overall increased flows. Sc LO3 and LO4 represent an improvement in PD and the REC.

The driver consequences are summarised in Table 3.1 and the response consequences in Table 3.2. Summaries are provided in Table 3.3 and Figure 3.1.

3.2 LO_R_EWR1: ECOLOGICAL DRIVER COMPONENTS

Table 3.1 LO_R_EWR1: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC B/C (80.4%)		
3	*B (86.4%)*	*Consistently higher flows will result in a dilution of nutrients and toxics presumed present in the system.*
4	*A/B (89%)*	*The significantly higher flows, particularly in the low flow season, will result in an improved state in nutrient levels, toxics and turbidity.*
Geomorphology: PES and REC B (85%)		
3 4	*B (85%)*	*This was a rapid site and no geomorphological PES or floods for geomorphology were determined. The B EC is based on specialist opinion. Evaluation of the flow scenarios and photographs of the EWR site suggested that Sc LO3 and 4 will, due to increased base flows, result in improved in-channel bed condition (cleaner substrates) during the low flow seasons.*

3.3 LO_R_EWR1: ECOLOGICAL RESPONSE COMPONENTS

Table 3.2 LO_R_EWR1: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC B/C (78.9%)		
3	*B (85.7%)*	*Improved flow can be expected to improve conditions for species such as Barbus gurneyi, and to a lesser degree B. natalensis. Overall increase in flow during all months and flow durations will also lead to improved habitat availability (abundance) and condition. This will improve the FROC (Kleynhans and Louw, 2007) of species Anguilla mossambica, B. gurneyi, B. natalensis and Tilapia sparrmanii. Increased flows will also result in improved depth and hence an improvement in longitudinal and lateral migration.*
4	*A/B*	*A further improvement (compared to Sc LO3) in flow will result in even better water quality*

Sc	EC	Consequences
	(88.7%)	*(improvement in B. gurneyi), and habitat availability and condition (improvement in A. mossambica, B. gurneyi, B. natalensis and T. sparrmanii). Increased flows will also result in improved depth and hence an improvement in longitudinal and lateral migration.*
Macro-invertebrates: PES and REC B/C (80.6%)		
3	*B (84.5%)*	*Although there is no change in floods, the higher flows scour the river bed and remove sediment and stagnant backwaters. Some inundation of marginal vegetation occurs and the water quality improves. Although some nutrients and turbidity is present, conditions will be better in dry season compared to PD. The improved habitat (water column due to higher flows), bottom substrates (scouring), overhang (inundation of marginal vegetation)) and less stress during the dry season (higher flows during dry season) improves conditions for the macro-invertebrates and there is an improvement to a B EC compared to PD.*
4	*A/B (87.4%)*	*A further improvement (compared to Sc LO3) in flow will result in even better water quality, more inundation of the marginal vegetation, and improved habitat leading to lower stress in the dry season. The macro-invertebrates will improve to an A/B EC.*
Riparian vegetation: PES and REC B/C (77.7%)		
3	*B/C (77.7%)*	*The main impacts at the site were grazing and trampling by livestock (low impacts to sedges and woody seedlings), and invasion by alien species (mainly Sesbania punicea and Wattle). Some wood harvesting was also noted. Responses to flow were not discernable. LO3 results in more flow than PD and the EWR in the wet season. Inundation of marginal and lower zone vegetation increases slightly, by up to 10 cm (Table 12.1, Appendix A). A measurable response by vegetation is unlikely in the wet season. The flooding regime has remained unchanged and a response by vegetation is unlikely. Levels of inundation of marginal and lower zone vegetation are slightly more in the dry season but only by a few centimetres. Inundation of vegetation during dormancy can result in mortality but the inundation levels are not severe enough and the EC will not change.*
4	*B/C (77.7%)*	*There is slightly more water than Sc LO3 but effects on vegetation will be the same (see above and Table 12.1, Appendix A) for detail.*

3.4 LO_R_EWR1: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 3.3. The ranking of the scenarios are provided on a traffic diagram (Figure 3.1). The results illustrate that all the scenarios meet the ecological objectives with Sc LO4 resulting in an improvement in the PES and REC.

Table 3.3 Ecological consequences at LO_R_EWR1

Component	PES & REC	Sc LO2	Sc LO3	Sc LO4
Physico chemical	**B/C**	**B/C**	**B**	**A/B**
Geomorphology	**B**	**B**	**B**	**B**
Fish	**B/C**	**B/C**	**B**	**A/B**
Invertebrates	**B/C**	**B/C**	**B**	**A/B**
Riparian vegetation	**B/C**	**B/C**	**B/C**	**B/C**
EcoStatus	**B/C**	**B/C**	**B/C**	**B**

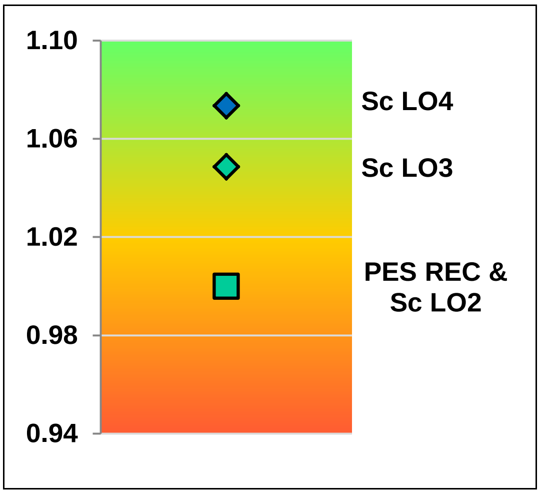


Figure 3.1 Ecological ranking of operational scenarios at LO_R_EWR1

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4 MKOMAZI CATCHMENT (U10) – ECOLOGICAL CONSEQUENCES AT MK_I_EWR1: MKOMAZI RIVER

Scenario MK2, MK21, MK22, MK31, MK32, MK4, MK41 and MK42 were evaluated at MK_I_EWR1. The analysis of the operational scenarios indicated that Sc MK22 was similar to Sc MK23 and Sc MK32 was similar to Sc MK33 and no distinguishable ecological responses could be differentiated. Therefore Sc MK22 and Sc MK32 represent these scenarios respectively.

4.1 CHANGES IN FLOW REGIME

The natural MAR at MK_I_EWR1 is 683 Mm^3 and the present day MAR is reduced to 661 Mm^3. The PES EWR requirement is only 243 Mm^3. In some cases critical flow reductions proposed under some scenarios in the low flow and early wet seasons can be expected to have dire ecological consequences for instream biota and habitat conditions in the reach below the dam. A summary of the effects of the operational scenarios is provided below:

- *Sc MK2: Relative to the PD (661 Mm^3) it represents significant decrease in flow (486.4 Mm^3) as no EWR requirements are catered for. This scenario represents reduced base flows frequently less than the EWR and reduced flood volumes (wet season; Oct - Dec). The few floods that will be provided will be much delayed. It is similar to MK4 but lower flows occur in all months and zero flows occur during drought periods in Oct - Dec.*
- *Sc MK21: Relative to the PD (661 Mm^3) it represents reduced flows (540.5 Mm^3) and only supplies the EWR at MK_I_EWR2. This scenario includes the total EWR flows (i.e. all floods) and provides more flows in the wet season than Sc MK22. Low flows are similar to PD, generally meets the EWR requirement or more and more than natural for some of the time.*
- *Sc MK22: Relative the PD (661 Mm^3) it represents reduced flows (532.1 Mm^3) and only supplies the EWR at MK_I_EWR2. Scenario MK 22 only includes some of the required floods, but no floods are provided for during Nov - Dec. Low flows are similar to PD, generally meet the EWR requirement or more and flows are more than natural for some of the time.*
- *Sc MK31: Relative to the PD (661 Mm^3) it represents reduced flows (532.5 Mm^3) and only supplies the EWR at MK_I_EWR3. This scenario includes the total EWR flows (i.e. all floods) and provides more flows in the wet season than Sc MK32. Wet season is delayed with significantly less flow in the early wet season (Oct - Dec), especially the base flow component, and is frequently less than the EWR.*
- *Sc MK32: Relative to the PD (661 Mm^3) it represents reduced flows (521.7Mm^3) and only supplies the EWR at MK_I_EWR3. Scenario MK 32 only includes some of the required floods, but no floods are provided for during Nov - Dec. Wet season is delayed with significantly less flow in the early wet season (Oct - Dec), especially the base flow component, and is frequently less than the EWR requirement.*
- *Sc MK4: Relative the PD (661 Mm^3) it represents reduced flows (539.8 Mm^3). This scenario is similar to Sc MK41 and MK42 but no EWR is catered for. Wet season is delayed with significantly less flow in the early wet season (Oct - Dec), especially the base flow component, and is frequently less than the EWR requirement.*
- *Sc MK41: Relative to the PD (661 Mm^3) it represents reduced flows (598.5 Mm^3) and only supplies the EWR at MK_I_EWR2. This scenario includes the total REC flows (i.e. all floods) and during drought periods flows are higher than natural (and present day) from May to October. The wet season is delayed with significantly less flow in the early wet season (Oct - Dec), especially the base flow component, but mostly meets the EWR requirement.*

- *Sc MK42: Relative to the PD (661 Mm^3) it represents reduced flows (590.1 Mm^3) and only supplies the low flow EWR at EWR at MK_I_EWR2. Flows are similar to Sc MK41 with flows closer to EWR requirements during Oct – Dec. Wet season is delayed with significantly less flow in the early wet season (Oct - Dec), especially the base flow component, and is frequently less than the EWR requirement.*

The driver consequences are summarised in Table 4.1 and the response consequences in Table 4.2. Summaries are provided in Table 4.3 and Figure 4.1.

4.2 MK_I_EWR1: ECOLOGICAL DRIVER COMPONENTS

Table 4.1 MK_I_EWR1: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC B/C (89.9%)		
2	*C (65.2%)*	*Impacts will be experienced on most water quality variables, but particularly salts, nutrients and temperature which would increase and oxygen levels will decrease.*
21 22	*A/B (89.8%)*	*As the current water quality state is good and the base flows are maintained, the impact of fewer high flows are not very significant and no change in the water quality state is expected.*
31 32	*B (87.2%)*	*There is a small drop in flows, both for high and low flows, which may have some impact on nutrient and salt levels which will increase.*
4	*C (70%)*	*Flows are lower than PD, except for during the lowest flows of the dry season. Impacts include increased salts, nutrients and temperature and oxygen decreases.*
41 42	*A/B (91%)*	*Higher base flows, particularly at lowest flow months, will result in the flushing of some accumulated nutrients, but temperature impacts may be experienced as downstream of Smithfield Dam.*
Geomorphology: PES and REC A/B (88.6%)		
2	*C/D (58.1%)*	*The dam upstream will cut off all sediment supply, so the marginal zones downstream of the dam can be expected to erode, and recovery of eroded banks will be poor because of the reduced sediment loads. Suspended sediments coming through the dam would accumulate in the pools and over the bed during the prolonged (and reduced flow) dry seasons.*
21 31 41	*B/C (78.9%)*	*These scenarios have sufficient volumes to meet the EWR high flow and flood requirements during all months, but sediment trapping in the dam would cause downstream erosion of the marginal zones. The bedrock channel would remain free of sediment.*
22 32	*C (67.9%)*	*These scenarios propose reduced baseflows and delayed, reduced floods relative to PD. The monthly volumes of these scenarios in the early wet season will, on average, be insufficient to meet the EWR requirements. Additionally, the sediment trapping impacts of the dam will cause erosion of the marginal zones.*
4 42	*C (67.9%)*	*This scenario proposes reduced late wet season baseflows, slightly elevated dry season flows (slightly above natural) and very slightly reduced early wet season flow requirements. The reduced and delayed early wet season floods would result in more prolonged accumulation periods of fines (suspended material which is transported through the dam) on the bed of the channel and in the pools. Additionally, the sediment trapping impacts of the dam will cause erosion of the marginal zones.*

4.3 MK_I_EWR1: ECOLOGICAL RESPONSE COMPONENTS

Table 4.2 MK_I_EWR1: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC B (83.5%)		
2	*D (51.6%)*	*The rheophilic A. natalensis and large semi-rheophilic B. natalensis will especially be impacted by the reduction in fast flowing habitat and the lack of flow at times. This may*

Sc	EC	Consequences
		even result in the eradication of this species from this river reach, which may only be sustained by tributaries and lower reaches for recolonisation when conditions improve in the wet season. The change in sediment regime can also be expected to impact on the fish in terms of habitat and possibly food (soft sediments and associated invertebrates), resulting in a decreased FROC of most species present. A notable deterioration of overhanging vegetation is also expected, which will impact especially on B. anoplus which have a preference for this cover feature. Deterioration in overall water quality will impact on all species and especially A. natalensis which is the most intolerant species in terms of water quality deterioration.
21	*B/C (79%)*	*Conditions are estimated to remain very similar than under PES. Although improved flows (especially in the dry season) will create more habitat, a slight deterioration in terms of geomorphological aspects (sediment) and marginal vegetation is estimated, which cancels out any notable change in the ecological status.*
22	*C (76%)*	*A slight deterioration in the PES can be expected due to primarily decreased flows in some wet season months (Oct - Dec). This coupled with the delay in early summer floods can be expected to impact on spawning and nursery success rate of especially B. natalensis. The decrease in flows may result in a general decreased FROC of the rheophilic A. natalensis and semi-rheophilic B. natalensis. Alteration in sediment regime may result in change in food source (soft sediment) while the alteration in the marginal zone vegetation will impact negatively on B. anoplus which requires this cover feature.*
31	*C (70.5%)*	*Maintenance flows and thus habitats are very similar than Sc MK22, while drought flows are similar but better than Sc MK32 (no zero flows). The lower than PD and exceedance of requested EWR flows especially in the early wet season months (Oct - Dec) will result in loss of fast habitats impacting on especially the rheophilic A. natalensis as well as the semi-rheophilic B. natalensis. A notable deterioration in the FROC of these species can be expected. Slight deterioration in the marginal vegetative zone will also impact negatively on B. anoplus which has a preference for this cover feature.*
32	*C (64%)*	*The lower than PD and exceedance of requested EWR flows especially in the early wet season months (Oct - Dec) will result in loss of fast habitats. Extreme conditions (zero flows) during droughts in these months will have a critical impact on especially the rheophilic A. natalensis as well as the semi-rheophilic B. natalensis. A significant deterioration in the FROC of these species can be expected. Deterioration in the marginal vegetative zone will also impact negatively on B. anoplus which has a preference for this cover feature.*
4	*D (55.9%)*	*This scenario will result in similar trends but slightly higher flows and thus habitat suitability and availability as described under Sc MK2. The rheophilic A. natalensis and large semi-rheophilic B. natalensis will especially be impacted by the reduction in fast flowing habitat. The change in sediment regime can also be expected to impact on the fish in terms of habitat and possibly food (soft sediments and associated invertebrates), resulting in a decreased FROC of most species present. A notable deterioration of overhanging vegetation is also expected, which will impact especially on B. anoplus which have a preference for this cover feature. Deterioration in overall water quality will impact on all species and especially on A. natalensis which is the most intolerant species in terms of water quality deterioration.*
41	*C (76%)*	*In general flow, and thus habitat availability and suitability will be higher than under PD, and meet the EWR. The higher than natural flow during some winter and early summer months (Jun to Nov) will lead to a loss in slow habitats required by B. anoplus. This coupled with deterioration in the marginal vegetative zone (based on VEGRAI) will decrease the FROC of this species due to its preference for slow habitats and overhanging vegetation. The change in the sediment regime will impact negatively on the food source (invertebrates) of some species (e.g. A. mossambica, A. natalensis and B. natalensis).*
42	*C (76%)*	*Conditions will be very similar than under Sc MK41. The slight improvement in flow (compared to Sc MK41) due to shorter period of natural flow exceedance may improve the availability of slower habitats (for B. anoplus) but the deterioration in sediment and marginal vegetation will again decrease the condition, therefore cancelling out potential improvement.*
Macro-invertebrates: PES and REC B/C (80.1%)		
2	*D (54.3%)*	*Instream habitats (water column) and connectivity (both downstream and lateral) will be compromised due to reduced flows, especially during the dry season. The dams will cut off sediment transport to the areas downstream, and the silt-hungry water will elevate bank erosion and this will impact on the marginal habitats, especially overhanging and inundated*

Sc	EC	Consequences
		vegetation, as well as undercut banks. Important alluvial sediment habitat will be scoured and lost to the reach. Sensitive macro-invertebrate species will be impacted by deteriorated water quality.
21	*B/C (79.6%)*	*Higher dry season flows will benefit the instream habitats, while the lower wet flows will not impact too much in the form of erosion (sediment hungry water out of the dam). Good lateral connectivity and favourable water quality result in an EC slightly lower than the PES/REC.*
22	*C (76.4)*	*Lower flows in the early wet season will stress the macro-invertebrate environment in the sense that scouring of stagnant backwater pools and lateral habitats due to delayed floods will have localised water quality impacts. Although the overall water quality will not deteriorate, the sediment-hungry water from the dam will erode embankments and the marginal vegetation integrity will be slightly reduced.*
31	*C (75.1%)*	*Lower flows (lower than Sc MK22) in the early wet season will stress the macro-invertebrate environment in the sense that scouring of stagnant backwater pools and lateral habitats by delayed floods will have localised water quality impacts. Although the overall water quality will not deteriorate, the sediment-hungry water from the dam will erode embankments and the marginal vegetation integrity will be slightly reduced.*
32	*C (71.4%)*	*Significant lower flows in the early wet season (zero flows in the drought period) add stress to the macro-invertebrate environment. Scouring of stagnant backwater pools and lateral habitats will not occur efficiently due to the delay in floods, which will have localised water quality impacts. The overall water quality will deteriorate somewhat relating to nutrient and salt levels. The sediment-hungry water from the dam will erode embankments, impacting on the marginal vegetation integrity due to reduced cover.*
4	*C/D (58.7%)*	*Base flows are reduced under this scenario especially reduced late wet season base flows which impacts on the habitats and zero flow situations might occur during droughts. Instream habitats (water column) and connectivity (both downstream and lateral) will be compromised. The sediment-hungry water from the dam will erode embankments, impacting on the marginal vegetation integrity due to reduced cover. Sensitive macro-invertebrate species will be impacted to a greater extent by deteriorated water quality.*
41	*C (74.7%)*	*Higher than natural low flows will impact on the shallow habitats during the dry season. Sediment-hungry flows erode the marginal habitats and impact adversely on the overhanging vegetation habitats. Lack of shallow water and overhanging cover makes the macro-invertebrates vulnerable to predation in the persistent deeper water (fish) and invertivores on the unprotected margins.*
42	*C (73.1%)*	*Higher than natural low flows will impact on the shallow habitats during the dry season. Sediment-hungry flows erode the marginal habitats and impact adversely on the overhanging vegetation habitats, while fines are deposited in the slower flowing areas. Lack of shallow water and overhanging cover makes the macro-invertebrates vulnerable to predation in the persistent deeper water (fish) and invertivores on the unprotected margins.*
Riparian vegetation: PES and REC C (71.2%)		
2	*D (55.9%)*	*Inundation of marginal and lower zone vegetation is more in February at 50% (Table 12.2, Appendix A), but inundation would be less than the requirement in Oct - Dec. This is likely to result in a shortened growth season with reduced productivity and reproduction. Stream permanency at 91% i.e. significant increase in zero flows which will promote terrestrialisation of the riparian zone. In the dry season the riparian vegetation is generally up to 10 cm higher above water level than PD or EWR which will elevate water stress and may cause desiccation at the upper limits of indicator populations. A likely reduction in non-woody vegetation in the marginal and lower zones due to desiccation stress.*
21	*C (70.6%)*	*Wet season is delayed with less flow in the Dec (less than the EWR). Inundation of marginal and lower zone vegetation is more than EWR and less than PD in Feb (at 50%; see Table 12.2, Appendix A), but inundation would be less than the requirement in Dec. Stream permanency remains at 100% i.e. there is no significant increase in zero flows. The PES is unlikely to change.*
22	*C (68.8%)*	*Wet season is delayed with significantly less flow in the early wet season (Oct - Dec), and is frequently less than the EWR requirement. Inundation of marginal and lower zone vegetation is more than the EWR requirement in Feb (at 50%; Table 12.2, Appendix A), but inundation would be less than the requirement in Oct - Dec. This is likely to result in a shortened growth season with reduced productivity and reproduction. Stream permanency remains at 100% i.e. there is no significant increase in zero flows.*

Sc	EC	Consequences
31	*C (67.8%)*	*Inundation of marginal and lower zone vegetation is more than the EWR requirements but the same as PD in Feb (at 50%; Table 12.2, Appendix A), but inundation would be less than the requirement in Oct - Dec. This is likely to result in a shortened growth season with reduced productivity and reproduction. Stream permanency is at 97% i.e. moderately reduced due to the prevalence of zero flows. The EWR requirement is not met in the dry season for a large proportion of time, but for small periods exceeds natural. The height above water level is not different from PD in Aug (50%) but additional water stress in winter will likely result in some loss of non-woody vegetation.*
32	*C (66%)*	*Inundation of the marginal and lower zone vegetation is more than the EWR requirement but the same as PD in Feb (at 50%; Table 12.2, Appendix A), but inundation would be less than the requirement in Oct - Dec. This is likely to result in a shortened growth season with reduced productivity and reproduction. Stream permanency is at 93% i.e. significant increase in zero flows, which will promote terrestrialization of the riparian zone. The scenario is similar to Sc MK31 but the dry season and early wet season has less flow so vegetative response is more severe.*
4	*C/D (59.3%)*	*Inundation of marginal and lower zone vegetation is more in Feb (at 50%; Table 12.2, Appendix A), but inundation would be less than the requirement in Oct, Nov or Dec. This is likely to result in a shortened growth season with reduced productivity and reproduction. Stream permanency is at 96% i.e. moderately reduced due to prevalence of zero flows. Inundation (or lack thereof) in dry season is similar or slightly worse than PD (August at 50%) but low flows are frequently more than natural in Aug and Sep and less than the EWR requirement in May and Jun. Oscillation between water stress and unnatural inundation is likely to cause mortality of vegetation in the marginal and lower zones.*
41	*C/D (59%)*	*Inundation of marginal and lower zone vegetation is more in than the EWR requirement and the same as PD in Feb (at 50%; Table 12.2, Appendix A). This is likely to result in PD conditions not changing. Stream permanency remains at 100% i.e. no significant increase in zero flows. Low flows are significantly higher than the EWR requirement and Natural in dry season. Inundation stress of vegetation during dormancy is likely to result in mortality with reduced woody and non-woody cover in the marginal and lower zones.*
42	*C/D (58.8%)*	*Inundation of the marginal and lower zone vegetation is more than the EWR requirement in Feb (at 50%; Table 12.2, Appendix A), but inundation would be less than the requirement in Oct, Nov or Dec. This is likely to result in a shortened growth season with reduced productivity and reproduction. Stream permanency remains at 100% i.e. no significant increase in zero flows. Low flows are significantly higher than the EWR requirement and Natural in the dry season. Inundation stress of vegetation during dormancy is likely to result in mortality with reduced woody and non-woody cover in the marginal and lower zones and is very similar to Sc MK41.*

4.4 MK_I_EWR1: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 4.3. The ranking of the scenarios are provided on a traffic diagram (Figure 4.1). The results illustrate that most of the scenarios meet the ecological objectives in terms of EcoStatus except for Sc MK4 and MK2. These two scenarios do not cater for EWR requirements and are similar, however under Sc MK2 lower flows occur in all months and zero flows occur during drought periods in October to December months and therefore Sc MK2 has the greatest impact. None of the scenarios meet the ecological objectives for all the components. Sc Mk 21 is the best of the options overall and is therefore ranked the highest

Table 4.3 Ecological consequences at MK_I_EWR1

Component	PES & REC	Sc MK2	Sc MK21	Sc MK22	Sc MK23	Sc MK31	Sc MK32	Sc MK33	Sc MK4	Sc MK41	Sc MK42
Physico chemical	A/B	C	A/B	A/B	A/B	B	B	B	B	A/B	A/B
Geomorphology	A/B	C/D	B/C	C	C	B/C	C	C	C	B/C	C
Fish	B	D	B/C	C	C	C	C	C	D	C	C
Invertebrates	B/C	D	B/C	C	C	C	C	C	C/D	C	C
Riparian vegetation	C	D	C	C	C	C	C	C	C/D	C/D	C/D
EcoStatus	C	D	C	C	C	C	C	C	C/D	C	C

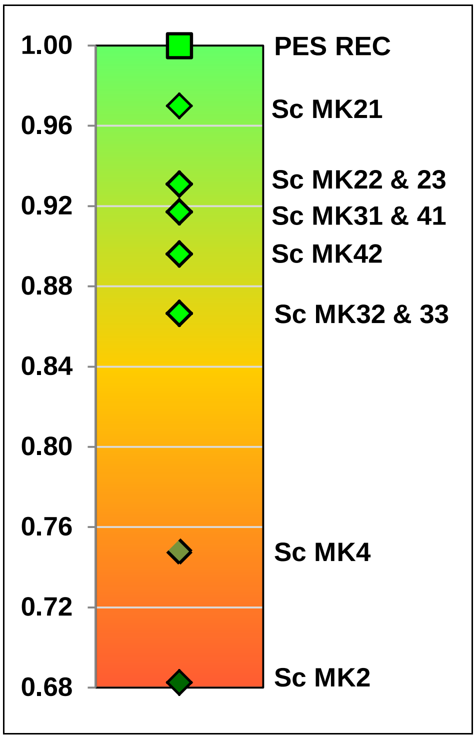

Figure 4.1 Ecological ranking of operational scenarios at MK_I_EWR1

5 MKOMAZI CATCHMENT (U10) – ECOLOGICAL CONSEQUENCES AT MK_I_EWR2: MKOMAZI RIVER

Scenario MK2, MK21, MK22, MK31, MK32, MK4, MK41 and MK42 were evaluated at MK_I_EWR2. The analysis of the operational scenarios indicated that Sc MK22 was similar to Sc MK23 and Sc MK32 was similar to Sc MK33 and no distinguishable ecological responses could be differentiated. Therefore Sc MK22 and Sc MK32 represent these scenarios respectively.

5.1 CHANGES IN FLOW REGIME

The naturalised MAR at MK_I_EWR2 is 891 Mm^3 and the PD MAR is very slightly reduced to 838 Mm^3. The PES EWR requirement is 318 Mm^3. The MAR associated with all of the scenarios considered far exceeds the PES requirement at the gross annual volumetric scale, but many scenarios will not be able to meet the monthly volumetric requirements for the EWRs at MK_I_EWR2 in terms of the wet season floods and/or dry season baseflow requirements. A summary of the effects of the operational scenarios is provided below:

- *Sc MK2: Relative to the PD (838 Mm^3) it represents a decrease in flow (621 Mm^3) as no EWR requirements are catered for. This scenario proposes an impact all year round due to very reduced dry and early wet season baseflows relative to the PD flows. Monthly volumes allocated to the river are insufficient to meet the EWR demands in all but the peak wet season (Dec - Apr) months. Wet season is delayed with significantly less flow in the early wet season (Oct - Dec), especially the base flow component. This is a typical impact of large dams, but tributary events will provide some of these flows. Dry season base flows do not meet the EWR demand.*
- *Sc MK21: Relative to the PD (838 Mm^3) it represents reduced flows (677 Mm^3), supplies the EWR requirement and includes the total EWR flows (i.e. all floods). During the dry season the EWR is met (up to but excluding Oct) and flows are higher than the natural baseflows. Natural stress is thus being removed from the system. Flows are lower than the EWR requirement in early wet season under maintenance conditions and the entire wet season under drought conditions due to a lack of floods during Nov and Dec.*
- *Sc MK22: Relative to the PD (838 Mm^3) it represents reduced flows (669 Mm^3) and only supplies the low flow EWR. Scenario MK 22 is similar to Sc MK21 during the dry season and better during Oct and more than natural at times. There are lower flows during the early wet season (Nov and Dec), and early wet season floods are delayed.*
- *Sc MK31: Relative to the PD (838 Mm^3) it represents reduced flows (669 Mm^3) and only supplies the EWR at MK_I_EWR3. This scenario includes the total EWR flows (i.e. all floods). This scenario is similar to Sc MK21 with slightly less flows for some of the dry season and sometimes below the EWR. Lower flows occur in early wet season and there is a slight delay in early wet season floods.*
- *Sc MK32: Relative the PD (838 Mm^3) it represents reduced flows (658 Mm^3) and only supplies the low flow EWR at MK_I_EWR3. Scenario MK32 is similar to Sc MK22, with lower flows in early wet season and dry season base flows that are sometimes below the EWR and less than Sc MK22. Early wet season floods are delayed.*
- *Sc MK4: Relative the PD (838 Mm^3) it represents reduced flows (673 Mm^3). Sc MK4 is the same as user requirements but the EWR is not supplied except when downstream requirements are more than the EWR requirements (Jul – Sep). The scenario is significantly lower than the EWR requirement. Low flows throughout the dry season and into the early wet season occur and wet season is delayed with significantly less flow in the early wet season*

(Oct – Dec), especially the base flow component. Sc MK4 oscillates between not meeting the EWR to being higher than Natural, and is often similar to Sc MK2.

- *Sc MK41: Relative the PD (838 Mm^3) it represents reduced flows (733 Mm^3). Dry season base flows are much more than EWR, PD and Natural for large portions of time with higher than natural maintenance flows from Jun – Oct. Flows are high during the dry season because water is being supplied to downstream users and the EWR are released additional to this. It is similar to Sc MK21 in the wet season, but with slightly more flow. Most of the time it occurs between Sc MK21 and PD and the EWR is easily met in the wet season.*
- *Sc MK42: Relative the PD (838 Mm^3) it represents reduced flows (724 Mm^3). Similar to Sc MK41 in the wet season, with reduced early wet season baseflows which do not meet the EWR, and delayed early wet season floods. Higher than natural flow occurs in the dry season.*

The driver consequences are summarised in Table 5.1 and the response consequences in Table 5.2. Summaries are provided in Table 5.3 and Figure 5.1.

5.2 MK_I_EWR2: ECOLOGICAL DRIVER COMPONENTS

Table 5.1 MK_I_EWR2: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC A/B (91%)		
2	*C (76.8%)*	*Impacts will be experienced on most water quality variables, with increases in particularly salts, nutrients and temperature.*
21 22 31 32	*A/B (91%)*	*Although there appears to be an impact on high flows under the scenarios, especially for Oct – Dec, the EWR is still being met most of the time. Water quality is expected to remain at current state under these scenarios.*
4	*B (85.4%)*	*The reduction in flushing will result in a small increase in nutrients and salts, and impacts on temperature and oxygen levels.*
41 42	*A (95.2%)*	*Higher base flows, particularly at lowest flow months, will result in the flushing of some accumulated nutrients and sediments.*
Geomorphology: PES and REC B (86.6%)		
2	*C (67.1%)*	*The active channel can be expected to shrink (narrow) due to the reduced baseflows, and the bed become finer due to reduced and delayed floods (flushing events will be smaller and less frequent).*
21 41	*C (75.3%)*	*Although there is sufficient volume to meet the EWRs, the impacts of the dam on sediment supply, and delayed floods (and attenuated large floods) would cause a small decline in the PES. The active channel can be expected to shrink (narrow) slightly and increase the bed stabilisation slightly.*
22 31 32 4 42	*C (71.3%)*	*Wet season flood volumes, the most important season for geomorphology, are more than sufficient to meet the flood season EWRs under all of these scenarios. The slightly delayed and reduced early wet season flows and floods would extend the period of fines accumulating on the river bed, and reduced and delayed flushing events would slightly increase embeddedness and the proportion of fines in the channel. Very large floods would be reduced due to attenuation in the upstream dam, and this would cause some slight channel narrowing and slight increase in bed stability.*

5.3 MK_I_EWR2: ECOLOGICAL RESPONSE COMPONENTS

Table 5.2 MK_I_EWR2: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC B (82.2%)		
2	*D (55.2%)*	*These flows will be notably lower than PD and the EWR flows for most months and flow durations resulting in a serious deterioration in habitat suitability and availability for fish. The potential loss of variation in flow, and thus habitat, for long durations (May - Dec) will also result in decreased FROC of most fish. Increased fines due to loss of floods will result in beds becoming more covered by fine sediment, impacting on especially those species with a preference and requirement for substrate (juvenile eels, A. natalensis and B. natalensis). Delayed wet season floods/flushes will also reduce spawning cues and substrate quality and thus breeding success of species such as B. natalensis. Alteration in the marginal vegetative zone will impact negatively on species such as B. anoplus and B. viviparus while water quality deterioration will especially impact negatively on A. natalensis, B. anoplus and B. natalensis.*
21	*C (77.1%)*	*The scenario is expected to impact on fish habitat negatively. Increased high flows in dry season will result in a loss of slow habitats impacting on species such as B. anoplus and B. viviparus. Decreased flow in the early wet season will result in a loss of fast habitats impacting negatively on the FROC of species such as A natalensis and B. natalensis. The slight alteration in the sediment input is expected to have only a slight negative impact on fish (food and habitat condition).*
22 31 32	*C (76.8%)*	*A slightly higher impact on the marginal vegetative zone will impact the species with a preference for this habitat type (Barbus species) resulting in an overall very slight further deterioration (compared to Sc MK21).*
4	*C/D (61.6%)*	*The impact on fish will be very similar but slightly less significant as described for Sc MK2. Maintenance flows will only comply with EWRs from Jan - Apr while drought flows only from Jul to Sep. Therefore many months and flow durations are significantly lower than EWR requirements resulting in significant habitat and species stress. Impacts and species affected will be similar than under Sc MK2.*
41	*B/C (81.7%)*	*Higher than natural maintenance flows from Jun - Oct might have a slightly negative impact on the fish with a preference for slow habitats (B. anoplus and B. viviparus). The potential slight negative impact due to decreased habitats will be negated by the wet season flows that will provide close to optimal habitat. Water quality will improve resulting in a slight improvement in some species while no notable change is expected in marginal vegetative habitats. The slight alteration in the sediment input is expected to have only a slight negative impact on fish (food and habitat condition).*
42	*B/ (77.6%)*	*Base flows, and hence flow related impacts on fish, will be very similar than under Sc MK41. A slight decrease in habitat suitability can again be expected due to higher than natural flows in dry season resulting in a loss of slow habitats (impacting on Barbus spp.). The impact on this group of species is further increased due to slight deterioration of the marginal vegetated zone (species with a preference for overhanging vegetation). Reduced early wet season baseflows and delayed early wet season floods will negatively impact on spawning and breeding success of especially species such as B. natalensis.*
Macro-invertebrates: PES and REC B (84.5%)		
2	*D (57.3%)*	*Low flows throughout the dry season and into the early wet season impact on the aquatic habitats (water column and stones-in-current (SIC)). Also lack of scouring (delayed floods) and deposition of fines, as well as poor water quality (salts and nutrients) and high temperature in the early wet season (combined with the low flows) add to the adverse conditions at the site. The delayed floods combined with the early wet season low flows will have a detrimental effect on the breeding period for a number of macro-invertebrates.*
21	*B/C (81.2%)*	*Marginal vegetation inundation in dry season will reduce non-woody cover.*
22	*B/C (79.6%)*	*Although there is an improvement in water quality, marginal vegetation inundation in dry season will reduce non-woody cover, and lack of early floods will allow for fines to accumulate. The delayed early wet season floods, combined with the lower early wet*

Sc	EC	Consequences
		season flows, will have an impact on the breeding success of a number of macro-invertebrates.
31	*B/C (80.8%)*	*Marginal vegetation inundation in dry season will reduce non-woody cover slightly, and lack of early floods will allow for fines to accumulate.*
32	*B/C (78.8%)*	*Marginal vegetation inundation in dry season will reduce non-woody cover, and lack of early floods will allow for fines to accumulate. The delayed early wet season floods, combined with the lower early wet season flows, will have an impact on the breeding success of a number of macro-invertebrates.*
4	*C (63.8%)*	*Low flows throughout the dry season and into the early wet season impact on the aquatic habitats (water column and SIC). Also the lack of scouring (delayed floods) and deposition of fines, as well as poor water quality (salts and nutrients) and high temperature (resulting in lower oxygen levels) in the early wet season (combined with the low flows) add to the adverse conditions at the site. The delayed floods combined with the early wet season low flows will have a detrimental effect on the breeding period for a number of macro-invertebrates.*
41	*B (86%)*	*Impacts of the dam relating to sediment supply, and delayed floods (and attenuated large floods) may impact the site.*
42	*B/C (81.9)*	*Due to higher base flows the EWR are met and flows are even better than Natural resulting in water quality improvement. Impacts of the dam relating to sediment supply, reduced early wet season base flows and delayed floods (and attenuated large floods) may impact the macro-invertebrates.*
Riparian vegetation: PES and REC B (85.9%)		
2	*C (76.4%)*	*Inundation of marginal and lower zone vegetation is more than the EWR in Feb but less than PD (at 50%; see Table 12.3, Appendix A), however inundation would be less than the EWR in Oct, Nov or Dec. The late onset of high flows is likely to result in a shortened growth season with reduced productivity and reproduction or recruitment. Stream permanency remains at 100% i.e. no significant increase in zero flows. Dry season base flows do not meet the EWR demand. The height above water level increases for all indicators by 10 or more centimetres which will increase desiccation stress in all vegetation and some loss may occur at the upper limits of indicator populations.*
21	*B (85.7%)*	*Inundation of marginal and lower zone vegetation is more than EWR in Feb (at 50%; Table 12.3, Appendix A), but not more than natural and change in the PES is unlikely. Stream permanency remains at 100% i.e. no significant increase in zero flows. Inundation in dry season will reduce non-woody cover in marginal and lower zones.*
22	*B/C (79.8%)*	*Inundation of marginal and lower zone vegetation is more than EWR in Feb (at 50%; Table 12.3, Appendix A), but not more than natural, and change in the PES is unlikely. Stream permanency remains at 100% i.e. no significant increase in zero flows. Similar to Sc MK21 in the dry season, but better in Oct.*
31	*B (84.8%)*	*Similar to Sc MK21, but slightly less flow for some of the dry season.*
32	*B/C (77.7%)*	*Similar to Sc MK22, but slightly less flow for some of the dry season.*
4	*C (75.5%)*	*Inundation of marginal and lower zone vegetation is more than EWR in Feb but less than PD at 50%; Table 12.3, Appendix A), but inundation would be less than the requirement in Oct, Nov or Dec. The late onset of high flows is likely to result in a shortened growth season with reduced productivity and reproduction or recruitment. Inundation of vegetation is similar to PD.*
41	*B (85.9%)*	*Inundation of vegetation (Table 12.3, Appendix A) is similar to PD and more than the EWR. No response to wet season component is envisaged. Stream permanency remains at 100% i.e. no significant increase in zero flows. Although dry season base flows are more than EWR, PD and Natural for large portions of time inundation of vegetation does not occur during the dormant phase so no mortality is expected. There may be a slight loss in non-woody cover in places but this will not change the PES.*
42	*B (84.9%)*	*Inundation of vegetation is similar to PD in Feb (at 50%; Table 12.3, Appendix A) but will be less in the early wet season. Conditions during dry season is similar to Sc MK41.*

5.4 MK_I_EWR2: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 5.3. The ranking of the scenarios are provided on a traffic diagram (Figure 5.1). The results illustrate that none of the scenarios meet the ecological objectives. Although Sc MK21, 41 and 42 results in the same EcoStatus, the instream biota are impacted by the reduced wet season base flows and reduced floods. Sc MK41 is the best scenario of these three scenarios because it provides more flows during wet season. Scenario MK2 and MK4 has the worst impact due to reductions in baseflows during dry and wet seasons.

Table 5.3 Ecological consequences at MK_I_EWR2

Component	PES & REC	Sc MK2	Sc MK21	Sc MK22	Sc MK23	Sc MK31	Sc MK32	Sc MK33	Sc MK4	Sc MK41	Sc MK42
Physico chemical	A/B	C	A/B	A/B	A/B	A/B	A/B	A/B	B	A	A
Geomorphology	B	C	C	C	C	C	C	C	C	C	C
Fish	B	D	C	C	C	C	C	C	C/D	B/C	B/C
Invertebrates	B	D	B/C	B/C	B/C	B/C	B/C	B/C	C	B	B/C
Riparian vegetation	B	C	B	B/C	B/C	B	B/C	B/C	C	B	B
EcoStatus	B	C	B	B/C	B/C	B/C	B/C	B/C	C	B	B

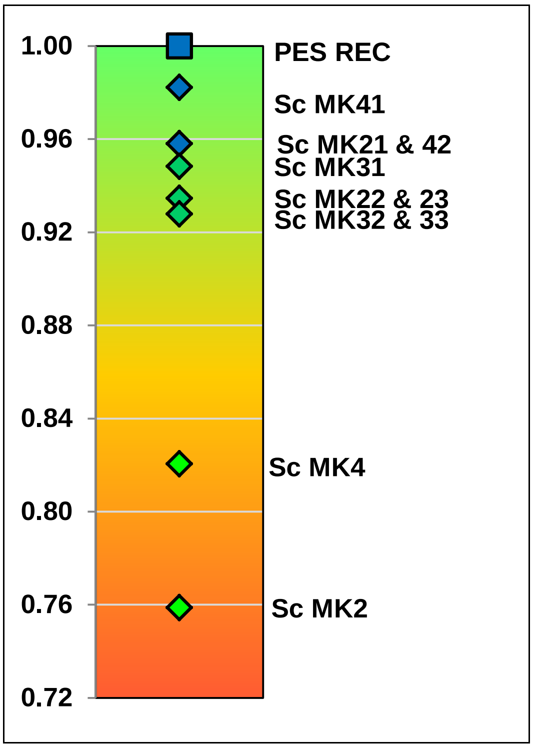

Figure 5.1 Ecological ranking of operational scenarios at MK_I_EWR2

6 MKOMAZI CATCHMENT (U10) – ECOLOGICAL CONSEQUENCES AT MK_I_EWR3: MKOMAZI RIVER

Scenario MK2, MK21, MK22, MK32 and MK42 were evaluated at MK_I_EWR3. The analysis of the operational scenarios indicated that the following scenarios were similar and no distinguishable ecological responses could be differentiated:

- *Sc MK2 was similar to Sc MK4.*
- *Sc MK21 was similar to Sc MK31 and Sc MK41.*
- *Sc MK22 was similar to Sc MK23.*
- *Sc MK32 was similar to Sc MK33*

Therefore Sc MK2, MK21, MK22 and MK32 represent these scenarios respectively.

6.1 CHANGES IN FLOW REGIME

The Naturalised MAR at MK_I_EWR3 is 1069 Mm^3 and the PD MAR is reduced to 983 Mm^3. The PES EWR requirement is 333 Mm^3. The MAR associated with all of the scenarios considered exceed the PES requirement at the gross annual volumetric scale, but some scenarios will not be able to meet the monthly volumetric requirements for the EWRs at MK_I_EWR3 in terms of the early wet season floods and/or dry season baseflow requirements. A summary of the effects of the operational scenarios is provided below:

- *Sc MK2: Relative to the PD (983 Mm^3) it represents significant decrease in flow (756 Mm^3) as no EWR requirements are catered for. These scenarios propose reduced dry and early wet season baseflows relative to the PD flows. Monthly volumes allocated to the river are insufficient to meet the EWR demands during early wet season (Oct – Dec) while EWR demands are met during the peak wet season (Dec - Apr) months and early wet season floods will be delayed constricting the wet season duration. In general maintenance flows of all dry season months are below the EWR (worst exceedance in May) while under drought flows (95%) it exceeds the EWR from Jul - Oct.*
- *Sc MK21: Relative to the PD (983 Mm^3) it represents reduced flows (814 Mm^3) and only supplies the EWR at MK_I_EWR2. Maintenance flows for all months are adequate to maintain the PES (within EWR and PD flows). Drought flows are however below the recommended EWR flows in the early summer months (Dec - Feb), and natural flows are exceeded for about 10% of the time during some dry season months (Aug - Oct). Most of the EWR being met, and it is only early wet season base and drought flows that is below the EWR.*
- *Sc MK22: Relative the PD (983 Mm^3) it represents reduced flows (805 Mm^3) and only supplies the EWR at MK_I_EWR2. This scenario has reduced early wet season base flows and delayed early wet season floods, but the early dry season flows are equal or above the EWR. This situation is accentuated during the drought flows. Low flows are similar to Sc MK21 while flows during Nov – Dec are similar to Sc MK2.*
- *Sc MK32: Relative the PD (983 Mm^3) it represents reduced flows (796 Mm^3) and only supplies the EWR at MK_I_EWR3. This scenario has quite reduced early wet season base flows and delayed early wet season floods, but the early dry season flows are equal or above the EWR.*
- *Sc MK42: Relative the PD (983 Mm^3) it represents reduced flows (814 Mm^3) and only supplies the low flow EWR at EWR at MK_I_EWR2. The scenario is similar to Sc MK2 in that*

the onset of the wet season is delayed with an extended dry season however wet season flows (Oct and Nov) are more than under Sc MK2.

The driver consequences are summarised in Table 6.1 and the response consequences in Table 6.2. Summaries are provided in Table 6.3 and Figure 6.1.

6.2 MK_I_EWR3: ECOLOGICAL DRIVER COMPONENTS

Table 6.1 MK_I_EWR3: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC A/B (88.8%)		
2	*B/C (80.6%)*	*The reduction in flushing flows will result in an increase in nutrients and salts.*
21	*A/B (88.8%)*	*Water quality state may improve slightly during lowest flow months, but should remain in an A/B category.*
22 32 42	*B (84.4%)*	*There is an impact on flushing flows from Oct - Dec which will impact on nutrients and temperature levels.*
Geomorphology: PES and REC B (85.6%)		
2	*C (72.8%)*	*The active channel can be expected to shrink (narrow) due to the reduced baseflows, and some of the cobbles may be lost as sand accumulates (flushing events will be smaller and less frequent). Very large floods would be reduced due to attenuation and would cause some slight channel narrowing and increase in bed stability.*
21	*B/C (80%)*	*Although this scenario proposes a dam, this is very far upstream of the site, so tributary inputs would ameliorate the sediment reduction impacts and the flow volumes are sufficient to meet the REC EWR. Very large floods would be reduced due to attenuation and would cause some slight channel narrowing and increased bed stability.*
22 32 42	*C (76.4%)*	*These scenarios propose reduced early wet season baseflows and delayed early wet season floods, but sufficient volumes to meet the EWR at all other times. The slightly delayed and reduced early wet season flows and floods may cause some of the some of the cobbles to be lost as sand accumulates (flushing events will be smaller and less frequent). Very large floods would be reduced due to attenuation and would cause some slight channel narrowing and increase in bed stability.*

6.3 MK_I_EWR3: ECOLOGICAL RESPONSE COMPONENTS

Table 6.2 MK_I_EWR3: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC B (83.5%)		
2	*C (64.8%)*	*In general the fish assemblage will be notably stressed during the dry season with a loss of fast habitat availability and condition resulting in decreased FROC of especially the semi-rheophilic species (such as B. natalensis). Water quality deterioration in the dry period will also impact negatively on water quality intolerant species (especially B. gurneyi). Wet month (Feb) falls below the EWR under drought (>92% flow duration) while the rest of the months flow are above the EWR and should maintain the PES. In general wet season maintenance flows (Feb - Apr) complies with EWR flows while drought period flows are below the EWR requirement. It is therefore estimated that fish will also be stressed during the wet season albeit to a lesser extent than during the dry season. No notable impact on substrate apart from increased embeddedness and sedimentation is expected, impacting negatively on species with a requirement for this habitat (especially B. natalensis, juvenile eels, etc.). Some deterioration in the marginal vegetative zone will impact on species with a preference for this habitat feature (such as B. viviparus).*
21	*B/C (80.5%)*	*Drought flows below the recommended EWR flows in the early summer months (Dec - Feb), may result in decreased habitat suitability and availability during drought conditions. This will especially impact on species with a requirement for fast habitats during summer (e.g. B.*

Sc	EC	Consequences
		natalensis for spawning in this period). A slight deterioration in the PES can therefore be expected due to this potential limitations envisaged for drought periods. The exceedance of natural flows during some dry season months (Aug - Oct) will not be significant to result in deterioration of the fish assemblage and may in fact improve conditions (such as water quality improvement). The overall very slight deterioration in the fish is therefore primarily related to the potential deteriorated conditions of fish in the wet season during drought periods, a small alteration in the sediment regime (due to upstream dam and floods) and slight deterioration in the marginal vegetation as overhang.
22 *32* *42*	*C* *(74.6%)*	*In terms of maintenance flows the EWR is generally met except for the early wet season months (Nov and Dec). This exceedance (lower than) in the EWR is more evident under drought conditions when the flows are below the EWR from Dec - Feb. Most fish species that require adequate habitat and flow for breeding in this period (especially semi-rheophilic species such as B. natalensis) can be expected to be impacted negatively due to loss in habitat availability and suitability. Delayed early wet season floods will furthermore impact species that require spawning cues and substrate of good quality for spawning. The primary negative impact on the fish assemblage is therefore related to the deterioration in flows, and hence habitat suitability and availability, during the early wet season. Slight water quality deterioration will also impact negatively on water quality intolerant species (e.g. B. gurneyi).*
Macro-invertebrates: PES and REC B (86.9%)		
2	*C/D* *(60.9%)*	*Lack of scouring (delayed floods) and deposition of fines, as well as poor water quality (salts and nutrients) and high temperature in the early wet season (combined with the low flows) add to the adverse conditions at the site. The delayed floods combined with the early wet season low flows will have a detrimental effect on the breeding period for a number of macro-invertebrates.*
21	*B/C* *(80.4%)*	*No change in water quality, however marginal vegetation may experience some inundation stress in the dry season and result in reduced reed cover while very large floods will be reduced. None of these stresses will be very high and the slight late wet season flows, together with slight reduced marginal vegetation influences and reduced large floods will impact marginally on the macro-invertebrate population structure.*
22	*B/C* *(77.2%)*	*The delay in early wet season floods might impact on flushing flows and thus influence nutrients and temperature levels adversely. Very large floods will be reduced.*
32	*C* *(76.4%)*	*The delay in early wet season floods might impact on flushing flows and thus influence sedimentation, nutrients and temperature levels adversely, and marginal vegetation may experience some inundation stress in the dry season which will reduce reed cover.*
42	*C* *(74.5%)*	*Similar to Sc MK32 but flows levels are fractionally lower.*
Riparian vegetation: PES and REC D (54.5%)		
2	*D* *(51.2%)*	*The wet season EWR is met during Jan - Mar although not all the time. At 50% in Feb inundation of vegetation is the same as other scenarios (see Table 12.4, Appendix A) with flows more than the EWR and slightly less than PD. Flows in the early wet season (Oct - Dec) do not meet the EWR and constrict wet season duration. The site has the potential however to increase in woody cover and abundance and with a dam in place reduced frequency of large floods will likely favour woody species. Stream permanency remains at 100% i.e. no significant increase in zero flows. The EWR is generally not met in dry season. This together with an extended dry season may result in decline of non-woody marginal and lower zone vegetation.*
21	*D* *(51.9%)*	*Inundation of marginal and lower zone vegetation is more than EWR in Feb (at 50%; see Table 12.4, Appendix A), and slightly less than PD although this should not result in a response by vegetation. The site has the potential however to increase in woody cover and abundance and with a dam in place reduced frequency of large floods will likely favour woody species (including perennial aliens). Stream permanency remains at 100% i.e. no significant increase in zero flows. EWR is met in dry season but is also more than natural for about 10% of the time in some winter months. Inundation in dry season can result in mortality of some species due to inundation stress when in a dormant state. These above-natural flows result in inundation of reeds only and up to 30 cm; the result being that reeds may reduce slightly in abundance at their lower limit, but other marginal and lower zone vegetation is unlikely to respond.*

Sc	EC	Consequences
22 *32* *42*	*D* *(51.3%)*	*Similar to Sc MK21 for most of the wet season but similar to Sc MK2 in that the onset of the wet season is delayed with an extended dry season. Vegetation will respond as under Sc MK2. Dry season is the same as Sc MK21.*

6.4 MK_I_EWR3: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 6.3. The ranking of the scenarios are provided on a traffic diagram (Figure 6.1). The results illustrate that none of the scenarios meet the ecological objectives. Sc MK 21, 31 and 41 results in the same EcoStatus and has the least impact with a slight deterioration in geomorphology and instream biota. Sc MK22, 23, 32 and 33 also has the same EcoStatus as the PES/REC but there is further deterioration in the instream biota as well as geomorphology and water quality. Scenario MK2 and 4 have the biggest impact as overall they drop a category for while Sc MK42 only caters for the low flow EWR and the impact is therefore slightly less, i.e. it drops half a category.

Table 6.3 Ecological consequences at MK_I_EWR3

Component	PES & REC	Sc MK2	Sc MK21	Sc MK22	Sc MK23	Sc MK31	Sc MK32	Sc MK33	Sc MK4	Sc MK41	Sc MK42
Physico chemical	A/B	B/C	A/B	B	B	A/B	B	B	B/C	A/B	B
Geomorphology	B	C	B/C	C	C	B/C	C	C	C	B/C	C
Fish	B	C	B/C	C	C	B/C	C	C	C	B/C	C
Invertebrates	B	C/D	B/C	C	C	B/C	C	C	C/D	B/C	C
Riparian vegetation	D	D	D	D	D	D	D	D	D	D	D
EcoStatus	C	D	C	C	C	C	C	C	D	C	C/D

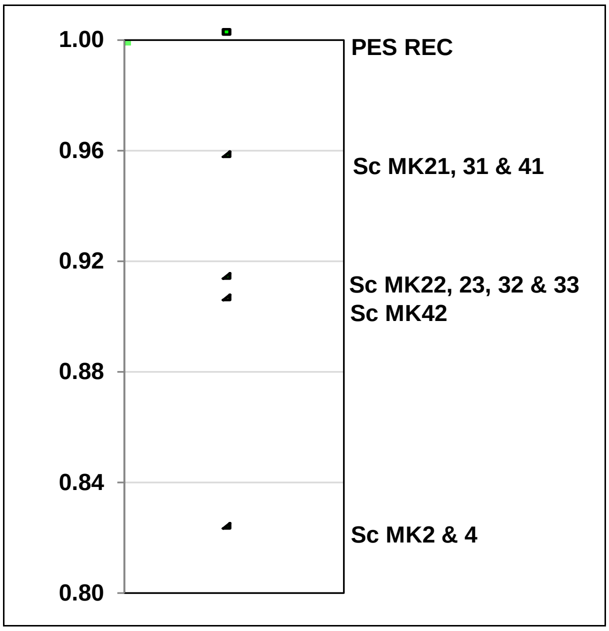

Figure 6.1 Ecological ranking of operational scenarios at MK_I_EWR3

7 MVOTI CATCHMENT (U40) – ECOLOGICAL CONSEQUENCES AT MV_I_EWR2: MVOTI RIVER

Scenario MV3, MV42 and MV43 were evaluated at MV_I_EWR2. Scenario MV1 and MV41 were not evaluated as they are similar to PD.

7.1 CHANGES IN FLOW REGIME

The Naturalised MAR at MV_I_EWR2 is 274 Mm^3 and the PD MAR is reduced to 169 Mm^3. The PES EWR requirement is 67 Mm^3. Scenarios MV3, 42 and 43 all propose dams in the catchment which will cause reduced early wet season flows and delayed early wet season floods. In median years, the volumes allocated for the early wet season under these scenarios will not be sufficient to achieve the EWR. A summary of the effects of the operational scenarios is provided below:

- *Sc MV3: Relative to the PD (169 Mm^3) it represents a decrease in flow (129 Mm^3). The EWR requirements are not catered for and the dry season base flows are less than the EWR although flows exceed PD and the EWR from Jul - Oct. High flows are also lower than PD and the EWR most of the time and wet season is delayed with significantly less flow in the early wet season (Oct - Dec, even Jan), especially the base flow component.*
- *Sc MV42: Relative to the PD (169 Mm^3) it represents a decrease in flow (149 Mm^3). The low flow EWR are catered for but exclude floods. The EWR is met from Feb - Apr but not from Oct - Jan and therefore flows are more than the EWR during the dry season and less than the EWR during the wet season resulting in reduced early wet season floods (Oct – Dec), especially the base flow component.*
- *Sc MV43: Relative to the PD (169 Mm^3) it represents a decrease in flow (153 Mm^3). This scenario includes the total EWR flows for Jan - Mar and low flows for remaining months. The scenario is therefore similar to Sc MV42 but floods are partially provided.*

The driver consequences are summarised in Table 7.1 and the response consequences in Table 7.2. Summaries are provided in Table 7.3 and Figure 7.1.

7.2 MV_I_EWR2: ECOLOGICAL DRIVER COMPONENTS

Table 7.1 MV_I_EWR2: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC C (76.2%)		
3	*C/D (60.6%)*	*The water quality state will deteriorate under these conditions, with an expected impact on all parameters.*
42 43	*B/C (79.8%)*	*The improvement in baseflows results in an associated improvement in nutrient and toxic levels due to flushing and dilution respectively.*
Geomorphology: PES and REC C (73.5%)		
3	*D (56.9%)*	*Reduced early wet season floods and reduced baseflows will have a rapid impact in this sand/cobble bed channel bed. The channel can be expected to narrow with associated vegetation encroachment in response to the reduced baseflows and floods and reduced sediment loads. The low baseflows and prolonged low flow season together with delayed wet season freshettes will increase bed stability.*
42 43	*C/D (61.8%)*	*Reduced early wet season floods will have an impact in this sand/cobble bed channel bed. The channel can be expected to narrow with associated vegetation encroachment in response to the reduced floods and reduced sediment loads. The prolonged low flow season and delayed freshette floods will increase bed stability.*

7.3 MV_I_EWR2: ECOLOGICAL RESPONSE COMPONENTS

Table 7.2 MV_I_EWR2: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC B/C (77.8%)		
3	*C/D (61.9%)*	*Maintenance flow during all months is lower than the EWR and it is expected to impact the fish notably due to an overall decrease in availability and condition of especially fast habitats. This, in turn will significantly impact the abundance of many species and in particular species such B. natalensis (and to a lesser degree) juvenile eels and B. trimaculatus. Although the maintenance flows will be better (closer to the EWR) during the late dry season the exceedance during the early and middle dry season will still have a negative impact on fish habitat suitability. Drought flows (95%) will be much lower than the EWR during the entire wet season impacting again on most species. The EWR are met in the late dry season (Jul - Oct) but the significant exceedance during the early dry season will also have a notable impact on the fish assemblage due to reduced habitat quality and availability (especially on juvenile fish and recruitment). Water quality deterioration will impact on water quality intolerant species (especially B. gurneyi). Reduced early wet season floods will decrease cues for migration, flushing of substrate and resetting of water quality. It will therefor also reduce or postpone breeding of species such as B. natalensis. The impact on sediment loads will be minimal (reduced) but early wet season floods will result in some substrate quality deterioration during this period. Some deterioration in the marginal vegetative zone (based on VEGRAI) will impact negatively on species with a preference for overhanging vegetation (B. gurneyi, B. viviparus, T. sparrmanii and P. philander).*
42 43	*C (76.7%)*	*Maintenance flows will be adequate to maintain the PES during the early wet season (Nov) to early dry season (Jun) after which flows will be better than the EWR and PD (late dry season; Jun – Sep). It is therefore expected that the fish assemblage will also improve due to the better habitat suitability and water quality prevailing during this period. The change will however be minimal as it is a short duration on an annual scale and a relatively dormant phase (no recruitment) in the fish assemblage. Drought flows will be notably better than EWR and PD flows during most months and especially the dry season when conditions can be expected to improve. The delay in the onset of the wet season (especially total EWR flows including floods) is impacting negative on the marginal vegetation (VEGRAI) and is can also have a negative impact on cues for and habitat suitability for spawning of some species (such as B. natalensis). Change in marginal vegetation will negatively impact on species with a preference for overhanging vegetation (B. gurneyi, B. viviparus, T. sparrmanii and P. philander). Overall conditions are expected to remain very similar or slightly lower than the PES.*
Macro-invertebrates: PES and REC B/C (79.8%)		
3	*C/D (58.4%)*	*The delayed floods combined with the early wet season low flows will have a detrimental effect on the breeding period for a number of macro-invertebrates. The delayed wet season freshettes will increase bed stability with associated vegetation encroachment. All the water quality parameters will deteriorate and further impact the sensitive macro-invertebrate species.*
42 43	*B/C (79.6%)*	*Reduced early wet season floods will have an impact in this sand/cobble bed channel bed. This will increase the bed stability which will lead to encroachment in summer and the overhanging habitats will be adversely affected. Overall the overhanging marginal vegetation habitats might improve, but the sediment and SIC habitats will deteriorate somewhat.*
Riparian vegetation: PES and REC C/D (62%)		
3	*D (55.4%)*	*The EWR is met from Feb - Apr but not from Oct - Jan. Inundation of marginal and lower zone vegetation is more than the EWR in Feb but less than PD (at 50%; see Table 12.5, Appendix A), but inundation would be less than the requirement in Oct - Dec. The late onset of high flows is likely to result in a shortened growth season with reduced productivity and reproduction or recruitment. Encroachment by marginal zone vegetation is likely. Stream permanency remains at 100% i.e. no significant increase in zero flows but for the most part the EWR is not met. All round vegetation cover and abundance is likely to increase due to reduced flooding disturbance, the maintenance of stream permanency and reduced low flows with available habitat (gravel, sand, mud (GSM)) for encroachment by*

Sc	EC	Consequences
		vegetation.
42	*C (61.7%)*	*Inundation of marginal and lower zone vegetation is more than EWR in Feb but less than PD (at 50%; see Table 12.5, Appendix A), but inundation would be less than the requirement in early summer. The late onset of high flows is likely to result in a shortened growth season with reduced productivity and reproduction or recruitment of upper and lower zone vegetation but encroachment by marginal zone vegetation is likely during this time. Stream permanency remains at 100% i.e. no significant increase in zero flows. The EWR is met during the dry season and inundation of some marginal zone vegetation increases slightly. No response by vegetation is likely during winter, however this may reduce encroachment that takes place in summer.*
43	*C/D (59.4%)*	*Inundation of the marginal and lower zone vegetation is more than the EWR in Feb but less than PD (at 50%; see Table 12.5, Appendix A), but inundation would be less than the requirement in early summer. The late onset of high flows is likely to result in a shortened growth season with reduced productivity and reproduction or recruitment. Encroachment by marginal zone vegetation is likely during this time. Dry season response is similar to Sc MV43.*

7.4 MV_I_EWR2: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 7.3. The ranking of the scenarios are provided on a traffic diagram (Figure 7.1). The results illustrate that Sc 41 meets the ecological objectives. Although Sc MV42 and 43 results in the same EcoStatus the ecological objectives are not met due to a slight deterioration in geomorphology and fish. Sc MV3 has the biggest impact with deterioration in all components as the EWR are not provided.

Table 7.3 Ecological consequences at MV_I_EWR2

Component	PES & REC	Sc MV3	Sc MV41	Sc MV42	Sc MV43
Physico chemical	**C**	**C/D**	**C**	**B/C**	**B/C**
Geomorphology	**C**	**C/D**	**C**	**C/D**	**C/D**
Fish	**B/C**	**C/D**	**B/C**	**C**	**C**
Invertebrates	**B/C**	**C/D**	**B/C**	**B/C**	**B/C**
Riparian vegetation	**C/D**	**D**	**C/D**	**C/D**	**C/D**
EcoStatus	**C**	**D**	**C**	**C**	**C**

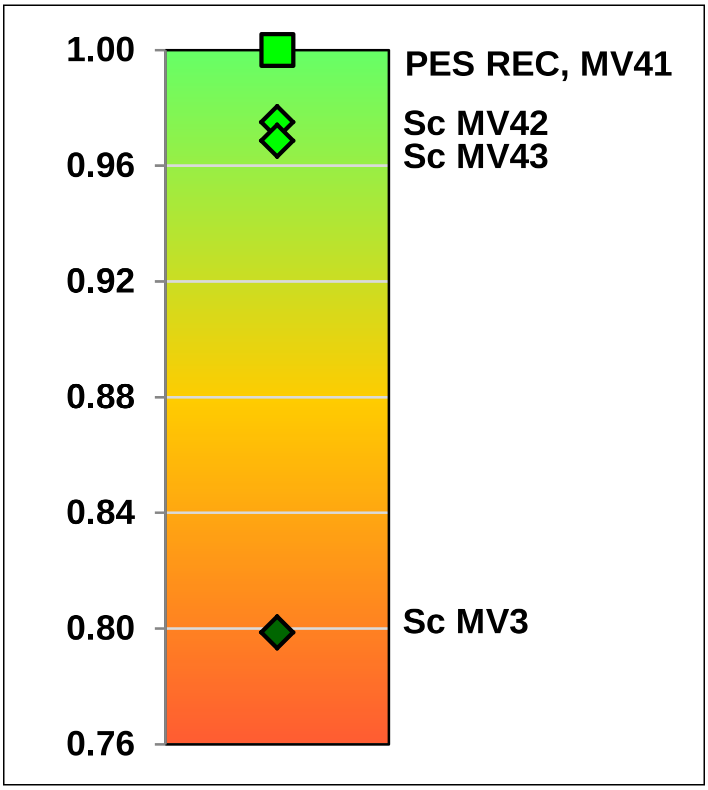

Figure 7.1 Ecological ranking of operational scenarios at MV_I_EWR2

8 uMNGENI CATCHMENT (U20) – ECOLOGICAL CONSEQUENCES AT MG_I_EWR2: uMNGENI RIVER

Scenario MG2 and MG41 were evaluated at MG_I_EWR2. The analysis of the operational scenarios indicated that Sc MG41 was similar to Sc MG42, MG51 and MG52 and no distinguishable ecological responses could be differentiated.

8.1 CHANGES IN FLOW REGIME

The naturalised MAR at MG_I_EWR2 is 228 Mm^3 and the PD MAR is reduced to 105 Mm^3. The PES EWR requirement is 47 Mm^3. A summary of the effects of the operational scenarios is provided below:

- *Sc MG2: Flows exceed PD and the EWR under drought flows, with other flows similar to PD and the PES (EWR is mostly met in the dry season) with lower flow during Mar and Apr.*
- *Sc MG41: Flows exceed PD and the EWR all year round.*

The driver consequences are summarised in Table 8.1 and the response consequences in Table 9.2. Summaries are provided in Table 8.3 and Figure 8.1.

8.2 MG_I_EWR2: ECOLOGICAL DRIVER COMPONENTS

Table 8.1 MG_I_EWR2: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC C/D (61.4%)		
2	*C (65.2%)*	*A small improvement in water quality is expected for nutrients and toxics.*
41	*C (76.2%)*	*The scenario will result in an improvement in all water quality variables, particularly the highly elevated nutrient levels and expected toxics in the system.*
Geomorphology: PES and REC D (45.4%)		
2 *41*	*D (45.4%)*	*No significant change in geomorphological condition is expected with altered release patterns.*

8.3 MG_I_EWR2: ECOLOGICAL RESPONSE COMPONENTS

Table 8.2 MG_I_EWR2: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC E (D) (27%)		
2	*E (28.5%)*	*Maintenance flows are mostly similar than PD and although it is lower than EWR flows it is estimated to maintain the PES. Drought flows will be slightly better than EWR and PD for most months and no significant change is therefore expected based on the flows changes to habitat conditions and availability to fish. The slight improvement in water quality may result in improvement in the abundance and occurrence of species such as A. natalensis and B. viviparus. The improvement in water quality is thought to be inadequate for the recolonisation (from tributaries) of water quality intolerant species such as B. gurneyi. The overall change in the fish assemblage is therefore thought to be insignificantly small and the ecological status will remain unchanged.*
41	*D/E (38.4%)* *D (42.5%)*	*Changes in geomorphology and marginal vegetation are not expected to be significant enough to have any impact on the fish assemblage. The notable improvement in water quality would result in an improvement in species intolerant to water quality alteration. Should flooding/flushing events be reduced/eradicated, some species may recolonise the reach from tributaries (B. anoplus and B. gurneyi). The improvement would to some extent*

Sc	EC	Consequences
		be limited by non-flow related impacts namely the presence of various predatory alien fish species. Conditions are therefore expected to improve somewhat but still do not reach the REC (D), but this is partly related to non-flow related impacts (if the impact of alien species are excluded, a FRAI score of 42.5% will mean that the fish should reach the REC of a D).
Macro-invertebrates: PES and REC C (76.1%)		
2	*C (76.2%)*	*No response from vegetation is likely and a small improvement in water quality is expected for nutrients and toxics. The slight base flow in Feb and the slight improvement in water quality have a minor positive effect on the habitat of macro-invertebrates.*
41 42	*B/C (78.4%)*	*This will result in an improvement in all water quality variables such as nutrient levels and toxics. Improved wet season flows will result in an improvement at the site, however no response from vegetation is likely in winter. The significantly improved flows and associated water quality will benefit macro-invertebrate populations and the EC will improve.*
Riparian vegetation: PES and REC C (68.6%)		
2	*C 73.1%*	*Inundation of vegetation (assessed at 50% in Feb for wet season; see Table 12.6, Appendix A) is slightly more than EWR and less than PD. This is however unlikely to elicit a response from riparian vegetation in summer. Stream permanency remains at 100% i.e. no significant increase in zero flows. The EWR is mostly met in the dry season and inundation of vegetation is slightly less than PD and EWR (in Aug at 50%) but no response from vegetation is likely.*
41	*C 73.2*	*Inundation of vegetation (assessed at 50% in Feb for wet season; see Table 12.6, Appendix A) is more than the EWR and slightly more than PD, but less than Natural. Improved wet season flows are likely to reduce sedge cover due to additional inundation. This move would be an improvement at the site. Stream permanency remains at 100% i.e. no significant increase in zero flows. Flows are better than EWR and PD and better than Nat during droughts and inundation of vegetation is the same as PD and the EWR in the dry season and no response from vegetation is likely in winter.*

8.4 MG_I_EWR2: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 8.3. The ranking of the scenarios are provided on a traffic diagram (Figure 8.1). The results illustrate that Sc MG41, 42, 51 and 52 meet the ecological objectives of the REC when the presence of alien fish species is excluded from FRAI calculations. Sc MG2 meets the ecological objectives of the PES but not the REC due to the lower flows and smaller improvements in water quality compared to other scenarios which do not result in the improvement of habitat or fish availability; and therefore the presence of alien fish species.

Table 8.3 Ecological consequences at MG_I_EWR2

Component	PES	REC	Sc MG2	Sc MG41	Sc MG42	Sc MG51	Sc MG52
Physico chemical	C/D	C/D	C	C	C	C	C
Geomorphology	D	D	D	D	D	D	D
Fish	E	D	E	D	D	D	D
Invertebrates	C	C	C	B/C	B/C	B/C	B/C
Riparian vegetation	C	C	C	C	C	C	C
EcoStatus	C	C	C	C	C	C	C

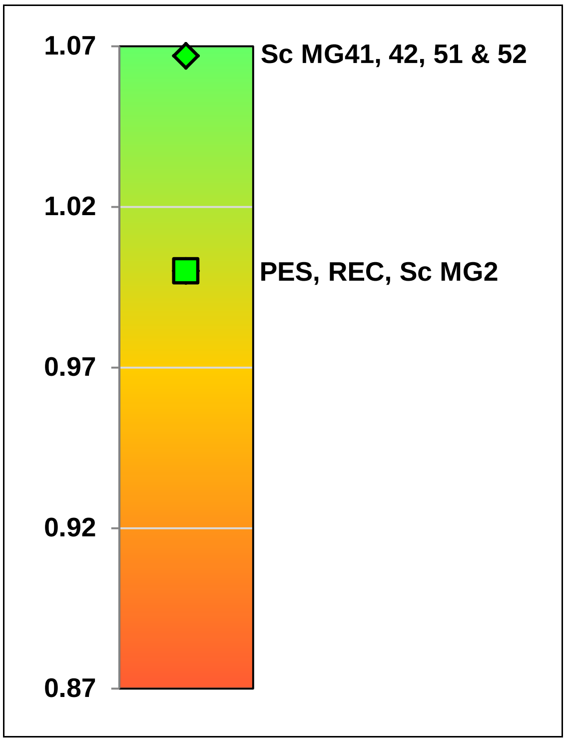

Figure 8.1 Ecological ranking of operational scenarios at MG_I_EWR2

9 uMNGENI CATCHMENT (U20) – ECOLOGICAL CONSEQUENCES AT MG_I_EWR5: uMNGENI RIVER

Scenario MG2, MG41 and MG51 were evaluated at MG_I_EWR5. The analysis of the operational scenarios indicated that Sc MG41 was similar to Sc MG42 and MG51 was similar to MG52 and no distinguishable ecological responses could be differentiated. Therefore Sc MG41 and Sc MG51 represent these scenarios respectively.

9.1 CHANGES IN FLOW REGIME

The naturalised MAR at MG_I_EWR5 is 584 Mm^3 and the PD MAR is reduced to 245 Mm^3. The PES EWR requirement is 156 Mm^3. A summary of the effects of the operational scenarios is provided below:

- *Sc MG2: Baseflows are similar or better than PD and slightly exceed the EWR, with a small increase in base flows. There is also an improvement in wet season maintenance flows due to increased small floods.*
- *Sc MG41: Conditions are consistently better than PD and meet the EWRs; there is a marked increase in base flows during the dry season (higher than PD) and probably increased small floods during the wet season.*
- *Sc MG51: Base flows are similar to PD but slightly lower than the REC; although elevated during drought flows.*

The driver consequences are summarised in Table 9.1 and the response consequences in Table 9.2. Summaries are provided in Table 9.3 and Figure 9.1.

9.2 MG_I_EWR5: ECOLOGICAL DRIVER COMPONENTS

Table 9.1 MG_I_EWR5: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC C/D (61.8%)		
2	*C (70.0%)*	*Elevated baseflows during drought flows are expected to result in a small improvement in nutrient and toxic levels. There is also an improvement in high flows resulting in some flushing of high nutrient levels. Note that this assessment assumes the increased releases from Darville Waste Water Treatment Work (WWTW) meet the required water quality standards.*
41	*C (77.4%)*	*Conditions are consistently better than PD and the REC, resulting in an overall improvement in water quality. Note that this assessment assumes the increased releases from Phoenix, Mhlanga and Tongati WWTWs meet the required water quality standards.*
51	*C (68.6%)*	*A small improvement in nutrient and toxic levels is expected. The small impact in high flows is unlikely to impact on water quality. Note that this assessment assumes the increased releases from Darville WWTW meet the required water quality standards.*
Geomorphology: PES and REC C/D (59%)		
2 41	*C/D (59.6%)*	*The higher wet season flows and increased provision of small floods should create a small improvement of the inchannel condition through increased bed scour (removal of sand off coarser larger sediments) and possibly create a few deeper areas of the channel and small pools, as well as keep more of the secondary channels in the reach open.*
51	*D (53.1%)*	*These flow scenarios will not have a distinguishable impact on the geomorphology as they are equivalent to the PD flow conditions (Sc MK51 and 52 provide slightly lower baseflows than the REC during median flow months, but this will not have a marked impact on the geomorphology).*

9.3 MG_I_EWR5: ECOLOGICAL RESPONSE COMPONENTS

Table 9.2 MG_I_EWR5: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC D (54.8%)		
2	*C/D (59.1%)*	*In terms of flow related change to habitat suitability and availability for fish there will be a slight improvement in the condition of the fish assemblage primarily associated with improved wet season maintenance flows. This will especially improve conditions for rheophilic and semi-rheophilic species (e.g. A. natalensis and B. natalensis). The improvement in substrate through increased bed scour (removal of sand off coarser larger sediments) will improve the habitat for species with a preference for substrate as cover (e.g. A. natalensis, B. natalensis, and Glossogobius spp.). Scouring may create deeper areas and also improve habitat conditions for species such as A. aeneofuscus, adult eels, C. gariepinus, O. mossambicus and T. rendalli. A slight improvement in water quality is also expected to improve the conditions for water quality intolerant species such as A. natalensis and B. gurneyi. The overall condition of the fish assemblage is therefore expected to increase to a category C/D.*
41	*C (62.3%)*	*Geomorphological changes are similar to Sc MK2, and hence similar improvements in the fish assemblage are expected (improvement in substrate and creation of deeper channel). Water quality is expected to improve notably which will again improve conditions for water quality intolerant species. In terms of flow related change to habitat suitability and availability for fish there will a notable change in the condition of the fish assemblage (due to flows that are generally higher than the EWR and PD) creating better habitat for all species (especially rheophilic and semi-rheophilic species).*
51	*D (56.6%)*	*In terms of flow related change to habitat suitability and availability for fish there will* **not** *be a notable change in the condition of the fish assemblage (although flows are sometimes higher than the EWR, it simulates the PD flow to a great extent). No geomorphological change is expected and therefore no change in the suitability and availability of substrates will take place. The slight improvement in water quality may improve conditions slightly for the water quality intolerant species (see Sc MK2) and therefore improve overall conditions for fish to some extent but the fish will still remain in a slightly improved PES of a D.*
Macro-invertebrates: PES and REC C/D (61.7%)		
2	*C (64.3%)*	*Increased bed scour and some flushing of high nutrient levels would occur although no response from vegetation is likely. For the macro-invertebrates the slight improvement in water quality and flows will improve the EC marginally.*
41	*C (69.2%)*	*The scenario results in increased bed scour and an overall improvement in water quality with no likely response from vegetation. For the macro-invertebrates the improvement in water quality and dry season base flows will improve the EC markedly.*
51	*C (63.0%)*	*These circumstances are expected to result in a small improvement in nutrient and toxic levels while no response from vegetation is likely. An improvement in EC is likely.*
Riparian vegetation: PES and REC D (42.7%)		
2	*42.7*	*Inundation of vegetation (assessed at 50% in Feb for wet season (Table 12.7, Appendix A for detail) is more than EWR and PD. This is unlikely to elicit a response from riparian vegetation especially since other non-flow related impacts (such as overgrazing) are so high. Stream permanency remains at 100% i.e. no significant increase in zero flows. Inundation of vegetation is also the same as PD and the EWR in the dry season and no response from vegetation is likely.*
41	*D (42.7%)*	*No response by riparian vegetation is envisaged.*
51	*D (42.7%)*	*Differences are small however (see inundation of vegetation in Table 12.7, Appendix A) and no response by riparian vegetation is envisaged.*

9.4 MG_I_EWR5: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 9.3. The ranking of the scenarios are provided on a traffic diagram (Figure 9.1). The results illustrate that Sc MG2, 41, 42, 51 and 52 meet the ecological objectives of the REC and is an improvement in some cases. Not *that this improvement also relies on an eradication programme for alien fish. Sc MG 51 and 52 shows a decrease in geomorphology but an improvement in invertebrates and water quality.*

Table 9.3 Ecological consequences at MG_I_EWR5

Component	PES & REC	Sc MG2	Sc MG41	Sc MG42	Sc MG51	Sc MG52
Physico chemical	C/D	C	C	C	C	C
Geomorphology	C/D	C/D	C/D	C/D	D	D
Fish	D	C/D	C	C	D	D
Invertebrates	C/D	C	C	C	C	C
Riparian vegetation	D	D	D	D	D	D
EcoStatus	D	D	D	D	D	D

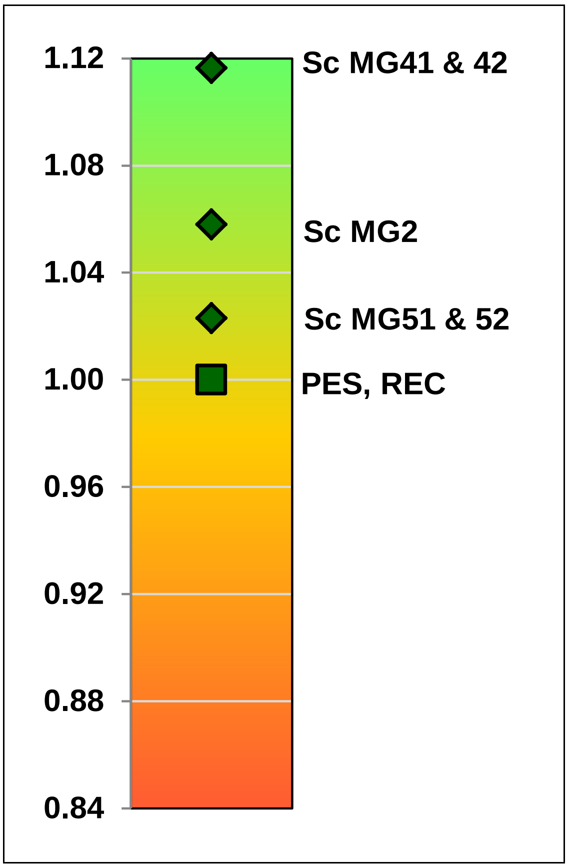

Figure 9.1 Ecological ranking of operational scenarios at MG_I_EWR5

10 CONCLUSIONS

10.1 SCENARIO ECOLOGICAL CONSEQUENCES: LOVU RIVER

The results illustrate that all the scenarios meet the ecological objectives with Sc LO4 resulting in an improvement in the PES and REC. All scenarios are therefore acceptable from an ecological viewpoint.

10.2 SCENARIO ECOLOGICAL CONSEQUENCES: MKOMAZI CATCHMENT

The ranking of the scenarios at each site in terms of how successful the scenarios are in meeting the REC is provided in Figure 10.1. The ranking shows that Sc MK2 and 4 are the lowest in the ranking order at all sites and significantly lower than the other scenarios. This is because Sc MK2 and 4 includes Smithfield Dam with no EWRs. All the rest of the scenarios still maintain the EcoStatus of a C at Mk_I_EWR1 but do not achieve the REC (PES). The major problem at Mk_I_EWR 1 is that the site is close to the dam and therefore only received the water being released from the dam or spills. As the river acts as a conduit to convey water from the dam down the system, the main reasons for not achieving the REC (PES) is the increased (above natural) and unseasonal base flows as well as the decrease in floods.

As one moves further downstream of the dam, the impacts become less pronounced. At Mk_I_EWR 2, tributary inflows mitigate some of the impacts of the unseasonal flows and the lack of floods. However the main users are downstream of Mk_I_EWR 2, and therefore the impacts are still felt to some degree. Sc MK 21, 41 and 42 still maintain the EcoStatus of a B with Sc MK41 being the better scenario.

At Mk_I_EWR3 Sc MK21, 41 and 31 maintains the C EcoStatus and are the best scenarios, although it also does not achieve all the ecological objectives.

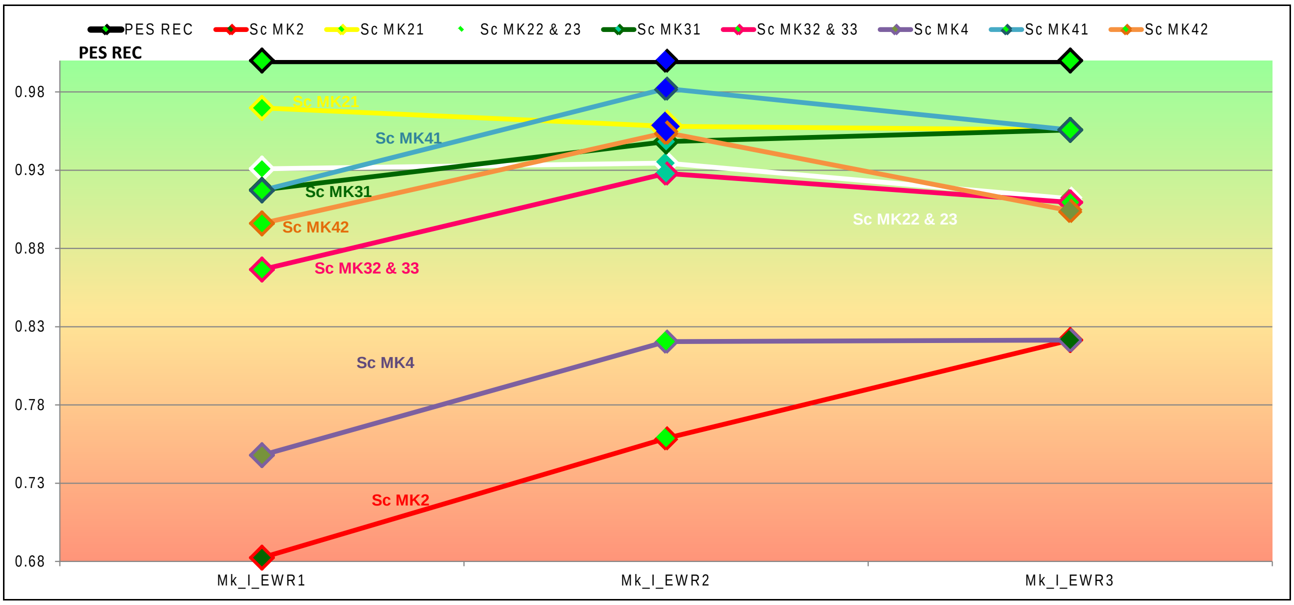

Figure 10.1 Mkomazi River: Ranking of scenarios at each EWR site

The process to determine an integrated ranking of the different scenarios is described below. The first step was to determine the relative importance of the different EWR sites. The site weight (Table 10.1) indicates that Mk_I_ EWR 3 carries the highest weight due to the longer river distance which the scenario consequences are relevant for. The importance of Mk_I_EWR 2 is slightly *lower due to the shorter distance it represents, which is offset in the higher ecological importance and presence in a protected area. Mk_I_EWR 1 will have a much lower weight, largely because the scenario consequences are only applicable to 14 km of the total length of river.*

The weights are provided in the Table 10.1. The weight is based on the conversion of the PES and EIS to numerical values to determine the normalised weight.

Table 10.1 Weights allocated to EWR sites relative to each other

EWR site	PES	EIS	Locality in protected areas (0 - 5)	Distance	Normalised Weight
EWR 1	C	*Moderate*	*1*	*0.08*	**0.22**
EWR 2	B	*High*	*3*	*0.32*	**0.37**
EWR 3	C	*Moderate*	*1*	*0.6*	**0.41**

The weight is applied to the ranking value for each scenario at each EWR site and this provides an integrated score and ranking for the operational scenarios of the Mkomazi system. The ranking of '1' refers to the REC and the rest of the ranking illustrate the degree to which the scenarios meet the REC. The results are provided in Table 10.2 after the weights have been taken into account.

Table 10.2 Ranking value for each scenario resulting in an integrated score and ranking

EWR	PES	REC	Sc MK2	Sc MK21	Sc MK22	Sc MK23	Sc MK31	Sc MK32	Sc MK33	Sc MK4	Sc MK41	Sc MK42
Mk_I_EWR1	*0.22*	*0.22*	*0.15*	*0.21*	*0.21*	*0.21*	*0.20*	*0.19*	*0.19*	*0.17*	*0.20*	*0.20*
Mk_I_EWR2	*0.37*	*0.37*	*0.28*	*0.35*	*0.35*	*0.35*	*0.35*	*0.34*	*0.34*	*0.30*	*0.36*	*0.35*
Mk_I_EWR3	*0.41*	*0.41*	*0.34*	*0.39*	*0.37*	*0.37*	*0.39*	*0.37*	*0.37*	*0.34*	*0.39*	*0.37*
	1.00	*1.00*	*0.77*	*0.96*	*0.92*	*0.92*	*0.94*	*0.91*	*0.91*	*0.80*	*0.96*	*0.92*

The above results are plotted on a traffic diagram (Figure 10.2) to illustrate the integrated ecological ranking.

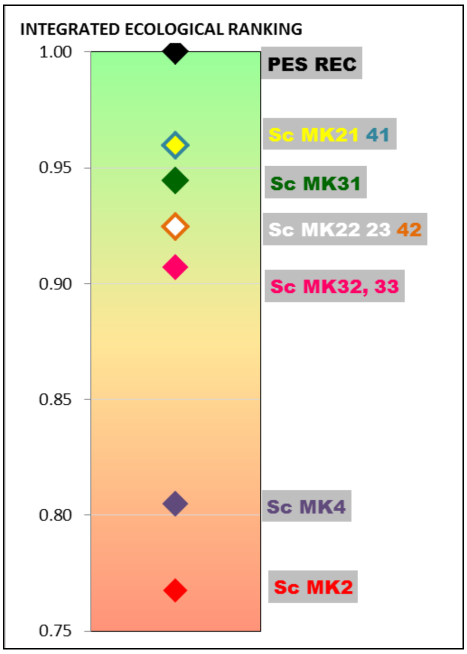

Figure 10.2 Integrated ecological ranking of the scenarios on the Mkomazi River system

Sc MK 21 and 41 are the best options as they are the closest to meeting the ecological objectives. Both these scenarios include the total EWR flows and the impacts are mostly due to the impacts on the dam itself, such as the barrier effect, impact on larger frequency of floods and largely due to the increased (above natural) base flows.

10.3 SCENARIO ECOLOGICAL CONSEQUENCES: MVOTI CATCHMENT

Scenario MV41 which includes the dam and releases the full EWR will meet the ecological objectives. Sc MV 42 and 43 are very similar, still maintain the REC EcoStatus but overall do not comply with all the objectives. Sc MV3 is the least acceptable as it drops a category overall (D EC) and for most of the components.

10.4 SCENARIO ECOLOGICAL CONSEQUENCES: uMNGENI CATCHMENT

All scenarios meet the ecological objectives and improve the situation.

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12 APPENDIX A: INUNDATION LEVELS OF RIPARIAN VEGETATION INDICATORS UNDER DIFFERENT FLOW REGIMES

Table 12.1 LO_R_EWR1: Levels of inundation (m) of upper and lower limits of riparian vegetation indicators under different flow regimes

Species	Natural		PD		EWR		LO3		LO4	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Feb (Wet season)										
P. australis	0.34	-0.38	0.42	-0.30	0.48	-0.24	0.40	-0.32	0.38	-0.34
S. sphacelata	-0.08	-0.30	0.00	-0.22	0.06	-0.16	-0.02	-0.24	-0.04	-0.26
C. dives	0.63	-0.20	0.71	-0.12	0.77	-0.06	0.69	-0.14	0.67	-0.16
Eleocharis	0.70	0.30	0.78	0.38	0.84	0.44	0.76	0.36	0.74	0.34
Ficus (saplings)		0.34		0.42		0.48		0.40		0.38
Backwater		0.60		0.68		0.74		0.66		0.64
Pluchea	1.23	0.76	1.31	0.84	1.37	0.90	1.29	0.82	1.27	0.80
A. gerardii		1.30		1.38		1.44		1.36		1.34
Large tree line (A. gerardii, E. lysystemon)		2.03		2.11		2.17		2.09		2.07
Aug (Dry season)										
P. australis	0.56	-0.16	0.64	-0.08	0.66	-0.06	0.62	-0.10	0.60	-0.12
S. sphacelata	0.14	-0.08	0.22	0.00	0.24	0.02	0.20	-0.02	0.18	-0.04
C. dives	0.85	0.02	0.93	0.10	0.95	0.12	0.91	0.08	0.89	0.06
Eleocharis	0.92	0.52	1.00	0.60	1.02	0.62	0.98	0.58	0.96	0.56
Ficus (saplings)		0.56		0.64		0.66		0.62		0.60
Backwater		0.82		0.90		0.92		0.88		0.86
Pluchea	1.45	0.98	1.53	1.06	1.55	1.08	1.51	1.04	1.49	1.02
A. gerardii		1.52		1.60		1.62		1.58		1.56
Large tree line (A. gerardii, E. lysystemon)		2.25		2.33		2.35		2.31		2.29

Table 12.2 MK_I_EWR1: Levels of inundation (m) of upper and lower limits of riparian vegetation indicators under different flow scenarios

February (wet season)		Indicator Species (lower and upper elevation above channel bed (m))											
		Cyperus longus		*Setaria sphacelata*		*Salix mucronata*		*Miscanthus junceus*		*Combretum erythrophyllum*		*Arundinella napalensis*	
Scenario	**Discharge at 50%**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**
		0.98	**1.80**	**1.30**	**1.79**	**1.33**	**1.78**	**1.50**	**1.79**	**3.39**	**8.68**	**n/a**	**1.68**
Nat	*51.81*	*-0.66*	*0.16*	*-0.34*	*0.15*	*-0.31*	*0.14*	*-0.14*	*0.15*	*1.75*	*7.04*		*0.04*
PD	*49.95*	*-0.64*	*0.18*	*-0.32*	*0.17*	*-0.29*	*0.16*	*-0.12*	*0.17*	*1.77*	*7.06*		*0.06*
EWR	*15.27*	*-0.26*	*0.56*	*0.06*	*0.55*	*0.09*	*0.54*	*0.26*	*0.55*	*2.15*	*7.44*		*0.44*
Sc 2	*45.38*	*-0.62*	*0.20*	*-0.30*	*0.19*	*-0.27*	*0.18*	*-0.10*	*0.19*	*1.79*	*7.08*		*0.08*
Sc 21	*44.86*	*-0.60*	*0.22*	*-0.28*	*0.21*	*-0.25*	*0.20*	*-0.08*	*0.21*	*1.81*	*7.10*		*0.10*
Sc 22	*46.03*	*-0.62*	*0.20*	*-0.30*	*0.19*	*-0.27*	*0.18*	*-0.10*	*0.19*	*1.79*	*7.08*		*0.08*
Sc 31	*46.05*	*-0.62*	*0.20*	*-0.30*	*0.19*	*-0.27*	*0.18*	*-0.10*	*0.19*	*1.79*	*7.08*		*0.08*
Sc 32	*46.55*	*-0.62*	*0.20*	*-0.30*	*0.19*	*-0.27*	*0.18*	*-0.10*	*0.19*	*1.79*	*7.08*		*0.08*
Sc 4	*47.07*	*-0.62*	*0.20*	*-0.30*	*0.19*	*-0.27*	*0.18*	*-0.10*	*0.19*	*1.79*	*7.08*		*0.08*
Sc 41	*48.14*	*-0.64*	*0.18*	*-0.32*	*0.17*	*-0.29*	*0.16*	*-0.12*	*0.17*	*1.77*	*7.06*		*0.06*
Sc 42	*48.73*	*-0.64*	*0.18*	*-0.32*	*0.17*	*-0.29*	*0.16*	*-0.12*	*0.17*	*1.77*	*7.06*		*0.06*
August (dry season)		**Indicator Species (lower and upper elevation above channel bed (m))**											
Nat	*3.05*	*0.02*	*0.84*	*0.34*	*0.83*	*0.37*	*0.82*	*0.54*	*0.83*	*2.43*	*7.72*		*0.72*
PD	*2.76*	*0.04*	*0.86*	*0.36*	*0.85*	*0.39*	*0.84*	*0.56*	*0.85*	*2.45*	*7.74*		*0.74*
EWR	*2.44*	*0.06*	*0.88*	*0.38*	*0.87*	*0.41*	*0.86*	*0.58*	*0.87*	*2.47*	*7.76*		*0.76*
Sc 2	*1.72*	*0.10*	*0.92*	*0.42*	*0.91*	*0.45*	*0.90*	*0.62*	*0.91*	*2.51*	*7.80*		*0.80*
Sc 21	*2.86*	*0.04*	*0.86*	*0.36*	*0.85*	*0.39*	*0.84*	*0.56*	*0.85*	*2.45*	*7.74*		*0.74*
Sc 22	*2.86*	*0.04*	*0.86*	*0.36*	*0.85*	*0.39*	*0.84*	*0.56*	*0.85*	*2.45*	*7.74*		*0.74*
Sc 31	*2.63*	*0.04*	*0.86*	*0.36*	*0.85*	*0.39*	*0.84*	*0.56*	*0.85*	*2.45*	*7.74*		*0.74*
Sc 32	*2.62*	*0.04*	*0.86*	*0.36*	*0.85*	*0.39*	*0.84*	*0.56*	*0.85*	*2.45*	*7.74*		*0.74*
Sc 4	*3.64*	*0.00*	*0.82*	*0.32*	*0.81*	*0.35*	*0.80*	*0.52*	*0.81*	*2.41*	*7.70*		*0.70*
Sc 41	*4.74*	*-0.04*	*0.78*	*0.28*	*0.77*	*0.31*	*0.76*	*0.48*	*0.77*	*2.37*	*7.66*		*0.66*
Sc 42	*4.74*	*-0.04*	*0.78*	*0.28*	*0.77*	*0.31*	*0.76*	*0.48*	*0.77*	*2.37*	*7.66*		*0.66*

Table 12.3 MK_I_EWR2: Levels of inundation (m) of upper and lower limits of riparian vegetation indicators under different flow scenarios

February (wet season)		Indicator Species (lower and upper elevation above channel bed (m))															
		Cyperus longus		*Juncus effasus*		*Salix mucronata*		*Miscanthus junceus*		*Setaria sphacelata*		*Syzygium guineense*		*Acacia gerardii*		*Arundinella napalensis*	
Scenario	**Discharge @ 50%**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**
		0.92	**n/a**	**0.99**	**1.89**	**1.17**	**1.24**	**1.41**	**1.87**	**1.22**	**1.57**	**1.51**	**2.82**	**3.63**	**n/a**	**1.24**	**1.96**
Nat	*62.25*	*-0.74*		*-0.67*	*0.23*	*-0.49*	*-0.42*	*-0.25*	*0.21*	*-0.44*	*-0.09*	*-0.15*	*1.16*	*1.97*		*-0.42*	*0.30*
PD	*60.51*	*-0.74*		*-0.67*	*0.23*	*-0.49*	*-0.42*	*-0.25*	*0.21*	*-0.44*	*-0.09*	*-0.15*	*1.16*	*1.97*		*-0.42*	*0.30*
EWR	*19.94*	*-0.26*		*-0.19*	*0.71*	*-0.01*	*0.06*	*0.23*	*0.69*	*0.04*	*0.39*	*0.33*	*1.64*	*2.45*		*0.06*	*0.78*
Sc 2	*53.00*	*-0.66*		*-0.59*	*0.31*	*-0.41*	*-0.34*	*-0.17*	*0.29*	*-0.36*	*-0.01*	*-0.07*	*1.24*	*2.05*		*-0.34*	*0.38*
Sc 21	*52.17*	*-0.66*		*-0.59*	*0.31*	*-0.41*	*-0.34*	*-0.17*	*0.29*	*-0.36*	*-0.01*	*-0.07*	*1.24*	*2.05*		*-0.34*	*0.38*
Sc 22	*52.90*	*-0.66*		*-0.59*	*0.31*	*-0.41*	*-0.34*	*-0.17*	*0.29*	*-0.36*	*-0.01*	*-0.07*	*1.24*	*2.05*		*-0.34*	*0.38*
Sc 31	*53.43*	*-0.66*		*-0.59*	*0.31*	*-0.41*	*-0.34*	*-0.17*	*0.29*	*-0.36*	*-0.01*	*-0.07*	*1.24*	*2.05*		*-0.34*	*0.38*
Sc 32	*53.95*	*-0.68*		*-0.61*	*0.29*	*-0.43*	*-0.36*	*-0.19*	*0.27*	*-0.38*	*-0.03*	*-0.09*	*1.22*	*2.03*		*-0.36*	*0.36*
Sc 4	*55.73*	*-0.68*		*-0.61*	*0.29*	*-0.43*	*-0.36*	*-0.19*	*0.27*	*-0.38*	*-0.03*	*-0.09*	*1.22*	*2.03*		*-0.36*	*0.36*
Sc 41	*55.81*	*-0.70*		*-0.63*	*0.27*	*-0.45*	*-0.38*	*-0.21*	*0.25*	*-0.40*	*-0.05*	*-0.11*	*1.20*	*2.01*		*-0.38*	*0.34*
Sc 42	*56.85*	*-0.70*		*-0.63*	*0.27*	*-0.45*	*-0.38*	*-0.21*	*0.25*	*-0.40*	*-0.05*	*-0.11*	*1.20*	*2.01*		*-0.38*	*0.34*
August (dry season)		**Indicator Species (lower and upper elevation above channel bed (m))**															
Nat	*4.40*	*0.18*		*0.25*	*1.15*	*0.43*	*0.50*	*0.67*	*1.13*	*0.48*	*0.83*	*0.77*	*2.08*	*2.89*		*0.50*	*1.22*
PD	*3.55*	*0.22*		*0.29*	*1.19*	*0.47*	*0.54*	*0.71*	*1.17*	*0.52*	*0.87*	*0.81*	*2.12*	*2.93*		*0.54*	*1.26*
EWR	*3.06*	*0.26*		*0.33*	*1.23*	*0.51*	*0.58*	*0.75*	*1.21*	*0.56*	*0.91*	*0.85*	*2.16*	*2.97*		*0.58*	*1.30*
Sc 2	*2.00*	*0.34*		*0.41*	*1.31*	*0.59*	*0.66*	*0.83*	*1.29*	*0.64*	*0.99*	*0.93*	*2.24*	*3.05*		*0.66*	*1.38*
Sc 21	*3.34*	*0.24*		*0.31*	*1.21*	*0.49*	*0.56*	*0.73*	*1.19*	*0.54*	*0.89*	*0.83*	*2.14*	*2.95*		*0.56*	*1.28*
Sc 22	*3.34*	*0.24*		*0.31*	*1.21*	*0.49*	*0.56*	*0.73*	*1.19*	*0.54*	*0.89*	*0.83*	*2.14*	*2.95*		*0.56*	*1.28*
Sc 31	*2.91*	*0.26*		*0.33*	*1.23*	*0.51*	*0.58*	*0.75*	*1.21*	*0.56*	*0.91*	*0.85*	*2.16*	*2.97*		*0.58*	*1.30*
Sc 32	*2.91*	*0.26*		*0.33*	*1.23*	*0.51*	*0.58*	*0.75*	*1.21*	*0.56*	*0.91*	*0.85*	*2.16*	*2.97*		*0.58*	*1.30*
Sc 4	*3.66*	*0.22*		*0.29*	*1.19*	*0.47*	*0.54*	*0.71*	*1.17*	*0.52*	*0.87*	*0.81*	*2.12*	*2.93*		*0.54*	*1.26*
Sc 41	*4.77*	*0.16*		*0.23*	*1.13*	*0.41*	*0.48*	*0.65*	*1.11*	*0.46*	*0.81*	*0.75*	*2.06*	*2.87*		*0.48*	*1.20*
Sc 42	*4.73*	*0.16*		*0.23*	*1.13*	*0.41*	*0.48*	*0.65*	*1.11*	*0.46*	*0.81*	*0.75*	*2.06*	*2.87*		*0.48*	*1.20*

Table 12.4 MK_I_EWR3: Levels of inundation (m) of upper and lower limits of riparian vegetation indicators under different flow scenarios

February (wet season)		Indicator Species (lower and upper elevation above channel bed (m))													
		Cyperus longus		*Juncus effasus*		*Phragmites australis*		*Cyperus dives*		*Setaria sphacelata*		*Syzygium guineense*		*Ludwigia octovalvis*	
Scenario	Discharge @ 50%	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
		1.06	1.41	1.06	1.68	0.68	1.72	1.33	1.78	1.04	1.53	1.23	1.72	1.48	1.72
Nat	*70.85*	*-0.74*	*-0.39*	*-0.74*	*-0.12*	*-1.12*	*-0.08*	*-0.47*	*-0.02*	*-0.76*	*-0.27*	*-0.57*	*-0.08*	*-0.32*	*-0.08*
PD	*67.43*	*-0.69*	*-0.34*	*-0.69*	*-0.07*	*-1.07*	*-0.03*	*-0.42*	*0.03*	*-0.71*	*-0.22*	*-0.52*	*-0.03*	*-0.27*	*-0.03*
EWR	*21.48*	*-0.29*	*0.06*	*-0.29*	*0.33*	*-0.67*	*0.37*	*-0.02*	*0.43*	*-0.31*	*0.18*	*-0.12*	*0.37*	*0.13*	*0.37*
Sc 2	*59.80*	*-0.64*	*-0.29*	*-0.64*	*-0.02*	*-1.02*	*0.02*	*-0.37*	*0.08*	*-0.66*	*-0.17*	*-0.47*	*0.02*	*-0.22*	*0.02*
Sc 21	*61.36*	*-0.64*	*-0.29*	*-0.64*	*-0.02*	*-1.02*	*0.02*	*-0.37*	*0.08*	*-0.66*	*-0.17*	*-0.47*	*0.02*	*-0.22*	*0.02*
Sc 22	*61.09*	*-0.64*	*-0.29*	*-0.64*	*-0.02*	*-1.02*	*0.02*	*-0.37*	*0.08*	*-0.66*	*-0.17*	*-0.47*	*0.02*	*-0.22*	*0.02*
Sc 32	*61.08*	*-0.64*	*-0.29*	*-0.64*	*-0.02*	*-1.02*	*0.02*	*-0.37*	*0.08*	*-0.66*	*-0.17*	*-0.47*	*0.02*	*-0.22*	*0.02*
Sc 42	*61.61*	*-0.64*	*-0.29*	*-0.64*	*-0.02*	*-1.02*	*0.02*	*-0.37*	*0.08*	*-0.66*	*-0.17*	*-0.47*	*0.02*	*-0.22*	*0.02*
August (dry season)		**Indicator Species (lower and upper elevation above channel bed (m))**													
Nat	*5.47*	*0.01*	*0.36*	*0.01*	*0.63*	*-0.37*	*0.67*	*0.28*	*0.73*	*-0.01*	*0.48*	*0.18*	*0.67*	*0.43*	*0.67*
PD	*3.92*	*0.06*	*0.41*	*0.06*	*0.68*	*-0.32*	*0.72*	*0.33*	*0.78*	*0.04*	*0.53*	*0.23*	*0.72*	*0.48*	*0.72*
EWR	*3.12*	*0.11*	*0.46*	*0.11*	*0.73*	*-0.27*	*0.77*	*0.38*	*0.83*	*0.09*	*0.58*	*0.28*	*0.77*	*0.53*	*0.77*
Sc 2	*2.30*	*0.11*	*0.46*	*0.11*	*0.73*	*-0.27*	*0.77*	*0.38*	*0.83*	*0.09*	*0.58*	*0.28*	*0.77*	*0.53*	*0.77*
Sc 21	*3.67*	*0.06*	*0.41*	*0.06*	*0.68*	*-0.32*	*0.72*	*0.33*	*0.78*	*0.04*	*0.53*	*0.23*	*0.72*	*0.48*	*0.72*
Sc 22	*3.67*	*0.06*	*0.41*	*0.06*	*0.68*	*-0.32*	*0.72*	*0.33*	*0.78*	*0.04*	*0.53*	*0.23*	*0.72*	*0.48*	*0.72*
Sc 32	*3.19*	*0.11*	*0.46*	*0.11*	*0.73*	*-0.27*	*0.77*	*0.38*	*0.83*	*0.09*	*0.58*	*0.28*	*0.77*	*0.53*	*0.77*
Sc 42	*3.67*	*0.06*	*0.41*	*0.06*	*0.68*	*-0.32*	*0.72*	*0.33*	*0.78*	*0.04*	*0.53*	*0.23*	*0.72*	*0.48*	*0.72*

Table 12.5 MV_I_EWR2: Levels of inundation (m) of upper and lower limits of riparian vegetation indicators under different flow regimes

February (wet season)		Indicator Species (lower and upper elevation above channel bed (m))													
		Marginal guild		*Paspalum distichum*		*Setaria sphacelata*		*Juncus effasus*		*Syzygium cordatum*		*Combretum erythrophyllum/tree line*		*Acacia sieberiana*	
Scenario	Discharge @ 50%	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
		0.34	n/a	0.44	n/a	0.52	0.97	0.61	1.15	n/a	1.95	1.45	n/a	1.27	n/a
Nat	*11.68*	*-0.50*		*-0.40*		*-0.32*	*0.13*	*-0.23*	*0.31*		*1.11*	*0.61*		*0.43*	
PD	*6.49*	*-0.34*		*-0.24*		*-0.16*	*0.29*	*-0.07*	*0.47*		*1.27*	*0.77*		*0.59*	
EWR	*3.51*	*-0.22*		*-0.12*		*-0.04*	*0.41*	*0.05*	*0.59*		*1.39*	*0.89*		*0.71*	
Sc 3	*4.81*	*-0.28*		*-0.18*		*-0.10*	*0.35*	*-0.01*	*0.53*		*1.33*	*0.83*		*0.65*	
Sc 42	*5.78*	*-0.32*		*-0.22*		*-0.14*	*0.31*	*-0.05*	*0.49*		*1.29*	*0.79*		*0.61*	
Sc 43	*5.22*	*-0.30*		*-0.20*		*-0.12*	*0.33*	*-0.03*	*0.51*		*1.31*	*0.81*		*0.63*	
August (dry season)		**Indicator Species (lower and upper elevation above channel bed (m))**													
Nat	*1.72*	*-0.12*		*-0.02*		*0.06*	*0.51*	*0.15*	*0.69*		*1.49*	*0.99*		*0.81*	
PD	*0.72*	*-0.04*		*0.06*		*0.14*	*0.59*	*0.23*	*0.77*		*1.57*	*1.07*		*0.89*	
EWR	*0.72*	*-0.04*		*0.06*		*0.14*	*0.59*	*0.23*	*0.77*		*1.57*	*1.07*		*0.89*	
Sc 3	*0.46*	*0.00*		*0.10*		*0.18*	*0.63*	*0.27*	*0.81*		*1.61*	*1.11*		*0.93*	
Sc 42	*1.18*	*-0.08*		*0.02*		*0.10*	*0.55*	*0.19*	*0.73*		*1.53*	*1.03*		*0.85*	
Sc 43	*1.18*	*-0.08*		*0.02*		*0.10*	*0.55*	*0.19*	*0.73*		*1.53*	*1.03*		*0.85*	

Table 12.6 Mg_I_EWR2: Levels of inundation (m) of upper and lower limits of riparian vegetation indicators under different flow regimes

February (wet season)		Indicator Species (lower and upper elevation above channel bed (m))																	
		Phragmites australis		*Setaria sphacelata*		Marginal suite (*Persicaria, Nasturtium, Cotula*)		*Cyperus dives*		*Ludwigia octovalvis*		*Juncus effasus*		*Arundinella napalensis*		*Combretum erythrophyllum*	
Scenario	Discharge @ 50%	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
		0.24	0.54	0.46	0.54	0.46	n/a	0.53	0.63	0.63	0.87	0.66	1.05	1.05	1.86	1.56	3.22
Nat	*11.40*	*-0.66*	*-0.36*	*-0.44*	*-0.36*	*-0.44*		*-0.37*	*-0.27*	*-0.27*	*-0.03*	*-0.24*	*0.15*	*0.15*	*0.96*	*0.66*	
PD	*4.93*	*-0.46*	*-0.16*	*-0.24*	*-0.16*	*-0.24*		*-0.17*	*-0.07*	*-0.07*	*0.17*	*-0.04*	*0.35*	*0.35*	*1.16*	*0.86*	
EWR	*1.97*	*-0.30*	*0.00*	*-0.08*	*0.00*	*-0.08*		*-0.01*	*0.09*	*0.09*	*0.33*	*0.12*	*0.51*	*0.51*	*1.32*	*1.02*	
Sc 2	*3.23*	*-0.38*	*-0.08*	*-0.16*	*-0.08*	*-0.16*		*-0.09*	*0.01*	*0.01*	*0.25*	*0.04*	*0.43*	*0.43*	*1.24*	*0.94*	
Sc 41	*5.76*	*-0.48*	*-0.18*	*-0.26*	*-0.18*	*-0.26*		*-0.19*	*-0.09*	*-0.09*	*0.15*	*-0.06*	*0.33*	*0.33*	*1.14*	*0.84*	
Sc 42	*5.76*	*-0.48*	*-0.18*	*-0.26*	*-0.18*	*-0.26*		*-0.19*	*-0.09*	*-0.09*	*0.15*	*-0.06*	*0.33*	*0.33*	*1.14*	*0.84*	
Sc 51	*5.76*	*-0.48*	*-0.18*	*-0.26*	*-0.18*	*-0.26*		*-0.19*	*-0.09*	*-0.09*	*0.15*	*-0.06*	*0.33*	*0.33*	*1.14*	*0.84*	
Sc 52	*5.76*	*-0.48*	*-0.18*	*-0.26*	*-0.18*	*-0.26*		*-0.19*	*-0.09*	*-0.09*	*0.15*	*-0.06*	*0.33*	*0.33*	*1.14*	*0.84*	
		0.20	*0.50*	*0.42*	*0.50*	*0.42*		*0.49*	*0.59*	*0.59*	*0.83*	*0.62*	*1.01*	*1.01*	*1.82*	*1.52*	
		0.20	*0.50*	*0.42*	*0.50*	*0.42*		*0.49*	*0.59*	*0.59*	*0.83*	*0.62*	*1.01*	*1.01*	*1.82*	*1.52*	
		0.20	*0.50*	*0.42*	*0.50*	*0.42*		*0.49*	*0.59*	*0.59*	*0.83*	*0.62*	*1.01*	*1.01*	*1.82*	*1.52*	
August (dry season)		**Indicator Species (lower and upper elevation above channel bed (m))**															
Nat	*2.15*	*-0.32*	*-0.02*	*-0.10*	*-0.02*	*-0.10*		*-0.03*	*0.07*	*0.07*	*0.31*	*0.10*	*0.49*	*0.49*	*1.30*	*1.00*	
PD	*0.86*	*-0.22*	*0.08*	*0.00*	*0.08*	*0.00*		*0.07*	*0.17*	*0.17*	*0.41*	*0.20*	*0.59*	*0.59*	*1.40*	*1.10*	
EWR	*0.86*	*-0.22*	*0.08*	*0.00*	*0.08*	*0.00*		*0.07*	*0.17*	*0.17*	*0.41*	*0.20*	*0.59*	*0.59*	*1.40*	*1.10*	
Sc 2	*0.83*	*-0.20*	*0.10*	*0.02*	*0.10*	*0.02*		*0.09*	*0.19*	*0.19*	*0.43*	*0.22*	*0.61*	*0.61*	*1.42*	*1.12*	
Sc 41	*0.98*	*-0.22*	*0.08*	*0.00*	*0.08*	*0.00*		*0.07*	*0.17*	*0.17*	*0.41*	*0.20*	*0.59*	*0.59*	*1.40*	*1.10*	
Sc 42	*0.98*	*-0.22*	*0.08*	*0.00*	*0.08*	*0.00*		*0.07*	*0.17*	*0.17*	*0.41*	*0.20*	*0.59*	*0.59*	*1.40*	*1.10*	
Sc 51	*0.98*	*-0.22*	*0.08*	*0.00*	*0.08*	*0.00*		*0.07*	*0.17*	*0.17*	*0.41*	*0.20*	*0.59*	*0.59*	*1.40*	*1.10*	
Sc 52	*0.98*	*-0.22*	*0.08*	*0.00*	*0.08*	*0.00*		*0.07*	*0.17*	*0.17*	*0.41*	*0.20*	*0.59*	*0.59*	*1.40*	*1.10*	
		0.20	*0.50*	*0.42*	*0.50*	*0.42*		*0.49*	*0.59*	*0.59*	*0.83*	*0.62*	*1.01*	*1.01*	*1.82*	*1.52*	
		0.20	*0.50*	*0.42*	*0.50*	*0.42*		*0.49*	*0.59*	*0.59*	*0.83*	*0.62*	*1.01*	*1.01*	*1.82*	*1.52*	

		0.20	0.50	0.42	0.50	0.42		0.49	0.59	0.59	0.83	0.62	1.01	1.01	1.82	1.52	

Table 12.7 Mg_I_EWR5: Levels of inundation (m) of upper and lower limits of riparian vegetation indicators under different flow regimes

February (wet season)		Indicator Species (lower and upper elevation above channel bed (m))															
		Cyperus dives		*Nasturtium officinale*		*Juncus effasus*		*Setaria sphacelata*		*Ludwigia octovalvis*		*Syzygium cordatum*		*Acacia sieberiana (saplings)*		*Acacia sieberiana (adults)*	
Scenario	**Discharge @ 50%**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**
		0.53	**0.87**	**0.54**	**0.77**	**0.63**	**0.87**	**0.66**	**n/a**	**0.85**	**1.24**	**0.80**	**n/a**	**1.24**	**n/a**	**2.41**	**n/a**
Nat	*31.17*	*-0.61*	*-0.27*	*-0.60*	*-0.37*	*-0.51*	*-0.27*	*-0.48*		*-0.29*	*0.10*	*-0.34*		*0.10*		*1.27*	
PD	*8.06*	*-0.21*	*0.13*	*-0.20*	*0.03*	*-0.11*	*0.13*	*-0.08*		*0.11*	*0.50*	*0.06*		*0.50*		*1.67*	
EWR	*5.99*	*-0.17*	*0.17*	*-0.16*	*0.07*	*-0.07*	*0.17*	*-0.04*		*0.15*	*0.54*	*0.10*		*0.54*		*1.71*	
Sc 2	*11.15*	*-0.29*	*0.05*	*-0.28*	*-0.05*	*-0.19*	*0.05*	*-0.16*		*0.03*	*0.42*	*-0.02*		*0.42*		*1.59*	
Sc 41	*7.53*	*-0.21*	*0.13*	*-0.20*	*0.03*	*-0.11*	*0.13*	*-0.08*		*0.11*	*0.50*	*0.06*		*0.50*		*1.67*	
Sc 42	*7.53*	*-0.21*	*0.13*	*-0.20*	*0.03*	*-0.11*	*0.13*	*-0.08*		*0.11*	*0.50*	*0.06*		*0.50*		*1.67*	
Sc 51	*6.81*	*-0.19*	*0.15*	*-0.18*	*0.05*	*-0.09*	*0.15*	*-0.06*		*0.13*	*0.52*	*0.08*		*0.52*		*1.69*	
Sc 52	*6.81*	*-0.19*	*0.15*	*-0.18*	*0.05*	*-0.09*	*0.15*	*-0.06*		*0.13*	*0.52*	*0.08*		*0.52*		*1.69*	
August (dry season)		**Indicator Species (lower and upper elevation above channel bed (m))**															
Nat	*4.86*	*-0.13*	*0.21*	*-0.12*	*0.11*	*-0.03*	*0.21*	*0.00*		*0.19*	*0.58*	*0.14*		*0.58*		*1.75*	
PD	*2.44*	*-0.03*	*0.31*	*-0.02*	*0.21*	*0.07*	*0.31*	*0.10*		*0.29*	*0.68*	*0.24*		*0.68*		*1.85*	
EWR	*2.29*	*-0.03*	*0.31*	*-0.02*	*0.21*	*0.07*	*0.31*	*0.10*		*0.29*	*0.68*	*0.24*		*0.68*		*1.85*	
Sc 2	*2.36*	*-0.03*	*0.31*	*-0.02*	*0.21*	*0.07*	*0.31*	*0.10*		*0.29*	*0.68*	*0.24*		*0.68*		*1.85*	
Sc 41	*2.75*	*-0.05*	*0.29*	*-0.04*	*0.19*	*0.05*	*0.29*	*0.08*		*0.27*	*0.66*	*0.22*		*0.66*		*1.83*	
Sc 42	*2.75*	*-0.05*	*0.29*	*-0.04*	*0.19*	*0.05*	*0.29*	*0.08*		*0.27*	*0.66*	*0.22*		*0.66*		*1.83*	
Sc 51	*2.10*	*-0.01*	*0.33*	*0.00*	*0.23*	*0.09*	*0.33*	*0.12*		*0.31*	*0.70*	*0.26*		*0.70*		*1.87*	
Sc 52	*2.10*	*-0.01*	*0.33*	*0.00*	*0.23*	*0.09*	*0.33*	*0.12*		*0.31*	*0.70*	*0.26*		*0.70*		*1.87*	

13 APPENDIX B: REPORT COMMENTS

Page / Section	Report statement	Comments	Changes made?	Author comment
Comments from Mmaphefo Twala: 31 October 2014				
Whole document		*General editing and language*	*Y*	
2.2.2	*"Drew model"*	*Is this the formal name of the Model?*	*Y*	
2.4	*Report 7*	*Please specify the name of the report and is this report already available?*	*Y*	
Comment from Mr Bill Pfaff: 14 October 2014				
		I found the report to be particularly confusing. *First the report only deals with the Mkomazi , Mvoti , Lovu and uMngeni systems.* *This needs to be spelt out clearly in the title, the introduction, and the summary pages.* *The report considers the ecological effects of various operational scenarios at a number of EWR sites.* *Both the operational scenarios AND the location of the EWR sites all need to be summarised in this report , and clear reference made back to the report in which these are all described in some detail.* *Once these changes have been made the report needs to be recirculated for further comment please.*	*Y*	*It is important to note that this document serves as a supporting document that feeds into Report 8.7. Detailed information on scenarios and EWR sites are provided in separate reports. The EWR site and scenario information has been summarised as requested and reference has been made to the relevant reports. The location of EWR sites has now been included and the introduction and summary pages amended.*