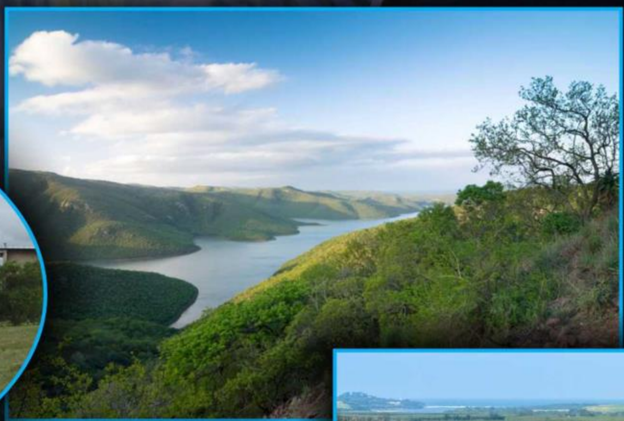
WEM/WMA3/4/00/CON/CLA/0123, volume 1

water and sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments

CONSEQUENCES REPORT, VOLUME 1: RIVERS



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Department of Water and Sanitation

Chief Directorate: Water Ecosystem Management

PROJECT NUMBER**:** WP 11387

Ecological Consequences Report
Volume 1: Rivers

CLASSIFICATION OF SIGNIFICANT WATER RESOURCES AND DETERMINATION OF RESOURCE QUALITY OBJECTIVES FOR WATER RESOURCES IN THE USUTU TO MHLATHUZE CATCHMENTS

SEPTEMBER 2023

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REFERENCE

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REPORT SCHEDULE

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2	WEM/WMA3/4/00/CON/CLA/0222	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Status Quo and Delineation of Integrated Units of Analysis and Resource Unit Report**
3	WEM/WMA3/4/00/CON/CLA/0322	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Resource Units Delineation and Prioritisation Report**
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5	WEM/WMA3/4/00/CON/CLA/0522	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **River EWR estimates for Desktop Biophysical Nodes Report**
6	WEM/WMA3/4/00/CON/CLA/0622	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **River Survey Report**
7	WEM/WMA3/4/00/CON/CLA/0722	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Basic Human Needs Report**
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APPROVAL

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EXECUTIVE SUMMARY

BACKGROUND

Chapter 3 of the National Water Act, 1998 (NWA) (Act 36 of 1998), deals with the protection of water resources. Section 12 of the NWA requires the Minister to develop a system to classify water resources. In response to this, the Water Resource Classification System (WRCS) was gazetted on 17 September 2010 and published in the Government Gazette no. 33541 as Regulation 810. The WRCS is a step-wise process, whereby water resources are categorised according to specific classes that represent a management vision of a particular catchment. This vision takes into account, the current state of the water resource, the ecological, social, and economic aspects that are dependent on the resource. Once significant water resources have been classified through the WRCS, Resource Quality Objectives (RQOs) have to be determined to give effect to the class.

The Chief Directorate: Water Ecosystems Management (CD: WEM) of the Department of Water and Sanitation (DWS), initiated a study to determine the Water Resource Classes and RQOs for all significant water resources in the Usutu to Mhlathuze Catchment. The Usutu to Mhlathuze Catchments are amongst many water-stressed catchments in South Africa. These catchment areas are important for conservation, and contain a number of protected areas such as natural heritage sites, cultural and historic sites, as well as other conservation areas that need protection.

STUDY AREA

The study area is the Usutu to Mhlathuze Catchment, which has been divided into six drainage areas, as well as secondary catchment areas:

- W1 catchment (main river: Mhlathuze).
- W2 catchment (main river: Umfolozi).
- W3 catchment (main river: Mkuze).
- W4 catchment (main river: Pongola) - part of this catchment area falls within Eswatini.
- W5 catchment (main river: Usutu) - much of this catchment falls within Eswatini.
- W7 catchment (Kosi Bay and Lake Sibaya).

PURPOSE OF THIS REPORT

The purpose of this report is to evaluate operational scenarios and to determine the ecological consequences of these scenarios. The consequences are measured as change in ecological state from the baseline (Present Ecological State - PES). If a range of scenarios are to be evaluated, they will be ranked.

RIVER SCENARIOS

The scenarios are documented in the scenario report (DWS, 2022), and have been presented to stakeholders for comment and input. The Table below summarises the scenarios that were applicable to river ecosystems.

Site	#	Abbr.	Scenario
Amatigulu - EWR MA1	1	CC	Climate change (CC).
Nseleni - EWR NS1	1	CC	Climate change.
Black Mfolozi - EWR BM1	1	CC	Climate change.
White Mfolozi - EWR WM1	1	CC	Climate Change.
	2	HFY-noEWR	Historic Firm Yield (HFY) abstracted from upstream dams, no EWR.
	3	HFYEWR	HFY abstracted from upstream dams, with EWR.
	4	KLPEWR	Raised Klipfontein HFY abstracted from upstream dams, with EWR.
Mkuze - EWR MK1	1	CC	Climate Change.
	2	2040	Present Day with increased upstream domestic use.
	3	IRR	Present Day with increased return flows due to increased irrigation supplied from Pongolapoort Dam.
Pongola - EWR UP1	1	CC	Climate Change.
	2	2040	Present Day with increased upstream domestic use (upgraded Frischgewaad Water Treatment Works).
Assegaai - EWR AS1	1	CC	Climate Change.
	2	2040	Present Day with increased upstream domestic use.
	3	EWR	Present Day with EWR included.
	4	noEWR	Present Day with no EWR.
Ngwempisi - EWR NG1	1	CC	Climate Change.
	2	2040	Present Day with increased upstream domestic use.
	3	EWR	Present Day with EWR included.

RESULTS

There were a few major operational and development scenarios that would impact on rivers and EWR sites, and therefore required evaluation. Of those identified, Scenario CC was often marginally 'worse' than the other scenarios. All scenarios met the Recommended Ecological Category (REC) and it is therefore recommended that the REC becomes the Target Ecological Category (TEC) and that RQOs are set for the REC.

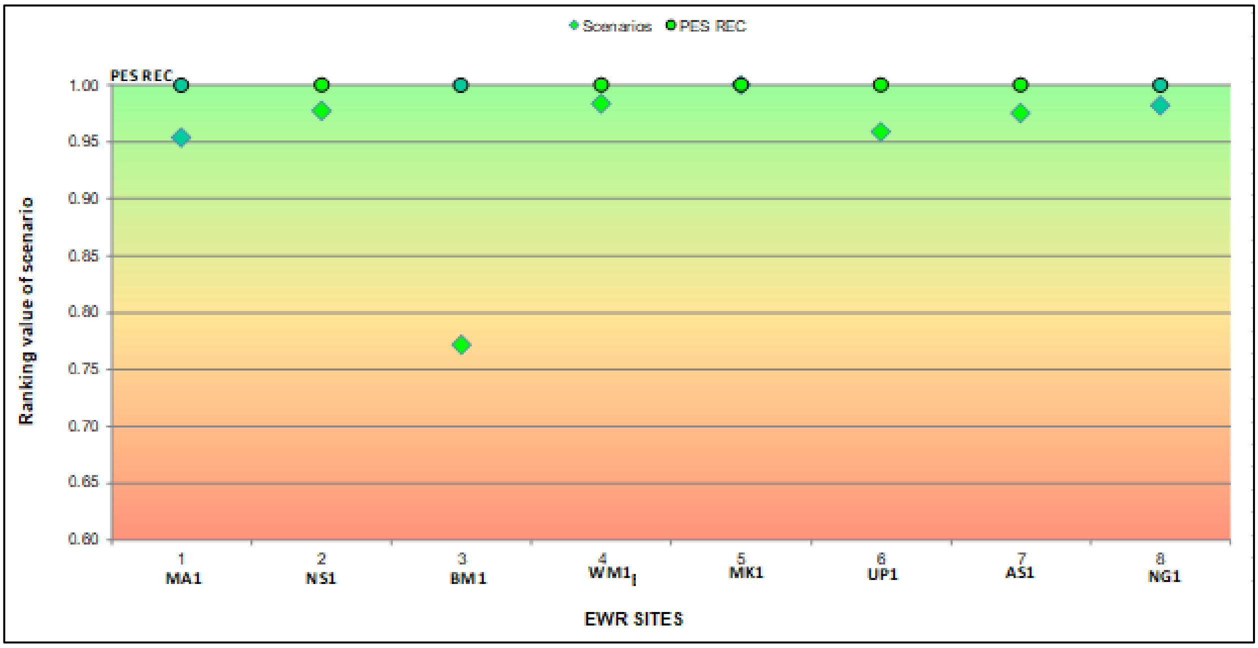
It must be noted that EWR MK1 (Mkuze River) requires improvement to achieve the REC, but these improvements are NON-FLOW RELATED. These improvements will be identified, and recommendations will be made as part of the RQO process.

A summary of the results showing the scenarios compared to the REC is provided in the **Table** and **Figure** below.

The scenario value refers to the ranking values of the scenarios in terms of a numerical scale with values 0 and 1 (typically, where one (1) indicates the scenario that the achieves the REC and a zero (0) representing the situation where the scenario results in a F category).

Scenario consequences results

	MA1_CC	NS1_CC	BM1_CC	WM1_CC	MK1 (all scenarios)	UP1_CC	AS1_CC	NG1_CC
Sc ranking value	0.95	0.98	0.77	0.98	1.00	0.96	0.98	0.98
REC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00



Summary traffic diagram of scenario consequences results

There were no operational scenarios identified for wetlands that are not linked to estuaries or river floodplains. For important wetlands that require improvement, a scenario of addressing non-flow related impacts to determine whether improvement can be achieved will be investigated to ensure that these are included in the determination of the TEC (Class and Catchment Configuration) and Resource Quality Objectives.

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TERMINOLOGY AND ACRONYMS

CD: WEM	Chief Directorate: Water Ecosystems Management
DO	Dissolved Oxygen
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EWR	Ecological Water Requirements
FDC	Flow Duration Curve
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurrence
GAI	Geomorphology Driver Assessment Index
Geom	Geomorphology
HFY	Historic Firm Yield
I IHI	Instream Index of Habitat Integrity
Inverts	Macro-invertebrates
IPCC	Intergovernmental Panel on Climate Change
IUA	Integrated Unit of Analysis
IWRM	Integrated Water Resource Management
MAR	Mean Annual Runoff
MCM	Million Cubic Metres
MIRAI	Macroinvertebrate Response Assessment Index
MWAAS	Mhlathuze Water Availability Assessment Study
nMAR	Natural Mean Annual Runoff
NWA	National Water Act
PAI	Physico-chemical driver Assessment Index
PC	Physico Chemical
PD	Present Day
PES	Present Ecological State
R IHI	Riparian Index of Habitat Integrity
RDRMv2	Revised Desktop Reserve Model version 2
REC	Recommended Ecological Category
Rip Veg	Riparian Vegetation
RQIS	Resource Quality Information Services
RQO	Resource Quality Objectives
RU	Resource Unit
Sc	Scenario
Sc CC	Climate Change scenario
SQ	Sub-quaternary
TEC	Target Ecological Category
VEGRAI	Riparian Vegetation Response Assessment Index
WRCS	Water Resource Classification System
WTW	Water Treatment Works
WWTW	Waste Water Treatment Works

Velocity Depth Classes of Fish and Macroinvertebrate habitat used in descriptions:

FD	Fast deep habitat
FI	Fast intermediate habitat

FS	Fast shallow habitat
SD	Slow deep habitat
SS	Slow shallow habitat

SPELLING

There are multiple references to the spelling of various Rivers, Lakes, Dams and Estuaries, depending on the source of information. For the purposes of this report, the following Table presents the selected spelling of indicated water resources and places.

Selected Spelling for this Study	**Alternate spellings**
Usutu River	Usuthu River
Mhlathuze River	Mhlatuze, uMhlatuze River
Pongola (river, Town & Pongolapoort Dam)	Phongola, Phongolo
Lake Sibaya	Lake Sibiya, Lake Sibhayi, Lake Sibhaya
Eswatini	eSwatini
Umfolozi River	Mfolozi River
Amatigulu River	Amatikulu, Matigulu River
Goedertrouw Dam	Lake Phobane
Mfuli River	Mefule River
aMatigulu/iNyoni Estuary	
Sibiya Estuary	
Mlalazi Estuary	
uMhlathuze /Richards Bay Estuary	
iNhlabane Estuary	
uMfolozi/uMsunduze Estuary	
St Lucia Estuary	
uMgobezeleni Estuary	
Kosi Estuary	
Hluhluwe Game Reserve	
iMfolozi Game Reserve	
Ithala Game Reserve	
Ndumo Game Reserve	
Tembe Elephant Reserve	
iSimangaliso Wetland Park	
Kosi Bay and Coastal Forest Area	
uMkhuze Game Reserve	

GLOSSARY

Ecological Water Requirements (EWR)	The flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.
Integrated Unit of Analysis (IUAs)	An IUA is a homogeneous area that can be managed as an entity. It is the basic unit of assessment for the Classification of water resources, and is defined by areas that can be managed together in terms of water resource operations, quality, socio-economics and ecosystem services.
Resource Quality Objectives (RQOs)	RQOs are numeric or descriptive goals or objectives that can be monitored for compliance to the Water Resource Classification, for each part of each water resource. "The purpose of setting RQOs is to establish clear goals relating to the quality of the relevant water resources" (NWA, 1998).
Scenario	Scenarios, in the context of water resource management and planning, are plausible definitions (settings) of factors (variables) that influence the water balance and water quality in a catchment and the system as a whole. Each scenario represents an alternative future condition, generally reflecting a change to the present condition.
Sub-quaternary (SQ) reaches	A finer subdivision of the quaternary catchments (the catchment areas of tributaries of main stem rivers in quaternary catchments), to a sub-quaternary reach.
Target Ecological Category (TEC)	This is the ecological category toward which a water resource will be managed once the Classification process has been completed and the Reserve has been finalised. The draft TECs are therefore related to the draft Classes and selected scenario.
Water Resource Class	The Water Resource Class (hereafter referred to as Class) is representative of those attributes that the DWS (as the custodian) and society require of different water resources. The decision-making toward a Class requires a wide range of trade-offs to be assessed and evaluated at a number of scales. Final outcome of the process is a set of desired characteristics for use and ecological condition of the water resources in a given catchment. The WRCS defines three management classes, Class I, II, and III, based on extent of use and alteration of ecological condition from the predevelopment condition.

1 INTRODUCTION

1.1 BACKGROUND

Chapter 3 of the National Water Act, 1998 (NWA) (Act 36 of 1998), deals with the protection of water resources. Section 12 of the NWA requires the Minister develop a system to classify water resources. In response to this, the Water Resource Classification System (WRCS) was gazetted on 17 September 2010 and published in Government Gazette 33541 as Regulation 810. The WRCS is a stepwise process whereby water resources are categorised according to specific classes that represent a management vision of a particular catchment. This vision takes into account the current state of the water resource, the ecological, social and economic aspects that are dependent on the resource. Once significant water resources have been classified through the WRCS, Resource Quality Objectives (RQOs) must be determined to give effect to the class. The implementation of the WRCS therefore assesses the costs and benefits associated with utilisation versus protection of a water resource. Section 13 of the NWA requires that Water Resource Classes and RQOs be determined for all significant water resources.

Thus, the Chief Directorate: Water Ecosystems Management (CD: WEM) of the Department of Water and Sanitation (DWS) initiated a study for determining the Water Resource Classes and RQOs for all significant water resources in the Usutu to Mhlathuze Catchment. The Usutu to Mhlathuze Catchments are amongst many water-stressed catchments in South Africa. These catchment areas are important for conservation and contain a number of protected areas, natural heritage sites, cultural and historic sites as well as other conservation areas that need protection. There are five RAMSAR[1] sites within the catchment, which includes the world heritage site, St Lucia. The others are Sibaya, Kosi Bay, Ndumo Game Reserve and Turtle Beaches.

1.2 STUDY AREA

The study area is the Usutu to Mhlathuze Catchment that has been divided into six drainage areas and secondary catchment areas as follows (refer to the locality map provided as **Figure 1.1**):

- W1 catchment (main river: Mhlathuze).
- W2 catchment (main river: Umfolozi).
- W3 catchment (main river: Mkuze).
- W4 catchment (main river: Pongola) - part of this catchment area falls within Eswatini.
- W5 catchment (main river: Usutu) - much of this catchment falls within Eswatini.
- W7 catchment (Kosi Bay estuary and Lake Sibaya).

Note that all assessments within Eswatini are excluded apart from the hydrological modelling required to assess any downstream rivers in South Africa that either run through Eswatini or originate (source) in Eswatini.

River Ecological Water Requirements (EWR) sites are shown on **Figure 1.1**.

[1] A Ramsar site is a wetland site designated to be of international importance under the Ramsar Convention, also known as "The Convention on Wetlands", an intergovernmental environmental treaty established in 1971 by UNESCO in the Iranian city of Ramsar, which came into force in 1975.

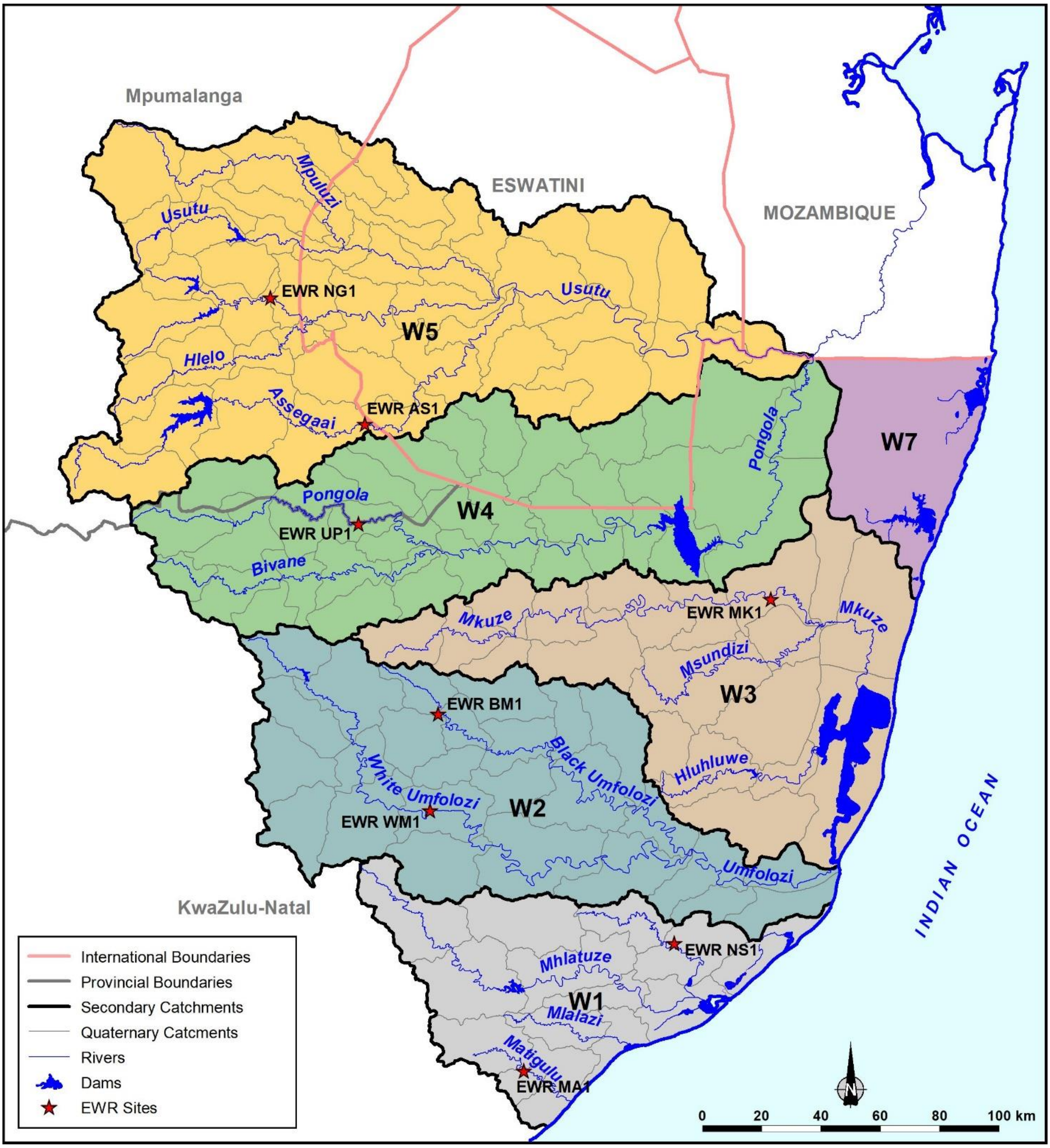


Figure 1.1 Locality Map of the Study Area showing EWR sites

1.3 PURPOSE OF THIS REPORT

The purpose of this report is to evaluate operational scenarios and to determine the ecological consequences of these scenarios. The consequences are measured as change in ecological state from the baseline (Present Ecological State (PES). If a range of scenarios are to be evaluated, they will be ranked.

The results form part of Task 4: Identify and Evaluate scenarios within Integrated Water Resource Management (IWRM) (**Figure 1.2**).

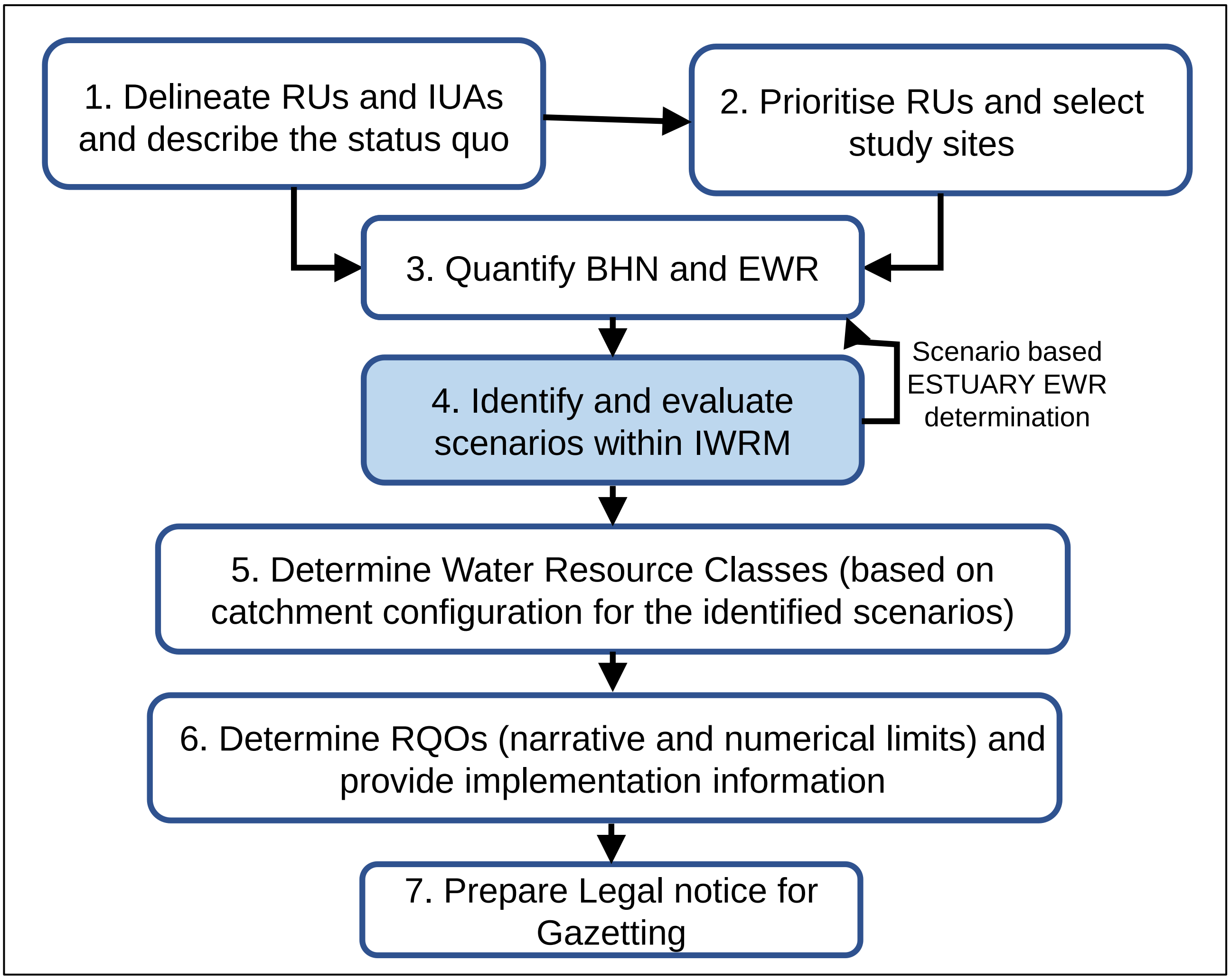


Figure 1.2 Project Plan for the Usutu-Mhlathuze Classification study

1.4 REPORT OUTLINE

The report outline is as follows:

- **Chapter 1** provides general background information on the study area and the Project Plan. This chapter also provides a general overview of the Ecological Water Requirements (EWR) sites that were assessed as part of Task 3.
- **Chapter 2** provides a summary of the different scenarios assessed.
- **Chapter 3** outlines the general approach and methodology to determining ecological consequences of operational scenarios on the riverine environment.
- **Chapter 4 – 11** provides the consequences of the operational scenarios on the various ecological riverine components at the EWR sites.
- **Chapter 12** summarises the ecological consequences of the operational scenarios.
- **Chapter 13** lists the references used in the report.

2 SCENARIO DESCRIPTION

Scenarios (Sc), in the context of water resource management and planning are plausible definitions (settings) of all the factors (variables) that influence the water balance and water quality in a catchment and the system as a whole. The scale (resolution) of the analysis requires the aggregation of land-use effects, and therefore individual and localised small-scale developments will not significantly influence the classification of a water resource. However, significant small-scale impacts on priority water resources should be managed by setting the RQOs at the specific point to protect the said water resource, especially in the case of sensitive aquatic resources.

Possible variables that make up scenarios have been identified for the Usutu-Mhlathuze Catchments. These variables have been combined into different scenarios which are described in (DWS, 2022). The variables and scenarios are illustrated in matrices that show scenario naming and which variables are applicable to each scenario. The operational scenarios are based on flow related aspects and not on non-flow related aspects. Mitigation measures to address non-flow related aspects will be identified and will be addressed as part of the RQO identification process.

The range of scenarios and associated variables were presented and discussed with the DWS and stakeholders, and a final (representative) range selected for the purposes of modelling and scenario assessment. The detailed descriptions of the scenarios and their resulting flows are included in the Scenario description report produced as part of this study (DWS, 2022). A summary table of the final scenarios that were assessed from a rivers, estuary or both (rivers and estuary) perspective is included in **Table 2.1**. EWR sites are indicated where present in the IUA.

Table 2.1 Description of river flow related scenarios (DWS, 2022)

IUA[1]	Scenario			Type
	#	Abbrev.	Description	
W11	1	CC	Climate Change.	Both, including MA1
	2	-20%MAR[2]	Reduction of present day MAR by 20%.	Matigulu Estuary
	3	-30%MAR	Reduction of present day MAR by 30%.	Matigulu Estuary
	4	+15%MAR	Increase of present day MAR by 15%.	Matigulu Estuary
W12-a	1	CC	Climate Change.	Rivers
W12-b	1	CC	Climate Change.	Rivers, including NS1
W12-c	1	CC	Climate Change.	Both
	2	+15%MAR	Increase of present day MAR by 15%.	uMhlathuze Estuary
	3	2030	2030 year projected water requirements on the system (including increased transfer from Thukela to Goedertrouw).	uMhlathuze Estuary
	4	2040	2040 year projected water requirements on the system (including increased transfer from Thukela to Goedertrouw).	uMhlathuze Estuary
W12-d	1	CC	Climate Change.	Both
	2	EWR	Present Day including EWR releases from Lake Nhlabane as obtained from Mhlathuze Water Availability Assessment Study (MWAAS - DWAF, 2009).	iNhlabane Estuary
	3	Rest	Restoration Scenario 1 to allow for mouth breaching each year.	iNhlabane Estuary
	4	Rest/Int	Restoration and interventions Scenario 2.	iNhlabane Estuary
W12-e	1	CC	Climate Change.	Rivers and Lake Msingazi
W13	1	CC	Climate Change.	Both
	2	-15%MAR	Reduction of present day MAR by 15% (SIYAYA).	Mlalazi and Siyaya estuaries
	3	+15%MAR	Increase of present day MAR by 15% (SIYAYA).	Mlalazi and Siyaya estuaries
	4	WWTW	Present day including the upgrade of the Mtunzini Waste Water Treatment Works (WWTW) increased to a 1.5 Ml/d plant (Mlalazi).	Mlalazi and Siyaya estuaries
	5	Sc1	Present day including additional demand of 10% on present day MAR supplied by Eshowe Dam with an increased capacity of 15 million m^3 (Mlalazi).	Mlalazi and Siyaya estuaries
	6	Sc2	Present day reduced by 10% through abstraction from lower reaches of river (Mlalazi).	Mlalazi and Siyaya estuaries
	7	Sc3	Present day reduced by 20% through abstraction from lower reaches of river (Mlalazi).	Mlalazi and Siyaya estuaries

IUA[1]	Scenario			Type
	#	Abbrev.	Description	
	8	Sc4	Scenario 3 including additional demand of 10% on present day MAR supplied by Eshowe Dam with an increased capacity of 20 million m^3 (Mlalazi).	Mlalazi and Siyaya estuaries
	9	Sc5	Restoration/Intervention Scenario 1: Mlalazi Estuary= REC; Siyaya Estuary= PES.	Mlalazi and Siyaya estuaries
	10	Sc6	Restoration/Intervention Scenario 2: Mlalazi Estuary= REC; Siyaya Estuary= REC.	Mlalazi and Siyaya estuaries
W21	1	CC	Climate Change.	Rivers, including. WM1
	2	HFY-noEWR	Historic Firm Yield (HFY) abstracted from upstream dams, no EWR.	Rivers, including. WM1
	3	HFYEWR	HFY abstracted from upstream dams, with EWR.	Rivers, including. WM1
	4	KLPEWR	Raised Klipfontein HFY abstracted from upstream dams, with EWR.	Rivers, including. WM1
W22	1	CC	Climate Change.	Rivers, including BM1
W23	1	CC	Climate Change.	Rivers
W31-a	1	CC	Climate Change.	Rivers
W31-b	1	CC	Climate Change.	Rivers, including MK1
	2	2040	Present Day with increased upstream domestic use.	Rivers, including MK1
	3	IRR	Present Day with increased return flows due to increased irrigation supplied from Pongolapoort Dam.	Rivers, including MK1
W32-a	1	CC	Climate Change.	Rivers
W32-b	1	CC	Climate Change.	Rivers
W41	1	CC	Climate Change.	Rivers
W42-a	1	CC	Climate Change.	Rivers, including UP1
	2	2040	Present Day with increased upstream domestic use (upgraded Frischgewaad Water Treatment Works - WTW).	Rivers, including UP1
W42-b	1	CC	Climate Change.	Rivers
W44	1	CC	Climate Change.	Rivers
W45	1	CC	Climate Change.	Rivers and Pongola Floodplain
W51-a	1	CC	Climate Change.	Rivers
W51-b	1	CC	Climate Change.	Rivers
W52	1	CC	Climate Change.	Both, including AS1 and NG1

IUA[1]	Scenario			Type
	#	Abbrev.	Description	
	2	2040	Present Day with increased upstream domestic use.	Rivers, including AS1 and NG1
	3	EWR	Present Day with EWR included.	Rivers, including AS1 and NG1
	4	noEWR	Present Day with no EWR.	Rivers, including AS1 and NG1
W55	1	CC	Climate Change.	Rivers, including Pans and Chrissiesmeer
W57	1	CC	Climate Change.	Rivers, including Ndumo Pans
W70-a	1	CC	Climate Change.	Both, including Kosi Lakes and Estuary
W70-Muzi Swamps	1	CC	Climate Change.	Muzi Swamps
W-70b	1	CC	Climate Change.	Both, including Lake Sibaya, uMgobezeleni Estuary
St Lucia	1	CC	Climate Change.	St Lucia, W2 and W3 feeder streams. W32-Mkuze Floodplain/Swamp

1 Integrated Unit of Analysis
2 Mean Annual Runoff

3 APPROACH AND METHODOLOGY

The main aim of the scenario (Sc) evaluation process is to determine the appropriate balance between the level of environmental protection and the use of the water to sustain the status quo of socio-economic activities. Once the preferred scenario has been selected the Water Resource Class is defined by the level of environmental protection embedded in that scenario.

There are three main variables to consider in this integration process, namely the Ecology, Ecosystem Services and the Economic benefits obtained from the use of a portion of the water resource. The scenario evaluation process therefore estimates the consequences each scenario from a plausible set of scenarios will have on these variables. The evaluation process uses the quantification of selected metrics to compare the scenarios on a relative basis with one another.

3.1 DETERMINING RIVERINE ECOLOGICAL CONSEQUENCES

3.1.1 Available data

Data used during this task used the results of the EcoClassification process as outlined in DWS (2023). The results of the individual EcoStatus models (presented as electronic data) were used to assess the changes in ecological state for EWR sites potentially affected by scenarios, and present the results as Ecological Categories per component, as well as an integrated ecological state (the EcoStatus), for each identified scenario.

3.1.2 Selection of scenarios for assessment

At every EWR sites, all scenarios are compared to determine whether any scenarios are similar and can be grouped and evaluated together. The specific scenarios to be evaluated are provided in the chapters providing the ecological consequences at each EWR site.

Estuaries scenarios in some cases consisted of flows higher than the present day flows. It was confirmed that these scenarios are not higher than the nMAR and also follow a natural seasonal distribution. There would therefore be no detrimental impact on the rivers if any of these scenarios are recommended for the estuaries and evaluation of these in terms of river ecological consequences will not be required.

3.1.3 EWR sites affected by operational scenarios

All eight EWR sites (**Figure 1.1**) are affected by the supplied scenarios. The impact of operational scenarios in a river system is assessed at EWR sites located within the river system potentially impacted by those scenarios.

3.2 ECOLOGICAL CONSEQUENCES METHODS

The suite of EcoStatus models used during this task were:

- Physico-chemical Driver Assessment Index (PAI): Kleynhans *et al*. (2005); DWAF (2008).
- Geomorphology Driver Assessment Index (GAI): Rowntree (2013) – Level IV
- Fish Response Assessment Index (FRAI): Kleynhans (2007).
- Macroinvertebrate Response Assessment Index (MIRAI): Thirion (2007).
- Riparian Vegetation Response Assessment Index (VEGRAI): Kleynhans *et al*. (2007a) – Level IV.

The process to determine ecological consequences of scenarios is shown in the following chronological steps:

- The operational scenarios were modelled and a time series produced for each scenario at each EWR site.
- The time series for the scenarios were converted to flow duration tables and exceedance graphs and provided to the specialists, using a Scenario Comparison Facility Tool. This tool was developed to evaluate a series of scenarios for the use of the ecological river team by Mr Pieter van Rooyen and Dr Andrew Birkhead. Time-series data can be evaluated at a particular EWR site for a particular month, or at a percentage exceedance for all the months in the flow record (e.g. the 95% drought exceedance flow).
- The driver components, i.e. physico-chemical (or water quality) and geomorphology, provided a first assessment of consequences, which were provided to the rest of the team. The geomorphologist worked closely with the riparian vegetation specialist in terms of impacts on floods.
- The consequences and resulting Ecological Category (EC) of each operational scenario for water quality were assessed at each EWR site and the PAI was populated to determine the resulting EC.
- The riparian vegetation specialist then assessed the response on the marginal and other riparian zones, and supplied this information to the instream biota specialists (i.e. fish and macroinvertebrate specialists). This was done prior to the instream biota assessment as riparian vegetation is a driver in terms of habitat for the instream biota.
- The riparian vegetation specialist ran the VEGRAI model to predict the EC for the operational scenarios.

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

- The operational scenarios were 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 biotic response to the operational scenarios.
- The responses were modelled in the FRAI, MIRAI and VEGRAI to determine the EC.
- The VEGRAI, MIRAI and FRAI results (EC percentages and confidence evaluation) were used to determine the EcoStatus per scenario and compared to the PES and Recommended Ecological Category (REC) set during the EcoClassification process (DWS, 2023).

The component-specific approaches to determine ecological consequences are provided below.

3.2.1 Geomorphology

The assessment of the geomorphological response to different flow scenarios relies largely on a prediction of the extent to which flood magnitude and frequency will be impacted. Flow duration curves, focussing on flows with an exceedance of less than 20%, give an indication of how the larger flow events will be affected. The following notes expand on how catchment-based impacts were considered under the climate change scenario.

- Climate change models predict that, regardless of an increase or decrease in total annual rainfall, storms will become more intense, resulting in increased storm runoff and erosion (IPCC, 2018).
- The frequency of intermediate flood events may therefore increase.

- The sediment load will increase. It was assumed that the increase would be relative to the present day erosion status of the catchment with little increase from currently well-protected areas.
- With higher temperatures (IPCC, 2018) the extent and frequency of veld fires will increase, reducing the effectiveness of the land cover and increasing the erosion risk.

The flow exceedance curves for the different scenarios were examined to compare the scenario flows to the Present Day (PD) and the EWR. Where the scenario flows were close to the PD and above the EWR it was assumed that there would be negligible flow-related impacts other than those already accounted for. Where high-flow events were reduced relative to the PD but above the EWR, the impact of these flow reductions on geomorphological processes was assessed using the hydraulic relationships used to assess the EWR. If the scenario flow was below the EWR during the low flow season the impact on sediment inputs for local floods was assessed. September is the month when these local floods are most likely to occur. They can have a significant impact on fine bed sediment in the short term due to the absence of high flows capable of flushing sediment from the bed (Huchzermeyer, 2017).

The GAI (Rowntree, 2013 – Level 4) was used to assess the new ecological category under each scenario.

3.2.2 Water quality

The water quality approach to assessing ecological consequences is dependent on the results produced for the water quality component of EcoClassification for the affected EWR sites (DWS, 2023). The PAI model, water quality tables and associated text describes the driving variables for the assigned water quality state. The PD flow exceedance curves therefore represent the flow conditions linked to the present state PAI table, and the values assigned to the metrics used in the PAI model. The metrics are salts, nutrients, pH, dissolved oxygen (DO), turbidity, temperature and toxics. Toxics and nutrients are therefore an integrated measure, with salts primarily represented by electrical conductivity. The Scenario Comparison Facility Tool is used to evaluate changes to the flow regime under all months and exceedance percentages under each scenario as compared to PD, and linked to expected changes in water quality driving variables. The PAI model is re-run for each set of scenarios to arrive at an integrated water quality category per scenario or set of scenarios.

For the assessment, it is assumed that the only changing variable is flow, and that water quality state will stay constant other than fluctuating with flow. Water quality state is also assumed for the RU that the EWR site is located in. Notes are therefore added where an upstream water quality hotspot is located; implying that water quality state may deteriorate for reasons other than fluctuating flows, thereby exacerbating the predicted water quality under the scenarios, e.g. Mkuze River. It is assumed that these occasions, or downward trends, will be picked up by monitoring of the problem areas, and management actions will be undertaken accordingly.

3.2.3 Riparian vegetation

The following assumption applies to the evaluation of scenario flow regimes:

- In all instances the climate change scenario is assessed on the altered flow component of the scenario only and excludes the potential response of riparian vegetation to non-flow related changes that may accompany such a scenario, such as altered atmospheric carbon levels or temperature.

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

- An overall qualitative description of differences between the applicable scenario and natural, PD 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 (see **Figure 3.1** as an example).
- Seasonality is critical for biological cues, even vegetation. A check of seasonality was conducted for the Usutu-Mhlathuze study by expressing the monthly flow regime as a fraction of the natural annual flow (Dettinger and Diaz, 2000). Should a significant change to seasonality apply to any of the scenarios, then a response by riparian vegetation is predicted and used to make changes to the scores within VEGRAI (Kleynhans *et al*., 2007a) for the applicable site (see **Figure 3.2** as an example).

Figure 3.1 An example of the comparison of average monthly hydrological data (log plots) for EWR MA1

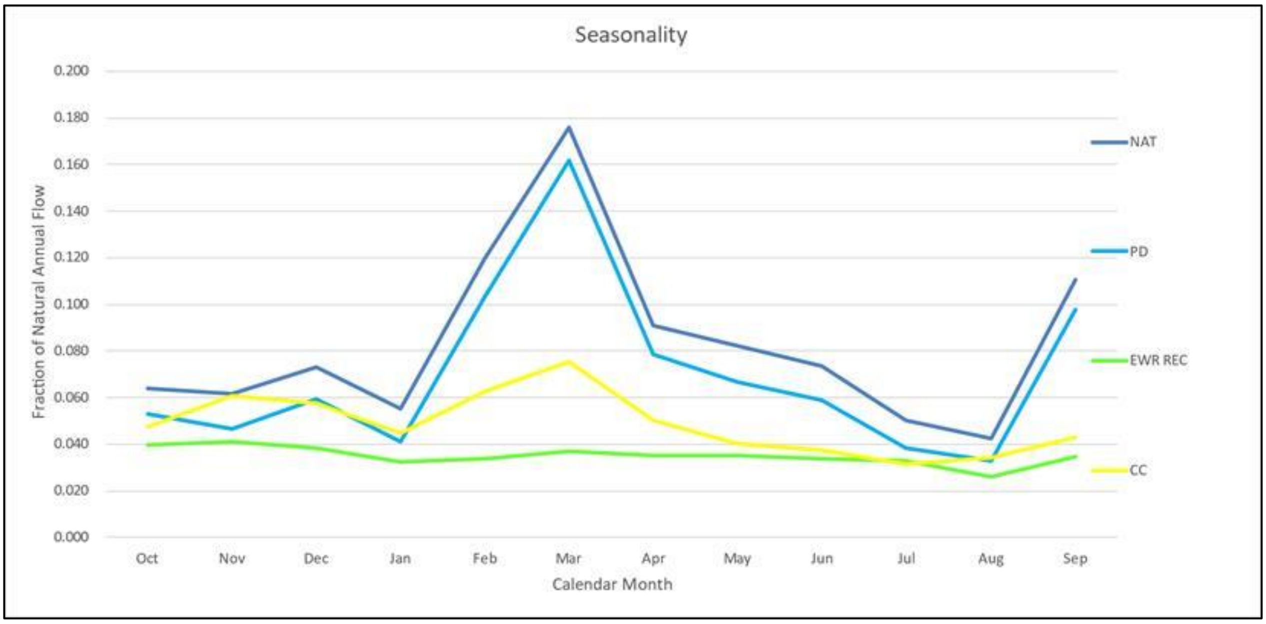


Figure 3.2 An example of a seasonality check for riparian vegetation at EWR MA1

A month-by-month comparison of the Flow Duration Curves (FDC) of the applicable scenario to natural, PD and EWR flows was 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 the months of March and July (**Figure 3.3**). Response-appropriate changes are made to scores within the VEGRAI in order to score the scenario's effect on the EcoStatus.

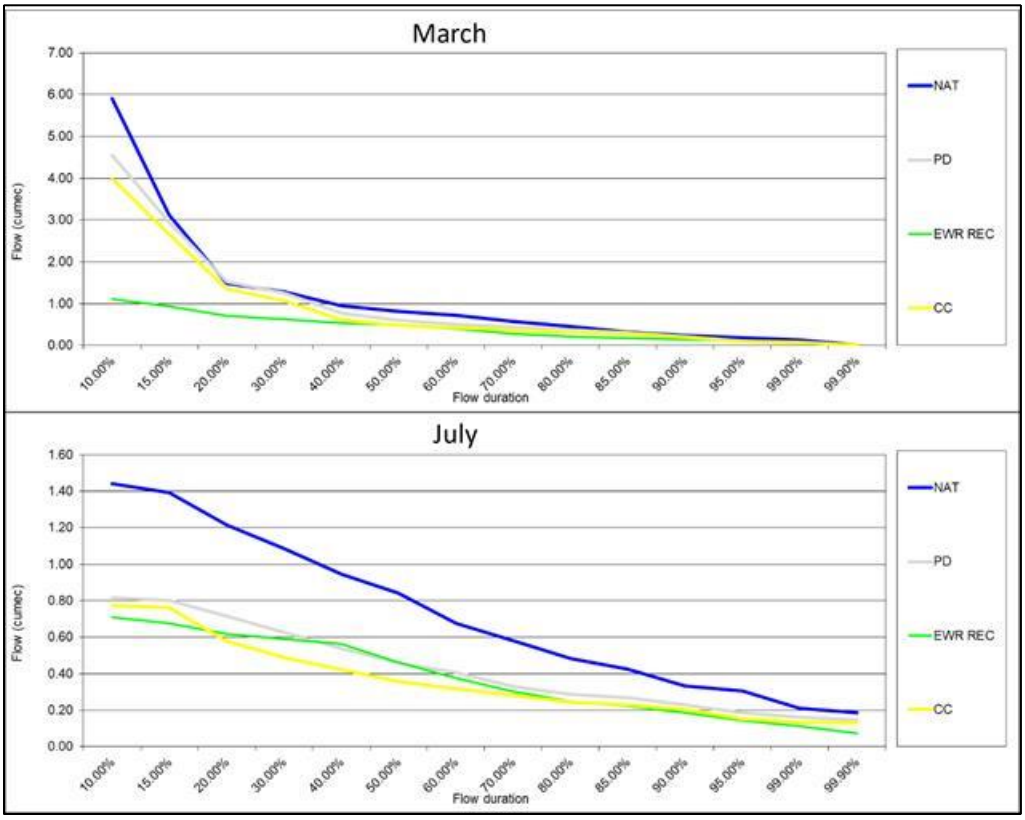


Figure 3.3 An example (Matigulu site) of the comparison of discharge exceedance patterns for wet (represented by March) and dry (represented by July) season

- A similar comparison was conducted at select percentiles (1%, 5%, 10%, 20%, 40%, 50%, 60%, 80%, 90% and 95%) to assess changes of seasonality i.e. compare temporal distribution over an average hydrological year (**Figure 3.4** as an example).

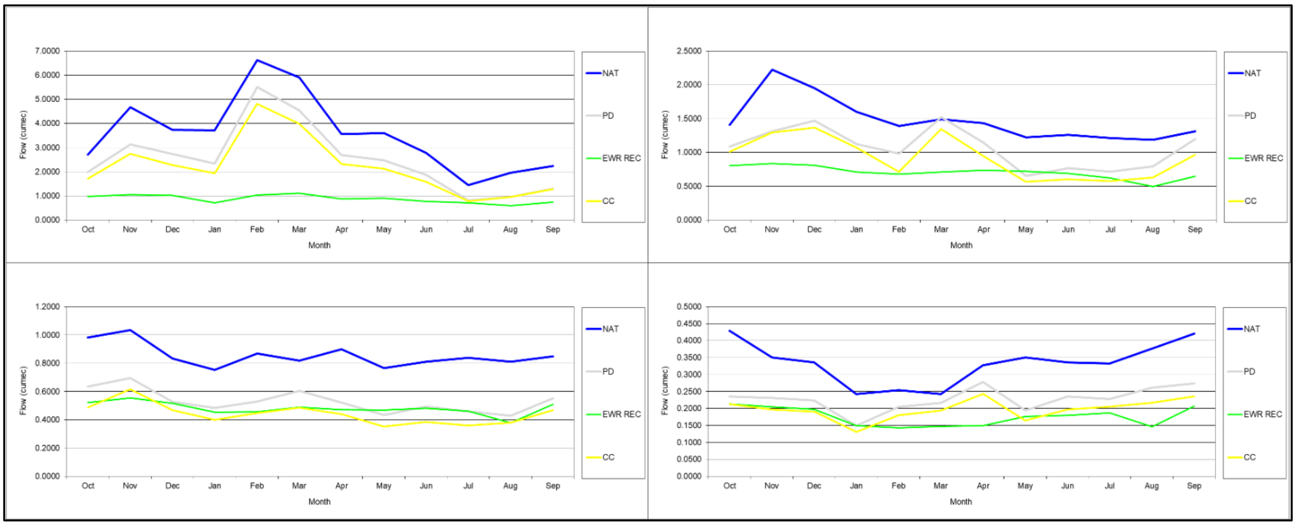


Figure 3.4 Average yearly temporal distribution of discharge at the 10th (top left), 20th (top right), 50th (bottom left) and 90th (bottom right) percentiles for EWR MA1

- Stream permanency has been shown to be important for the persistence of riparian vegetation in perennial rivers (Lite and Stromberg, 2005; Leenhouts *et al*., 2006). Once stream permanency declines below 10%, population density declines and once stream permanency declines below 20%, many species likely disappear or are replaced by other hardy drought-tolerant or terrestrial species. Each scenario was 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. Conditions under scenarios were also checked against natural flows to ascertain whether flow ever exceeds natural. Such an increase in inundation may elicit a vegetation response such as zone shrinkage and changes to species composition.
- The flooding range for each riparian indicator (species or guild) was 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 wet and dry season (using two or three representative months for each), and at percentiles representative of base flows. Knowledge of indicator-specific drought tolerance, maximum rooting depths 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-zones (such as marginal and lower zones) and (additional) changes made within the VEGRAI (Kleynhans *et al*., 2007) to translate a vegetative response into a change in ecological state or category. The example below shows a comparison of the proportion of inundation of indicator habitats at the 50th percentile for wet and dry seasons at the Matigulu site, MA1 (**Table 3.1**).

Table 3.1 Example (EWR MA1) of assessment showing the proportion (%) of the indicator population inundated at a given discharge

Elevation above bed (m)			
Indicator	**Lower**	**Upper**	**Range**
Marginal zone graminoids	0.67	1.76	1.1
Lower zone graminoids	0.80	1.76	1.0
Marginal zone trees	0.95	2.56	1.6
Lower zone trees	1.07	2.56	1.5
Upper zone trees (riparian)	3.37		
Upper zone trees (terrestrial)	4.98		
Discharge	**2**		**% of population inundated**
Marginal zone graminoids	-0.11	0.98	10.4
Lower zone graminoids	0.02	0.98	0.0
Marginal zone trees	0.17	1.78	0.0
Lower zone trees	0.29	1.78	0.0
Upper zone trees (riparian)	2.59		
Upper zone trees (terrestrial)	4.20		

3.2.4 Fish

The estimated change from PES 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 and water quality:

- ***Flow*:** The change in fast (fast-shallow (FS), fast-intermediate (FI) and fast-deep (FD)) and slow (slow-shallow (SS) and slow-deep (SD)) habitats were considered for the maintenance and drought flows during both wet and dry seasons. This change was considered for each species using its specific preference rating for different velocity-depth categories.
- ***Substrate*:** Geomorphological change (based particularly on changes in flood regimes) was used to determine the estimated percentage change in substrate quality and availability for fish. This change was considered for each species using its specific preference rating for substrate as cover.
- ***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 change was applied to the relevant species based on their preference rating for, and/or their requirement for overhanging vegetation as cover.
- ***Water quality*:** The change in water quality under each scenario was based on input from the PAI and water quality specialist. The expected change in water quality state was applied for each species based on their preference for unmodified water quality (intolerance level to change in water quality).
- ***Seasonality/Seasonal variability*:** The change in seasonality and seasonal variability was assessed using the Scenario Comparison Facility Tool.

The expected change of these aspects/metrics (or sub-components of these metrics) was rated as follows:

- 5: Extreme/critical increase/improvement (>80%).
- 4: Serious increase/improvement (60 – 80%).
- 3: Large increase/improvement (40 – 60%).
- 2: Moderate increase/improvement (20 – 40%).
- 1: Slight increase/improvement (<20%).

- 0: No change.
- -1: Slight decrease/deterioration (0 – 20%).
- -2: Moderate decrease/deterioration (20 – 40%).
- -3: Large decrease/deterioration (40 – 60%).
- -4: Serious decrease/deterioration (60 – 80%).
- -5: Extreme/critical decrease/deterioration (>80%).

The overall change in these variables (metrics) were then used to change the present Frequency of Occurrence (FROC) ratings (Kleynhans and Louw, 2007b) of each fish species in the FRAI – but only considering the variable relevant to the specific species (e.g. eels would be more impacted by migratory impacts than potadromous species; a rheophilic species would be more intolerant to alterations in fast habitats than a limnophilic species, etc.).

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

3.2.5 Macroinvertebrates

The hydrological details of each scenario were reviewed and assessed relative to natural, PD and EWR flows, using the flow duration graphs and tables in the Scenario Comparison Facility Tool. In assessing the effects of a scenario on the macroinvertebrate community, any alteration in the following parameters relative to the PES and EWR is taken into consideration: hydraulic habitat availability (especially the fast habitats), water quality, vegetative cover and seasonality. 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 model and water quality specialist input.

The changes in each parameter (increase, improvement, decrease, deterioration) were assessed for dry and wet season. The MIRAI model with the PES and EWR data, was then adjusted by revising the relevant ratings in the four MIRAI spreadsheets (flow modification, habitat, water quality, connectivity and seasonality).

By using the taxa preference data in the MIRAI sheets (Thirion, 2007), the indicator taxa for different criteria were selected. These sheets indicate the habitat value and preference (1 - 5) for each taxa related to the different variables (flow, water quality and habitat). The physical and hydraulic-habitat criteria were considered to be those relevant to the indicator taxa per reach or site:

- Vegetation dwellers with slow flowing water. Slow (0.1 - 0.3 m/s) with vegetation.
- Cobble dwellers with fast flow. Very fast (>0.6 m/s) with cobbles.
- Cobble dwellers with moderate flow. Moderate (0.3 - 0.6 m/s) with cobbles.
- Gravel, sand, mud dwellers. Slow (0.1 - 0.3 m/s), with GSM.
- Standing water over cobbles. Standing water (<0.1 m/s) with cobbles.

3.3 DETERMINING THE RANKING OF SCENARIOS PER EWR SITE

Deriving a single metric (one number), that reflects the ecological health relative to the REC for the river requires several steps, sub-steps and the application of various tools. Broadly, the rationale to achieve this single rating is based on the degree to which the scenarios meet the REC.

The steps and sub-steps to derive a single number are discussed below, and are presented generically in a step-by-step way.

3.3.1 Rank scenarios at each EWR site

- Apply the EcoClassification process (Kleynhans and Louw, 2007c) at each EWR site where the scenario influences flow or water quality to determine the EC for each component[2].
- Provide the associated percentage that represents the category.
- Calculate the degree to which the scenario meets the ecological objectives which are represented by the REC. That is, if the REC for a component is 62% and the scenario results in this component being at 62%, then the resulting score would be a 1 (or a 100% successful in meeting the REC). If a scenario's rating for the component is 48%, then the score would be 0.77 (or 77% successful in meeting the REC).
- A weighted average score is calculated to obtain a score for the scenario at the site.
- Each site's score is then normalised to obtain a rating that is 1 if the REC is achieved, above one if the REC is exceeded (i.e. 1.1) or between 1 and 0 if the score (EC) is below the REC.
- Rank the scenarios in terms of a numerical scale with values 0 and 1 (typically, where one (1) indicates the scenario that achieves the REC and a zero (0) representing the situation where the scenario results in a F category).

3.3.2 Traffic diagrams

A traffic diagram is used to present results of the consequences. The description of a traffic diagram is as follows:

- A traffic diagram is a bar graph that is shaded according to the colours of a traffic light.
- This implies that the items at the top (in the green section) are better than the ones below.
- The scale of the bar graph should be noted. The importance is the ranking of scores relative to each other.
- The purpose is to rank scenarios for all the different components using different scales of measurements, but visually being able to compare the rankings using traffic diagrams.

[2] Components: Habitat drivers (geomorphology and water quality (hydrology is a given)); Biological responses (fish, macroinvertebrates, riparian vegetation).

4 ECOLOGICAL CONSEQUENCES: EWR MA1 (MATIGULU RIVER)

4.1 ECOCLASSIFICATION RESULTS

EWR MA1: Matigulu River

Coordinates	S29.02010 E31.47040
SQ[1] code	W11A-03612
RU[2]	RU W11-2
IUA[3]	IUA W11
Level 2 EcoRegion	17.01
Geomorphic Zone[4]	Upper foothills

PRESENT ECOLOGICAL STATE: PES								
I IHI[4]	**R IHI[5]**	**PC[6]**	**Geom[7]**	**Rip Veg[8]**	**Fish**	**Inverts[9]**	**Instream**	**EcoStatus**
B/C (80%)	**B/C (78%)**	**B (84.5%)**	**B (87.4%)**	**B/C (79.4%)**	**B (86.4%)**	**B/C (80.9%)**	**B (83.3%)**	**B/C (81.3%)**

ECOLOGICAL IMPORTANCE AND SENSITIVITY
MODERATE
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES
REC = B/C for ECOSTATUS

ECOLOGICAL WATER REQUIREMENTS (EWR)			
Natural MAR: 55.17 MCM[11]		Present day MAR: 41.85 MCM	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
13.04	23.6	18.75	34

1 Sub-quaternary reach
2 Resource Unit.
3 Integrated Unit of Analysis
4 Instream component of Index of Habitat Integrity
5 Riparian component of Index of Habitat Integrity
6 Physico-Chemical (Water Quality)
7 Geomorphology
8 Riparian Vegetation
9 Macro-invertebrates

4.2 CONSEQUENCES

Scenario MA1_CC was evaluated. A summary explanation of the consequences of the scenarios compared to the PES and the REC are provided in **Table 4.1**, with the rating of the scenarios shown in **Figure 4.1**.

Table 4.1 EWR MA1: Consequences of the scenarios on the driver and response component ECs

Component	PES & REC	Sc MA1_CC	Comment
Physico-chemical (Water quality)	B (84.5%)	B/C (80.6%)	PES is driven by elevated turbidity and salts; with a small increase in nutrient levels. There is expected to be small impact on most variables under the scenario, particularly at low flows.
Geomorphology	B (87.4%)	B (81.6%)	Small increase in catchment erosion and overbank flooding predicted due to climate change. Possible small increase in fines (sand) on bed but strong flows should maintain clean gravel habitat.
Riparian vegetation	B/C (79.4%)	B/C (78.7%)	Stream permanency and seasonality remain unaltered. Flooding regime remains intact, slightly less than PD but more than required by EWR. Base flows mostly lower than PD and the EWR, particularly in the dry season. Differences are small and

Component	PES & REC	Sc MA1_CC	Comment
			not likely to result in vegetation shifts but duration of inundation of marginal zone grasses and sedges will be reduced providing less instream habitat to aquatic fauna, and possible reduced density.
Fish	B (86.4%)	B/C (79.4%)	Semi-rheophilic and flow intolerant species will be negatively impacted by slightly reduced availability of fast habitats during the wet season (compared to EWR). Species with preference for substrate may be impacted by slight increase in sedimentation (especially in pools). Vegetative cover should not be impacted notably but reduced duration of inundation of vegetation may reduce spawning success slightly in some species. Reduced water quality may negatively impact water quality intolerant species and predatory species (increased turbidity).
Macro-invertebrates	B/C (80.9%)	B/C (78.5%)	The reduced availability of fast flowing habitats during the wet season might impact slightly on the abundance of taxa with a preference for moderately fast to very fast flowing water, especially cobble dwellers. The increase in salts and turbidity will influence the abundance and/or frequency of occurrence of taxa with a high requirement for unmodified physico-chemical conditions. However, the better flows during the dry season might alleviate this slight adverse situation.
EcoStatus	B/C (81.3%)	B/C (79.15%)	All components indicate a slight decrease in category due to largely small changes in the drivers (increased turbidity and silt, decrease in velocity during the wet season and possible changes in marginal vegetation.

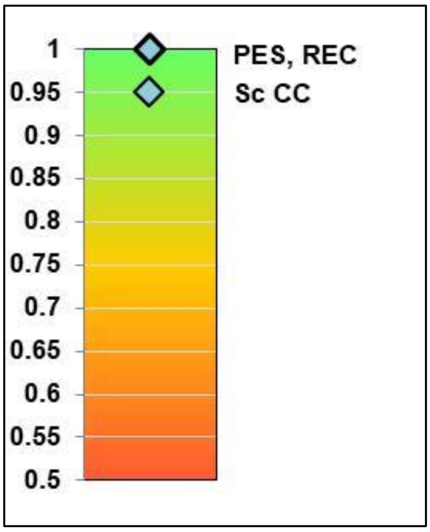


Figure 4.1 EWR MA1: Ecological ranking of operational scenarios

4.3 CONCLUSIONS

Scenario MA1_CC maintains the EcoStatus of a B/C at a lower percentage. The PES of all components is maintained, except fish, geomorphology and water quality which reflect a small drop in percentage. Fish, geomorphology and water quality decrease from a B to a B/C EC.

5 ECOLOGICAL CONSEQUENCES: EWR NS1 (NSELENI RIVER)

5.1 ECOCLASSIFICATION RESULTS

EWR NS1: Nseleni River

Coordinates	S28.63410 E31.92517
SQ code	W12G-03229
RU	RU W12-8
IUA	IUA W12-b
Level 2 EcoRegion	13.03
Geomorphic Zone[4]	Lower foothills

PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
B/C (81%)	**C (70.3%)**	**B (82.7%)**	**B (84%)**	**C (64.4%)**	**C (67.9%)**	**B/C (79.5%)**	**C (74.3%)**	**C (68.4%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = C for ECOSTATUS								

ECOLOGICAL WATER REQUIREMENTS (EWR)			
Natural MAR (nMAR): 31.23 MCM		Present day MAR: 31.56 Million Cubic Metres (MCM)	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
4.76	17.4	6.85	21.9

5.2 CONSEQUENCES

Scenario NS1_CC was evaluated. A summary explanation of the consequences of the scenarios compared to the PES and the REC are provided in **Table 5.1**, with the rating of the scenarios shown in **Figure 5.1**.

Specialists identified that there are problems with the PD flows. The PD provided during this study is likely an under estimate (less flows) than the actual PD flows. This also effects the evaluation of scenario flows and the predictions are therefore of low confidence. If the PD flows are updated and refined during monitoring, the EcoSpecs set as part of Resource Quality Objectives determination must be updated.

Table 5.1 EWR NS1: Consequences of the scenarios on the driver and response component ECs

Component	PES & REC	Sc NS1_CC	Comment
Physico-chemical (Water quality)	B (82.7%)	B/C (80.6%)	PES is driven by elevated turbidity and salts due to extensive subsistence farming and erosion. There is expected to be small impact on some variables under this scenario, particularly at low flows, but a significant impact is not expected.
Geomorphology	B (84.0%)	B/C (82.0%)	Erosion in the upper catchment likely to be increased but high flows slightly reduced increasing potential for deposition; small increase in deposition of fines in pools and in lee of coarse material in riffles.

Component	PES & REC	Sc NS1_CC	Comment
Riparian vegetation	C (64.4%)	C (64.2%)	Stream permanency and seasonality remain unaltered. Flooding regime remains intact, slightly less than PD but more than required by EWR. Base flows lower than PD but more than the EWR. Inundation of marginal zone graminoids is slightly reduced compared to PD, but is more than the EWR requirement. Marginal zone vegetation likely to have slight increase with less inundation in the wet season and slight increase in deposition of fines (see geomorphology response). Negligible change to the VEGRAI score is evident.
Fish	C (67.9%)	C (65.8%)	As the scenario low flows are notably higher than the EWR flows and only slightly lower than PD (and Natural) low flows, no change in fish assemblage can be justified based on flow changes expected under this scenario. A slight change can possibly be expected due to increased sedimentation (catchment erosion), slight water quality deterioration (based on PAI) and slightly reduced vegetative cover and spawning habitats (VEGRAI)
Macro-invertebrates	B/C (79.5%)	B/C (77.9%)	As the scenario low flows are notably higher than the EWR flows and only slightly lower than PD (and Natural) low flows, no change in macro-invertebrate assemblage can be justified based on flow changes expected under this scenario. The increase in salts and turbidity will influence the abundance and/or frequency of occurrence of taxa with a high requirement for unmodified physico-chemical conditions. A slight reduction in vegetative cover which serve as overhanging habitat for macro-invertebrates.
EcoStatus	C (68.4%)	C (67.5%)	All components indicate a slight decrease in category due to largely small changes in the drivers (increased turbidity and silt, decrease in velocity during the wet season and possible changes in marginal vegetation and water quality changes).

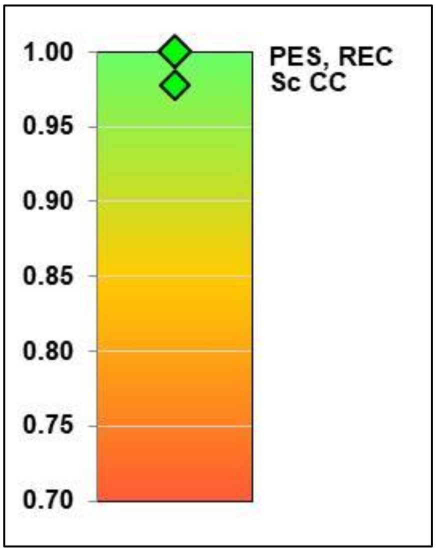


Figure 5.1 EWR NS1: Ecological ranking of operational scenarios

5.3 CONCLUSIONS

Scenario NS1_CC maintains the EcoStatus of a C at a lower percentage. The PES of all components is maintained, except geomorphology and water quality which reflected a small drop in percentage. Water quality and geomorphology decrease from a B to a B/C Category.

6 ECOLOGICAL CONSEQUENCES: EWR BM1 (BLACK MFOLOZI RIVER)

6.1 ECOCLASSIFICATION RESULTS

<table>
<tr><th colspan="9">EWR BM1: Black Mfolozi River</th></tr>
<tr><td colspan="7" rowspan="6"></td><td>Coordinates</td><td>S27.93890
E31.21030</td></tr>
<tr><td>SQ code</td><td>W22A-02610</td></tr>
<tr><td>RU</td><td>RU W22-1</td></tr>
<tr><td>IUA</td><td>IUA W22</td></tr>
<tr><td>Level 2 EcoRegion</td><td>3.1</td></tr>
<tr><td>Geomorphic Zone[4]</td><td>Upper foothills</td></tr>
<tr><th colspan="9">PRESENT ECOLOGICAL STATE: PES</th></tr>
<tr><th>I IHI</th><th>R IHI</th><th>PC</th><th>Geom</th><th>Rip Veg</th><th>Fish</th><th>Inverts</th><th>Instream</th><th>EcoStatus</th></tr>
<tr><td>B/C (77.7%)</td><td>C (74.4%)</td><td>B/C (81.8%)</td><td>A (93.4%)</td><td>C (74.9%)</td><td>C (75.9%)</td><td>B/C (81.3%)</td><td>B/C (78.9%)</td><td>C (76.9%)</td></tr>
<tr><th colspan="9">ECOLOGICAL IMPORTANCE AND SENSITIVITY</th></tr>
<tr><th colspan="9">MODERATE</th></tr>
<tr><th colspan="9">RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES</th></tr>
<tr><th colspan="9">REC = C for ECOSTATUS</th></tr>
<tr><td colspan="9"></td></tr>
<tr><th colspan="9">ECOLOGICAL WATER REQUIREMENTS (EWR)</th></tr>
<tr><td colspan="4">Natural MAR: 166.72 MCM</td><td colspan="5">Present Day MAR: 144.13 MCM</td></tr>
<tr><th colspan="4">Low flow EWR</th><th colspan="5">Total flow EWR</th></tr>
<tr><td colspan="2">MCM</td><td colspan="2">% of nMAR</td><td colspan="2">MCM</td><td colspan="3">% of nMAR</td></tr>
<tr><td colspan="2">18.38</td><td colspan="2">11</td><td colspan="2">43.58</td><td colspan="3">26.1</td></tr>
</table>

6.2 CONSEQUENCES

Scenario BM1_CC was evaluated. A summary explanation of the consequences of the scenarios compared to the PES and the REC are provided in **Table 6.1**, with the rating of the scenarios shown in **Figure 6.1**.

Table 6.1 EWR BM1: Consequences of the scenarios on the driver and response component ECs

Component	PES & REC	Sc BM1_CC	Comment
Physico-chemical (Water quality)	B/C (81.8%)	C/D (61.8%)	The scenario will have a significant impact, particularly at low flows, which will not be effectively balanced by higher flows. Intermittently elevated sulphates are likely to worsen in the short term due to disruptions of water availability to mines (impacting on pollution control dams, for example) Instream impacts on temperature and oxygen conditions are also expected, and increased sedimentation expected due to increased catchment erosion.
Geomorphology	A (93.4%)	C (73.5%)	Given the extensive afforestation the threat of forest fires is likely to increase, which could increase catchment erosion. Fire hazard in riparian zone could also increase impacting on bank and flood bench stability. Channel dominated by bedrock with limited potential for instream sediment deposition but reduced scouring by intermediate flows resulting in increased fine sediment deposition in low velocity areas. Increased deposition of fine

Component	PES & REC	Sc BM1_CC	Comment
			gravels and silt at top of pool. Significant reduction in overbank floods impacts flood benches. Contraction of channel width, increased development of marginal zone and associated vegetation.
Riparian vegetation	C (74.9%)	C (68.5%)	Stream permanency and seasonality remain unaltered. Flooding regime remains intact, but magnitude is reduced compared to PD and to the EWR requirement. This reduction is likely to promote woody encroachment onto flood features. Base flows are lower than PD and the EWR requirement for both wet and dry season. Inundation of marginal zone graminoids will be reduced on average from 78 and 42% of the population for PD and the EWR requirement respectively to 26% for the climate change scenario in the wet season. Similarly, during the dry season, inundation of marginal zone graminoids will be reduced on average from 17% of the population to zero. Marginal zone vegetation is likely to shift and / or increase with less inundation in the wet season along the riparian/ aquatic interface, but will also promote woody establishment in the upper reaches of the population. Encroachment by terrestrial woody species also likely in the upper zone and bank.
Fish	C (75.9%)	D (55.5%)	Significantly reduced flows will be expected, resulting in loss of fast habitats (especially FD and FI) during wet and dry seasons. This will especially impact rheophilic and semi-rheophilic species negatively. Although seasonal variation may be retained, seasonal variation in conditions will be reduced which will influence most species (especially breeding). Substrate quality is expected to be reduced (as a result of sedimentation and lower flows) impacting especially riffle dwelling species. Although vegetative cover may remain in an altered state, this will still change from current and is expected to impact species with a requirement for this habitat type. Overall deterioration in water quality will impact most species (especially water quality intolerant) while reduced migratory success (longitudinal and lateral) can be expected as a result of reduced depth and migratory cues. The food sources (esp. invertebrates) will also be negatively impacted resulting in overall deterioration of fish assemblage and condition.
Macro-invertebrates	B/C (81.3%)	C/D (58.03%)	The availability of fast flowing habitats (fast deep and intermediate flows) have been reduced extensively during both wet and dry seasons under this scenario. These flows will impact greatly on the presence and abundance of rheophilic macro-invertebrate taxa with a preference for moderately fast to very fast flowing water, especially cobble dwellers. The reduction of marginal vegetation inundation will impact adversely on macro-invertebrate overhanging vegetation habitat. Poor water quality will impact on sensitive species, while sedimentation and siltation will impact on the macro-invertebrate habitat types, especially pool- and backwater habitat.
EcoStatus	C (76.9%)	C (62.9%)	Impact due to change in flow regime, geomorphological impact and water quality changes.

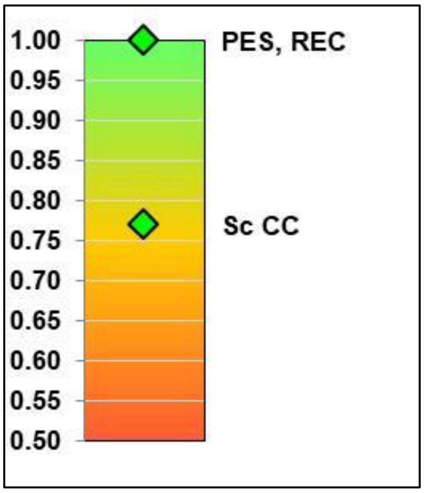


Figure 6.1 EWR BM1: Ecological ranking of operational scenarios

6.3 CONCLUSIONS

Even though the EcoStatus stays a C, the percentage has dropped significantly. The PES is close to a B/C and the scenario evaluation results in a PES close to a C/D. Water quality, fish and macro-invertebrates all drop one category whereas geomorphology drops with two categories. In conclusion, this Climate Change scenario will have a significant impact on the Ecological Status.

7 ECOLOGICAL CONSEQUENCES: EWR WM1 (WHITE MFOLOZI RIVER)

7.1 ECOCLASSIFICATION RESULTS

EWR WM1: White Mfolozi River

Coordinates	S28.23146 E31.18666
SQ code	W21H-02897
RU	RU W21-5
IUA	IUA W21
Level 2 EcoRegion	14.05
Geomorphic Zone[4]	Lower foothills

PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
B/C (79.3%)	**B/C (77.4%)**	**B (84.5%)**	**B/C (78.8%)**	**B/C (81.3)**	**C (73.1%)**	**B/C (81.1%)**	**C (77.08**	**B/C (79.2%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = B/C for ECOSTATUS								

ECOLOGICAL WATER REQUIREMENTS (EWR)			
Natural MAR: 222.51 MCM		Present Day MAR: 191.8 MCM	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
54.74	26.6	89.31	40.1

7.2 CONSEQUENCES

All scenarios were evaluated and it was found that there is no discernible difference between scenarios. All scenarios are the same or higher than the EWR except for Sc WM1_CC which was marginally lower in the dry and drought season. As all other scenarios will meet the REC, the evaluation focussed on WM1_CC to determine if it meets the REC. A summary explanation of the consequences of the scenarios compared to the PES and the REC are provided in **Table 7.1**, with the rating of the scenarios shown in **Figure 7.1**.

Table 7.1 EWR WM1: Consequences of the scenarios on the driver and response component ECs

Component	PES & REC	Sc WM1_CC	Comment
Physico-chemical (Water quality)	B (84.5%)	B (84.5%)	Wet and dry season flows are similar to the PD conditions under which the water quality state was assessed. Even with a potential slight elevation in instream sediment loads and turbidity levels, the integrated water quality state is not expected to change under this scenario.
Geomorphology	B/C (78.8%)	C (75.02%)	Peak flows from January to March are little impacted by climate change so there are no predicted flow related impacts. The upper catchment is already extensively degraded and is likely to be further impacted by climate change, increasing sediment supply.

Component	PES & REC	Sc WM1_CC	Comment
			This will increase the extent of sand deposition on the bed and also in the riparian zone. Strong flows at the site limit the impact of deposition, which at present is highly variable in time.
Riparian vegetation	B/C (81.3%)	B/C (78.9%)	All scenarios will similarly impact riparian vegetation: Stream permanency and seasonality remain unaltered. Flooding regime remains intact and more than the EWR requirement. Wet season base flows are similar to PD and more than the EWR requirement e.g. in March at the 60^{th} percentile 40% of the marginal zone graminoid population is inundated. This increases to 45% for PD and the climate change scenario (31% if only low flows are considered for the climate change scenario) and to 47% for all other scenarios. There are no differences in these levels during dry season base flows. Given the slight increase in marginal and lower zone inundation and the potential for some sediment deposition (refer to geomorphology reasoning) there is likely to be an increase in marginal and lower zone non-woody cover and abundance and the abundance of *Salix mucronata* is also probable.
Fish	C (73.1%)	C (72.1%)	A slight impact (reduced availability) on fast habitats (especially FD) can be expected in the dry season, which will have a minor impact on rheophilic and semi-rheophilic species. Water quality is not expected to change and the potential impact of sedimentation on substrate quality of riffle dwelling species is also expected to be minimal. The remainder of the scenarios will be better than scenario CC, falling between CC and EWR flows and should also maintain the PES/REC.
Macro-invertebrates	B/C (81.1%)	B/C (80.7%)	Scenario flows are similar to the EWR flows and thus no significant changes are expected to take place. Most of the driver and response components are similar to PD conditions: sediment loads do not expect to have a major influence and vegetation-related changes will not influence the PES significantly.
EcoStatus	B/C (79.2%)	C (77.6%)	Change in geomorphology results in minor impacts on the responses.

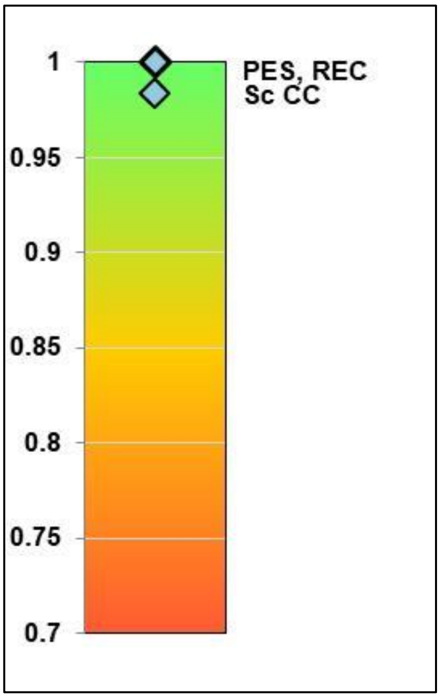


Figure 7.1 EWR WM1: Ecological ranking of operational scenarios

7.3 CONCLUSIONS

Only geomorphology drops by half a category resulting in the EcoStatus to also drop from a B/C to a C. The changes are minor and largely related to the increase in sedimentation. There is also a marginal reduced availability of fast habitats during the dry season, which may have an impact on some key fish species.

8 ECOLOGICAL CONSEQUENCES: EWR MK1 (MKUZE RIVER)

8.1 ECOCLASSIFICATION RESULTS

<table>
<tr><th colspan="9">EWR MK1: Mkuze River</th></tr>
<tr><td colspan="7" rowspan="6"></td><td>Coordinates</td><td>S27.59210
E32.21800</td></tr>
<tr><td>SQ code</td><td>W31J-02480</td></tr>
<tr><td>RU</td><td>RU W31-5</td></tr>
<tr><td>IUA</td><td>IUA W31-b</td></tr>
<tr><td>Level 2 EcoRegion</td><td>3.08</td></tr>
<tr><td>Geomorphic Zone[4]</td><td>Lowland</td></tr>
<tr><th colspan="9">PRESENT ECOLOGICAL STATE: PES</th></tr>
<tr><th>I IHI</th><th>R IHI</th><th>PC</th><th>Geom</th><th>Rip Veg</th><th>Fish</th><th>Inverts</th><th>Instream</th><th>EcoStatus</th></tr>
<tr><td>C
(66.3%)</td><td>C
(72.1%)</td><td>C/D
(58.3%)</td><td>B
(82.3%)</td><td>C
(73%)</td><td>C
(75.4%)</td><td>C
(77.7%)</td><td>C
(76.6%)</td><td>C
(74.8%)</td></tr>
<tr><th colspan="9">ECOLOGICAL IMPORTANCE AND SENSITIVITY</th></tr>
<tr><td colspan="9">HIGH</td></tr>
<tr><th colspan="9">RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES</th></tr>
<tr><td colspan="9">REC = B for ECOSTATUS (Improvement will be achieved by addressing non-flow related impacts)</td></tr>
<tr><td colspan="9"></td></tr>
<tr><th colspan="9">ECOLOGICAL WATER REQUIREMENTS (EWR)</th></tr>
<tr><td colspan="4">Natural MAR: 158.75 MCM</td><td colspan="5">Present Day MAR: 106.13 MCM</td></tr>
<tr><th colspan="4">Low flow EWR</th><th colspan="5">Total flow EWR</th></tr>
<tr><td colspan="2">MCM</td><td colspan="2">% of nMAR</td><td colspan="2">MCM</td><td colspan="3">% of nMAR</td></tr>
<tr><td colspan="2">34.74</td><td colspan="2">21.9</td><td colspan="2">58.87</td><td colspan="3">37.1</td></tr>
</table>

8.2 CONSEQUENCES

All scenarios were evaluated, and it was found that there is no discernible difference between scenarios, with all scenarios being similar to PD. During the EWR assessment it was observed that the PD hydrology appears very low during dry months (note that the present day hydrology is currently being updated through other studies). Due to this uncertainty, the Revised Desktop Reserve Model (RDRM) used to produce the EWRs was therefore not constrained to PD. This implies that the EWR for low flows appear higher than modelled PD, even though NO improvement is required in terms of flow, i.e. higher flows than PD are not required. This makes the yield model output impossible to evaluate as the FDCs all show the EWR and scenarios to be much higher than PD (**Figure 8.1**). The only conclusion that can be made is that as all scenarios are similar to the modelled PD, the Ecological Category will remain the same for all scenarios.

Although flow patterns between scenarios and PD are similar, the water quality state in this reach is already compromised, with a water quality priority area delineated in the SQ reach directly upstream of the reach containing the EWR site, i.e. SQ W31J-02469, with impacts being from the High Risk Mkuze Waste Water Treatment Works (WWTW). Although the MK1_IRR scenario (increased return flows due to increased irrigation supplied from Pongolapoort Dam) does not indicate a change in flows, any deteriorating quality of the return flows would impact on the integrated state.

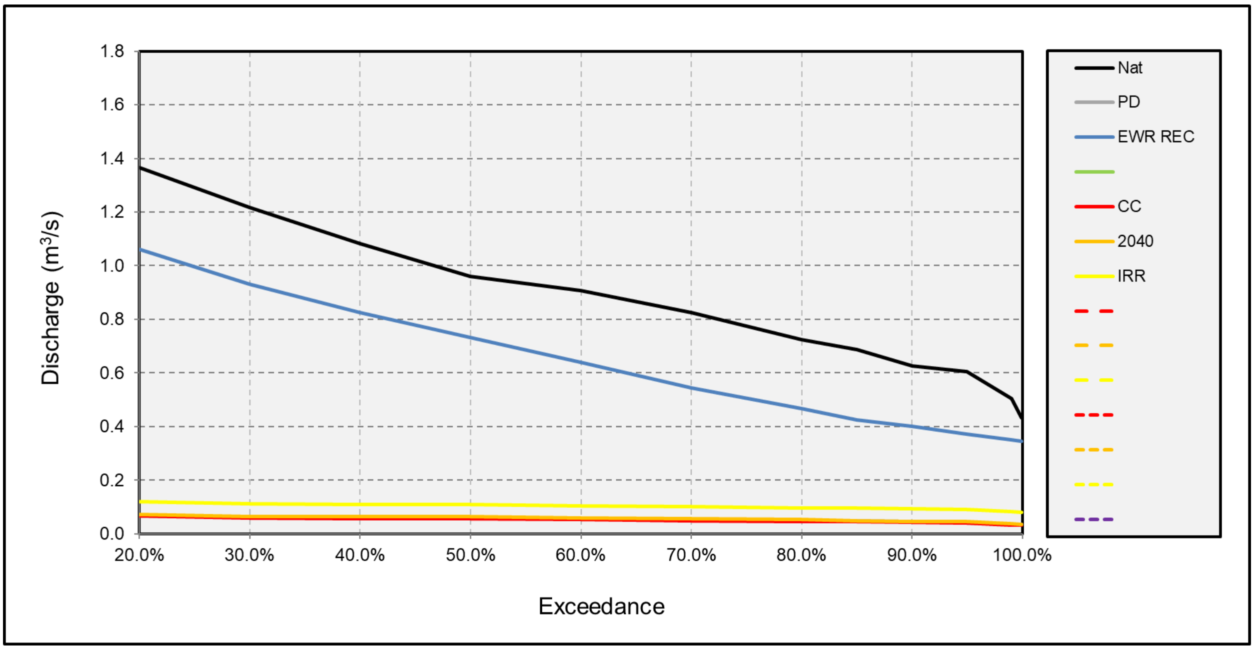


Figure 8.1 Flow duration curve for EWR MK1 during the driest month of August

9 ECOLOGICAL CONSEQUENCES: EWR UP1 (PONGOLO RIVER)

9.1 ECOCLASSIFICATION RESULTS

<table>
<tr><th colspan="9">EWR UP1: Pongola River</th></tr>
<tr><td colspan="7" rowspan="6"></td><td>Coordinates</td><td>S27.36413
E30.96962</td></tr>
<tr><td>SQ code</td><td>W42E-02221</td></tr>
<tr><td>RU</td><td>RU W42-2</td></tr>
<tr><td>IUA</td><td>IUA W42-b</td></tr>
<tr><td>Level 2 EcoRegion</td><td>3.1</td></tr>
<tr><td>Geomorphic Zone[4]</td><td>lower/upper foothills</td></tr>
<tr><th colspan="9">PRESENT ECOLOGICAL STATE: PES</th></tr>
<tr><th>I IHI</th><th>R IHI</th><th>PC</th><th>Geom</th><th>Rip Veg</th><th>Fish</th><th>Inverts</th><th>Instream</th><th>EcoStatus</th></tr>
<tr><td>B/C
(85.7%)</td><td>B/C
(77.8%)</td><td>A/B
(88.3%)</td><td>A/B
(89.8%)</td><td>C
(70%)</td><td>C
(73.9%)</td><td>B/C
(79.5%)</td><td>C
(77%)</td><td>C
(73.5%)</td></tr>
<tr><th colspan="9">ECOLOGICAL IMPORTANCE AND SENSITIVITY</th></tr>
<tr><th colspan="9">MODERATE</th></tr>
<tr><th colspan="9">RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES</th></tr>
<tr><th colspan="9">REC = C for ECOSTATUS</th></tr>
<tr><td colspan="9"></td></tr>
<tr><th colspan="9">ECOLOGICAL WATER REQUIREMENTS (EWR)</th></tr>
<tr><td colspan="4">Natural MAR: 356.84 MCM</td><td colspan="5">Present Day MAR: 299.39 MCM</td></tr>
<tr><th colspan="4">Low flow EWR</th><th colspan="5">Total flow EWR</th></tr>
<tr><td colspan="2">MCM</td><td colspan="2">% of nMAR</td><td colspan="2">MCM</td><td colspan="3">% of nMAR</td></tr>
<tr><td colspan="2">54.84</td><td colspan="2">15.4</td><td colspan="2">97.31</td><td colspan="3">27.3</td></tr>
</table>

9.2 CONSEQUENCES

All scenarios were evaluated, and showed that there is no discernible difference between the 2040 Scenario and the EWR, and this scenario will therefore meet the REC. Scenario UP1_CC is marginally lower than the EWR and was evaluated. A summary explanation of the consequences of the scenarios compared to the PES and the REC are provided in **Table 9.1**, with the rating of the scenarios shown in **Figure 9.1**.

Table 9.1 EWR UP1: Consequences of the scenarios on the driver and response component ECs

Component	PES & REC	Sc UP1_CC	Comment
Physico-chemical (Water quality)	A/B (88.3%)	B (85.5%)	Lower flows under the CC scenario could have an impact on instream water quality parameters (temp, oxygen, clarity), but overall state will remain good.
Geomorphology	A/B (89.8%)	B (84.3%)	Sediment supply from middle of catchment increased as a result of more intense storms and reduced vegetation cover under CC. Increased frequency of forest and veld fires would strip vegetation and could also increase sediment supply. Local floods during decreased CC low flows in August and September could result in increased deposition of fine sediment on channel bed. Low flows during dry season could prevent activation of secondary channels.

Component	PES & REC	Sc UP1_CC	Comment
Riparian vegetation	C (70.0%)	C (68.7%)	Stream permanency and seasonality remain unaltered. Flooding regime remains intact and more than the EWR requirement. Wet season base flows are similar to PD and more than the EWR requirement (considering total flows) e.g. in Feb at the 60th percentile 20% of the marginal zone graminoid population is inundated (climate change scenario). This increases to 25% for PD and the 2040 scenario while only 1% of the population is inundated by the EWR. If the base flow is considered using low flows only (no high flows or floods) then there is no inundation of the marginal zone graminoids for the climate change scenario in the wet season. During dry season base flows there is no inundation of marginal zone vegetation for any of the scenarios, including PD and the EWR, but the climate change scenario flows (both total flows and low flows only) are less than the EWR requirement. Nevertheless, flows remain perennial and marginal and lower zone vegetation should survive the winter period. Given the slight increase in marginal and lower zone inundation in the growing season and the potential for some sediment deposition (refer to geomorphology reasoning) there is likely to be an increase in marginal and lower zone non-woody cover and abundance.
Fish	C (73.9%)	C (68.7%)	No notable change in habitat expected during the wet season (between EWR and PD). Some reduction in fast habitat expected in dry season (especially loss in FD) which will have negative impact on rheophilic and semi-rheophilic species. Only slight deterioration in water quality expected (minor impact on species with high requirement for unmodified water quality), slight increase in sedimentation/siltation of bottom substrate (impacting riffle dwelling species and reducing feeding and spawning habitat quality) while vegetative cover should remain largely unchanged and not impact any fish species notably. Sc 2040 should not have notable impact on fish assemblage (remains very similar to PD) and therefore no notable change in PES expected.
Macro-invertebrates	B/C (79.5%)	B/C (77.6%)	Scenario flows are similar to the EWR flows and thus no significant changes are expected to take place. Some reduction in fast flowing habitat expected during the dry season; mostly fast/deep. There will be a slight deterioration in temperature, oxygen and clarity expected, as well as a slight increase in the deposition of fine sediment on channel bed, but the overall state will remain good. Vegetative cover should remain largely unchanged and the lower zone vegetation should survive the winter period; thus, vegetation-related changes will not influence the PES significantly.
EcoStatus	C (73.5%)	C (71.1%)	Water quality impacts and changes in sedimentation have resulted in small response changes.

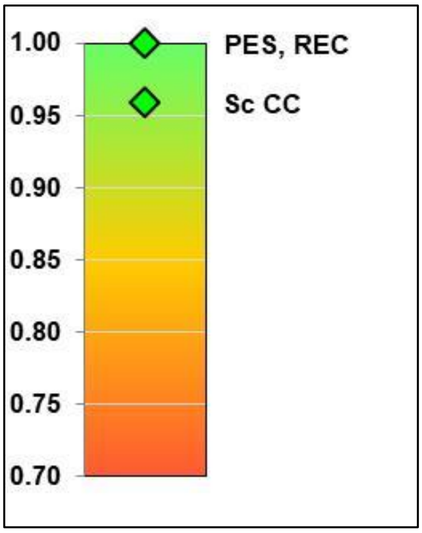


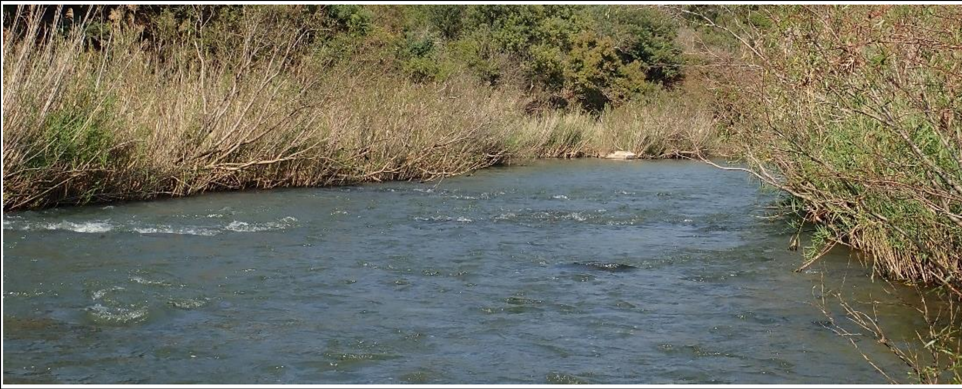
Figure 9.1 EWR UP1: Ecological ranking of operational scenarios

9.3 CONCLUSIONS

Only water quality and geomorphology drop a half a category which results in a small change in the C category rating for the CC scenario.

10 ECOLOGICAL CONSEQUENCES: EWR AS1 (ASSEGAAI RIVER)

10.1 ECOCLASSIFICATION RESULTS

<table>
<tr><th colspan="9">EWR AS1: Assegaai River</th></tr>
<tr><td colspan="7" rowspan="6"></td><td>Coordinates</td><td>S27.06230
E30.98880</td></tr>
<tr><td>SQ code</td><td>W51E-02049</td></tr>
<tr><td>RU</td><td>RU W51-3</td></tr>
<tr><td>IUA</td><td>IUA W52</td></tr>
<tr><td>Level 2 EcoRegion</td><td>4.06</td></tr>
<tr><td>Geomorphic Zone[4]</td><td>lower/upper foothills</td></tr>
<tr><th colspan="9">PRESENT ECOLOGICAL STATE: PES</th></tr>
<tr><th>I IHI</th><th>R IHI</th><th>PC</th><th>Geom</th><th>Rip Veg</th><th>Fish</th><th>Inverts</th><th>Instream</th><th>EcoStatus</th></tr>
<tr><td>C/D
(59.1%)</td><td>C/D
(58.7%)</td><td>B/C
(80.6%)</td><td>C
(70.8%)</td><td>C
(69.9)%</td><td>C
(69.2%)</td><td>B/C
(78. 4%)</td><td>C
(77.8%)</td><td>C
(74.16%)</td></tr>
<tr><th colspan="9">ECOLOGICAL IMPORTANCE AND SENSITIVITY</th></tr>
<tr><th colspan="9">MODERATE</th></tr>
<tr><th colspan="9">RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES</th></tr>
<tr><th colspan="9">REC = C for ECOSTATUS</th></tr>
<tr><td colspan="9"></td></tr>
<tr><th colspan="9">ECOLOGICAL WATER REQUIREMENTS (EWR)</th></tr>
<tr><td colspan="4">Natural MAR: 328.61 MCM</td><td colspan="5">Present Day MAR: 164.11 MCM</td></tr>
<tr><th colspan="4">Low flow EWR</th><th colspan="5">Total flow EWR</th></tr>
<tr><td colspan="2">MCM</td><td colspan="2">% of nMAR</td><td colspan="2">MCM</td><td colspan="3">% of nMAR</td></tr>
<tr><td colspan="2">40.06</td><td colspan="2">12.2</td><td colspan="2">70.85</td><td colspan="3">21.6</td></tr>
</table>

10.2 CONSEQUENCES

All scenarios were evaluated, and it was found that most scenarios are similar to PD and higher than the EWR, indicating that all scenarios should meet the REC. Scenario AS1_CC is marginally lower than the EWR and was evaluated. A summary explanation of the consequences of the scenarios compared to the PES and the REC are provided in **Table 10.1**, with the rating of the scenarios shown in **Figure 10.1**.

Table 10.1 EWR AS1: Consequences of the scenarios on the driver and response component ECs

Component	PES & REC	Sc AS1_CC	Comment
Physico-chemical (Water quality)	B/C (80.6%)	B/C (80.6%)	The PD flows and CC scenario flows are very similar. No impact on water quality is expected under this scenario.
Geomorphology	C (70.8%)	C (65.7%)	There is a small to moderate reduction in high flows; this would exacerbate the impact of the Heyshope Dam as it would overtop less frequently. The main areas subject to erosion are upstream of the dam so increases in sediment supply to the EWR site are expected to be small. Bed armouring will continue to have a significant impact. There may be a slight decrease in scour of the marginal zone and subsequent loss of marginal zone habitat. Bed condition in runs should not be greatly impacted by increased

Component	PES & REC	Sc AS1_CC	Comment
			sediment due to sediment trapping upstream but less frequent flooding may result in a more stable bed structures with limited overturning of cobble.
Riparian vegetation	C (69.9%)	C (65.8%)	Stream permanency and seasonality remain unaltered. Flooding regime remains intact and more than the EWR requirement. Wet season base flows are similar to PD and more than the EWR requirement (considering total flows) e.g. in March at the 60th percentile 18% of the marginal zone graminoid population is inundated (climate change scenario). This is the same as PD at 18% and increases to 21% for the 2040 scenario while only 2% of the population is inundated by the EWR. If the base flow is considered using low flows only (no high flows or floods) then 9% of the marginal zone graminoids are inundated by the climate change scenario in the wet season. During dry season base flows less than 4% of marginal zone vegetation is inundated for any of the scenarios, including PD and zero inundation by the EWR. Nevertheless, flows remain perennial and marginal and lower zone vegetation should survive the winter period. Given the slight increase in marginal and lower zone inundation in the growing season there is likely to be an increase in marginal and lower zone non-woody cover and abundance, particularly reeds.
Fish	C (69.2%)	C (68.8%)	No loss of fast and slow habitat expected under scenario and no notable change in water quality. Only a small potential deterioration in substrate quality (reduced floods/flushing) expected (see geomorphology section) that may impact intolerant fish species with requirement for rocky and gravel substrates as habitats (feeding, spawning etc.). The expected overall impact on the fish assemblage is however very small and fish should remain in the PES/REC under all scenarios assessed for this site.
Macro-invertebrates	B/C (78.4%)	C (77.3%)	There is only a small reduction in high flows but it will not impact the macro-invertebrate assemblages and the water quality will also not change significantly. The deterioration in substrate quality due to reduced floods and flushing may have a small impact. Vegetative cover should remain largely unchanged and no impact is expected on the marginal vegetation taxa.
EcoStatus	C (74.2%)	C (69.7%)	All scenarios maintain the REC apart from Macroinvertebrates which drop by 0.1% to fall from a B/C to a C. The REC will therefore be the preferred scenario.

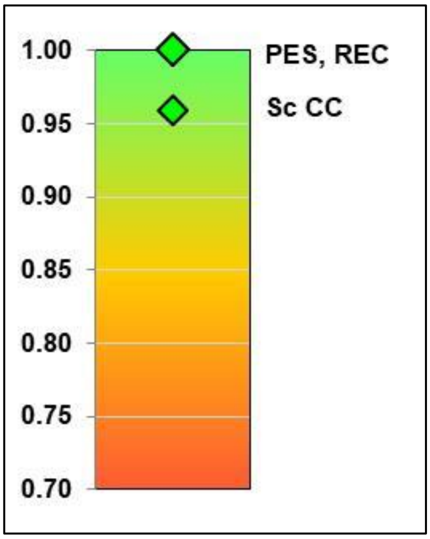


Figure 10.1 EWR AS1: Ecological ranking of operational scenarios

10.3 CONCLUSIONS

All scenarios maintain the REC apart from Macroinvertebrates which drop by 0.1% to fall from a B/C to a C. The REC will therefore be the preferred scenario. There are minor decreases within category due to decreased spilling from the large upstream dams under Sc AS1_CC.

11 ECOLOGICAL CONSEQUENCES: EWR NG1 (NGEMPISI RIVER)

11.1 ECOCLASSIFICATION RESULTS

<table>
<tr><th colspan="9">EWR NG1: Ngwempisi River</th></tr>
<tr><td colspan="7" rowspan="6"></td><td>Coordinates</td><td>S26.679448
E30.70213</td></tr>
<tr><td>SQ code</td><td>W53E-01790</td></tr>
<tr><td>RU</td><td>RU W53-3</td></tr>
<tr><td>IUA</td><td>IUA W52</td></tr>
<tr><td>Level 2 EcoRegion</td><td>11.04/4.06</td></tr>
<tr><td>Geomorphic Zone[4]</td><td>Upper foothills/ Transitional</td></tr>
<tr><th colspan="9">PRESENT ECOLOGICAL STATE: PES</th></tr>
<tr><th>I IHI</th><th>R IHI</th><th>PC</th><th>Geom</th><th>Rip Veg</th><th>Fish</th><th>Inverts</th><th>Instream</th><th>EcoStatus</th></tr>
<tr><td>C
(64.3%)</td><td>C/D
(61.8%)</td><td>B
(85.5)</td><td>B
(83.3%)</td><td>B/C
(77.4%)</td><td>C
(72.8%)</td><td>B
(87.3%)</td><td>B/C
(80.36%)</td><td>B/C
(79.8%)</td></tr>
<tr><th colspan="9">ECOLOGICAL IMPORTANCE AND SENSITIVITY</th></tr>
<tr><td colspan="9">MODERATE</td></tr>
<tr><th colspan="9">RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES</th></tr>
<tr><td colspan="9">REC = B/C for ECOSTATUS</td></tr>
<tr><td colspan="9"></td></tr>
<tr><th colspan="9">ECOLOGICAL WATER REQUIREMENTS (EWR)</th></tr>
<tr><td colspan="4">Natural MAR: 156.33 MCM</td><td colspan="5">Present Day MAR: 79.15 MCM</td></tr>
<tr><th colspan="4">Low flow EWR</th><th colspan="5">Total flow EWR</th></tr>
<tr><td colspan="2">MCM</td><td colspan="2">% of nMAR</td><td colspan="2">MCM</td><td colspan="3">% of nMAR</td></tr>
<tr><td colspan="2">30.46</td><td colspan="2">19.5</td><td colspan="2">50.82</td><td colspan="3">32.5</td></tr>
</table>

11.2 CONSEQUENCES

All scenarios were evaluated and it was found that there is no discernible difference between the 2040 Scenario and the Sc NG1_CC. The scenarios are lower than the EWR during the dry season. Scenario NG1_CC is marginally lower than the 2040 and was evaluated. A summary explanation of the consequences of the scenarios compared to the PES and the REC are provided in **Table 11.1**, with the rating of the scenarios shown in **Figure 11.1**.

Table 11.1 EWR NG1: Consequences of the scenarios on the driver and response component ECs

Component	PES & REC	Sc NG1_CC	Comment
Physico-chemical (Water quality)	B (85.5%)	B (85.5%)	The PD flows and CC scenario flows are very similar. No impact on water quality is expected under this scenario.
Geomorphology	B/C (83.3%)	B/C (80.2%)	Climate change has an insignificant impact on the geomorphology of the channel at this site. High flows are little altered relative to present day conditions; both are impacted by the upstream dams which reduce floods and trap sand, gravel and coarser sediment and result in bed armouring and scour of marginal zones and flood benches. There may be a small increase in sediment supply but the lower catchment is at present generally well

Component	PES & REC	Sc NG1_CC	Comment
			vegetated and unlikely to be affected significantly by climate change. There may be an increase in fire frequency but burning is already widely practiced, thereby reducing the severity of this impact.
Riparian vegetation	B/C (77.4%)	B/C (77.4%)	Stream permanency and seasonality remain unaltered. Flooding regime remains intact, similar to PD, and more than the EWR requirement. Wet season base flows are similar to PD and more than the EWR requirement. Similarly, dry season base flows are similar to PD and either meet the EWR requirement or are marginally lower. Nevertheless, flows remain perennial and marginal and lower zone vegetation should survive the winter period. Response by riparian vegetation should be minimal and no change to the PES.
Fish	C (72.8%)	C (69.6%)	Scenario CC is the only one that results the 60th percentile to be lower than PD and EWR during the wet season, with very small decrease in fast habitats (mostly FD) expected which would have slight impact on FROC of rheophilic and semi-rheophilic spp. No water quality changes expected that could influence fish assemblage and only very minor potential change in substrate condition due to sedimentation, affecting riffle dwelling spp. No notable change in vegetative cover expected under any of the scenarios. Overall, the impact on the fish assemblage expected to be very small under all scenarios assessed.
Macro-invertebrates	B (87.3%)	B (85.6%)	The wet season 60th percentile flows are lower than the EWR which will result in a very small decrease in fast deep habitats, while dry season base flows are similar to the EWR requirement or are marginally lower. Although there is very little change in water quality, bed armouring and scour of marginal zones and flood benches may have a small impact on macro-invertebrate marginal habitats.
EcoStatus	B/C (79.8%)	B/C (77.8%)	All Scenarios are very similar to the EWR and close to Present Day; therefore, all scenarios will maintain the REC.

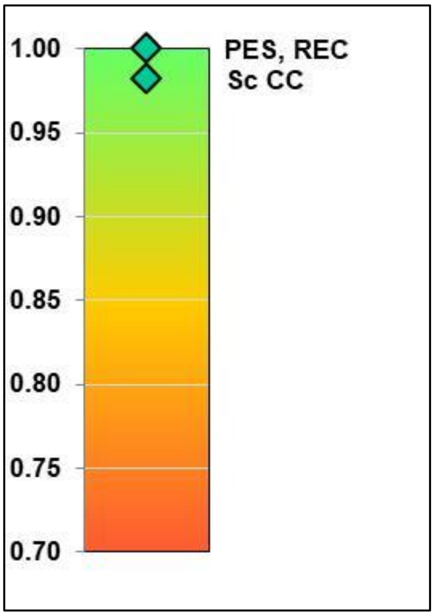


Figure 11.1 EWR NG1: Ecological ranking of operational scenarios

11.3 CONCLUSIONS

Although there are minor geomorphological changes, all component RECs are maintained and the EcoStatus for Sc NG_CC is very similar to the PES EcoStatus.

12 CONCLUSIONS

There are few major operational and development scenarios that would impact on rivers and EWR sites, and therefore require evaluation. Of those identified, Sc CC was often marginally 'worse' than the other scenarios. All scenarios meet the REC and it will, therefore, be recommended that the REC becomes the Target Ecological Category (TEC) and that Resource Quality Objectives (RQOs) are set accordingly.

It must be noted that EWR MK1 (Mkuze River) requires improvement to achieve the REC, but these improvements are NON-FLOW RELATED. These improvements will be identified, and recommendations made as part of the RQO process.

A summary of the results showing the scenarios compared to the REC is provided in **Table 12.1** and **Figure 12.1**. The scenario value refers to the ranking values of the scenarios in terms of a numerical scale with values 0 and 1 (typically, where one (1) indicates the scenario that the achieves the REC and a zero (0) representing the situation where the scenario results in a F category).

Table 12.1 Scenario consequences results

	MA1_CC	NS1_CC	BM1_CC	WM1_CC	MK1_all Scenarios	UP1_CC	AS1_CC	NG1_CC
Sc ranking value	0.95	0.98	0.77	0.98	1.00	0.96	0.98	0.98
REC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

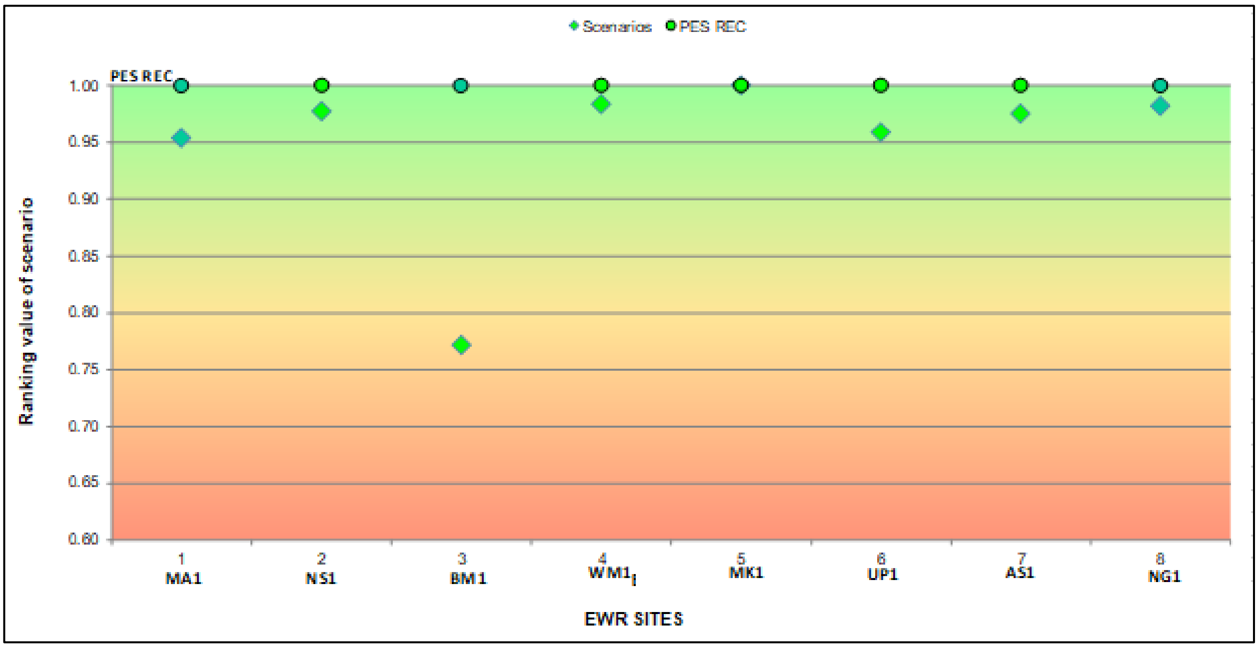


Figure 12.1 Summary traffic diagram of scenario consequences results

There were no operational scenarios identified for wetlands that are not linked to estuaries or river floodplains. For important wetlands that require improvement, a scenario of addressing non-flow related impacts to determine whether improvement can be achieved will be investigated to ensure that these are included in the determination of the TEC (Class and Catchment Configuration) and RQOs.

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14 APPENDIX A: COMMENTS AND RESPONSE REGISTER

No.	Section	Comment	From	Addressed?
1.	Sec. 12 Pg 12-1	Are there no priority wetlands that will be affected by the scenarios? In which Report are the Ecological Consequences of scenarios to priority wetlands going to be incorporated?	M Sekoele	Addressed. Refer to Chapter 12.
2.	Sec. 8.1 Pg 8-1	Reference is made to the EcoClassification Results Table for the Mkuze River (MK1): Page 8-1 of the report: • When I read the REC (highlighted in the blue cell) it appears to me that both “non flow related impacts and flow requirements will be set for a C category” – this is based on the way the sentence is written in the document. • However, at the end of the report (Conclusion) it states that only non-flow related impacts will need to be addressed to achieve the proposed B category for the Mkuze River. • Firstly, I just want to confirm if the C category applies to both flow requirements and non-flow related impacts or is the C category set for only the flow requirements. • If the C category only applies to the flow requirements, then I suggest that the sentence in blue section of the table (above) be reworded to indicate that the C category is for flows only and that the B category requires an improvement in non-flow related impacts. This does not come out clearly in the way it is currently written.	R. Pillay	The C PES for the EcoStatus refers to the complete spectrum of habitat and biota responses to flow, water quality and other non-flow related disturbances. There is therefore no category only associated with flows. Improvements to a B category are required. Flow is NOT the key problem at this site. Non-flow related issues however, are. Therefore, as there is sufficient flow in the river, an improvement can only be achieved by addressing the non-flow related issues to achieve a B status. In reality,once the hydrology for present day has been addressed (there are issues regarding this) it may be possible to utilize more flows but keep the river in the same state.
3.	Whole report	Generally, the report is good and accurate. My main problem is that the inconsistent allocation of boundary categories (See Table below). I know that some of the earlier versions of the EcoStatus models had slightly different cut-off points for the boundary categories. One should always consider the actual % obtained and compare that to the table, rather than blindly using the Category indicated in the model. My other concern is that I am not sure that the correct version of the MIRAI was used. It should not have a major impact as there is a very good correlation between the results obtained in the original (2007) and the updated (2016) version.	C Thirion	See section below the comment register addressing all comments regarding inconsistencies in category percentages.

<table>
<tr><th>No.</th><th>Section</th><th>Comment</th><th>From</th><th>Addressed?</th></tr>
<tr><td></td><td></td><td>Table 1: Generic Ecological Categories (EC) for Ecological Integrity Categories (modified from Kleynhans 1996 & Kleynhans 1999).
<table>
<tr><th>ECOLOGICAL CATEGORY</th><th>GENERIC DESCRIPTION OF ECOLOGICAL CONDITIONS</th></tr>
<tr><td>A</td><td>Unmodified/natural. Close to natural or close to predevelopment conditions within the natural variability of the system drivers: hydrology, physico-chemical and geomorphology. The habitat template and biological components can be considered close to natural or to pre-development conditions. The resilience of the system has not been compromised.</td></tr>
<tr><td>A/B</td><td>The system and its components are in a close to natural condition most of the time. Conditions may rarely and temporarily decrease below the upper boundary of a B category.</td></tr>
<tr><td>B</td><td>Largely natural with few modifications. A small change in the attributes of natural habitats and biota may have taken place in terms of frequencies of occurrence and abundance. Ecosystem functions and resilience are essentially unchanged.</td></tr>
<tr><td>B/C</td><td>Close to largely natural most of the time. Conditions may rarely and temporarily decrease below the upper boundary of a C category.</td></tr>
<tr><td>C</td><td>Moderately modified. Loss and change of natural habitat and biota have occured in terms of frequencies of occurrence and abundance. Basic ecosystem functions are still predominantly unchanged. The resilience of the system to recover from human impacts has not been lost and it is ability to recover to a moderately modified condition following disturbance has been maintained.</td></tr>
<tr><td>C/D</td><td>The system is in a close to moderately modified condition most of the time. Conditions may rarely and temporarily decrease below the upper boundary of a D category.</td></tr>
<tr><td>D</td><td>Largely modified. A large change or loss of natural habitat, biota and basic ecosystem functions have occurred. The resilience of the system to sustain this category has not been compromised and the ability to deliver Ecosystem Services has been maintained.</td></tr>
<tr><td>D/E</td><td>The system is in a close to largely modified condition most of the time. Conditions may rarely and temporarily decrease below the upper boundary of an E category. The resilience of the system is often under severe stress and may be lost permanently if adverse impacts continue.</td></tr>
<tr><td>E</td><td>Seriously modified. The change in the natural habitat template, biota and basic ecosystem functions are extensive. Only resilient biota may survive, and it is highly likely that invasive and problem (pest) species may dominate. The resilience of the system is severely compromised as is the capacity to provide Ecosystem Services. However, geomorphological conditions are largely intact but extensive restoration may be required to improve the system's hydrology and physico-chemical conditions.</td></tr>
<tr><td>F</td><td>Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete change of the natural habitat template, biota, and basic ecosystem functions. Ecosystem Services have largely been lost This is likely to include severe catchment changes as well as hydrological, physico-chemical, and geomorphological changes. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible. Restoration of the system to a synthetic but sustainable condition acceptable for human purposes and to limit downstream impacts is the only option.</td></tr>
</table>
</td><td></td><td></td></tr>
<tr><td>4.</td><td>Exec sum Sc results table</td><td>“These numbers should be explained. I am assuming it is explained in the document but you cannot include it in the executive summary without any explanation.</td><td>C Thirion</td><td>Yes.</td></tr>
<tr><td>5.</td><td>Exec sum Sc results figure</td><td>Y axis label?</td><td>C Thirion</td><td>Yes.</td></tr>
<tr><td>6.</td><td>Glossary</td><td>Sub-quaternary (SQ) reaches: What is the official definition of a quinary and how does it differ from a sub-quaternary reach?</td><td>C Thirion</td><td>Yes.</td></tr>
<tr><td>7.</td><td>Section 3.2 Pg 3-1</td><td>PAI: These are more general references, not specific to the PAI.
GAI: Did you use Level 3 or Level 4?
MIRAI: Also reference the updated version (Thirion 2016) which is the version (MIRAI v2) you should have used.
VEGRAI: Did you use level 3 or level 4?</td><td>C Thirion</td><td>MIRAI – Version 1 (Thirion, 2007) was used in this study as this version of the MIRAI was used in the previous study and therefore allowed comparison of results.
FRAI: Although various beta versions of the FRAI model are available, these versions have not been finalised or officially released for public use. Therefore Version 1, Kleynhans (2007) was used as it is the only published version available.</td></tr>
</table>

No.	Section	Comment	From	Addressed?
				GAI and VEGRAI: Addressed – Assessment level added. PAI: DWAF (2008) describes the use of the PAI model in Reserve studies in detail while the DWAF (2005) document introduces the PAI model. These references are deemed adequate.
8.	Section 3.2.3 Figure 3.2 Pg 3-5	It is difficult to distinguish between the colours. Maybe make then brighter. The yellow is particularly difficult to see.	C Thirion	Yes.
9.	Sec 3.2 Pg 3-8	MIRAI sheets (Thirion, 2007) - You should really use the information in MIRAIv2 (Thirion 2016), it is higher confidence.	C Thirion	To ensure consistency throughout the project, the same versions of the assessment models as used during Task 3 were used
10.	Sec 4.1 Pg 4-1	R IHI: Need to check the decimals. It is only a B/C if it is>78%. 78% will still be a C category.	C Thirion	See note below.
11.	Table 4.1 Pg 4-2	Geomorphology: Should be a B/C Category.	C Thirion	See note below.
12.	Table 5.1 Pg 5-2	Invertebrates: Your EC % reflects a C category rather than a B/C.	C Thirion	See note below.
13.	Section 6.1 Pg 6-1	I IHI must be a C Category, based on %.	C Thirion	See note below.
14.	Table 6.1 Pg6-1	Riparian Vegetation: How will the forest fires impact the riparian vegetation?	C Thirion	Addressed in geomorphology explanation.
15.	Section 7.1 Pg 7-1	R IHI must be a C Category, based on %.	C Thirion	See note below.
16.	Table 10.2 Pg 10-2	Invertebrates: Your EC % reflects a C category rather than a B/C. REC: Looking only at flows? The EcoStatus decreased by 4.5%. Check conclusion.	C Thirion	Addressed.
17.	Section 11.1 Pg 11-1	Rip Veg must be a C Category, based on %.	C Thirion	See note below.
18.	Table 11.1	Rip Veg and EcoStatus must be a C Category, based on %. Check conclusion.	C Thirion	See note below.
19.	Section 12 Pg 12-1	All scenarios meet the REC: See earlier comments. You did not deal with the boundary categories consistently.	C Thirion	See note below.
20.	Whole report	I just managed to go through the areas I am familiar with (Pongolo River system and Kosi/Sibaya area), and the following issues needs to be considered in ecological category response consideration: 1. The Northern Part of KZN is prone to tropical storm which is normally trough the Mozambican cell channel. With these frequent storms, especially between November and March, they may have increased effect on how our resources behave and how they need to be managed. For example, the Dam safety management strategies may need to be considered, and this may affect other issues. In the past, emergency dam	M Salagane	All queries where considered in the relevant reports.

No.	Section	Comment	From	Addressed?
		water releases had to be made especially on the Pongolapoort Dam. The releases impacted on the ecosystem downstream. 2. The releases of water from the Pongolopoort Dam often have some challenges. The release tends to result with fluvial deposit within the river and river banks. This to some extent affects microbial organisms. If releases are not done in ideal time, they tend to have a serious negative impact. For example, releases of a good magnitude need to correspond with fish spawning, which is often in the pans. If releases are not good enough, fish spawning in the pans would be affected. 3. Fluvial deposit along the riverbanks and between the river and pans has to some extend changed or affected the vegetation. 4. Land use such as cultivation along the river and between the river and pans has and is impacting on the ecology of the river. 5. Studies have indicated that climate change may have added the challenge of drop in the groundwater levels especially around the Kosi/Sibaya Bay. Due to the interaction between surface and groundwater, this would ultimately affect river levels flow and ultimately the river system ecology. This may be also due to high evaporation levels.		
21.		It's difficult to read and understand because of the detachment from previous steps. For example, the present day, EWR, various scenarios' flows (MAR) could have been brought into the report and shown maybe in a table format.	N Jafta	Yes. Additional information added in summary table for every EWR site.
22.		It's difficult to accept that the climate change scenario was the only one that is demonstrated in the report. When you read it, some of the components refer to assessments done on other scenarios, but the results are not demonstrated. Why would other scenario consequences not be shown? Especially since the team have indicated that there are actually a lot of uncertainties when it comes to the CC scenario? And, does this mean it has already been decided that CC will be the preferred scenario even after considering the socio-economic consequences?	N Jafta	Yes, refer to Section 3.1.2.
23.		For sites closer to estuaries, may the team please make sure that the estuaries' scenarios are also considered. For example, the Amatigulu site made no mention of the additional 15% MAR that would be required by the estuary. The scenario is being re-looked but a significant portion of that water would have also had to come from the upper catchment (since it's a small catchment altogether) and that water would have run through the EWR site. For St Lucia, it's accepted this may not be the case for sites like BM1 and WM1, but could possibly be applicable for MK1.	N Jafta	Yes, refer to Section 3.1.2.
24.	3.1.3	Remember the comment I added about inserting a table that shows the scenario hydrological consequences. Atleast the scenario that is being discussed in this document, CC.	N Jafta	No. Please note that these statistics are not relevant for river scenarios and are not used in evaluation. A different approach is followed in the estuary where they make use of these statistics and summary evaluation. Rivers focus on the flow duration graphs and tables whereas estuaries focus on time series. These hydrological statistics is part of the scenario description report.
25.	Executive Summary	Restoration scenario	N Jafta	No. In the case of these river scenarios, we refer to improvement required to increase the ecological category. Restoration scenarios as used in estuaries

No.	Section	Comment	From	Addressed?
				have a different connotation as they are trying to resotre certain functions of the estuary.
26.	3.2	Level 1 and Level 4 attached to EcoStatus model names	C Thirion	Level 1 next to the FRAI has been deleted. Level 4 or IV next to the GAI and VEGRAI refers to the model used for comprehensive assessments. Will change to the roman numbers as more consistently used.
27.	Comments register	If you look at the different models you will notice that the cutoff points differ from model to model and that there actually were some errors in the "IF statements" (sometimes related to the decimal point) sometimes provided a completely wrong category.	C Thirion	n/a and for general information. All the models we used except for EcoStatus has the same cutoff points – those provided by DWS. Yes, it is possible that there were mistakes in some of the models, but these were fixed during use during previous projects after discussion with Dr Kleynhans and others. During this project we again checked that the MIRAI, GAI, VEGRAI, FRAI, PAI and IHI used the same cut-off points. It is only the EcoStatus model that is different and we did not change that as it would impact on all categories previously provided and gazetted.
28.	Table 5.1	Marginal zone vegetation likely to have slight increase with less inundation. Comment: Likely to increase in cover/abundance? Even with the reduced inundation? Is that what the statement is about?	N Jafta	This refers to the area of the marginal zone that will increase as it is not inundates. So the cover or area of marginal zone vegetation will increase.

Inconsistency in EcoStatus models

The assessment models that were used in this study, and provided by DWS, i.e. IHI, VEGRAI (IV), GAI (IV), FRAI, MIRAI and PAI consistently use these cut-off points for the ECs:

```
=IF(AND(87.4<C3,C3<92.01),"A/B",IF(AND(77.4<C3,C3<82.01),"B/C",IF(AND(57.4<C3,C3<62.01),"C/D",IF(AND(37.4<C3,C3<42.01),"D/E",IF(AND(
17.4<C3,C3<22.01),"E/F",F3)))))
```

If updated or more recent versions of models have a different cut-off point, they cannot be applied in this report as specialists used these cut-off points in the EWR report where the EcoStatus models were set up for this study and reported on. These models listed above, are also the models used in all previous studies that have been undertaken by the consultants for DWS. The cut-off points were queried with DWS and we were informed to use as is. It is possible that the GAI (IV) version, which was not the DWS version, has different cut-off points and these have been corrected in the report in order to ensure consistency with all other EcoStatus models.

The EcoStatus model (IV) provided by DWS, however, uses the cut-off values below which are different to the above-mentioned assessment models.

=IF(D28="","",IF(D28>=92,"A",IF(AND(D28<92,D28>88),"A/B",IF(AND(D28>82,D28<=88),"B",IF(AND(D28>78,D28<=82),"C/B",IF(AND(D28>62,D28<=78),"C", IF(AND(D28>58,D28<=62),"C/D",IF(AND(D28>42,D28<=58),"D",IF(AND(D28>38,D28<=42),"D/E",IF(AND(D28>22,D28<38),"E",IF(AND(D28>18,D28<=22),"E/F","F")))))))))))).

Discussions have previously been held with DWS regarding inconsistencies. Although differences are generally small, it is recommended that DWS update the models to avoid inconsistencies in future and provide a formal instruction to consultants regarding the cut-off values and modify the models accordingly. It should always be noted in documentation that e.g. a B/C determined for the Crocodile River in 2015 will be different to a B/C category if assessed using updated models. The EcoStatus will be the same, but the original models and categories used in the gazetted RQOs will not be the same. For this project, consultants needed to apply the models used and reported on consistently since Task 3, to ensure consistency in cut-off values used. As Dr Thirion indicates, it is the actual percentage from the models that matters when generating the EcoStatus results. We will make sure that this is the case and that percentages are always documented. The populated models are also stored as part of the raw data so the percentages will always be readily available.