COMPREHENSIVE RESERVE DETERMINATION

INTEGRATED VAAL RIVER SYSTEM

SURFACE WATER

ECOLOGICAL AND GOODS & SERVICES CONSEQUENCES OF VARIOUS OPERATIONAL SCENARIOS

RDM/WMA8C000/01/CON/0110

TECHNICAL COMPONENT: UPPER VAAL

JULY 2010

REPORT NO.: RDM/WMA8C000/01/CON/0110
PROJECT NO.: 8829/1

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

COMPREHENSIVE RESERVE DETERMINATION STUDY OF THE INTEGRATED VAAL RIVER SYSTEM

UPPER VAAL WATER MANAGEMENT AREA TECHNICAL COMPONENT: ECOLOGICAL AND GOODS & SERVICES CONSEQUENCES OF VARIOUS OPERATIONAL SCENARIOS

Report number: RDM/WMA8C000/01/CON/0110

JULY 2010

This report should be cited as:
Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Ecological and Goods & Services Consequences of various Operational Scenarios. Report produced by Koekemoer Aquatic Services and Rivers for Africa. Report no: RDM/WMA8C000/01/CON/0110.

Technical document authorised by:

Koekemoer Aquatic Services
PO Box 1100
Parys, 9585
056 811 3082

Rivers for Africa
PO Box 1684
Derdepark, Pretoria, 0035
082 461 1289

DOCUMENT INDEX

Reports as part of this project:

Index number	RDM Report number	Report title
1.1	RDM/WMA8C000/01/CON/0107	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Inception Report
1.2	RDM/WMA8C000/01/CON/0207	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Desktop EcoClassification Report
1.3	RDM/WMA8C000/01/CON/0610	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Basic Human Needs Reserve. Included in the Main Report.
1.4	RDM/WMA8C000/01/CON/0208	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Resource Unit Report
1.5	RDM/WMA8C000/01/CON/0109 Volume 1 and 2	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoClassification Report
1.6	RDM/WMA8C000/01/CON/0209 Volume 1 and 2	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EWR Scenario Report
1.7	**RDM/WMA8C000/01/CON/0110**	**Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Ecological and Goods & Services Consequences of Various Operational Scenarios.**
1.8	RDM/WMA8C000/01/CON/0210	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Socio Economic Consequences of Various Operational Scenarios.
1.9	RDM/WMA8C000/01/CON/0310	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoSpecs Report
1.10	RDM/WMA8C000/01/CON/0410	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Wetland Report
1.11	RDM/WMA8C000/01/CON/0510	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Estimation Report
1.12	RDM/WMA8C000/01/CON/0610	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Main Report
1.13	RDM/WMA8C000/01/CON/0710	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Electronic information

Bold indicates this report

APPROVAL

TITLE:	Comprehensive Reserve determination study of the Integrated Vaal River System, Upper Vaal River Management Area. Ecological and Goods & Services Consequences of Various Operational Scenarios.
DATE:	July 2010
EDITORS:	S Koekemoer and MD Louw
REVIEW:	Ms Retha Stassen
LEAD CONSULTANT:	Koekemoer Aquatic Services and Rivers for Africa, Joint Venture
FILE NO.:	26/8/3/10/10
FORMAT:	MSWord and PDF
WEB ADDRESS:	www.dwaf.gov.za

Approved for Koekemoer Aquatic Services/Rivers for Africa Joint Venture:

Ms Shael Koekemoer
Administrative Project Leader

Ms Delana Louw
Technical Project Leader

Approved for the Department of Water Affairs by:

Ms Retha Stassen
Consultant Project Management Team Leader & Manager

Ms Barbara Weston
Deputy Director: Surface Water Reserve Requirements

MANAGEMENT AND STEERING COMMITTEES

Project Management Committee

Barbara Weston	Department of Water Affairs	Project Manager
Jacqueline Jay	Department of Water Affairs	Study Manager
Retha Stassen	Blue Science Consulting	Consultant Project Leader and Manager
Shael Koekemoer	Koekemoer Aquatic Services	Consultant Upper Vaal Technical Team
Delana Louw	Rivers for Africa	Consultant Upper Vaal Technical Team

Project Team

Shael Koekemoer	Koekemoer Aquatic Services	Administrative Project Leader
Delana Louw	Rivers for Africa	Technical Project Manager
Shileen Louw	Rivers for Africa	Project Administrator
Greg Huggins	Rivers for Africa	Team Leader: Basic Human Needs
Mark Rountree	Fluvius Environmental Consultants	Team Leader: Wetlands. Geomorphology
Toriso Tlou	Tlou Consulting	Team Leader: Resource Economics
Dr Patsy Scherman	Scherman Colloty and Associates	Team Leader: Capacity Building
Dr Neels Kleynhans	DWA: RQS	EcoClassification Process
Ms Christa Thirion	DWA: RQS	EcoClassification Process
Dr Drew Birkhead	Streamflow Solutions	EcoHydraulics
Prof Denis Hughes	Institute for Water Research	EcoHydrology
Mr Johan Koekemoer	Koekemoer Aquatic Services	Fish
Dr Pieter Kotze	Clean Stream Biological Services	Fish
Mr James MacKenzie	BioRiver Solutions	Riparian Vegetation
Dr Dawie Mullins	Conningarth Economists	Resource Economics
Mr William Mullins	Conningarth Economists	Resource Economics
Mr Rob Palmer	Nepid Consulting	Macroinvertebrates
Ms Riekie Cloete	Conningarth Economists	Trainee
Ms C Engelbrecht	Rivers for Africa	GIS
Mr Ahmed Desai	Rivers for Africa	Trainee
Mr Bennie Haasbroek	Innovative Solutions	Trainee
Mr Lindokuhle Hlongwane	Wetland Consulting Services (Pty.) Ltd.	Trainee
Ms Nonkanyiso Maphumulo	Wetland Consulting Services (Pty.) Ltd.	Trainee
Mr David Mosaka	Conningarth Economists	Trainee
Mr Brenton Niehaus	Clean Stream Biological Services	Trainee
Mr Ntaki Senoge	Clean Stream Biological Services	Trainee
Ms Lindi Schwartz	Conningarth Economists	Trainee
Mr Lungile Gaulana	DWA: RQS	Trainee
Ms Pumza Maseti	DWA: RQS	Trainee
Ms Nceba Ncaphayi	DWA: RQS	Trainee
Mr Ramogale Sekwele	DWA: RQS	Trainee

Members of Project Steering Committee

Barbara Weston	Resource Directed Measures, Surface Water Reserve Requirements
Jackie Jay	Resource Directed Measures, Surface Water Reserve Requirements
Yakeen Atwaru	Resource Directed Measures, Surface Water Reserve Requirements
Nancy Motebe	Resource Directed Measures, Groundwater Reserve Requirements
Shane Naidoo	Resource Directed Measures, Classification System
Ndeleka Mohapi	Resource Directed Measures, Compliance
Bonani Madikizela	WRC
Valerie Killian	Water Abstraction and Instream Use (Environment & Recreation)
Seef Rademeyer	National Water Resource Planning
Niel van Wyk	National Water Resources Planning
Dragana Ristic	National Water Resources Planning
Jurgo van Wyk	Water Resource Planning Systems
Peter Pike	Option Analysis
Churchill Mkwalo	Stream flow Reduction
Marius Keet	Gauteng Regional Office
Nndanganeni (Lucky) Musekene	Resource Protection and Waste
Abe Abrahamse	Northern Cape Regional Office
Hanke Du Toit	Northern Cape Regional Office
Sam Dywili	Northern Cape Regional Office
Willem Grobler	Free State Regional Office
Dr Neels Kleynhans	Resource Quality Services
Reghardt Strauss	Spatial & Land information management
Frans Matfield	SAPPI
Maryna Mohr	Chamber of Mines of SA
Retha Stassen	Arcus GIBB/ Blue Science Consulting Project Management team
Beyers Havenga	Arcus GIBB/ Blue Science Consulting Project Management team

AKNOWLEDGEMENTS

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

Contributors to the report and specialist meeting:
Ms Koekemoer, Shael (Editing)
Dr Kotze, Piet (Fish)
Ms Louw, Delana (Process facilitator)
Mr Mackenzie, James (Riparian vegetation)
Dr Palmer, Rob (Macroinvertebrates)
Mr Rountree, Mark (Fluvial Geomorphology)
Dr Heath, Ralph (Physico-chemical variables)

Contributors to the process:
Dr Kleynhans, Neels (D:RQS)

Trainees:
The following trainees participated in the workshop:
Ms Jay, Jaqueline (Riparian vegetation)

Goods and Services Consequences:
The specialists from the Project Team involved in this study were:
Mr Koekemoer, Johan (Fish)
Dr Kotze, Piet
Ms Louw, Delana
Mr Mackenzie, James
Dr Heath, Ralph

EXECUTIVE SUMMARY

INTRODUCTION

In order for the Department of Water Affairs (DWA) to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments in the Vaal River System, higher levels of confidence is needed for the Reserve Determination within this study area. Therefore a Comprehensive Reserve determination study within Water Management Area (WMA) 8 has been undertaken to provide input to the Reconciliation studies and the integrated water quality management plan recently undertaken by the National Water Resources Planning Directorate (D: NWRP) of the DWA.

STUDY AREA

The Upper Vaal WMA is one of three WMAs in the Vaal River catchment, which is the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWAF, 2004).

The Upper Vaal WMA includes the Vaal, Klip, Wilge, Liebenbergsvlei and Mooi Rivers and extends to the confluence of the Mooi and Vaal Rivers. It covers a catchment area of 55 565 km^2. The locality and characteristics of the Ecological Water Requirement (EWR) sites are provided in the Table below.

THIS REPORT

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

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

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

- The operational scenarios (DWA, 2010a) were modelled by WRP and a time series was provided for each scenario at each EWR site.
- The time series was converted to a flow duration table and both was provided to the physico chemical and geomorphology specialist.
- These specialists had to provide a conclusion and resulting EC of the operational scenario assessed at the EWR to the biological responses team.
- These specialists completed the Physico-chemical Assessment Index (PAI) and Geomorphology Assessment Index (GAI) models to predict the driver EC.
- The riparian vegetation specialist then assessed the response on the marginal and other riparian zones and supplied this information to the instream biota specialists. This was done prior to the instream biota assessment as riparian vegetation is a driver in terms of important habitat for the instream biota.
- Where required, the riparian vegetation specialist ran the Vegetation Response Assessment Index (VEGRAI) model to predict the EC for the operational scenario.

The consequences of the operational scenarios on Goods and Services delivered by the River were also assessed. The process adopted was the analysis of potential economic changes based on a valuation of the status quo, that is, the value of the Goods and Services (G&S) currently provided by the water in River system, identifying the potential change that each of the key G&S may undergo in each of the scenario clusters. And where required the current value of G&S was then multiplied by these factors for each scenario, to provide an indication of the potential future value of the Goods and Services. The change in value was thus measured.

RESULTS AND CONCLUSIONS: ECOLOGICAL CONSEQUENCES

An overall assessment was undertaken for the Vaal River system to compare the scenarios developed by WRP (DWA, 2010). The results are summarised according to whether the scenarios meet the REC or not, and if not, to what degree. Colour coding and symbols should be interpreted as follows:

✓ REC EcoStatus or REC instream IS met.

X REC EcoStatus or REC instream is NOT met.

Light green with black ✓:	Meets REC EcoStatus including all components.
Dark Green with black ✓:	Meets the REC EcoStatus, but not all the components.
Orange with X:	The scenario does not meet REC requirements but meets the PES.
Purple with X:	The scenario results in an EC below the PES; D EC.
Red with X:	The results are below a D EC.

Summary of the consequences of the operational scenarios (Sc 4 - 8) at each EWR site

VAAL RIVER					
EWR SITE	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
EWR 1	✓	✓	✓	✓	✓
EWR 2	✓	✓	✓	✓	✓
EWR 3	✓	✓	✓	✓	✓
EWR 4	X	X	X	X	X
EWR 5	X	✓	✓	X	X
KLIP RIVER					
EWR 6	✓	✓	✓	✓	✓
WILGE RIVER					
EWR 8	✓	X	X	X	X
SUIKERBOSRAND					
EWR 9	✓	X	✓	X	✓
EWR 10	✓	X	X	✓	✓
BLESBOKSPRUIT					
EWR 11	X	X	X	X	X
KLEIN VAAL					
RE-EWR 1	✓	✓	✓	✓	✓
MOOI RIVER					
RE-EWR 2	X	X	X	X	X

A simplified version of this table is provided in the table below2. There are three codes used in the table and indicate the following:

✓ EWR objectives (REC) are met.

X EWR objectives (REC) are not met. The PES is also not being maintained (see below).

X(PES) EWR objectives (REC) are not met but the PES is still being maintained. This is relevant for sites where the REC is an improvement of the PES. The improvement cannot be met, but the PES is still maintained.

Summary of where the EWR objectives are met/achieved in the Upper Vaal River system

Site	PES	REC	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
VAAL RIVER MAIN STEM							
EWR 1	**B/C**	**B/C**	√	√	√	X	√
EWR 2	**C**	**C**	X	√	√	√	X
EWR 3	**C**	**C**	√	√	√	√	√
EWR 4	**C**	**B/C**	X (PES)	X (PES)	X (PES)	X (PES)	X (PES)
EWR 5	**C/D**	**C**	X (PES)	√	√	X (PES)	X (PES)
VAAL RIVER TRIBUTARIES							
EWR 6 (Klip River)	**B/C**	**B/C**	√	√	√	√	√
EWR 8 (Wilge River)	**C**	**C**	√	X	X	X	X
EWR 9 (Suikerbosrand River)	**C**	**B/C**	√	√	√	PES	√
EWR 10 (Suikerbosrand River)	**C/D**	**C/D**	√	X	X	√	√
EWR 11 (Blesbokspruit River)	**D**	**D**	X (PES)	X	X	X (PES)	X (PES)

Evaluations also were based firstly on a comparison of consequences on the MAIN RIVER and then compared to the consequences on the tributaries of the Vaal River as some of the tributaries can be operated independently without influencing the main stem. For decision making purposes it was also necessary to take into consideration the relative Ecological Importance and Sensitivity (EIS) of the different EWR sites.

The scenario grouping is according to the same situation WITH and WITHOUT the EWRs as follows:

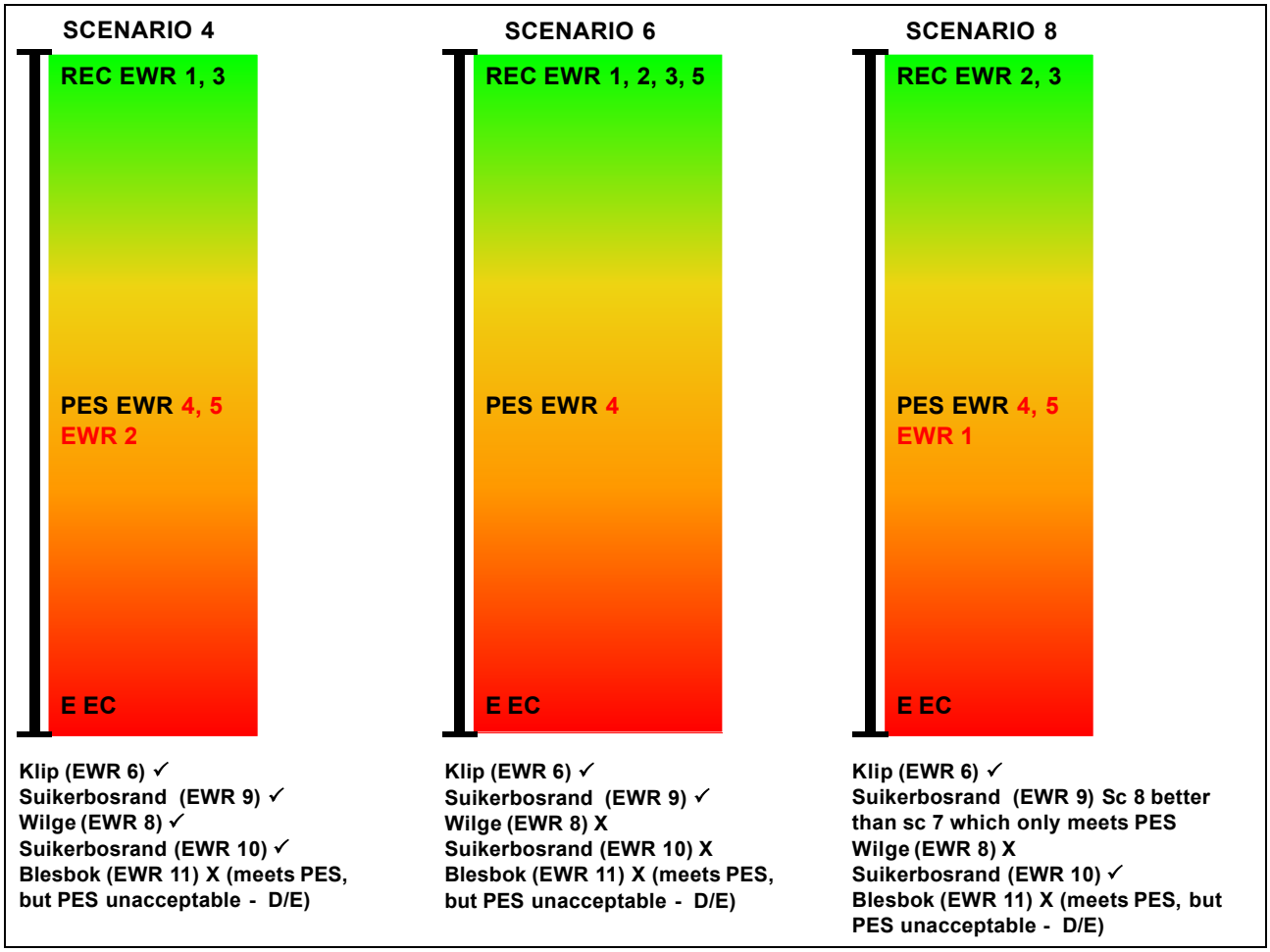
- Scenario 4 (current situation WITH EWR) – compared against the current situation and resulting PES.
- Scenario 6 (future development scenario WITH EWR) – compared against Scenario 5 which represents the future development scenario WITHOUT EWR).
- Scenario 8 (full utilisation scenario WITH EWR) – compared against Scenario 7 which represents the full utilisation scenario WITHOUT EWR).

Preliminary comparisons between scenario groupings showed that:

- Sc 4: there is no significant advantage in supplying the EWR under current conditions as there are no improvements. The current operation of the system meets the PES-REC at most sites.
- Sc 6 and Sc 5: There is no advantage in supplying the EWR under 2020 conditions as Sc 5 has the same ecological consequences as Sc 6.
- Sc 8 and Sc 7: There is no advantage in supplying the EWR under full utilisation as Sc 7 has the basically the same ecological consequences as Sc 8.

When comparing the 3 relevant scenario groupings (figure provided below), for the main Vaal River, Sc 5, related to the 2020 future development is the most desired. This is based on the fact that it achieves the REC at EWR 5 which is situated in the Vredefort Dome which is a World Heritage site. However, one must remember that this statement is based on the evaluation of the scenario provided by WRP and as there is no guarantee that in the interim, the operation could change from what WRP provided, or that there could actually be various possible scenarios, this statement could not hold true. Additionally, it is also the only scenario that achieves the EWR objectives at both EWR 1 and 2. It must be noted however that Scenario 7 does not meet the PES at EWR 1 only because fish drops with half a category. Taking into account the uncertainty coupled to the hydrological modelling and ecological interpretation, this can be evaluated as meeting the PES.

The tributaries are better off under current conditions, however, most of the tributaries can be addressed separately and further refinement of the Planning model rules could address some of the problems.



Comparison of Sc 4, 6 and 8

RESULTS AND CONCLUSIONS: GOODS AND SERVICES

The table below sets out a schematic summary of the impacts by scenario and EWR. Where shading is green the impact is positive. Darker green is more positive that light green. Yellow indicates neutral or results so mixed as to render a judgment of the impacts virtually impossible. Red indicates negative impact. Again darker red is a more sever negative impact than lighter red.

Consequences of the Operational scenarios on Goods and Services in the Upper Vaal

EWR site	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
1					
2					
3					
4					
5					
6					
8					
9					
10					
11					

Overall only two scenarios at EWR 2 and 11 could be said to be problematically negative from the perspective of goods and services.

RECOMMENDATIONS

Recommendations of further work required to confirm the results provided are described in the table below. The issue regarding each site which must be considered during any further development specifically around ad hoc monitoring is also provided in the table.

Identified issues to be addressed and further work needed in future

Site	Further work	Issues
EWR 1 Vaal	Yield modelling: Determine why there is a difference in hydrology under Sc 7 which results in fish dropping half an EC.	Unresolved water quality issues at this site that could be responsible for fish kills and the bad condition of fish. This site is critical (due to the unique and critical habitat) in this MRU in the Upper Vaal and monitoring is required which should also focus on identifying the cause of the problems regarding fish..
EWR 2 Vaal	Yield modelling: Determine why there is more water than required at both EWR 2 and 3.	There is currently too little flow at EWR 2 and 3. These two sites both consist of critical habitat in the stretch between Grootdraai and Vaal Dam. Any licenses that would require less flows must be tested to determine whether the EWR will be met.
EWR 3 Vaal	See above.	See above.
EWR 4 Vaal		This site is situated immediately below Vaal Dam in the short stretch of river available between the Vaal Dam and the Vaal Barrage and Lethabo Weir. EWR 4 requires an improvement under current conditions to meet the REC. It is acknowledged that the flow conditions are unlikely to be met. However, as this is the only stretch that still maintains viable breeding areas for the fish and therefore maintains the fish population in this stretch as well as acting as a refuge for tributaries, it is vital that there is no further degradation at the site. Monitoring is therefore required and any changes in the Vaal Dam's operation which exacerbates the current 'unfriendly' operating rules must be carefully considered.
EWR 5 Vaal		EWR 5 represents the stretch of river below the Vaal Barrage and upstream of the Mooi River confluence. This stretch runs through the Vredefort Dome and taking into account the importance of this world heritage site, no further degradation should be allowed. It is vital that non-flow related measures be considered that could improve this situation. No changes in flow operations that could be detrimental to this site should be considered. Monitoring is essential.
EWR 6 Klip	Although not part of this study, the hydrology regarding the present use must be updated. There are serious concerns on the illegal abstractions and it is highly likely that the modelled present day flows do not reflect reality. An update in hydrology for this site is important.	The biota seems to still be in good condition. However it is possible that they have not yet fully reacted to the obvious increase in abstractions and farm dams. Almost zero flow conditions were experienced during 2 field visits. There is also a very important wetland in the upper Klip River. Any licences that require further abstraction in flows should not be considered based on these results due to the uncertainty in the hydrology. A re-assessment would be required of the EWR once the updated hydrology is available. Monitoring is essential.
EWR 8 Wilge	Determine whether the operating rules associated with Sc 5 and 7 can be modified to accommodate the EWR. Test the EWR to determine whether any changes improve the situation. There is also uncertainty in the present hydrology as this does not reflect the extremely low flow conditions observed in the field. There is also potential of illegal abstractions.	The current problems at this site include too little flow and at times the river literally stops flowing. However, the fish species are mostly semi-rheophilic which means they can survive in pools and the macroinvertebrates could probably re-establish themselves after no-flow conditions. However, any licenses that further decrease flows must be carefully considered, taking into account the uncertainty regarding the hydrology.
EWR 9 Suikerbos-rand	Certain assumptions regarding the release capability of Balfour Dam has been made in the planning model. No	The current problems at this site include too little flow and almost zero flow conditions at times. The present hydrology did not reflect this during the EWR assessment. Any license

Site	Further work	Issues
	information is presently available to determine whether actual releases can be made. The evaluation of scenarios based on this assumption must be confirmed.	application that implies abstraction of flows must only be considered once more information on Balfour Dam is available. Balfour Dam (and Haarhoff) should be providing an EWR currently which it is not. Any decisions made on the basis of the evaluations of the scenarios must also be treated with care as these are based on an assumption that Balfour Dam can (and will) provide an EWR.
EWR10 Suikerbos-rand; EWR 11 Blesbok-spruit		Water quality issues with reference to urban run-off, mining and SAPPI are dominant at this site. Specific management plans that would probably not influence the main Vaal River are required to address the unacceptable PES in the Blesbokspruit.

The Upper Vaal River system has very high demands imposed on it by the irrigation sector, as well as industrial and domestic sectors and forms the backbone of the economic hub of South Africa.

No specific Ecological Reserve Monitoring has been initiated in this river system apart from the RHP monitoring conducted at EWR 9, 10, 11 and RE-EWR 2[1]. Immediate monitoring is necessary as the surveys undertaken during the Reserve study represent the baseline against which change is measured. These surveys were undertaken during 2007 and 2008 and it can already (pending changes in the catchments), not be applicable. The longer monitoring is delayed, the bigger the chance is that the baseline surveys will have to be repeated because of outdated data.

The main recommendation is that effective monitoring is started as soon as possible due to the economic importance of the Upper Vaal River and the presence of the Vredefort Dome Heritage site that falls within this study area below the Vaal River Barrage. The Upper Vaal River is exposed to regular water quality related impacts due to industrial activities that are not monitored as well as a failing municipal infrastructure that leads to pollution levels that lead to fish kills and the recreational activities being banned by the Department of Health, especially in the reaches below the Vaal Dam.

[1] According to Ms Hermien Roux and Mr Piet Muller, River Health Champions for the North West and Gauteng Provinces respectively (*Pers. Comm*., 2010).

ACRONYMS AND ABBREVIATIONS

AEC	Alternative Ecological Category
CD: RDM	Chief Directorate: Resource Directed Measures
COMBUD	Computer Based Budgets
D:NWRP	Directorate: National Water Resources Planning
DS	Downstream
DUV	Direct-use Values
DWA	Department of Water Affairs (Name change 2009)
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FDI	Flow dependent macroinvertebrate
FFHA	Fish Flow Habitat Assessment
FRAI	Fish Response Assessment Index
GAI	Geomorphology Assessment Index
GDP	Gross Domestic Product
GGP	Gross Geographic Product
G&S	Goods and Services
HFSR	Habitat Flow Stressor Response
IUV	Indirect-use Values
LSR	Large semi-rheophilic fish
LIM	Limnophilic fish
MDG	Millennium Development Goals
MIRAI	Macroinvertebrate Assessment Index
MRU	Management Resource Unit
MVI	Marginal vegetation macroinvertebrate
OV	Option Values
PAI	Physico-chemical Assessment Index
PD	Present Day
PDH	Present Day Hydrology
PES	Present Ecological State
PSS	Pump Storage Scheme
Quat	Quaternary catchment
REC	Recommended Ecological Category
RU	Resource Unit
Sc	Scenario
US	Upstream
VEGRAI	Riparian Vegetation Response Assessment Index
WMA	Water Management Area
WRPM	Water Resources Planning Model

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

1 BACKGROUND AND INTRODUCTION

1.1 BACKGROUND

In order for the Department of Water Affairs (DWA) to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments in the Vaal River System, higher levels of confidence is needed for the Reserve Determination within this study area. Therefore a Comprehensive Reserve determination study within Water Management Area (WMA) 8 has been undertaken to provide input to the Reconciliation studies and the integrated water quality management plan recently undertaken by the National Water Resources Planning Directorate (D: NWRP) of the DWA.

1.2 STUDY AREA

The Upper Vaal WMA is one of three WMAs in the Vaal River catchment, which is the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWAF, 2004).

The major tributaries in the Upper Vaal WMA include the Vaal, Klip, Watervals, Wilge, Liebenbergsvlei, Suikerbosrand, Klipspruit and Mooi Rivers and extend to the confluence of the Mooi and Vaal Rivers. It covers a catchment area of 55 565 km^2. The locality and characteristics of the Ecological Water Requirement (EWR) sites are provided in Table 1.1 and Figure 1.2. Information on site selection and the Management Resource Units (MRUs) are provided in DWAF (2008).

Table 1.1 EWR site detail of the Upper Vaal WMA

EWR site number	EWR site name	River	National RHP[1] site	Co-ordinates		EcoRegion (Level II)	Geomorphic Zone	Altitude (m)	RU[2]	Quat[3]	Hydrological gauge
				Latitude	Longitude						
EWR 1	Uitkoms	Vaal	C1Geel_Unspe	-26.8728	29.61384	11.05	Lowland	1570	MRU Vaal B	C11J	C1H007
EWR 2	Grootdraai	Vaal	C1Vaal Braks	-26.9211	29.27929	11.03	Lowland	1537	MRU Vaal C	C11L	C1H019
EWR 3	Gladdedrift	Vaal	C1Vaal-Villie	-26.99087	28.72971	11.03	Lowland	1487	MRU Vaal C	C12H	C1H012
EWR 4	De Neys	Vaal	C2Vaal-Deny	-26.84262	28.1123	11.03	Lower Foothills	1445	MRU Vaal D	C22F	C2H122
EWR 5	Skandinavia	Vaal		-26.93243	27.01367	11.08	Lowland	1309	MRU Vaal E	C23L	C2H018
EWR 6	Klip	Klip	C1Klip-Unspe2	-27.36166	29.48503	11.06	Lower Foothills	1593	MRU Klip C	C13D	
EWR 7	Upper Wilge	Wilge		-28.20185	29.55827	11.03	Lowland	1692	MRU Wilge A	C81A	Redmans Werf 319
EWR 8	Bavaria	Wilge	C8Wilg-Belwh	-27.80017	28.76778	11.03	Lowland	1573	MRU Wilge B	C82C	C8H028
EWR 9	Suikerbos US	Suikerbosrand	C2Suik-Dehoe	-26.6467	28.38197	11.01	Lower Foothills	1509	RU Suiker A	C21C	
EWR 10	Suikerbos DS	Suikerbosrand	Close to C2Suik-Badfo	-26.68137	28.16798	11.01	Lowland	1453	RU Suiker B	C21G	
EWR 11	Blesbokspruit	Blesbokspruit	C2Bles-Marai (locality incorrect)	-26.47892	28.42488	11.03	Lower Foothills	1528	RU Bles A	C21F	
Rapid Level sites											
RE-EWR 1	Klein Vaal	Klein Vaal	C1KVaal-unspe	-26.9128	30.17497	11.02	Lower Foothills	1620	MRU Kvaal A	C11C	
RE-EWR 2	Mooi	Mooi	Close to C2Mooi-Klerk	-26.2587	27.15973	11.01	Lower Foothills	1457	RU Mooi B	C23G	

1 River Health Programme 2 Resource Unit 3 Quaternary catchment

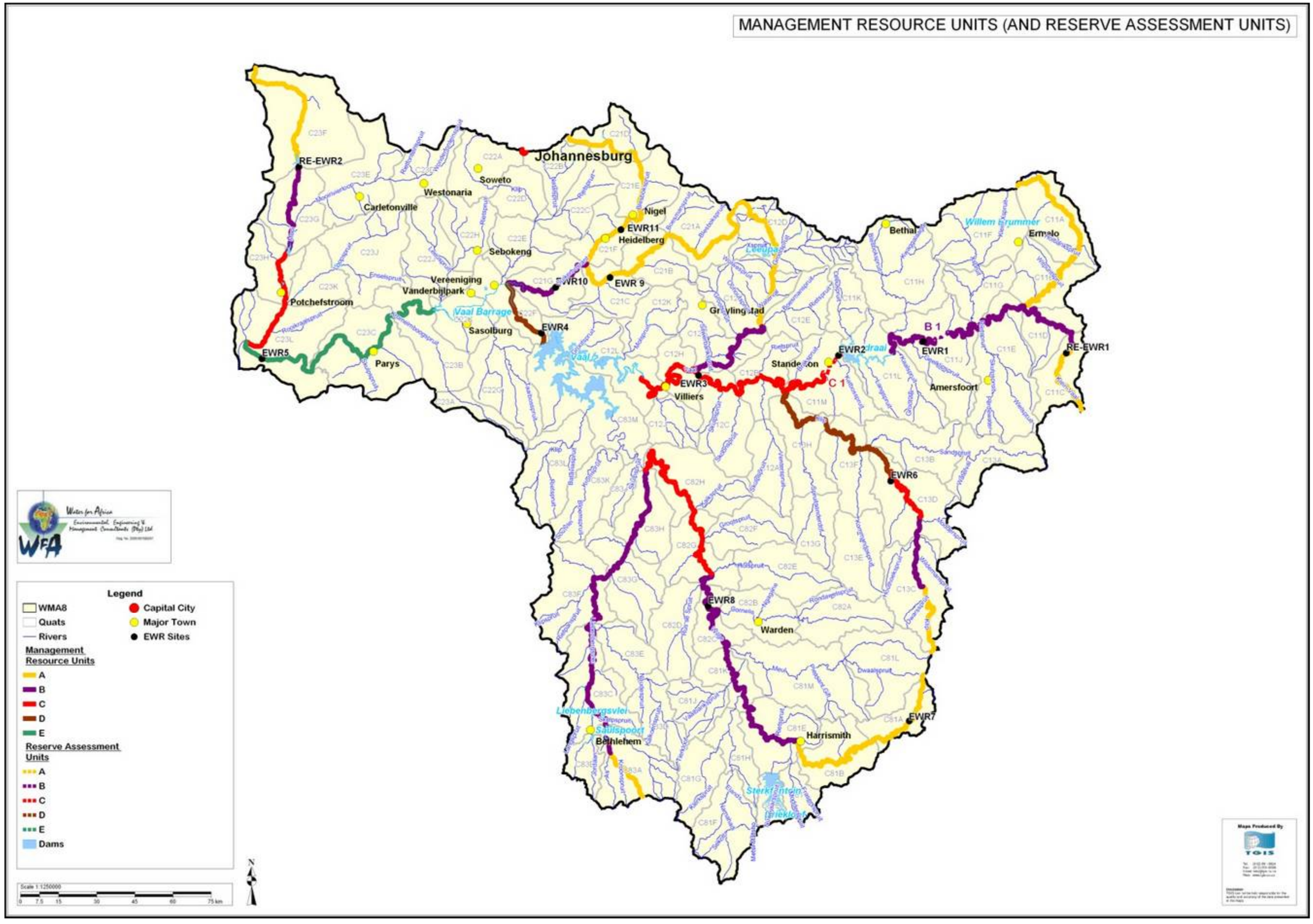


Figure 1.1 Locality of EWR sites and Management Resource Units

1.3 PURPOSE OF THE REPORT

This report serves to document the results of the specialist meetings held from 17 – 21 May 2010, providing ecological and Goods and Services (G&S) consequences of a range of operational scenarios based on the output from the planning model (refer to report produced by WRP, RDM/C000/01/CON/0607; DWA, 2010a).

1.4 OUTLINE OF THE REPORT

The report outline is given below. The suite of EcoStatus models and component assessment models applied during this task is provided electronically (RDM/WMA8C000/01/CON/0710) (DWA, 2010b).

1.4.1 Chapter 2: Ecological Consequences: Approach

This chapter provides the methods and approach followed for deriving ecological consequences for each Reserve component.

1.4.2 Chapter 3: Goods and Services: Approach and Method

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

1.4.3 Chapter 4: Preliminary screening of Scenarios

Background and a summary of the operational scenarios assessed at each EWR site are provided.

1.4.4 Chapter 5 - 15: Determination of Ecological consequences

This consists of the results of evaluating the effect of the various scenarios on the EC of the various EWR sites in the Upper Vaal WMA:

1.4.5 Chapter 16: Results and Conclusions: Ecological Consequences

The results of the ecological consequences of the operational scenarios in the Upper Vaal River system are summarised and discussed

1.4.6 Chapter 17: Results and Conclusions: Goods and Services

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

1.4.7 Chapter 18: Recommendations

Recommendations are made and issues are discussed which should be addressed in future studies.

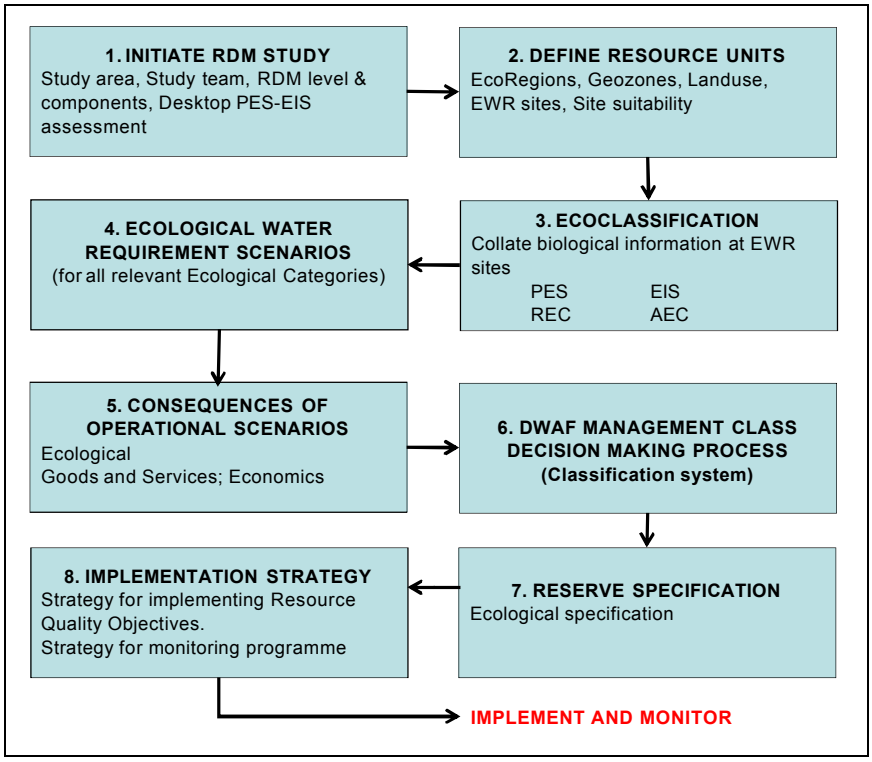
1.4.8 Chapter 19: References

2 ECOLOGICAL CONSEQUENCES: APPROACH

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

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

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



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

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

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

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

This should then allow for informed decision-making regarding which Ecological Category and Reserve should be signed off. This report provides the results of the ecological and G&S components. The socio economic consequences are discussed in RDM Report RDM/WMA8C000/01/CON/0210 (DWA, 2010c).

2.1 APPROACH

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

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

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

- The operational scenarios (DWA, 2010a) were modelled and a time series was provided for each scenario at each EWR site.
- The time series was converted to a flow duration table and both was provided to the physico chemical and geomorphology specialist.
- These specialists had to provide a conclusion and resulting EC of the operational scenario assessed at the EWR sites to the biological responses team.

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

- These specialists completed the Physico-chemical Assessment Index (PAI) and Geomorphology Assessment Index (GAI) models to predict the driver EC.
- The riparian vegetation specialist then assessed the response on the marginal and other riparian zones and supplied this information to the instream biota specialists. This was done prior to the instream biota assessment as riparian vegetation is a driver in terms of important habitat for the instream biota.
- Where required, the riparian vegetation specialist ran the Vegetation Response Assessment Index (VEGRAI) model to predict the EC for the operational scenario.

The following was then undertaken for the instream biota assessment:

- Each time series was converted into a stress duration table and provided on a graph for two months (the same months evaluated during the EWR workshop) that included the EWR scenarios, natural, and present day hydrology (PDH). For further explanation regarding the Habitat Flow Stressor Response (HFSR) process and interpretation of the stress graphs, refer to DWA (2009b) and below.
- The requirements set for the low flow EWR scenarios for both fish and macroinvertebrates were copied onto these graphs.
- The operational scenarios were then compared to the EWRs set for various ECs. For example, if the operational scenario lied between the B EC and C EC for fish for a maintenance flow in the dry season, the operational scenario could either be a B, a B/C or a C.

- The information on the driver responses were also used to interpret the response to the operational scenarios.
- If it was not obvious what the resulting EC was, the stress and habitat implications for the operational scenario were investigated and the responses modelled in the Fish Response Assessment Index (FRAI) and Macro invertebrate response Assessment Index (MIRAI) to determine the EC.

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

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

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

2.2 PHYSICO-CHEMICAL COMPONENT

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

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

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

2.3 GEOMORPHOLOGY

- Monthly volumes and flow duration curves provided a guideline for estimating the size and frequency of floods under each of the scenarios and allowed for some insight into the consequences for high flows at the EWR sites under each of the scenarios. This provided improved confidence in the assessment method.
- A qualitative description of the changes in geomorphology and riparian vegetation of each operational scenario per site was provided to the instream biota specialists.

- Floods: Total volumes of the EWR floods in each month were compared to the total volumes available under each scenario. Where possible guidance by the systems modeller was provided on whether the changes were likely to be in terms of small, moderate or large floods.
- The GAI/VEGRAI for the PES or Alternative Ecological Category (AEC) (whichever most appropriate) was adjusted and these adjustments to the different metrics were highlighted in the model and are available electronically.

2.4 RIPARIAN VEGETATION

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

the model and are available electronically (DWA, 2010b). The new Ecological Category was recorded for each scenario and the ecological consequences were documented (this report).

2.5 INSTREAM BIOTA

The two months assessed during the EWR specialist meeting represented the lowest (August) and highest (February) monthly volumes. During the assessment of operational scenarios, additional months might also require assessment as the initial design of the operational scenarios could result in other months being the higher or lowest flowing months. These months were then also assessed. .

2.5.1 Macroinvertebrates

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

2.5.2 Fish

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

- The resulting change in EC was described qualitatively (and provided in this report), and the models are provided as electronic data DWA (2010b).

2.6 INTERPRETATION OF STRESS DURATION GRAPHS

Figure 2.1 is an example of a stress duration graph representing a typical scenario evaluation and illustrates the stress requirements and stress points required for different ECs set during the EWR scenario step. For further information of the Habitat Flow Stressor Response (HFSR) method see HFSR manual (IWRS2S, 2004) and DWA (2009b) of this study. The graph should be interpreted as follows:

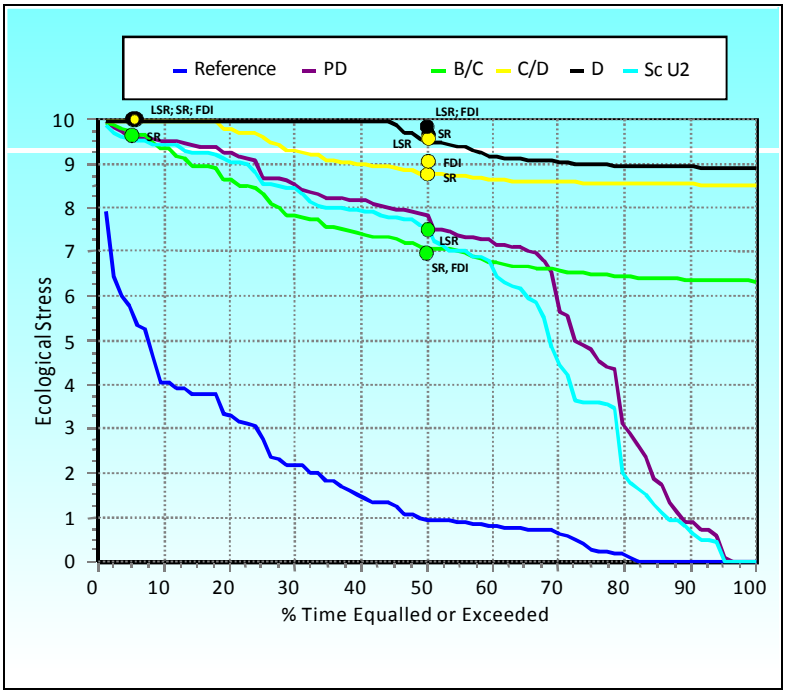


Figure 2.1 Example of a stress duration graph

Figure 2.1 illustrates the hypothetical stress requirements and stress points required for a C/D PES (yellow line), B/C REC (green line) and a D AEC (black line). The purple line illustrates Present Day flows while the blue line represents reference flows. The different coloured circles indicate the requirements of the instream biota as determined during the EWR scenario step (DWA, 2009b). Each circle is labeled as follows and indicates a different biotic component:
SR – Small rheophilic fish guild.
LSR – Large semi-rheophilic fish guild.
LIM – Limnophilic fish guild.
FDI – Flow dependent macroinvertebrates and/or MVI – marginal vegetation macroinvertebrates

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

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

The stress associated with Sc U2 lies closest to the B/C requirements for all the instream components. Specialists have to predict whether the scenario, which represents increased stress

from the B/C requirement (10% to 58% on the x axis), still lies within the B/C range or whether it represents a lower category (i.e. a C or C/D).

The process, as described in Section 2.1 - 2.5 is followed to determine the EC and then the EcoStatus associated with each scenario is determined.

2.7 COMPARISONS OF THE IMPACT OF THE DIFFERENT SCENARIOS

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

Table 2.1 EWR 1: Predicted ECs for each operational scenario

Driver Components	PES	REC	Sc 4, 7, 8	Sc 5, 6
WATER QUALITY	E	D/E	E	E
GEOMORPHOLOGY	C	C	C	C+
Response Components	**PES**	**REC**	**Sc 4**	**Sc 5**
FISH	C	B	C	B/C
MACROINVERTEBRATES	C	C	C	C
INSTREAM	C	B/C	C	C
RIPARIAN VEGETATION	D	C	D	C/D
ECOSTATUS	C/D	C	C/D	C

The above table is then summarised according to whether the scenarios meet the REC or not, and if not, to what degree.

The following coding is used throughout the document and an example is provided in Table 2.2. A fold-out A3 page (15-10) is also provided of the coding for easy reference at all times..

✓ REC EcoStatus or REC instream IS met.
X REC EcoStatus or REC instream is NOT met.

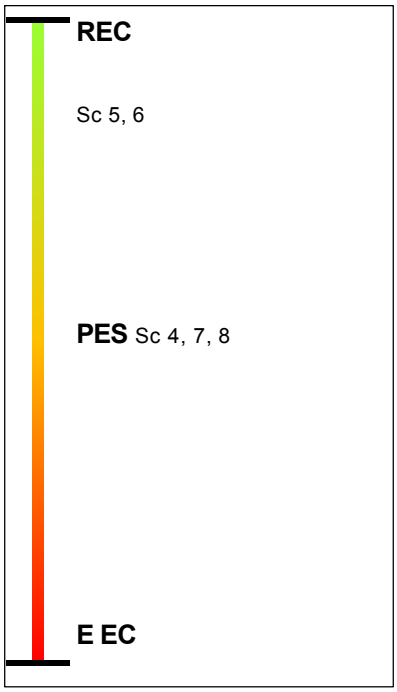
Light green with black ✓:	Meets REC EcoStatus including all components.
Dark Green with black ✓:	Meets the REC EcoStatus, but not all the components.
Orange with X:	The scenario does not meet REC requirements but meets the PES.
Purple with X:	The scenario results in an EC below the PES; D EC.
Red with X:	The results are below a D EC.

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

VAAL RIVER					
EWR SITE	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
EWR 5	X	✓	✓	X	X

The above example illustrates that Sc 4, 7 and 8 meets the PES but not the REC requirement and Sc 5 and 6 meet the REC but not all the components.

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



Scenario 4, 7 and 8 meets the PES requirement. Scenario 5 and 6 is an improvement of the PES but does not meet the REC requirement. Two components have improved by half a category and the EcoStatus has improved from the PES similar to the REC, although not all components.

Figure 2.2 Illustration of the degree to which a REC is met

2.8 ELECTRONIC DATA SUPPLEMENTING THIS REPORT

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

3 GOODS AND SERVICES: APPROACH AND METHODS

3.1 OVERVIEW OF GOODS AND SERVICES

Natural habitats and ecosystems provide a huge range of environmental goods and services that contribute enormously – and are even essential – to human well-being. Protecting these areas is essential in order to achieve sustainable development. River systems and their associated use values are of particular importance.

Use values associated with environmental goods and services accrue to humans from the use of the environment consumptively or productively. They are classified into direct-use values (DUV), indirect-use values (IUV), and option values (OV). The DUV refer to values associated with direct consumption, production, viewing landscapes, bird watching, or even viewing of photographic products. Hunting and slaughter of wildlife for meat or skins constitute direct consumption of species from the environment. Grazing by livestock, harvesting medicinal plants and animals, and harvesting indigenous or endemic plants for road-side sale constitute productive activities whose economic values are realised in the form of profits from sale of final goods such as livestock, medicinal services, and the natural resources themselves.

The IUV refer to ecological or ecosystem values such as production of nutrients, maintenance of efficiently functioning riverine ecosystems, water purification, maintenance of specific gaseous qualities and hydrological cycles, and formation of soil and organic matter. These values do not accrue directly to users but support production of resources that bear direct use to people.

In particular and important in the context of the Upper Vaal River Water Management Area (WMA) is the capacity of a water body to assimilate or dilute wastes. This represents a real economic value when the costs of water quality effects are considered. Water managers rely on dilution flows in maintaining water quality standards in rivers. The release of water from storage for low-flow augmentation is a recognised use of multiple purpose reservoirs. The value of water in this use is related to the variation in natural streamflows.

The value of water for waste dilution is usually calculated as either the waste-treatment costs foregone or downstream damages avoided. But damages are hard to estimate reliably.

Option values are values attached by individuals to the maintenance and preservation of environmental goods in order to reserve an option to use them, directly or indirectly, in the future. A different notion of option value known as vicarious value relates to creating use options for contemporary generations. Value is not derived from use but from creating an option for use by others in the same generation. It is in this vicarious sense that option value is also seen as a non-use value.

Although all three use values make up the range of goods and services that are pertinent to the last – option values – are not being directly considered within the context of this present study. Although it is theoretically possible to generate option values this is both a time consuming as well as, given the size of the catchment, very expensive.

A consideration of these goods and services is however an exercise that is of considerable importance within the context of development planning for resource utilisation in the context of the poverty and vulnerability that pervades much of the catchment. As King (2007) points out:

Environmental goods and services are typically public goods, many of which are also managed under common property systems. Difficulty arises in realising the value of these goods and services in such a way that allows them to be included in the decision-making framework so as to mitigate adverse impacts on these resources as government actions are implemented. This has adverse implications for the national economy and the vulnerable poor. Social welfare and livelihoods can only be sustained through a policy environment that reduces the vulnerability of society and nature to resource-scarcity threats.

This requires technical and food security interventions as well as interventions that offset market, policy and institutional failures.

A poor understanding of the value of environmental goods and services will continue to encourage their overuse and degradation, the poor internalisation of the associated costs and benefits of their use, and sub-optimal allocation among competing users, thus further exacerbating development constraints[2].

Further the 2005 Millennium Ecosystem Assessment[3] concluded that the degradation of environmental services is a significant barrier to achieving the Millennium Development Goals (MDGs) – and that this impediment could grow significantly worse over the next 50 years. It also found that the harmful effects of environmental service degradation are often the principal drivers of poverty and social conflict.

3.2 THE UPPER VAAL WMA IN THE CONTEXT OF GOODS AND SERVICES

The Upper Vaal WMA is one of the most important economic sectors in the country and nearly 20% of the GDP of South Africa originates from the Upper Vaal WMA. Only the adjacent Crocodile (West) and Marico WMA, with about 24%, contributes more to the GDP. The contribution of the different sectors to the Gross Geographic Product (GGP) in the Upper Vaal WMA reflects a diversified economy with a strong industrial and financial base.

Mining is critical to the WMA and products of the mining industry in the Upper Vaal WMA include coal, precious metals (gold, uranium, etc.), base metals, semi-precious stones and industrial minerals. The major impact of the mines on the water resource is the water pumped from the mines to dewater the underground workings mainly of the gold mines. The salinity loads associated with these mine discharges together with the sewage return flows contribute significantly to the salinity problems that are experienced in the Vaal Barrage and downstream river system. The mine dewatering and the diffuse salinity contributions from the highly developed urban and industrial areas in the Vaal Barrage catchment has resulted in the need for the currently applied blending and/or dilution operating rules applied downstream of Vaal Dam.

Despite the large areas under cultivation, agriculture only contributes about 2% of the GGP. Agriculture, however, has important linkages to other sectors and provides livelihood to a large proportion of the rural population.

[2] See King N.A (2007) Economic Valuation of Environmental Goods and Services in the Context of Good Ecosystem Governance, Water Policy 9 (Supplement 2)

[3] See www.millenniumassessment.org

In addition to being economically important the Upper Vaal WMA is the most populous WMA in South Africa. The total population is estimated at 7.5 million people in the year 2009.[4] More than 80% of the population in the WMA reside in the area downstream of the Vaal Dam with nearly 97% living in an urban environment.

The demography of the WMA is heavily influenced by economic opportunities and potential. Projections are therefore for continued strong growth in urban population in the sub-area downstream of Vaal Dam where most of the economic activity is centred. A decline in population is projected for the Wilge sub-area due to the movement of people out of Phuthaditjaba and the former QwaQwa area. The urban poor, and the poor in rural areas, are as important in the consideration of the distribution and use of water resources. However given the nature of the terrain and economic activities that apply there is not overall, a high dependence on goods and services for livelihoods.

Following a site visit and literature research the following goods and services were deemed to be essential to the area and warranted further assessment by the specialist team. These are set out in Table 3.1 below.

Table 3.1 List of Relevant Goods and Services

Resources	Common Name	Scientific
Vegetation		
	Sedges	*Cyprus marginatus*
		Schoenoplectus corymbosus
	Grazing	*Cynodon dactylon*
	Terrestrial grasses	*Themeda triandra*
Medicinal	Vlei lily	*Crinum bulbispermum*
Trees/Wood		*Diospyros lycioides*
		Rhus pyroides
		Celtis africana
		Salix mucronata
		Rhus lancea
		Rhus pyroides
Fish		
	Yellow Fish - small mouth	*Labeobarbus aeneus*
	Yellow Fish - largemouth	*Labeobarbus kimberleyensis*
	Sharptooth barbel	*Clarias gariepinus*
	Carp	*Cyprinus carpio*
	Largemouth bass	*Micropterus salmoides*
	Mudfish	*Labeo capensis (Umbratus)*
Subsistence fishing		
Recreational Fishing		
Services		
Waste assimilation		
Waste dilution		
Cultivated floodplains		
Disservices as costs		

[4] This is up from the 6 million recorded in the National Census 2001 and is based on population estimates generated by Statistics SA. The WMA is thus not only populous but growing at a rate above that of much of the rest of South Africa. This is largely due to in-migration.

Resources	Common Name	Scientific
Pathogens treatments		
Pathogens productivity loss		
Cholera treatment		
Cholera productivity loss		
Water treatment costs		

3.3 METHODS

This report provides the outcomes of the evaluation and forecast for each EWR scenario, the social and economic values of changes in the water availability to the socio-economic sectors as well as the value of the ecosystem services by leaving different amounts of water in the river reaches of the Upper Vaal WMA.

- Changes in value of ecosystem services for different EWR scenarios.
- Optimisation of the overall benefits from water re-allocation.

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

The analysis of potential economic changes will be based on a valuation of the status quo, that is, the value of the Goods and Services currently provided by the water in the catchment systems.

The biophysical specialists then identified the potential change that each of the key Goods and Services may undergo in each of the scenario clusters. The potential change will be noted as a factor and used in later calculations. For example, no change = 1, a 50% increase = 1.5, and a 20% decrease = 0.8.

Where required the current value of Goods and Services was then multiplied by these factors for each scenario, to provide an indication of the potential future value of the Goods and Services. The change in value is thus measured.

The Scenarios evaluated are as set out in Section 5, Table 5.1. Scenarios were considered, where relevant, against the EWR sites. Sites that were part of the overall study approach were the following:

- EWR 1: Uitkoms
- EWR 2: Grootdraai
- EWR 3: Gladdedrift
- EWR 4: De Neys
- EWR 5: Scandinavia
- EWR 6: Klip
- EWR 8: Bavaria
- EWR 9: Suikerbos US
- EWR 10: Suikerbos DS
- EWR 11: Blesbokspruit

4 PRELIMINARY SCREENING OF SCENARIOS

Detailed information regarding operational scenarios is documented in RDM/C000/00/CON/0607. Table 4.1 provides a summarised description of the scenarios, as well as reasoning for evaluating the specific scenario at the respective EWR sites.

Table 4.1 Summary of the evaluated Scenarios

Sc No	Dev Level	EWR Status	Scenario description	Reasoning
1	2008	Excluded	Base scenario representing the status quo.	This is a new PRESENT DAY. This scenario was not evaluated, but differences from the old PD (used for determination of EWR) were noted and reasoning was provided.
4	2008	Included	Based on Scenario 1. EWR Scenario: With exception of EWR 4 and EWR 5[1], all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Although EWRs are provided as a demand, it was still evaluated. One EWR site (e.g. in the Lower Vaal), could drive the requirements and result in unacceptable situations at EWR sites in the Upper Vaal (too much flow e.g.). NB: The EWR was included as a priority demand and this has a knock on effect on other users, and the operating rules of dams. This is relevant for all scenarios where dams are included.
5	2020	Excluded	Sc 1 representing the future 2020 development conditions excluding the EWRs. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system. Includes proposed Polihali Dam and conveyance infrastructure. Includes proposed re-use of mine water. Includes projected possible transfer to the Crocodile catchment.	Key scenarios. Includes most likely future developments and illustrates resulting flows at EWR sites. NO EWRs were included as a demand in the system. Basically, this is the WHAT IF scenarios, i.e., what if we manage the system in this manner without providing EWRs – will the EcoStatus change and if so, how much.
6	2020	Included	Based on Sc 5. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 5 and Sc 4.
7	Full utilization (Future development scenario)	Excluded	Scenario representing the full utilization of available water. Based on current infrastructure. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system.	This is also a future scenario, but brings in new developments apart from the VRESSAP pipeline. Full utilisation means that there is allocated water, or water available in dams, which have not been used yet.
8	Full utilization (Future development scenario)	Included	Based on Sc 7. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 7 and Sc 4.

1 To achieve the REC at EWR 4 and 5 less flow than present is required in the dry season and more flows in the wet seasons. Yield models will only include an EWR demand and then make provision if the flows passing the EWR site is less than required. It will therefore assume that if higher flows than the demand is achieved, this would be a positive outcome in terms of the Ecological Reserve. It was deemed impractical to set a high flow limit and therefore decrease supply to other users when the Reserve requires this. Including EWR 4 and 5 as a demand in a yield model would be contrary to the actual Reserve requirements.

EWR 7 was excluded from the scenario modeling due to the small catchment size, where the resolution is not compatible with that of the Water Resources Planning Model (WRPM).

5 EWR 1: UITKOMS (VAAL RIVER) - ECOLOGICAL CONSEQUENCES

The flow at this EWR site is influenced by inter-basin transfers from Heyshope and Zaaihoek dams in support of Grootdraai Dam. The 90% long-term operating rule was adopted for the Present Day (2008) scenario analyses whereby transfers are made from Heyshope and Zaaihoek dams to maintain a storage level of 90% within Grootdraai Dam. Transfers from Heyshope Dam are limited to a maximum rate of 4 m^3/s due to the constraints of the conveyance infrastructure and associated transfer losses. Transfers from Zaaihoek Dam can be made at a maximum rate of 0.651 m^3/s at the 2008 development level. The latter is dependant on the excess yield available from the Zaaihoek Dam after supplying the in-basin water requirements. For Sc 7 and 8 (maximum utilization of available water) the maximum transfer from Zaaihoek Dam was limited to 0.252 m^3/s.

Catchment development comprises of irrigation water abstractions from the main stem of the river as well as abstractions for urban water use from smaller dams in the tributaries of the Vaal River. For the purposes of the EWR analysis it was assumed that these small dams and their users will not contribute towards supplying the Ecological Reserve. Therefore, only the water supply to irrigators situated upstream (US) and downstream (DS) of EWR 1 was influenced by the implementation of the Ecological Reserve.

It should be noted that the EWR was not fully met during 8 of the 900 months of analysis (i.e. 0.9% of the time). This is due to the fact that the EWR at this site was based on the Present Day flows which included the support from Heyshope and Zaaihoek dams under 2008 development conditions. The EWR for this site were thus set to be higher than the natural flows. However, the operation of these two dams for Sc 7 and 8 (maximum utilization of available water) are different to that of Sc 1 and 4 resulting in less transfers to the Vaal and failure in supply to the EWR. Scenarios 4 – 8 were assessed and discussed in Section 5.1 – 5.9.

5.1 IMPACT OF SCENARIO 4

Figure 5.1 illustrates the stress requirements and stress points required for a B/C PES and B REC (purple curve). The red curve illustrates the original Present Day flows that were used during the study while the yellow curve is the new present day (PD) flows based on 2008 hydrology which is an improved representation of the current status quo. In the dry season, Sc 4 (black curve) represents decreased stress from PD 08 between 0 - 35% exceedence, where after the scenario is similar to PD 08. During summer stress is lower than PD 08 for 0 – 10% exceedence and is very similar to PD 08 for the rest of the season.

DRY SEASON **WET SEASON**

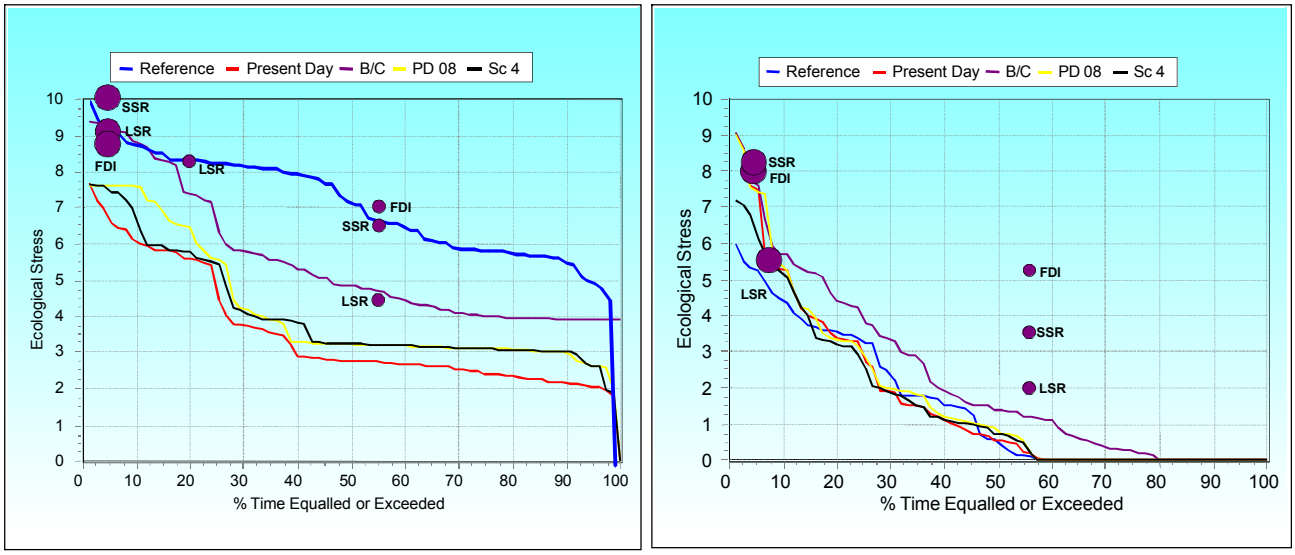


Figure 5.1 Stress duration for EWR 1: Dry and Wet season, Sc 4

5.2 ECOLOGICAL CONSEQUENCES OF SCENARIO 4

5.2.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC1↓	AEC2↓	Sc 4	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	C	C	C	Decreased base flows to below natural (no transfers) with decreased moderate floods. No dilution will occur and therefore mining impacts will increase.	Increased base flows in winter for longer period of time, greater fluctuations in temperatures due to interbasin transfers. This in effect will dilute any of the other water quality variables but increase turbidity due to higher erosion.
The water quality will remain in a C EC.					
GEOMORPHOLOGY					
B/C	C	C	B	Minor to moderate increased dry season base lows (relative to Present Day).	No major changes in the high flows (relative to Present Day).
The site is bedrock controlled and the morphology is very stable. However, moderate and large floods are required to recharge the more sensitive floodplains up- and downstream of the site. Floods do not differ markedly from Present Day, and base flow changes are minor, so no change in the EC is expected.					

5.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC1↓	AEC2↓	Sc 4	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
A/B	B/C	B/C	A/B	Inundation pressure is almost identical to PD flows and will not result in changes to riparian vegetation structure, composition or function. Scenario 5 and 6 have less severe dry season droughts which will facilitate higher survival rates during droughts, but not likely to make a difference to the PES in the longer term.	Similar inundation of sedges during wet season base flows. Inundation during the wet season is required and beneficial for *Cyperus marginatus* and *Gomphostigma virgatum* (the dominant species). Wet season drought flows are higher than PD and also tend more towards natural. This will result in a less stressed population and will maintain the current high density on both marginal and lower zones. There are no significant changes to high flows, so the effects of

					floods will not change anything.
The added inundation in the wet season will not result in changes to the PES since the two main impacts were too much inundation during the dry season and a small proportion of exotic species. The PES therefore remains A/B.					
FISH					
C (B)	D	D	C	Fish stress/habitat suitability for LSR guild (A EC) under maintenance, drought and overall flows during dry season is similar to Natural, PD, PES, REC (A). No change from PES is expected.	The LSR is in a C EC which is lower than natural and slightly lower than PES-REC (B), and better than PD (D).
The overall trends in flows and fish stress are that LSR will remain in same EC than natural hydrology, PD and PES-REC, namely EC of A. The overall conclusion is that the EC should probably improve slightly from PD conditions, but remain within the PES and REC of an overall C (based on FRAI).					
MACROINVERTEBRATES					
C (B)	C	D	C	No changes are expected and macroinvertebrates remain in the PES.	
ECOSTATUS					
B/C	C	C	B/C	Scenario 4 results in conditions very similar to the PES and REC as all the components remain stable.	

5.3 IMPACT OF SCENARIO 5 AND 6

The stress and flow duration graphs indicated that the 2020 development scenarios (Sc 5 and 6) were similar. Figure 5.2 illustrates Sc 5 and 6 represented by the light blue and dark green curves respectively. These scenarios represent decreased stress from PD 08 and similar to PD during drought periods. Maintenance conditions are similar to PD 08 and improved from the PES and REC requirements. Sc 6 provides less stress than Sc 5 during wet season. Both scenarios represent decreased drought stress while maintenance is similar to PD and PD 08.

DRY SEASON **WET SEASON**

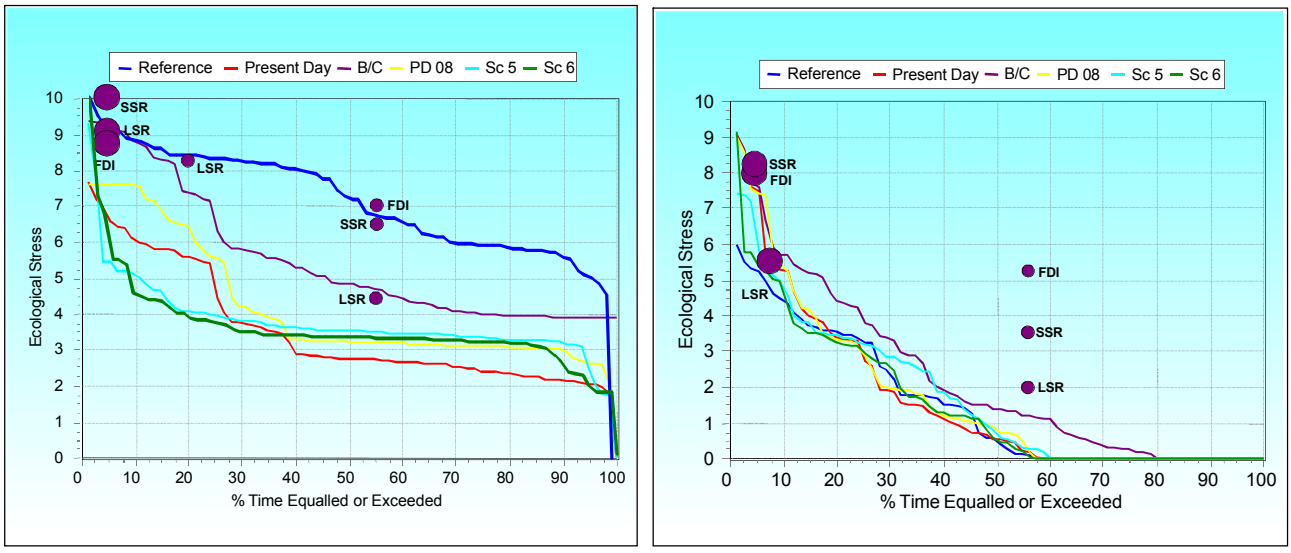


Figure 5.2 Stress duration for EWR 1: Dry and Wet season, Sc 5 and 6

5.4 ECOLOGICAL CONSEQUENCES: SCENARIO 5 AND 6

5.4.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC1↓	AEC2↓	Sc 5, 6	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	C	C	C	Refer to Sc 4.	
GEOMORPHOLOGY					
B/C	B/C	C	C	Minor changes (relative to PD) in the dry season flows.	An increase in late wet season base flows is likely to further accelerate the incision and erosion of the sensitive alluvial floodplain reaches up- and downstream of the site.
The site is bedrock controlled and the morphology is very stable. However, moderate and large floods are required to recharge the more sensitive floodplains up- and downstream of the site. Further incision will reduce overbank flooding; and simultaneously increase turbidity and fine sediment deposition in the main channel.					

5.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC1↓	AEC2↓	Sc 5, 6	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
A/B	B/C	B/C	A/B	Refer to Sc 4.	
FISH					
C(B)	D	D	C	Fish stress/habitat suitability for maintenance, drought and overall (all flow durations) are similar than Natural, PD, PES, REC and the LSR guild is in an A EC.	Fish stress/habitat suitability similar to Natural, indicating improved conditions from PD (D) and PES-REC (B) and the LSR guild is in an A EC.
The overall trends in flows and fish stress are that LSR may reach similar status than under natural conditions, therefore being in an improved status compared to PD, PES and REC conditions. The overall improvement under Sc 5 in terms of flow is however slight and will not result in a significantly higher FRAI score (slightly higher at 72.1%), as most impacts on fish at the site is non-flow related (water quality, alien fish species and migration barriers).					
MACROINVERTEBRATES					
C(B)	C	D	C	No changes are expected and macroinvertebrates remain in the PES.	
ECOSTATUS					
B/C	C	C	B/C	Scenario 5 and 6 result in the deterioration of geomorphology as increased base flows accelerate the incision and erosion of the sensitive alluvial floodplain reaches up- and downstream of the site. The rest of the components remain in the PES and therefore the scenario results in the same EcoStatus as the PES and REC.	

5.5 IMPACT OF SCENARIO 7

Scenario 7 represented by the orange curve in Figure 5.3 represents increased stress from PD 08 during the dry season. Stress is higher than the REC between 0 – 30% exceedence. During wet season stress is more than PD 08 and PD as well as the REC for most of the time although stress improves at 50% maintenance.

DRY SEASON **WET SEASON**

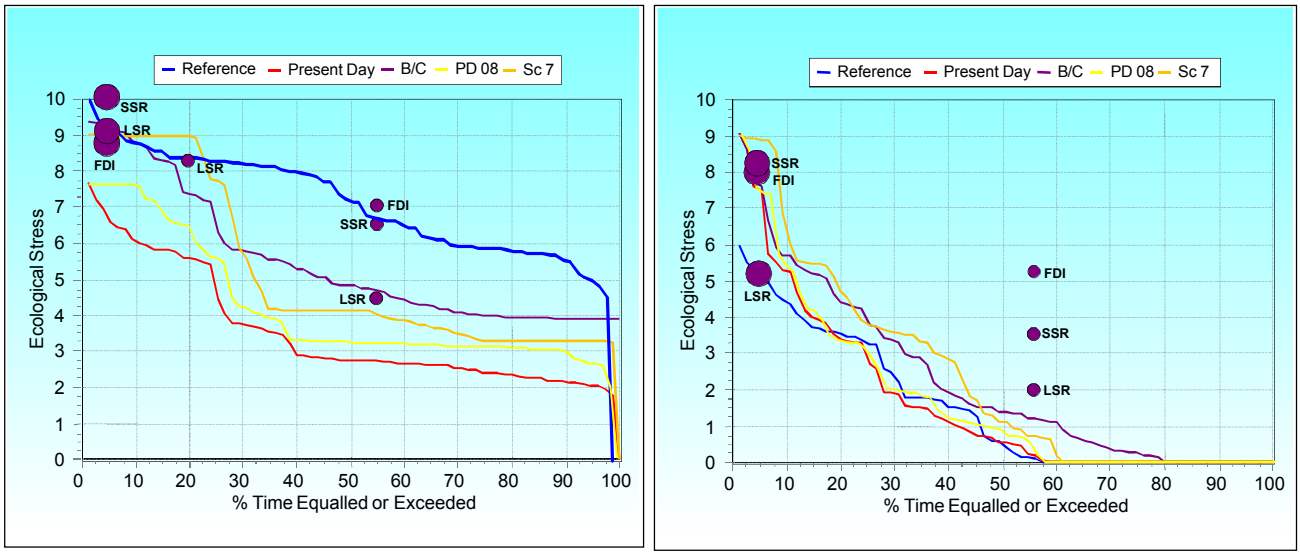


Figure 5.3 Stress duration for EWR 1: Dry and Wet season, Sc 7

5.6 ECOLOGICAL CONSEQUENCES: SCENARIO 7

5.6.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC1↓	AEC2↓	Sc 7	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	C	C	C/D	This scenario is similar to Sc 4 although there will be a slight deterioration.	
GEOMORPHOLOGY					
B/C	B/C	C	B	The large reductions in dry season low flows are proposed. This will create conditions closer to the natural flow condition and allow greater channel stability in the sensitive floodplain reaches up- and downstream of the site.	Minor reductions in wet season base flows should reduce the incision and undercutting of the floodplains up- and downstream of the site.
The site is bedrock controlled and the morphology is very stable. However, moderate and large floods are required to recharge the more sensitive floodplains up- and downstream of the site. Incision is reduced during the wet season and will probably permit better marginal vegetation to establish. Turbidity and fine sediments should reduce slightly. Overall this should promote an increase in the EC..					

5.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC1↓	AEC2↓	Sc 7	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
A/B	A/B	B/C	A/B	Conditions are drier than PD and tend more towards natural flows conditions, especially dry season drought flows. *C. marginatus* inundation reduces on average from 30 cm to 16 cm at the lower limit of its lateral distribution, and height above saturated water level increased from an average of 58 cm to 68 cm at its upper limit. This is unlikely to result in senescence within the current population, but sedge density is likely to reduce on the lower zone. Marginal zone instream habitat will be reduced by about 50%, but will remain. *Crinum bulbispermum* elevation increases from 25 to 36 cm above water level which will not affect the population because dormancy during the dry season occurs.	Wet season base flows are reduced by about 20%. Drought flows are comparable to PD, but significantly less than natural. The sedge population remains as is: high density coverage in marginal and lower zone. *Crinum bulbispermum* elevation increases from 9 to 13 cm above water level, which may affect recruitment, but because floods are similar, no change is expected.
The reduced inundation in the wet season will not result in changes to the PES since the two main impacts were too much inundation during the dry season and a small proportion of exotic species. The PES therefore remains A/B.					
FISH					
C(B)	D	D	C/D	LSR habitat suitability is similar to PES-REC.	LSR stress/habitat suitability for maintenance is similar to Natural, PD and PES-REC, BUT significantly lower for droughts of all the above.
Conditions will remain similar than PES-REC during dry season, but slight deterioration expected in wet season due to especially reduced flows under drought conditions. These are natural periods of stress that will have a negative impact on fish assemblages if it their duration and intensity is increased. The deterioration in water quality (from C to C/D) will furthermore result in deterioration in status of fish assemblage. It is estimated that the EC of the fish will be reduced from the PES-REC of a C (FRAI = 71%) to an EC = C/D (58.4%).					
MACROINVERTEBRATES					
C(B)	C	D	C	Deterioration in water quality is expected for both wet and dry season droughts is likely to reduce the abundance of macroinvertebrate taxa with a preference for good water quality, such as Tricorythidae and Elmiidae. These changes are expected to result in a deterioration of the macroinvertebrates from a present day MIRAI score of 74.6% to 70.4% (Category C). .	
ECOSTATUS					
B/C	C	C	B/C	Although the decrease improves geomorphology as incision is reduced the fish deteriorate by half an category. The deterioration in water quality impacts macroinvertebrates slightly as this component deteriorates within the PES and REC. Overall there are no major impacts on instream condition and the EcoStatus is a B/C.	

5.7 IMPACT OF SCENARIO 8

Scenario 8 is presented in Figure 5.4 by the pink curve and represents stress higher than PD 08 during dry season drought conditions and improving from 25% exceedence to conditions similar to the PES and REC. During wet season Sc 8 is similar to PD 08 up to 10% exceedence after which conditions are similar to the PES and REC.

DRY SEASON **WET SEASON**

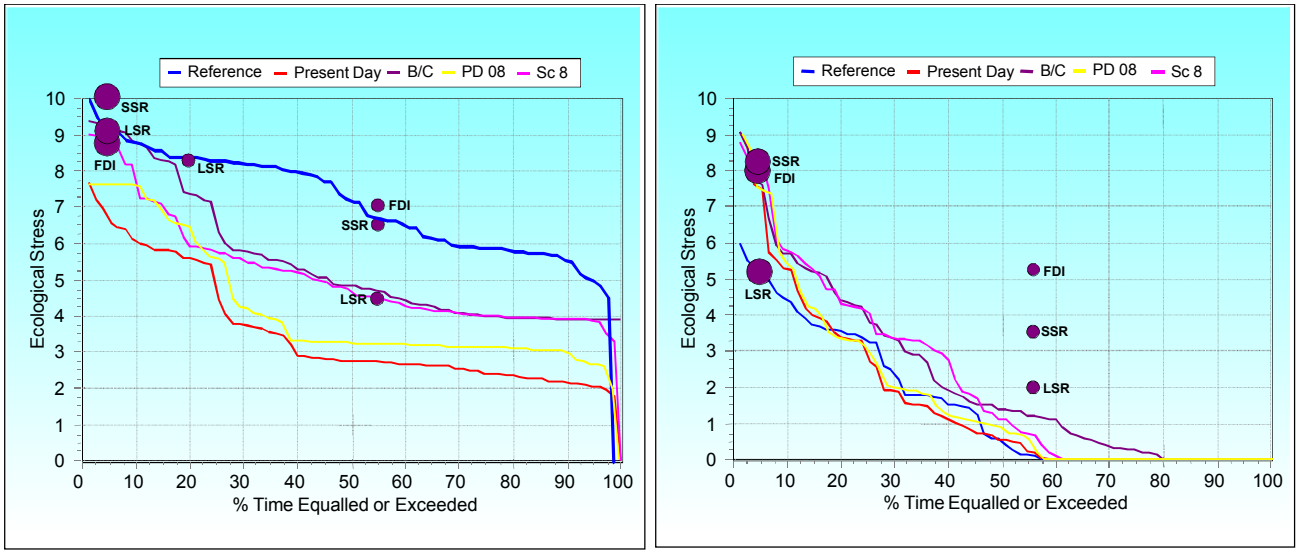


Figure 5.4 Stress duration for EWR 1: Dry and Wet season, Sc 8

5.8 ECOLOGICAL CONSEQUENCES: SCENARIO 8

5.8.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC1↓	AEC2↓	Sc 8	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	C	C	C	Refer to Sc 4.	
GEOMORPHOLOGY					
B/C	B/C	C	B/C	Refer to Sc 4.	

5.8.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC1↓	AEC2↓	Sc 8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
A/B	A/B	B/C	A/B	Refer to Sc 7.	
FISH					
C(B)	D	D	C	LSR habitat suitability similar than PES-REC.	LSR stress/habitat suitability for maintenance is similar to natural and slightly better than PD and PES-REC, BUT lower for droughts of all the above.
Conditions will remain similar than PES-REC during dry season, but slight deterioration expected in wet season due to especially reduced flows under drought conditions. These are natural periods of stress that will have a negative impact on fish assemblages if it their duration and intensity is increased. A slight deterioration can therefore be expected but it is estimated that the EC of the fish will remain in a similar EC than PES-REC of a C (FRAI = 71%) with a lower FRAI score calculated (64.5%).					
MACROINVERTEBRATES					
C(B)	C	D	C	Deterioration in water quality expected during this scenario for the dry season droughts is likely to reduce the abundance of macroinvertebrate taxa with a preference for good water quality, such as Tricorythidae and Elmiidae. These changes are expected to result in a slight deterioration of the macroinvertebrates from a present day MIRAI score of 74.6% to 72.4% (Category C).	

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC1↓	AEC2↓	Sc 8	DRY SEASON	WET SEASON
ECOSTATUS					
B/C	C	C	B/C	Scenario 8 results in an EcoStatus similar to the PES and REC. Fish and macroinvertebrates deteriorate within the PES EC while drivers and riparian vegetation remain stable. Instream condition will be slightly more impaired than under PES and REC conditions.	

5.9 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 1 are provided in Table 5.1.

Table 5.1 Ecological consequences of operational flow scenarios at EWR 1

Driver Components	PES and REC	Sc 4	Sc 5, 6	Sc 7	Sc 8
WATER QUALITY	C	C	C	C/D	C
GEOMORPHOLOGY	B/C	B/C	C	B	B/C
Response Components	**PES and REC**	**Sc 4**	**Sc 5, 6**	**Sc 7**	**Sc 8**
FISH	C (B)	C	C	C/D	C
MACROINVERTEBRATES	C (B)	C	C	C	C
INSTREAM	C	C	C	C	C
RIPARIAN VEGETATION	A/B	A/B	A/B	A/B	A/B
ECOSTATUS	B/C (B)	B/C	B/C	B/C	B/C

All the scenarios achieve the PES-REC EcoStatus to varying degrees. Scenario 4 and 8 achieves the REC requirements for all the components. Scenario 5 and 6 results in a deterioration in geomorphology as the increased base flows accelerate incision, while Sc 7 results in improved geomorphology due to decreased base flows. Increased base flows results in the fish deteriorating half a category. The degree to which each scenario at EWR 1 meets the REC is summarised in Figure 5.5 below.

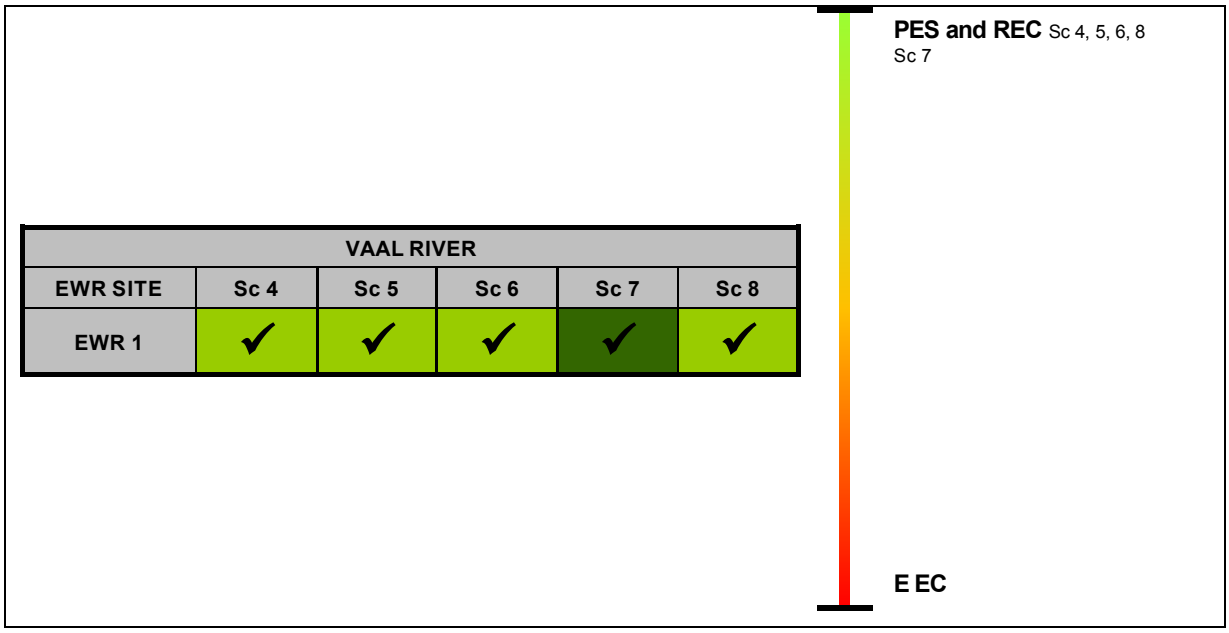


Figure 5.5 Summary of the impacts of operational flow scenarios at EWR 1

6 EWR 2: GROOTDRAAI (VAAL RIVER) - ECOLOGICAL CONSEQUENCES

EWR 2 is situated below Grootdraai Dam constructed in 1981. The Heyshope-Zaaihoek transfer to Grootdraai Dam ensures that water demands are met and therefore the 90% rule was adopted for transfers from Heyshope and Zaaihoek to Grootdraai Dam (i.e. transfers from these two dams are made when Grootdraai Dam is below 90% of its Full Supply Storage). Scenarios 4 - 8 were evaluated and are discussed in Section 6.1 to 6.11.

6.1 IMPACT OF SCENARIO 4

Figure 6.1 illustrates the stress requirements and stress points required for a C PES and REC (green curve), B AEC up (purple curve) and C/D AEC down (orange curve). The red curve illustrates the original Present Day flows that were used during the study while the yellow curve in Figure 6.1 is the new present day (PD) flows based on 2008 hydrology which is an improved representation of the current status quo. The blue curve represents reference flows and the yellow curve the new modelled Present Day flows. Scenario 4 (black curve) results in more flows than natural and PD for most of the time during the dry season.

DRY SEASON **WET SEASON**

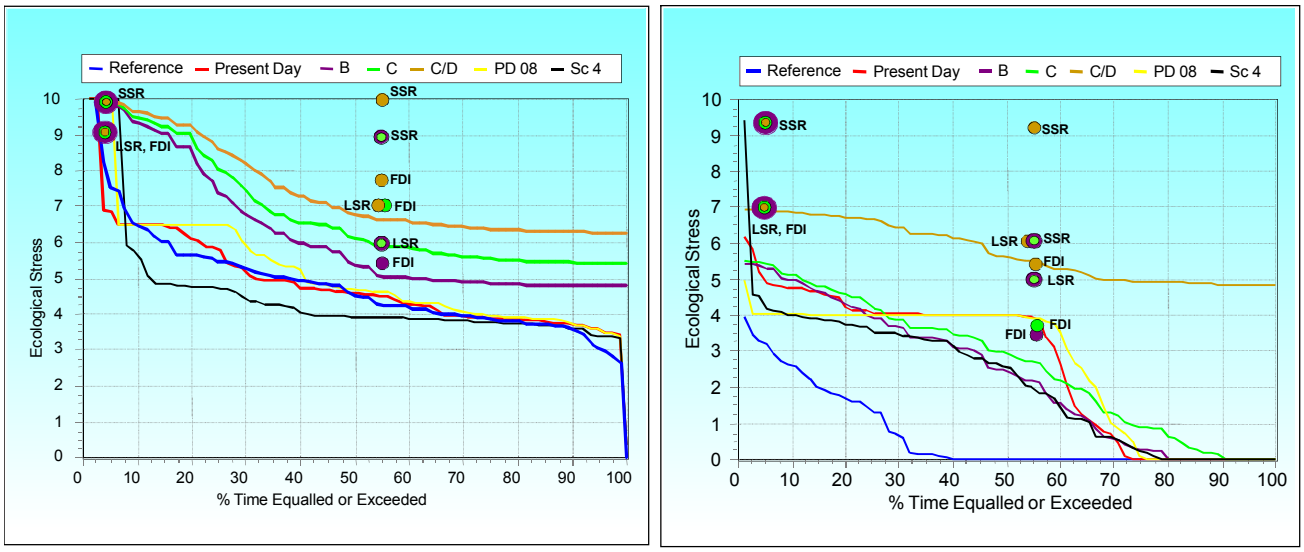


Figure 6.1 Stress duration for EWR 2: Dry and Wet season, Sc 4

6.2 ECOLOGICAL CONSEQUENCES: SCENARIO 4

6.2.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↓	AEC↑	Sc 4	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
B/C	B	B/C	B/C	Higher EWR releases in winter from Grootdraai Dam which results in a shorter residence time in the dam and slightly improved salinity values as well as less change of algal growth.	Summer releases from the dam are similar to the Present day flows.
GEOMORPHOLOGY					

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 4	DRY SEASON	WET SEASON
D	D	D	D	The site is immediately below the Grootdraai Dam. Since all but the fines (suspended sediment) are trapped in the dam, sediment deficits downstream result in high base flows and floods act as scouring events. Elevated flows will scour the bed but also erode marginal zones and the bank due to sediment deficit, so no net change in overall condition is expected.	

6.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 4	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
B/C	B	C	C	Severe droughts with no flow for 5% of time, but base flows are wetter than PD and Natural. Reduction in marginal zone sedge (*Cyperus marginatus*) and woody (*Gomphostigma virgatum*) cover, and promotion of sedge density on the lower zone. This is because inundation in the dry season will result in fatalities (marginal zone), but soil moisture will promote survival (lower zone).	Reduced floods and increased wet season base flows will similarly promote reduced vegetation cover on the marginal zone and increased cover on the lower zone.
Both wet and dry season drought stress is greater than PD and significantly greater than natural which will counter the trend toward increased sedge cover and density. Current the marginal zone will recede and merging of marginal and lower zones will be more apparent. The EC reduces from B/C to C (74.4%).					
FISH					
C	B	D	C	Removal of zero flows that are occurring <10% of time under PD, should result in some improvement in conditions. The overall extensive increase in dry season droughts will however have some negative impact on the abundance, connectivity and water quality and result in decrease in biotic integrity of fish.	It can be expected that the fish assemblage will at least remain in or slightly improve from the PES.
The overall trends in flows and fish stress indicate that LSR may improve slightly or remain similar than the PES (increased drought in dry season should not have critical impact due to fact that no rheophilic species are present, and most species will be able to survive these periods of cessation, with slight negative impact on population). Due to the fact that many of the impacts responsible for the PES (as calculated by FRAI) is non-flow related, the changes in flow associated with Scenario 4 is not expected to have any notable change in the PES FRAI score of 73.1% (C).					
MACROINVERTEBRATES					
C	B/C	C/D	D	Significantly reduced stress on macroinvertebrates for most of the time when compared to PD. However, zero flows during the low-flow period are certain to eliminate all flow-dependent macroinvertebrates, such as Hydropsychidae, Tricorythidae, Heptageniidae and Simuliidae. Wet season flows will improve conditions slightly for macroinvertebrate, and there is an increased seasonal variability that will improve conditions. However, the impacts of flow cessation on the macroinvertebrate community are expected to override these benefits. The overall changes are likely to be a significant deterioration of the macroinvertebrates from a present day MIRAI score of 71.1% to 57.6% (Category D).	
ECOSTATUS					
C	B/C	C/D	C	The EcoStatus remains in a C EC. Scenario 4 only impacts on the macroinvertebrates, which deteriorates to a lower category due to flow cessation during dry season drought periods which eliminate flow dependent taxa. However this deterioration is not substantial enough to change the instream condition and the overall EcoStatus.	

6.3 IMPACT OF SCENARIO 5

Scenario 5 is represented by the light blue curve in Figure 6. Decreased stress occurs during the dry season drought periods for biota. From 40% exceedence Sc 5 lies between the PES-REC (C EC) and AEC down (C/D EC) requirements. During wet season the stress is lower than the B (AEC up) and C (PES-REC) requirements and is similar to PD flows between 30 – 45% exceedence where-after stress decreases.

DRY SEASON **WET SEASON**

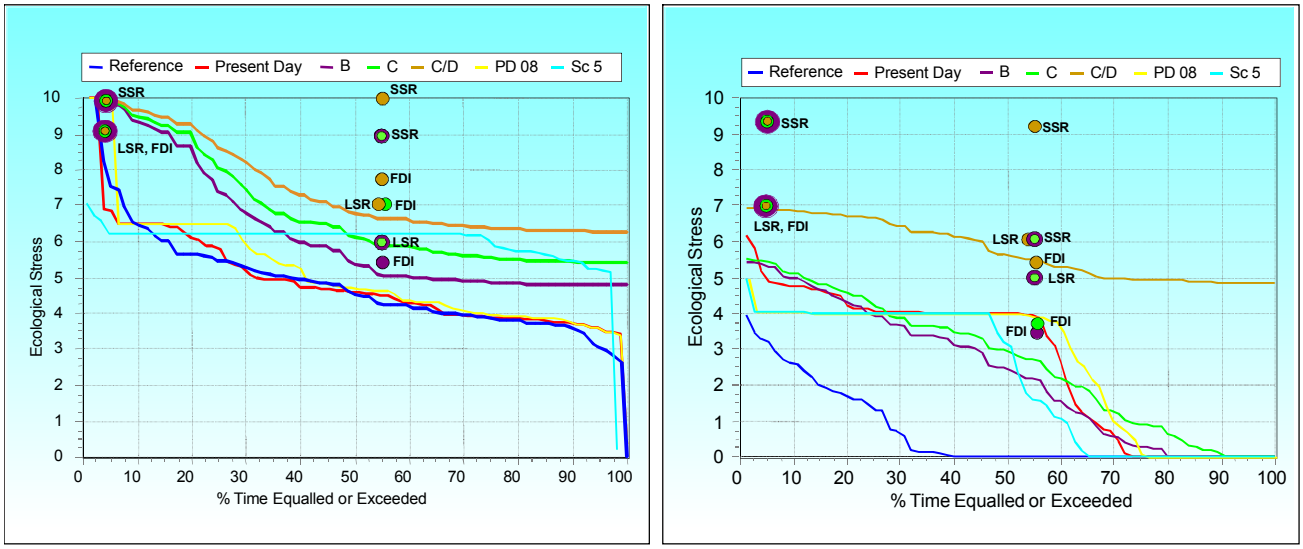


Figure 6.2 Stress duration for EWR 2: Dry and Wet season, Sc 5

6.4 ECOLOGICAL CONSEQUENCES: SCENARIO 5

6.4.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 5	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
B/C	B	D	B	Higher releases in winter from Grootdraai Dam result in a shorter residence time in the dam and slightly improved salinity values as well as less change of algal growth.	Summer releases from the dam are slightly higher than the PD flows to meet 2020 development conditions and VRESSAP pipecurve requirements. This will result in a slightly higher turbidity, less of a temperature differential and slightly higher dissolved oxygen.
GEOMORPHOLOGY					
D	D	D	D	Refer to Sc 4.	

6.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 5	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
B/C	B	C	B	Drought conditions are the same as PD, but base flows are less than PD and natural. This will result in reduced sedge cover in the lower zone (which is more natural) and facilitate an expansion of the current marginal zone as sedges colonize available habitat.	Wet season drought stress is the same as PD, but base flows are significantly more. Increased high flows (floods) also occur in the early part of the wet season.
The increased range between dry and wet season base flows restores seasonal differences that were missing with PD flows. This together with increased floods will increase patchiness in the marginal zone (increased hydrological disturbance) and demarcate the difference between the marginal and seasonal zones more. EC improves from B/C to B (86.9%).					
FISH					
C	B	D	C	During droughts conditions are similar to PD and natural and improved from the EWR scenarios.	The LSR guild remains in a C EC during drought and maintenance periods. The conditions under this

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 5	DRY SEASON	WET SEASON
				During maintenance the LSR guild deteriorates and conditions are worse than Natural and PD and worse than the PES-REC and similar to the AEC down. Removal of zero flows that are occurring <10% of time under PD, should also result in some improvement in conditions. Natural variability in flow duration will also have a negative impact on habitat diversity and result in further deterioration in status of fish assemblage. Overall conditions of the fish assemblage are expected to deteriorate in the dry season under this scenario.	scenario is similar to PD, worse than natural and improved from the PES and the AEC. It can therefore be expected that the fish assemblage will at least remain in similar or slightly improve from PES during wet season.
Conditions under this scenario is a deterioration from natural and PD, but slightly improved from the PES-REC conditions. Considering the overall deterioration in natural variability of flow duration, and hence the negative impact on natural seasonal variation, the overall integrity of the fish assemblage is expected to deteriorate under this scenario into a lower category C (FRAI score: 69.4%).					
MACROINVERTEBRATES					
C	B/C	C/D	C	This scenario results in very low variability of flows within seasons, but significantly increased variation between seasons and this is expected to improve overall macroinvertebrate diversity by providing a range of flow conditions over time. Dry season flows are consistently lower than PD flows, and stress values are slightly higher. The lower dry season flows are expected to reduce the risks of outbreaks of pest blackflies. The overall changes in FROC results in an improvement of the macroinvertebrates from a MIRAI score of 71.1% to 75.5% (Category C).	
ECOSTATUS					
C	B/C	C/D	B/C	Increased releases under Sc 5 leads to improved water quality conditions due to shorter residence time in Grootdraai Dam while improved flow ranges improves riparian vegetation to a B EC and macroinvertebrates within the PES EC. Fish deteriorates within the PES EC due to less seasonal variation. This results in an overall improvement of the EcoStatus to a B/C.	

6.5 IMPACT OF SCENARIO 6

Scenario 6 represents the dark green curve in Figure 6.3. There is less stress during dry season drought periods (slightly improved from Sc 5) following similar flow patterns from 25% exceedence to PD flows and improving from 45% exceedence. This scenario is better than Sc 5 during maintenance dry periods. During wet season drought conditions stress is slightly higher than Sc 5 and from 30% exceedence is similar to the AEC up scenario (B EC) with overall improvement in flows from 55% exceedence.

DRY SEASON **WET SEASON**

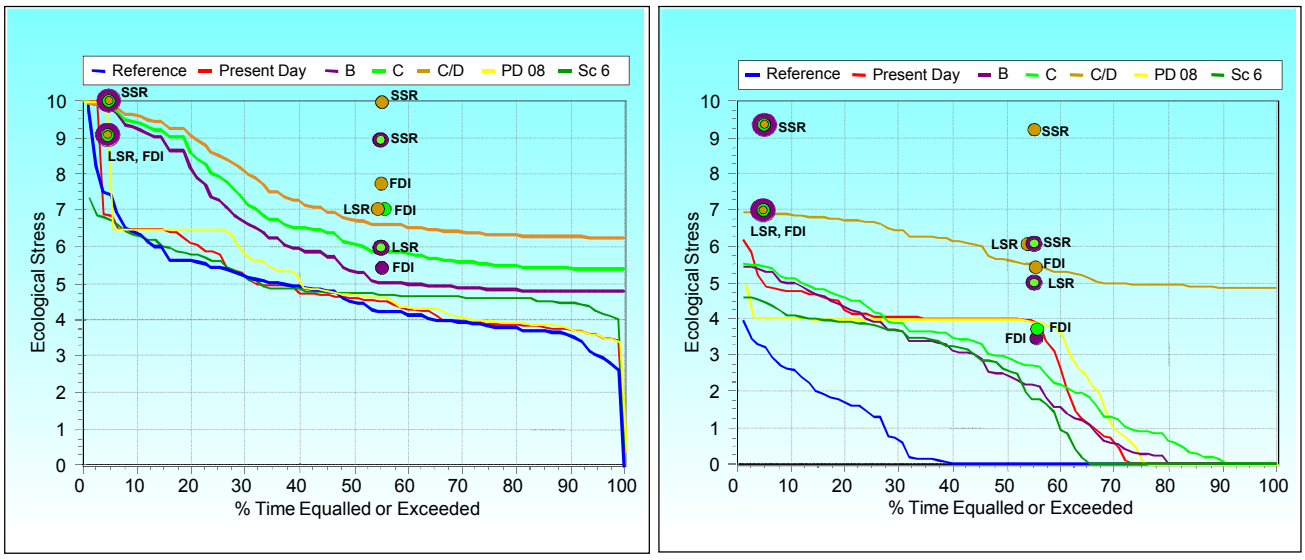


Figure 6.3 Stress duration for EWR 2: Dry and Wet season, Sc 6

6.6 ECOLOGICAL CONSEQUENCES: SCENARIO 6

6.6.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 6	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
B/C	B	D	B/C	Conditions are similar to the PES and REC and no change in the EC is expected.	This will result in a slightly higher turbidity, less of a temperature differential and slightly higher dissolved oxygen. Potential for dilution of nutrients downstream and salt concentrations will depend on the management upstream of the dam.
GEOMORPHOLOGY					
D	D	D	D	Refer to Sc 4.	

6.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 6	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
B/C	B	C	B	Dry season drought conditions are the same as PD, as well as the base flows. No change expected as a result of dry season flows.	Wet season drought stress is similar to PD, but base flows are significantly more. Increased high flows (floods) also occur in the early part of the wet season.
These conditions will cause inundation stress for marginal zone sedges, but promote lower zone sedge vigour. Marginal zone sedge cover will reduce i.e. EC will improve. The EC improves from B/C to B (84.9%).					
FISH					
C	B	D	C	The overall trend in flows and fish stress indicate that LSR may improve slightly or remain similar than the PES. Due to the fact that many of the impacts associated with the PES (as calculated with FRAI) is non-flow related, the changes in flow associated with Sc 6 is not expected to have any notable change in the PES FRAI score of 73.1%.	
MACROINVERTEBRATES					
C	B/C	C/D	B/C	Increased seasonal variation due to elevated wet season flows is likely to improve overall macroinvertebrate diversity by providing a range of flow conditions over time. Median wet season flows are significantly higher than present. The overall changes in FROC results in an improvement of the macroinvertebrates from a MIRAI score of 71.1% to 77.6% (Category B/C).	
ECOSTATUS					
C	B/C	C/D	B/C	There is an improvement in water quality and all biotic components except fish which remains in a C as the PES is mainly due to non-flow related issues. This improvement results in a B/C EcoStatus which is slightly higher than Sc 5 due to EWR releases being included and higher than the PES EcoStatus of a C.	

6.7 IMPACT OF SCENARIO 7

Scenario 7 is represented by the orange curve in Figure 6.4. Decreased stress occurs during dry season drought while maintenance conditions are similar to PD. During the wet season drought conditions are decreased and are similar to PD 08 and from 28% exceedence is similar to PD and improves from 45% exceedence.

DRY SEASON **WET SEASON**

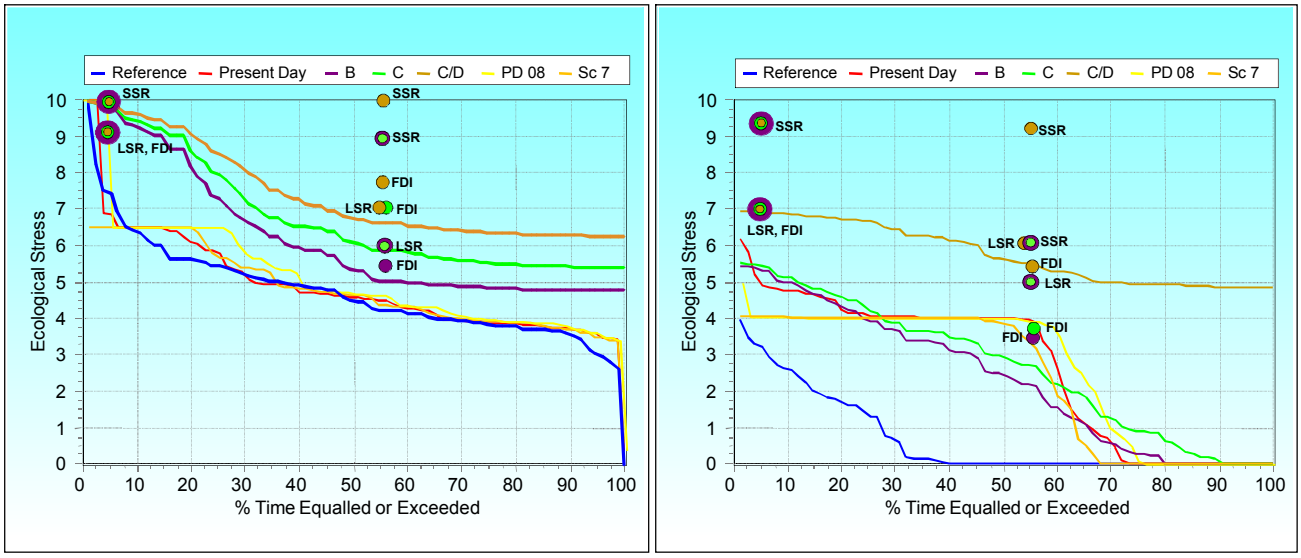


Figure 6.4 Stress duration for EWR 2: Dry and Wet season, Sc 7

6.8 ECOLOGICAL CONSEQUENCES: SCENARIO 7

6.8.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 7	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
B/C	B	D	C	EWR releases in winter from Grootdraai Dam are slightly higher than PD. A slight deterioration in water quality is expected due to upstream usage which results in increased salinity and nutrients.	
GEOMORPHOLOGY					
D	D	D	D	Refer to Sc 4.	

6.8.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 7	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
B/C	B	C	B/C	Flows similar to PD with slight increased base flows for wet and dry season. Early wet season floods increase. Although the slight increase in base flows is likely to reduce the overall width of the riparian zone, no change in the EC is expected.	
FISH					
C	B	D	C	Conditions are similar to Sc 6 and PD conditions. No changes in the PES are expected (same FRAI score of 73.1%).	
MACROINVERTEBRATES					
C	B/C	C/D	C	No change in current conditions is foreseen and therefore the macroinvertebrates remain in a C EC.	
ECOSTATUS					
C	B/C	C/D	C	Although there is a slight deterioration in water quality this will have no severe impacts on the biota. This scenario will maintain the PES requirements and therefore the EcoStatus remains in a C EC.	

6.9 IMPACT OF SCENARIO 8

The pink curve in Figure 6.5 represents Sc 8. Scenario 8 will result in decreased stress during drought periods in the dry and wet season. Dry season maintenance flow increase and is more than reference conditions while wet season maintenance flows are an improvement from the AEC up scenario, with increased floods.

DRY SEASON **WET SEASON**

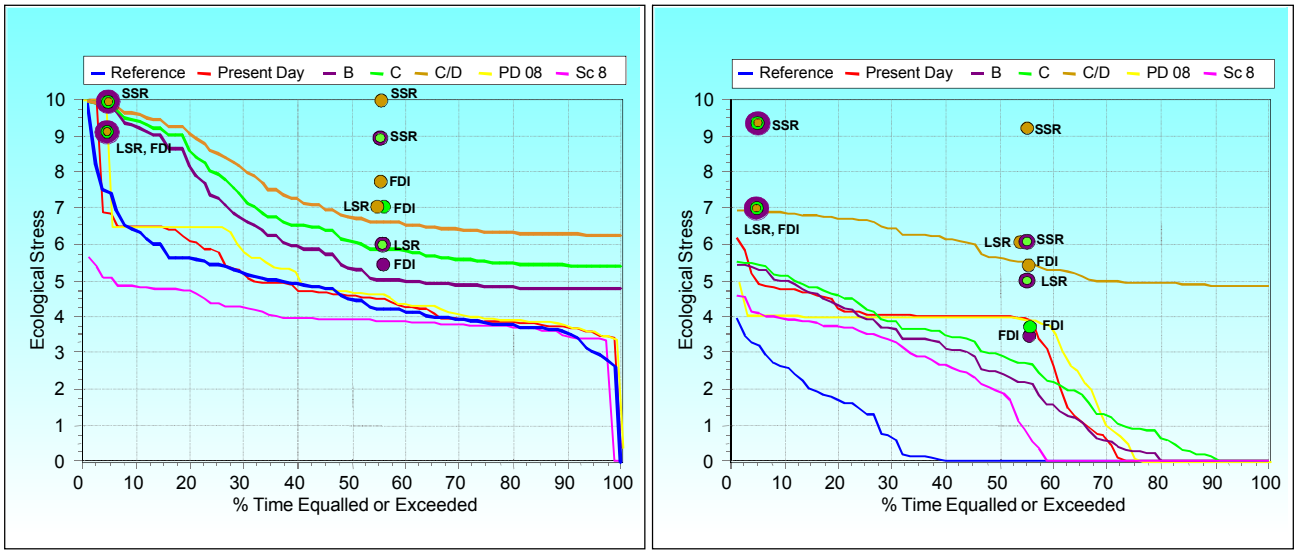


Figure 6.5 Stress duration for EWR 2: Dry and Wet season, Sc 8

6.10 ECOLOGICAL CONSEQUENCES: SCENARIO 8

6.10.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 8	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
B/C	B	D	C	EWR releases result in slightly higher flows than PD. There will be a slight deterioration in water quality due to the impacts of upstream usage i.e. increased salinity and nutrients.	Conditions are similar to the dry season although turbidity will increase due to increased releases from Grootdraai Dam.
GEOMORPHOLOGY					
D	D	D	E	Increased dry season base flows and very large dry season floods will scour the bed; erode the banks and bars of the reach.	Increased wet season base flows and floods will further erode the alluvial habitats of the reach.
Since the site is directly below the Grootdraai Dam all but the fines (suspended sediment) are trapped in the dam, and sediment deficits downstream result in high base flows and floods act as scouring events. The very large increases in base flow and floods, and introduction of large floods in the dry season, are expected to rapidly accelerate erosion in the reach and lead to deccurve in condition. This will be ameliorated by the resilient, often armoured or bedrock controlled morphology of some sections of the channel, but still results in a decreased EC.					

6.10.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
B/C	B/C	C	C	Drought and base flows are unnaturally wet, with flows higher than both PD and natural. This will cause a reduction or total loss of the current marginal zone as sedges and marginal zone woody plants succumb to yearlong inundation stress e.g. average sedge (*Cyperus marginatus*) inundation increased from 14 cm to 20 cm.	Tends more towards natural flows with increased drought and base flows and floods.
The deterioration in the PES is expected as a result of loss of vegetation on the marginal zone. The EC reduces from B/C to C (67.9%).					
FISH					
C	B	D	C	Similar to Sc 6 and PD conditions.	
Conditions will also be similar or slightly better than PD conditions. Most species with requirement for flow (semi-rheophilic guild) are however presently in good to optimal status, and increased flows will not result in a notable improvement. The reduction in water quality is also not expected to change the EC as most species are moderately tolerant to tolerant to water quality alteration. Fish can therefore be expected to remain in a C EC (FRAI score 73.1%).					
MACROINVERTEBRATES					
C	B/C	C/D	D	Elevated dry season flows and winter floods are certain to create suitable breeding conditions for pest blackflies. Marginal vegetation expected to be inundated during the non-growing period and this will lead to a reduction of marginal vegetation, which will affect taxa such as Hydrophilidae and Hydroptilidae. Changes in seasonal variation in flows are likely to cause a reduction in overall macroinvertebrate biodiversity. The overall changes in FROC, results in a significant deterioration of the macroinvertebrates from a MIRAI score of 71.1% to 56.1% (category D).	
ECOSTATUS					
C	B/C	C/D	C	There is a deterioration in all the components except fish, as the fish is in optimum conditions and not very sensitive to water quality changes. Although the macroinvertebrates deteriorates to a D the overall EcoStatus remains in a C albeit deteriorated from the PES.	

6.11 SUMMARY OF ECOLOGICAL CONSEQUENCES

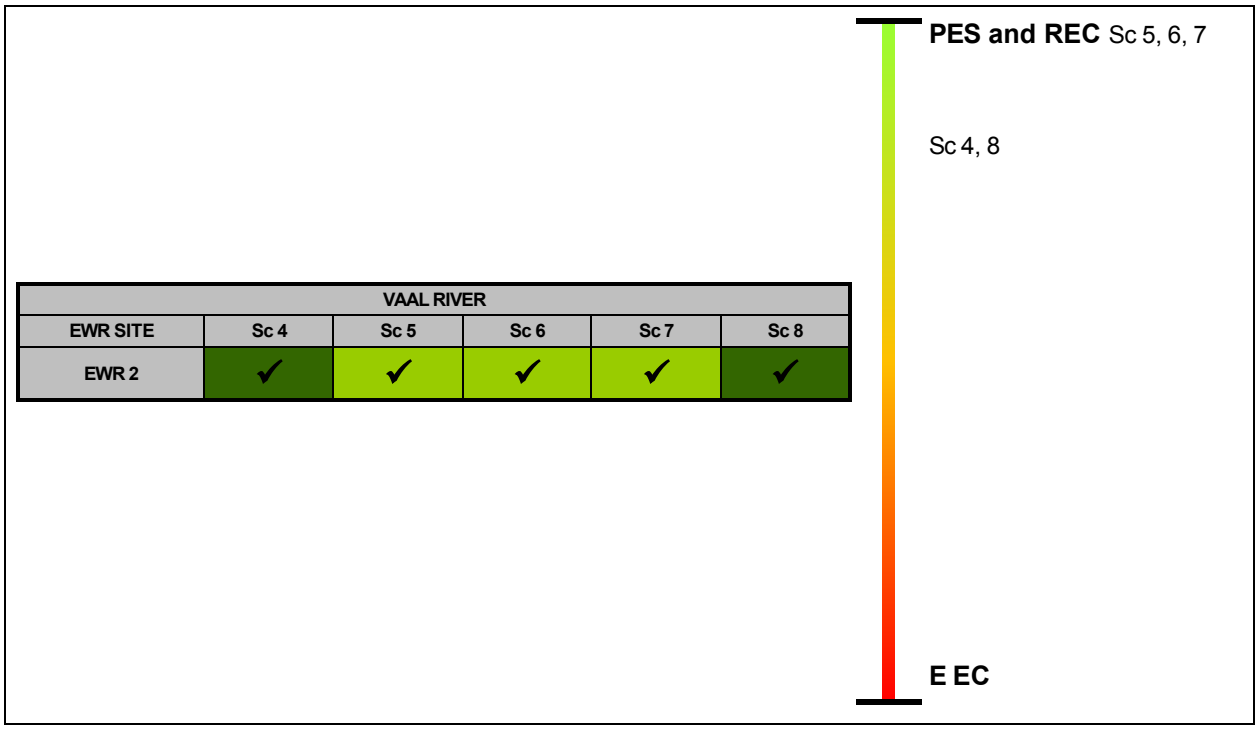
The ecological consequences of the operational flow scenarios at EWR 2 are provided in Table 6.1.

Table 6.1 Ecological consequences of operational flow scenarios at EWR 2

Driver Components	PES and REC	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
WATER QUALITY	B/C	B/C	B	B/C	C	C
GEOMORPHOLOGY	D	D	D	D	D	E
Response Components	**PES and REC**	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
FISH	C	C	C	C	C	C
MACROINVERTEBRATES	C	D	C	B/C	C	D
INSTREAM	C	C	C	C	C	C
RIPARIAN VEGETATION	B/C	C	B	B	B/C	C
ECOSTATUS	C	C	B/C	B/C	C	C

Scenario 5 and 6 resulted in a B/C EcoStatus which is an improvement of the PES-REC. Scenario 5 results in an improvement in water quality and riparian vegetation, while Sc 6 results in the same improvements including macroinvertebrates as well. Sc 4 meets the PES and REC although there is deterioration in macroinvertebrates due to no flow periods in the dry season drought which will eliminate flow dependent taxa. The future development scenarios meet the PES and REC to different extents. Scenario 7 excludes EWR releases and results in water quality deteriorating to a C EC while the rest of the components are similar to the PES and REC. Scenario 8 includes EWR release and the high volume release impacts negatively on the geomorphology of the site as well as water quality and macroinvertebrates. Scenario 4 and 8 will result in the PES being maintained although the requirements of the REC will not be met.

The degree to which each scenario at EWR 2 meets the REC is summarised in Figure 6.6 below.



VAAL RIVER					
EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
EWR 2	✓	✓	✓	✓	✓

Figure 6.6 Summary of the impacts of operational flow scenarios at EWR 2

7 EWR 3: GLADDEDRIFT (VAAL RIVER) - ECOLOGICAL CONSEQUENCES

EWR 3 is situated above the Waterval River confluence upstream of the Vaal Dam. It is important to note that the water quality data used in this study for this site was above the inflow of the Waterval River and hence did not accurately indicate the potential water quality impacts of this catchment. Scenarios 4 - 8 were evaluated and are discussed in Section 7.1 to 7.11.

7.1 IMPACT OF SCENARIO 4

Figure 7.1 illustrates the stress requirements and stress points required for a C PES and REC (green curve), B AEC up (purple curve) and C/D AEC down (brown curve). The solid red curve illustrates the original Present Day flow that was provided during the study while the dashed red curve indicates observed flows. The yellow curve is the new PD flow based on 2008 hydrology which is an improved representation of the current status quo and the blue curve represents natural flows. Scenario 4 (black curve) was modelled to include the EWR requirements and implies improved base flows in the dry season and an overall improvement from PD and the new PD. During wet season drought stress requirements are similar to the AEC↑ up requirements, lies between the PES-REC and AEC↑ up requirements for 15% exceedence and for the rest of the season is a slight improvement and/or very similar to the PES-REC requirements.

DRY SEASON **WET SEASON**

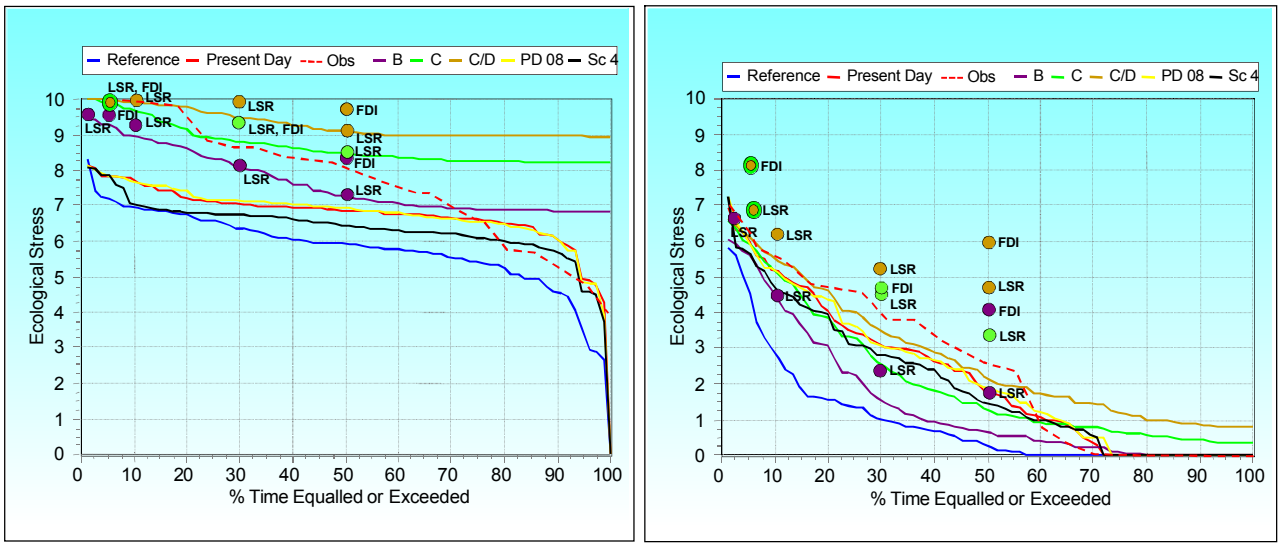


Figure 7.1 Stress duration for EWR 3: Dry and Wet season, Sc 4

7.2 ECOLOGICAL CONSEQUENCES: SCENARIO 4

7.2.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 4	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B/C	D	C	The slightly increased winter base flows will reduce the salinity and nutrients at this site.	Summer releases from Grootdraai Dam are similar to the PD flows but because of improved winter flows and flushing of the system the salt and nutrient values at this site would improve.
GEOMORPHOLOGY					
C	C	D	D	Small to moderate increases in base flows.	A decrease in instream habitat is expected due to fining of the channel bed and smothering of gravel and riffle areas.

7.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 4	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	C	C	Although flows are higher in general, changes are relatively small inside a wide incised channel and therefore make only small differences in terms of vegetation inundation. Vigour of the marginal zone vegetation may improve slightly due to increased water availability but no change to the EC occurs and remains at a C EC.	
FISH					
C	B	D	B	Habitat suitability will be very similar to that expected under PD modeled flows, and better than PES. Removal of zero flows will especially benefit the overall ecological integrity. It can therefore be expected that in terms of flow, conditions for fish will be improved from the PES, and the fish assemblage may improve from its present state.	The fish assemblage is expected to improve from the PES.
The overall trends in the LSR guild indicate improvement in the EC from the PES. The overall biotic integrity in terms of fish is expected to improve under this scenario from a C (76.7%) to a category B (86.2%).					
MACROINVERTEBRATES					
C	B/C	D	B	Macroinvertebrate stress profiles are close to natural. Macroinvertebrates that are expected to benefit include flow dependent taxa such as Heptageniidae, Hydropsychidae, Ecnomidae and Tricorythidae. These changes in FROC, results in an improvement of the macroinvertebrates from a PES of 66.7% to 82.6% (Category B).	
ECOSTATUS					
C	B	C/D	B/C	There is deterioration in geomorphology as fines increase in the channel bed therefore smothering of gravel and riffle areas and decreasing instream habitat. Water quality and riparian vegetation remain similar to the PES conditions while the instream biota improves from the PES. The improved biotic components result in improved instream condition and overall EcoStatus which is set at a B/C.	

7.3 IMPACT OF SCENARIO 5

The 2020 development scenario which excludes EWRs, Sc 5 (light blue curve, Figure 7.2) represents flow conditions with small improvements in the provision of floods relative to the modelled present day conditions. During wet season stress is similar to the PES (C EC – green curve) for 0 – 15 % of the time, and similar most of the time to new PD, PD (red curve).

DRY SEASON **WET SEASON**

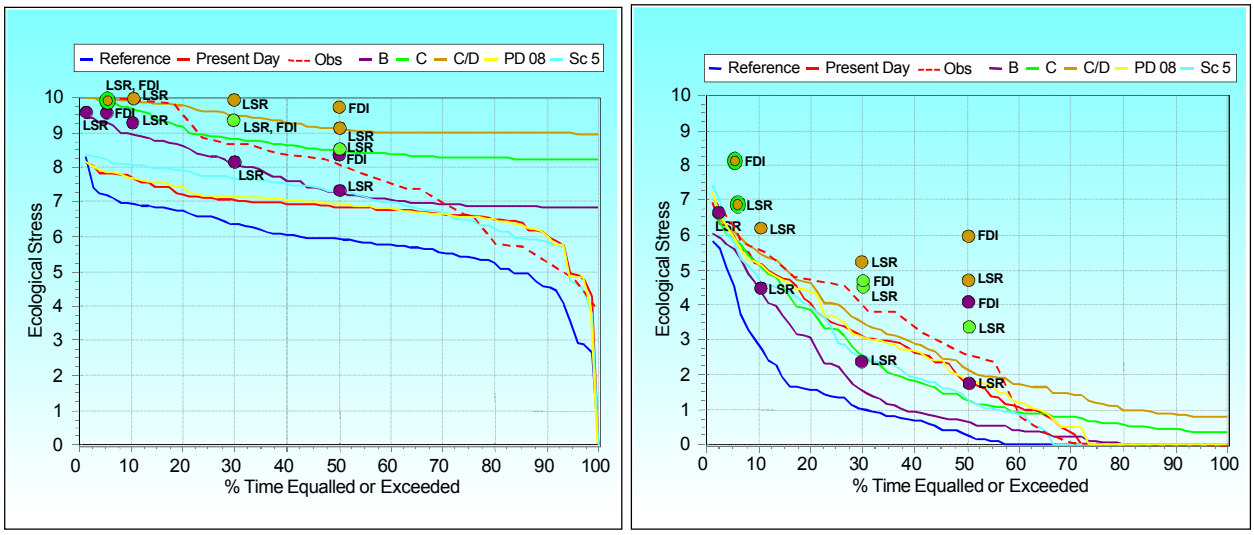


Figure 7.2 Stress duration for EWR 3: Dry and Wet season, Sc 5

7.4 ECOLOGICAL CONSEQUENCES: SCENARIO 5

7.4.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 5	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B/C	D	C	Higher EWR releases in winter from Grootdraai Dam which results in a shorter residence time in the dam and slightly improved salinity values as well as less change of algal growth.	Summer releases from the dam are slightly higher than the PD flows to meet 2020 development conditions and VRESSAP pipecurve requirements and despite increased development upstream the salinity and nutrients of this site would be slightly better than that of PD.
GEOMORPHOLOGY					
C	C	D	C	Small to moderate decreases in base flows.	No change in instream habitat expected.
Scenario 5 represents flow conditions with small improvements in the provision of floods relative to the modelled present day conditions. Whilst this would suggest a slight improvement, in reality, because of the limitations of the PD data discussed above, these are expected to result in no change to the EC.					

7.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 5	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	C	C	Refer to Sc 4.	
FISH					
C	B	D	B	Removal of zero flows, as occurring under PES, will be of benefit. Conditions are very similar to the AEC↑ with improved drought conditions. A small improvement from PES can therefore be expected in terms of flows.	Due to improved flows, an overall improvement in terms of flow can therefore be expected under this scenario.
The LSR guild will improve from the PES. Although some of the impacts on fish are non-flow related (especially presence of alien introduced species), the improvement may not be significant, but still improve conditions from a C (76.7%) to a B (84.2%).					

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 5	DRY SEASON	WET SEASON
MACROINVERTEBRATES					
C	B/C	D	B/C	The macroinvertebrate stress profile is close to the AEC up (B EC). Water temperature is expected to be affected, and this could impact on the life-histories of macroinvertebrates. This is expected to affect the abundance of taxa that are sensitive to changes in water quality. These changes results in a slight improvement of the macroinvertebrates from a present day MIRAI score of 66.7% to 79.4 % (Category B/C).	
ECOSTATUS					
C	B	C/D	B/C	The drivers remain stable under these conditions while improved low flows during the dry season may be delaying the improvement of the fish and macroinvertebrates resulting in the slight improvement of the instream condition and the EcoStatus.	

7.5 IMPACT OF SCENARIO 6

Scenario 6 is represented by the dark green curve in Figure 7.3. Conditions are very similar to PD (red curve) and the 2008 PD (yellow curve) during dry season for 50% of the time after which stress decreases. During wet season less stress is expected than under PD and 2008 PD.

DRY SEASON **WET SEASON**

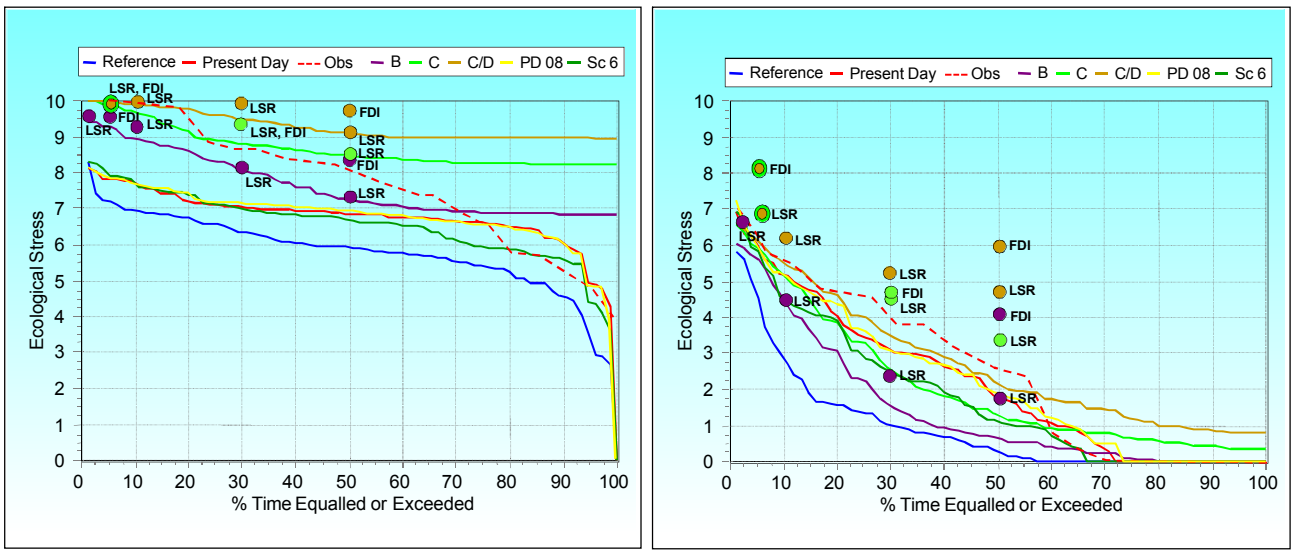


Figure 7.3 Stress duration for EWR 3: Dry and Wet season, Sc 6

7.6 ECOLOGICAL CONSEQUENCES: SCENARIO 6

7.6.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 6	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B/C	D	C	Refer to Sc 5.	
GEOMORPHOLOGY					
C	C	D	C	Refer to Sc 5	

7.6.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↓	AEC↑	Sc 6	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	C	C	Refer to Sc 5.	
FISH					
C	B	D	B	Removal of zero flows, as under PES, will especially benefit the overall ecological integrity. Habitat suitability will be very similar to that expected under PD modeled flows, and better than PES and even REC flows. It can therefore be expected that conditions for fish will be improved from the PES under this scenario, and the fish assemblage may improve from its present state.	The fish assemblage is expected to improve from the PES.
The overall trends in the LSR guild indicate improvement in the EC from PES. The fish are in a similar condition as Sc 4 and better than Sc 5. The improvement can therefore be expected to be similar to that under Sc 4, reaching a B (86.2%).					
MACROINVERTEBRATES					
C	B/C	D	B/C	Conditions are similar as for the AEC up scenario. Macroinvertebrates that are expected to benefit from these scenarios include flow dependent taxa such as Heptageniidae, Ecnomidae, Hydropsychidae and Tricorythidae. The changes in FROC results in an improvement of the macroinvertebrates (MIRAI score of 66.7% to 79.1%) to a B/C EC.	
ECOSTATUS					
C	B	C/D	B/C	The consequences of Sc 6 are very similar to Sc 5, and there is an improvement of the EcoStatus to a B/C.	

7.7 IMPACT OF SCENARIO 7

Scenario 7 is represented by the orange curve in Figure 7.4 and is very similar to PD (red curve) and modelled 2008 PD (yellow curve). No zero flow periods occurs. The stress conditions under this scenario are lower than observed hydrology and the EWR scenarios. During the wet season Sc 7 will result in less stress than the different PDs as well as the EWR scenarios.

DRY SEASON **WET SEASON**

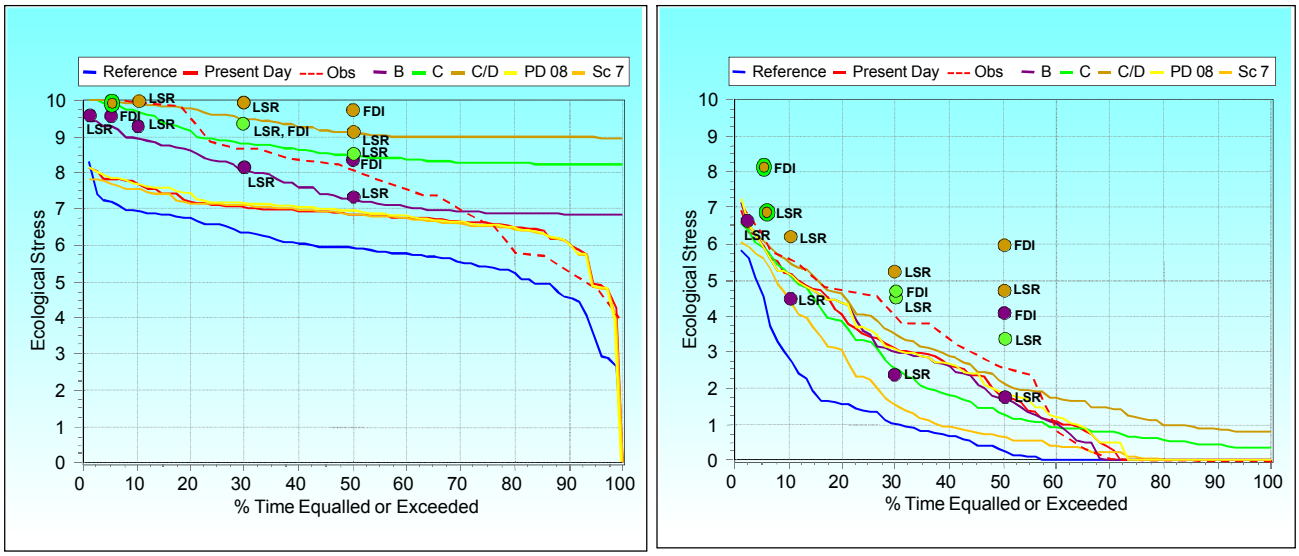


Figure 7.4 Stress duration for EWR 3: Dry and Wet season, Sc 7

7.8 ECOLOGICAL CONSEQUENCES: SCENARIO 7

7.8.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 7	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B/C	D	C	The water quality similar to present day.	Water quality slightly better than present day due to increased flows.
GEOMORPHOLOGY					
C	C	D	D	Refer to Sc 4.	

7.8.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 7	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	C	C	Refer to Sc 4.	
FISH					
C	B	D	B	Removal of zero flows, as occurring under PES-REC, will especially benefit the overall ecological integrity. Conditions are very similar than AEC up (with improved drought conditions). A small improvement from PES can therefore be expected under this scenario in terms of flows.	The fish assemblage is therefore expected to improve from the PES.
The overall trends in the LSR guild indicate improvement in the EC from PES (this improvement will be similar to Sc 5). The overall biotic integrity in terms of fish is expected to improve from a C (76.7%) to a category B (84.2%).					
MACROINVERTEBRATES					
C	B/C	D	B/C	Refer to Sc 6.	
ECOSTATUS					
C	B	C/D	B/C	Reduced moderate events result in a deterioration of geomorphology. Water quality is similar to present conditions while the improved drought flows in dry season results in fish and macroinvertebrates and therefore instream condition improving. The EcoStatus improves to a B/C.	

7.9 IMPACT OF SCENARIO 8

Figure 7.5 illustrates Sc 8 represented by the pink curve. During dry season this scenario is improved from PD, modelled PD and the EWR scenarios as base flows are improved. Wet season stress is also decreased and is similar to the PES (green curve) for most of the time with an improvement in moderate flood events.

DRY SEASON **WET SEASON**

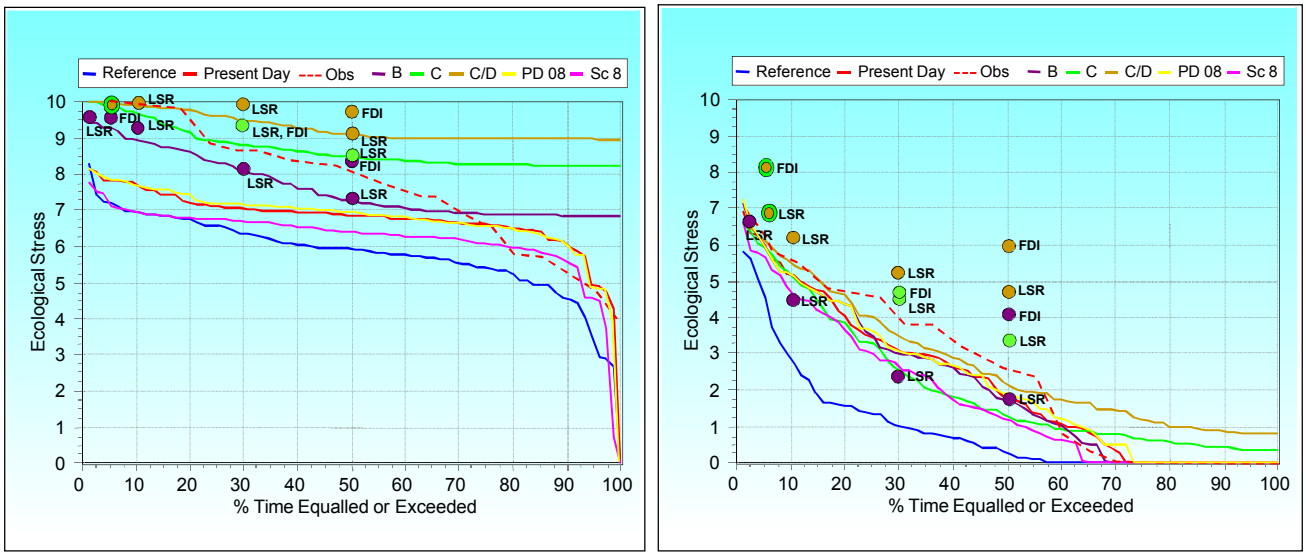


Figure 7.5 Stress duration for EWR 3: Dry and Wet season, Sc 8

7.10 ECOLOGICAL CONSEQUENCES: SCENARIO 8

7.10.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 8	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B/C	D	C	There are higher base flows in winter for EWR requirements. Water quality deterioration due to upstream usage – increased salinity and nutrients.	Summer releases from the dam are slightly higher than the Present day flows to meet the full utilisation of available water. Increased floods and general increased summer releases upstream will result in improved water quality (salinity and nutrients) but greater turbidity from releases from dam.
GEOMORPHOLOGY					
C	C	D	C	Increased base flows.	Increased base flows and increased high flows and floods which will increase scour, removing excess fines and activating gravels and cobbles. This will improve instream habitats.
The improved flood management (reinstatement and increase of moderate flood events) would allow scour of the bed and keep the bar/islands in check. Most importantly this would flush excessive fines from the bed, resulting in an improved PES from the current very low to a very high C condition.					

7.10.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B	C	B/C	Wetter than PD especially droughts, which are higher than Natural.	Wetter than PD and tends towards natural. Marked increase in floods.
Similar to the other scenarios, but with some additional water availability as well as floods. Improved flooding results in an improved EC of 80.5% (B/C) because vegetation on the upper parts of the lower zone is maintained. Flow related impacts are however difficult to assess due to non-flow related impacts being high and masking the effect if any.					
FISH					
C	B	D	B	Similar to Sc 4.	

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 8	DRY SEASON	WET SEASON
In terms of low flows (maintenance and droughts) this scenario will create very similar habitat suitability in the dry and wet season than under Sc 4. Improved (closer to natural) high flows (flood events) should create better quality substrates to be utilised by fish. The species with a preference for substrates are however already in a good to excellent state under Sc 4, and it is expected that the improvements created by Sc 8 would not have further notable improvement from Sc 4. The overall biotic integrity in terms of fish is therefore expected to improve from a C (76.7%) to a category B (86.2%).					
MACROINVERTEBRATES					
C	B/C	D	B	Refer to Sc 4.	
ECOSTATUS					
C	B	C/D	B	The improved base flows in dry season and improvement in moderate floods result in an improvement of all the components except water quality that remains the same as the PES. This scenario results in an improvement of the PES to a B EC.	

7.11 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 3 are provided in Table 7.1.

Table 7.1 Ecological consequences of operational flow scenarios at EWR 3

Driver Components	PES and REC	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
WATER QUALITY	C	C	C	C	C	C
GEOMORPHOLOGY	C	D	C	C	D	C+
Response Components	**PES and REC**	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
FISH	C	B	B	B	B	B
MACROINVERTEBRATES	C	B	B/C	B/C	B/C	B
INSTREAM	C	B	B/C	B	B	B
RIPARIAN VEGETATION	C	C	C	C	C	B/C
ECOSTATUS	C	B/C	B/C	B/C	B/C	B

All the scenarios resulted in an improvement of the PES-REC. Sc 8 was the best performer and resulted in the improvements of all the components with water quality remaining in the PES EC. Sc 4 resulted in a B/C EcoStatus and although fish and macroinvertebrates improved there was deterioration in geomorphology. The consequences of Sc 6 and 7 were similar although Sc 7 resulted in a deterioration of geomorphology. Scenario 5 improved the instream condition to a lesser extent than the other scenarios and it is important to note that the improvement of fish under Sc 5 and 7 is based on the assumption that the non-flow related problems i.e. exotic fish are addressed.

The degree to which each scenario at EWR 3 meets the REC is summarised in Figure 7.6 below.

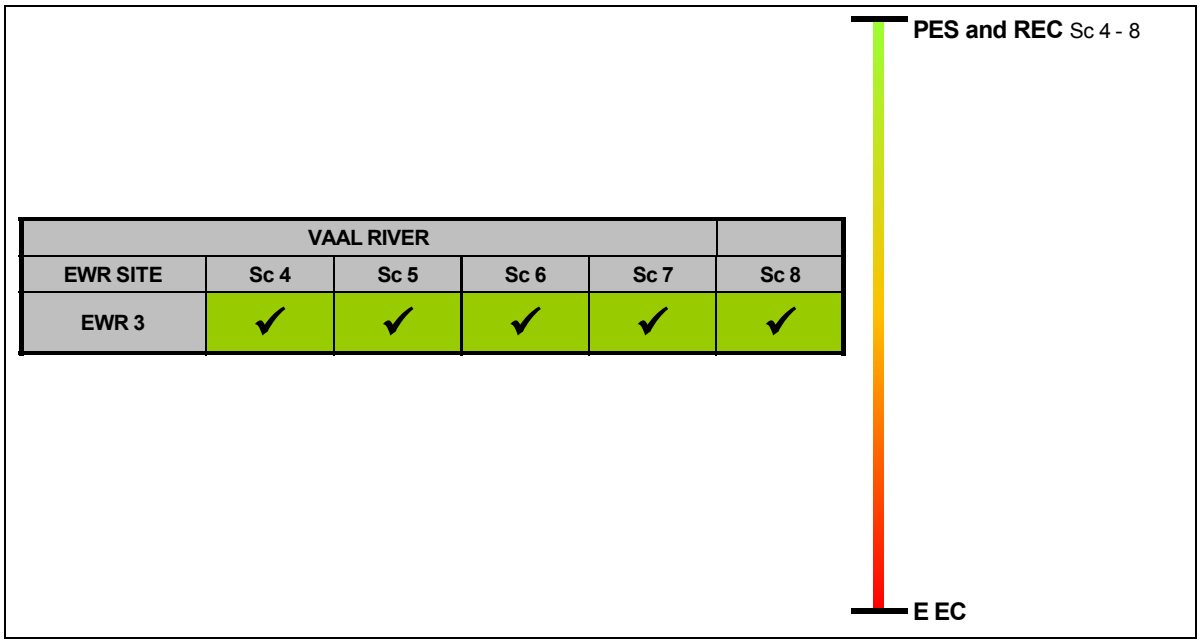


Figure 7.6 Summary of the impacts of operational flow scenarios at EWR 3

8 EWR 4: DE NEYS (VAAL RIVER): ECOLOGICAL CONSEQUENCES

EWR 4 is situated below Vaal Dam. Scenarios 4 – 8 were evaluated and are discussed in Section 8.1 - 8.6. During EWR scenario determination (Step 4 of the Ecological Reserve process) (DWA, 2009b) the following issues were identified:

The hydrological issues at this site are the following:

- Seasonal reversal has taken place.
- The present day flows are significantly higher than natural during the dry season and vice versa for the wet season.
- No small moderate floods occur, only floods from spills.

8.1 IMPACT OF SCENARIO 4 AND 8

The stress and flow duration graphs indicated that Sc 4, and 8 have the same impact at EWR 4 and is similar to PD 2008 (red dashed curve). Figure 8.1 illustrates the stress requirements and stress points required for a C PES, B/C REC (green and purple curves respectively) and D AEC down. The red curve illustrates the original PD flow that was provided during the study while the new present day (PD) flow based on 2008 hydrology and the blue curve represents Natural. Scenario 4 (black curve), and Sc 8 (pink curve) are very similar and lying on top of each other during wet season. During dry and wet season these scenarios represent similar stress conditions to PD 08 drought conditions while stress under maintenance conditions lay within the PES requirements.

DRY SEASON **WET SEASON**

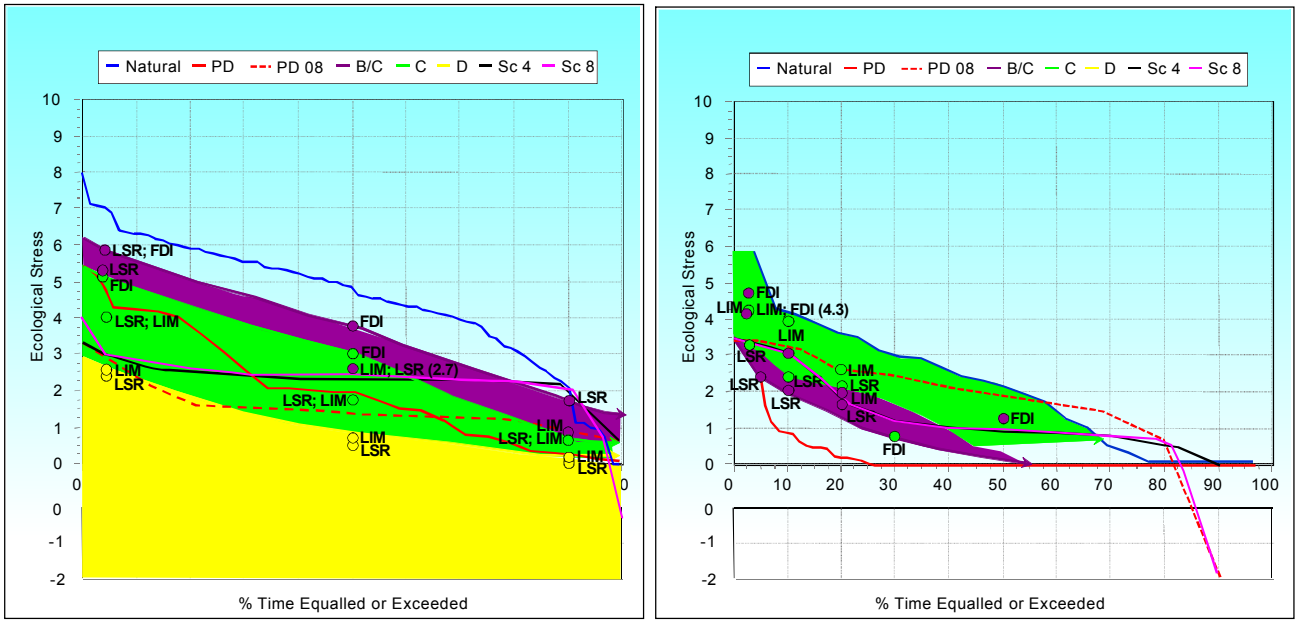


Figure 8.1 Stress duration for EWR 4: Dry and Wet season, Sc 4 and 8

8.2 ECOLOGICAL CONSEQUENCES: SCENARIO 4 AND 8

8.2.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 4, 8	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL VARIABLES					
C	C	C/D	C	Increased flows result in increased winter turbidity. Potential for algal blooms increase mainly due to diffuse agricultural runoff. Chlorophyll-*a* is seasonally variable.	The potential for algal blooms increase due to summer temperatures but this is masked by the higher turbidity levels.
GEOMORPHOLOGY					
D	D	D	D	No change to dry season base flows.	Slightly reduced floods.
The slight changes to the flow regime are not expected to have a major impact on the geomorphology.					

8.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 4, 8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B/C	D	C	Dry season base flows are slightly more than PD 08, but differences are too small to change the inundation regime of marginal zone plants.	Wet season base flows also increase slightly, which tends toward a more natural situation. Sedge inundation is increased at its lower limit, which favours fecundity, especially on the lower zone. Soil moisture is more available to *Salix mucronata* and also favours fecundity at the right time (summer).
The marginal zone remains inundated during summer and winter during base flows. Flood disturbance is generally reduced which means that the lower zone continues to function as the marginal zone and vegetation cover and density will remain high. The EC improves slightly from 62.7% to 63.9% (C).					
FISH					
C	B	D	C	The LSR guild is in a C EC which is similar to the PES as maintenance flows under this scenario are similar but drought conditions are worse than the PES droughts. Habitat suitability is overall similar than the PES and therefore the LSR guild is expected to remain in a C EC. The limnophilic guild is in a B EC which is similar to PES conditions with drought conditions being slightly worse. Habitat suitability is similar and therefore no change from the PES is expected. Overall the fish assemblage is expected to remain in PES under dry season flows.	The LSR guild is similar to the PES (especially in terms of drought flows) and no change from PES is expected for the guild during wet season. Overall the fish assemblage is expected to remain in or slightly improve from the PES (C) towards a higher EC.
Natural seasonal variability has been altered seriously from natural conditions. Under this scenario, seasonality will be mostly similar or improved from PD (higher late wet season flows but some loss in early wet season). Dry season flows will primarily maintain the PES but some improvement may take place during wet season (especially for the limnophilic guild). The overall biotic integrity in terms of fish is expected to improve under this scenario from a C (FRAI% = 66.7%) to a higher C (FRAI% = 72.5%).					
MACROINVERTEBRATES					
C/D	C	C/D	C/D	These scenarios are similar to Present Day, so no significant change is expected. The MIRAI is therefore expected to remain unchanged at 61.7% (Category C/D).	
ECOSTATUS					
C	B/C	D	C	Scenario 4 is very similar to PD and there is a slight improvement within the PES EC for vegetation and fish. Therefore the instream and overall EcoStatus improves within the PES.	

8.3 IMPACT OF SCENARIO 5 AND 6

The stress and flow duration graphs indicated that Sc 5, and 6 were very similar. Figure 8.2 illustrates the stress requirements and stress points required for a C PES, B/C REC (green and purple curves respectively) and D AEC down. The red curve illustrates the original PD flow that was provided during the study while the red dashed curve is the new present day (PD) flow based on 2008 hydrology and the blue curve represents Natural. Scenario 5 (light blue curve), and Sc 6 (dark green curve) are very similar and lying beneath each other during dry season for 50% of the time. These scenarios represent increased stress conditions during dry season drought conditions compared to PD. Maintenance stress conditions falls between the PES and REC requirements. Wet season drought conditions under Sc 5 are similar to the REC requirements while Sc 6 is similar to the PES requirements. Maintenance conditions are similar to the PES requirements for both scenarios. These scenarios represent more stress in the dry season than PD and less stress than PD in the wet season improving towards natural.

DRY SEASON **WET SEASON**

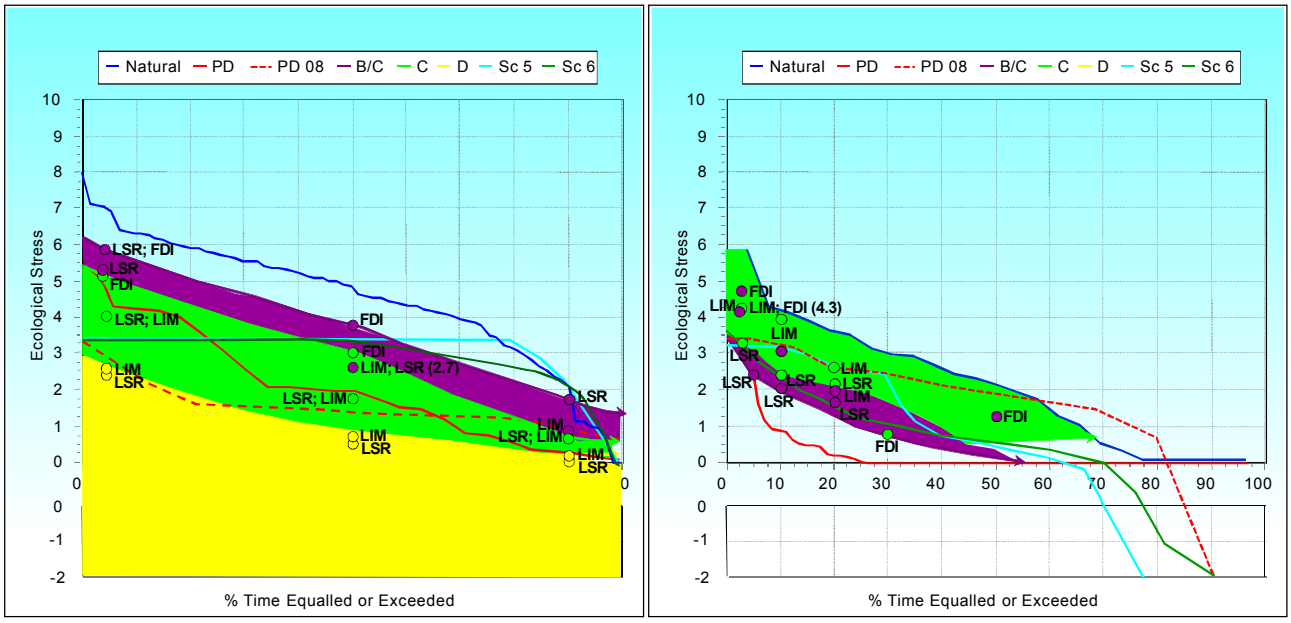


Figure 8.2 Stress duration for EWR 4: Dry and Wet season, Sc 5 and 6

8.4 ECOLOGICAL CONSEQUENCES: SCENARIO 5 AND 6

8.4.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 5, 6	DRY SEASON	WET SEASON
PHYSICAL-CHEMICAL VARIABLES					
C	C	C/D	C	The VRESSAP pipeline from Vaal Dam to Eastern Sub-system also removes water from this system. Increasing trend in phosphate concentrations. Potential for algal blooms increasing – mainly due to diffuse agricultural runoff and future 2020 development conditions.	The potential for algal blooms increases due to summer temperatures as well as the future 2020 development conditions (greater nutrients).
GEOMORPHOLOGY					
D	D	D	D	Reduced dry season base flows are not likely to have a major geomorphological impact.	Increased moderate floods. This should create some renewed scour and activation of gravel and cobbles beds in the channel.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 5, 6	DRY SEASON	WET SEASON
Very high wet season base flows (essentially small floods) occur for prolonged periods. These can be expected to erode marginal area, increase the extent of cut banks, armour the bed and increase turbidity. These impacts will cause the EC of the reach to degrade to a lower D EC.					

8.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC→	Sc 5, 6	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B/C	D	C	Dry season base flows are reduced, which tends more towards natural. This means that inundation stress during the winter dormancy is reduced, which will favour plant survival. The marginal zone however, remains inundated or saturated for the greater part of the year (base flow condition).	Wet season base flows and floods are improved and tend more towards natural. Seasonal differences also improve.
Seasonal difference is improved (the ratio of wet to dry season base flow increases from 1.14 for PD to 3.06 for scenario 5: natural ratio is 10.25). Currently riparian vegetation cover in the marginal zone is reduced due to increased dry season inundation, an impact that will slightly be alleviated under this scenario. The lower zone will also experience a more natural regime which will slightly reduce non-woody cover, but improve woody cover. The EC improves from 62.7% to 68.2% (C).					
FISH					
C	B	D	C	There is an overall improvement towards natural (especially maintenance flows) but droughts are still similar than PD and PES. The LSR and LIM guild is expected to improve from PES under this scenario during the dry season.	Conditions are similar to the PES (especially in terms of drought flows but slightly worse during maintenance) but no change from the PES is expected for LSR guild during wet season. The limnophilic guild overall in same EC as PES, with droughts being slightly better (B EC). A slight improvement can therefore be expected although they may remain in the PES.
Natural seasonal variability has been altered seriously from natural conditions. Under this scenario, seasonality will be mostly similar to PD and should not result in alteration of the fish assemblage. Dry season flows will improve conditions while wet season flows should only maintain the PES. An overall slight improvement can therefore be expected in the fish assemblage and fish is expected to improve under this scenario from a C (66.7%) to a higher C (71.5%).					
MACROINVERTEBRATES					
C/D	C	C/D	C	These scenarios have higher wet season base flows, and lower dry season base flows than present day. The seasonal variation is therefore improved, and this tends towards natural. The overall diversity of macroinvertebrates is therefore expected to increase. On the negative side, elevated wet season flows are expected to flush fine sediments, and this is likely to reduce the abundance of some taxa, such as Gomphidae, Ceratopogonidae, Tipulidae, Caenidae and Corixidae. The MIRAI is therefore expected to improve slightly to 65.5 % (Category C).	
ECOSTATUS					
C	B/C	D	C	Increased wet season base flows and lower dry season base flows along with improved seasonality results in an improvement of the biotic components within the PES EC.	

8.5 IMPACT OF SCENARIO 7

The stress and flow duration graphs indicated that Sc 7 was sufficiently similar to the PD and this scenario would not result in any change in the PES condition of the different components.

8.6 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 4 are provided in Table 8.1.

Table 8.1 Ecological consequences of operational flow scenarios at EWR 4

Driver Components	PES	REC	Sc 4, 8	Sc 5, 6	Sc 7=PES
WATER QUALITY	C	C	C	C	C
GEOMORPHOLOGY	D	D	D	D	D
Response Components	**PES**	**REC**	**Sc 4, 8**	**Sc 5, 6**	**Sc 7=PES**
FISH	C	B	C	C	C
MACROINVERTEBRATES	C/D	C	C/D	C	C/D
INSTREAM	C	B/C	C	C	C
RIPARIAN VEGETATION	C	B/C	C	C	C
ECOSTATUS	C	B/C	C	C	C

Scenario 4 – 8 did not meet the REC requirements at EWR 4. All the scenarios do however meet the PES EcoStatus. Of these scenarios Sc 5 and 6 are optimal as the increased wet season base flows and lower dry season base flows along with improved seasonality addresses (to an extent) the seasonal reversal that has occurred here. The other scenarios are very similar to PD conditions. The degree to which each scenario at EWR 6 meets the REC is summarised in Figure 8.3 below.

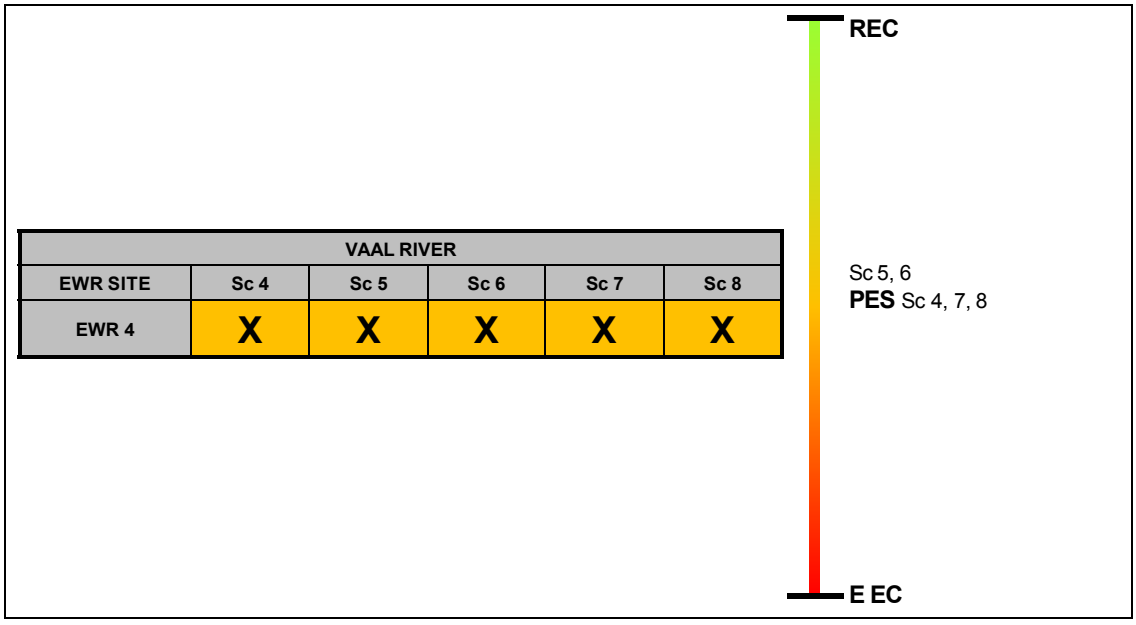


Figure 8.3 Summary of the impacts of operational flow scenarios at EWR 4

9 EWR 5: SCANDINAVIA (VAAL RIVER): ECOLOGICAL CONSEQUENCES

Scenarios 4 – 8 were evaluated and are discussed in Section 9.1 - 9.5. The issues at this site are similar to EWR 4.

9.1 IMPACT OF SCENARIO 5 AND 6

The stress and flow duration graphs indicated that Sc 5, and 6 were very similar. Figure 9.1 illustrates the stress requirements and stress points required for a C/D PES, C REC (green and purple curves respectively) and D AEC down. The red curve illustrates the original PD flow that was provided during the study while the red dashed curve is the new present day (PD) flow based on 2008 hydrology and the blue curve represents Natural. Scenario 5 (light blue curve), and Sc 6 (dark green curve) represent decreased stress from the new PD during drought conditions while maintenance stress lies between the PES and REC requirements for Sc 6 with stress similar to the REC requirements for Sc 5. Wet season drought conditions under Sc 5 are similar to the REC requirements while Sc 6 is similar to the PES requirements. Wet season drought stress is less than PD while maintenance stress lies between the PES and REC requirements and less than PD.

DRY SEASON **WET SEASON**

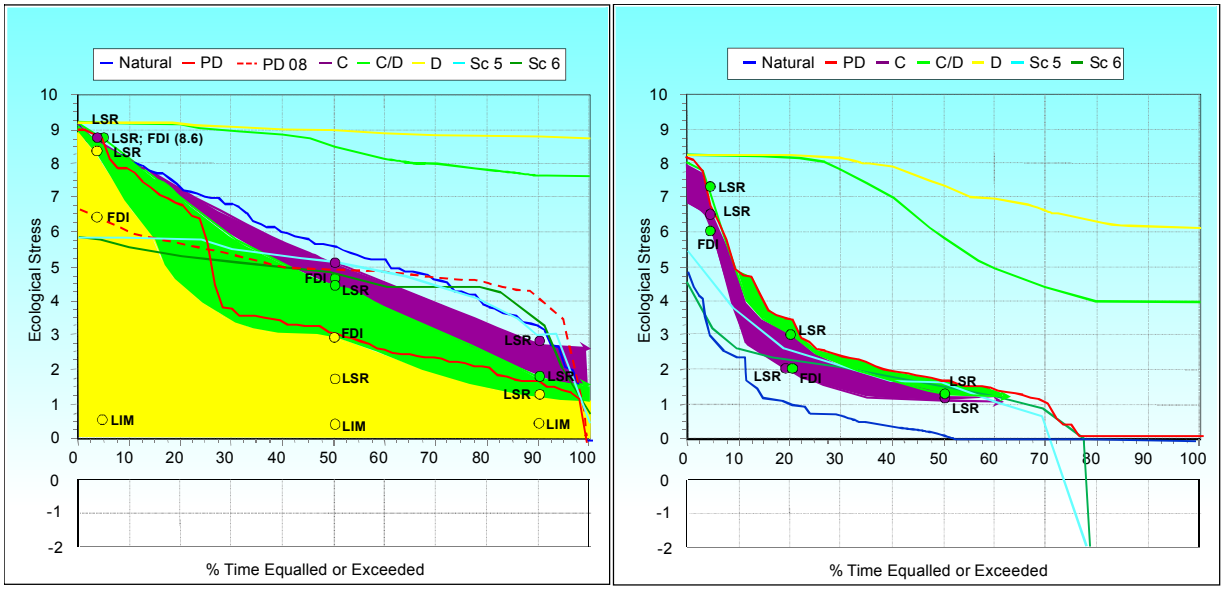


Figure 9.1 Stress duration for EWR 5: Dry and Wet season, Sc 5 and 6

9.2 ECOLOGICAL CONSEQUENCES: SCENARIO 5 AND 6

9.2.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc 5, 6	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL VARIABLES					
E	D/E	E	E	These scenarios supply EWR 5 with extra water and result in lower salinity values and potentially worsening nutrient levels due to increased urbanisation. It is important to note that nutrients are the driving force at this site.	
GEOMORPHOLOGY					
C	C	C/D	C	Reduced dry season base flows may allow for some minor seasonal accumulations of fines in the channel.	Increased base flows and small floods will occur. This should increase maintenance of the channel by ensuring sediment flushing.
The decreased winter flows, and provision of moderate floods in summer will inundate the lower banks and terraces; scour the channel; deepen pools; activate the gravels and cobbles; reduce embeddedness and flush out water hyacinth.					

9.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc 5, 6	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
D	C	-D	C/D	Same as PD 08, no altered response.	Wet season base flows and floods increased. Seasonality is markedly improved.
Marginal zone remains in a poor condition (D/E) as a result of inundation during the dry season. Existing marginal and lower zone populations completely inundated during wet season which, together with seasonal difference increases, will improve fecundity. Lower zone woody species will have improved recruitment opportunities, improve in cover and abundance and possibly reduce exotic species cover. The EC improves from 48.1 to 58% (C/D EC).					
FISH					
C	B	D	B/C	Overall conditions for the LSR guild is better than the PES and REC, approaching natural stress durations above 40% exceedence (therefore including maintenance flows). Conditions are significantly worse than PES and the AEC ↓ during stress durations <40% exceedence (therefore including droughts). Due to absence of rheophilic species that would be more vulnerable to drought or low flow impacts, it is estimated that the overall fish assemblage at the site will improve. A notable improvement from the PES can therefore be expected in the dry season.	Conditions are overall better than the PES (B/C to B) and overall similar to the REC with the LSR guild in a B EC. Maintenance flows are slightly worse than PES-REC (B vs. A/B), but drought conditions are moving closer to natural. Overall improvement is therefore expected during the wet season.
Natural seasonal variability has been altered seriously from natural conditions. Under this scenario, seasonality will be mostly similar or improved from PD. An overall slight improvement can therefore be expected in the fish assemblage and fish is expected to improve from a C (69.2%) to a B/C (81.7%). If non-flow related impacts (alien fish and migration barriers) and water quality are addressed, the conditions may improve towards a B.					
MACROINVERTEBRATES					
C	C	C/D	C	Median dry season flows for Sc 5 and Sc 6 are similar to PD, and are not expected to change macroinvertebrate composition or abundance. However, wet season high flows are higher than PD, and closer to natural, and this is expected to have a beneficial impact on instream habitats, particularly with respect to the flushing of hyacinth, as well as increased seasonal variability. The overall biodiversity is expected to increase, and taxa that are sensitive to water quality deterioration, such as Perlidae and Heptageniidae, are likely to benefit. The MIRAI is therefore expected to improve slightly to 69.7% (C EC).	
ECOSTATUS					
C/D	C	D	C	The improved seasonality and improved base flows during dry and wet season lead to improvement in the riparian vegetation and fish while macroinvertebrates improve within the PES EC. The overall improvement of the biotic components result in improved instream conditions and an improvement in the PES EcoStatus similar to the REC although the requirements of the REC are not met.	

9.3 IMPACT OF SCENARIO 4, 7, AND 8

The stress and flow duration graphs indicated that Sc 4, 7 and 8 was sufficiently similar to PD. Scenario 4 and 8 dry season flows were similar to PD while wet season base flows increased from PD and floods were slightly reduced. Scenario 7 was very similar to PD.

9.4 ECOLOGICAL CONSEQUENCES: SCENARIO 4, 7, AND 8

9.4.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc 4, 7, 8	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL VARIABLES					
E	D/E	E	E	As these scenarios do not supply EWR 5 with extra water the conditions are similar to PD with similar salinity values and potentially worsening nutrient levels due to increased urbanisation. It is important to note that nutrients are the driving force at this site and other variables such as microbiology and metals that are not measured are also variables of concern.	
GEOMORPHOLOGY					
C	C	C/D	C	No change to dry season base flows.	Slightly reduced floods.
Very small change, but within the EC, is expected due to the reduced floods, since this would slightly reduce the mobilisation and scouring of bed sediments.					

9.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc 4, 7, 8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
D	C	-D	D	Dry season base and drought flows slightly increased which tends to veer from natural, but differences are slight and key riparian species do not experience increased inundation stress during dormancy.	Wet season drought and base flows are also higher than PD 08, which improves seasonal differences slightly while floods are similar to PD 08.
The marginal zone remains in a poor condition (D/E) as a result of inundation during the dry season. Lower zone non-woody cover reduces slightly due to improved wet season base flows (an improvement) and seasonality. The EC improves slightly from 48.1 to 50.4%.					
FISH					
C	B	D	C	These scenarios are similar to PD, so no significant change is expected. The FRAI is therefore expected to remain unchanged at 69.2% (Category C).	
MACROINVERTEBRATES					
C	C	C/D	C	These scenarios are similar to PD, so no significant change is expected. The MIRAI is therefore expected to remain unchanged at 65.4% (Category C).	
ECOSTATUS					
C/D	C	D	C	There is a slight improvement within the PES EC for geomorphology and riparian vegetation while the rest of the component remain in the PES and the PES requirements are met under these scenarios.	

9.5 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 5 are provided in Table 9.1.

Table 9.1 Ecological consequences of operational flow scenarios at EWR 5

Driver Components	PES	REC	Sc 4, 7, 8	Sc 5, 6
WATER QUALITY	E	D/E	E	E
GEOMORPHOLOGY	C	C	C	C+
Response Components	**PES**	**REC**	**Sc 4**	**Sc 5**
FISH	C	B	C	B/C
MACROINVERTEBRATES	C	C	C	C
INSTREAM	C	B/C	C	C
RIPARIAN VEGETATION	D	C	D	C/D
ECOSTATUS	C/D	C	C/D	C

Scenario 4, 7 and 8 are very similar to PD and results in the PES. Scenario 5 and 6 result in an improvement of the PES but does not achieve the REC. The degree to which each scenario at EWR 5 meets the REC is summarised in Figure 9.2 below.

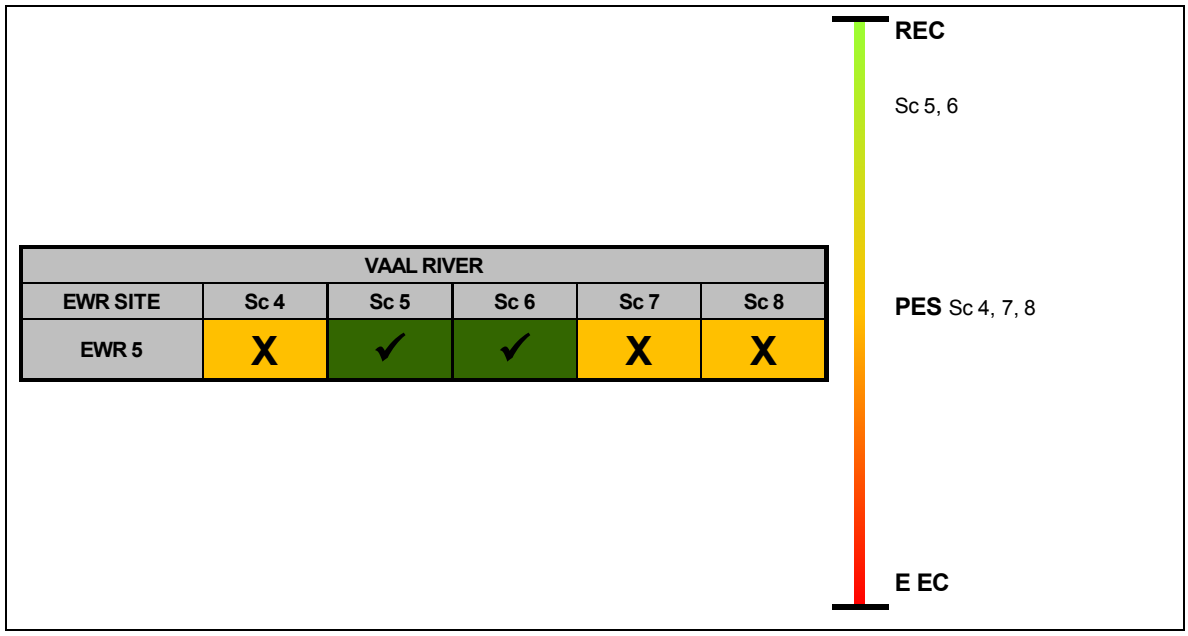


Figure 9.2 Summary of the impacts of operational flow scenarios at EWR 5

10 EWR 6: KLIP (KLIP RIVER) - ECOLOGICAL CONSEQUENCES

With the exception of run-of-river irrigation abstractions that take place directly from the Klip River there are no other catchment developments. The scenarios are similar to the Present Day as this site has no dams upstream and is not impacted by large scale future developments. Scenarios 4 – 8 were assessed and discussed in Section 10.1 – 10.5.

10.1 IMPACT OF SCENARIO 4, 7, AND 8

The stress and flow duration graphs indicated that Sc 4, 7 and 8 were sufficiently similar to be addressed as one. Figure 10.1 illustrates Sc 4, represented by the black curve and Sc 7 (orange curve) and Sc 8 (pink curve) which are lying beneath Sc 4. These scenarios are identical to PD and the modelled PD based on 2008 data represented by the red and yellow cure respectively. It is important to note that no realistic PD flows were available to use as a benchmark. Included in the figure are the stress requirements and stress points for a B/C PES and REC (purple curve) and AEC C (green). Reference is represented by the blue line while PD is represented by the red line.

DRY SEASON **WET SEASON**

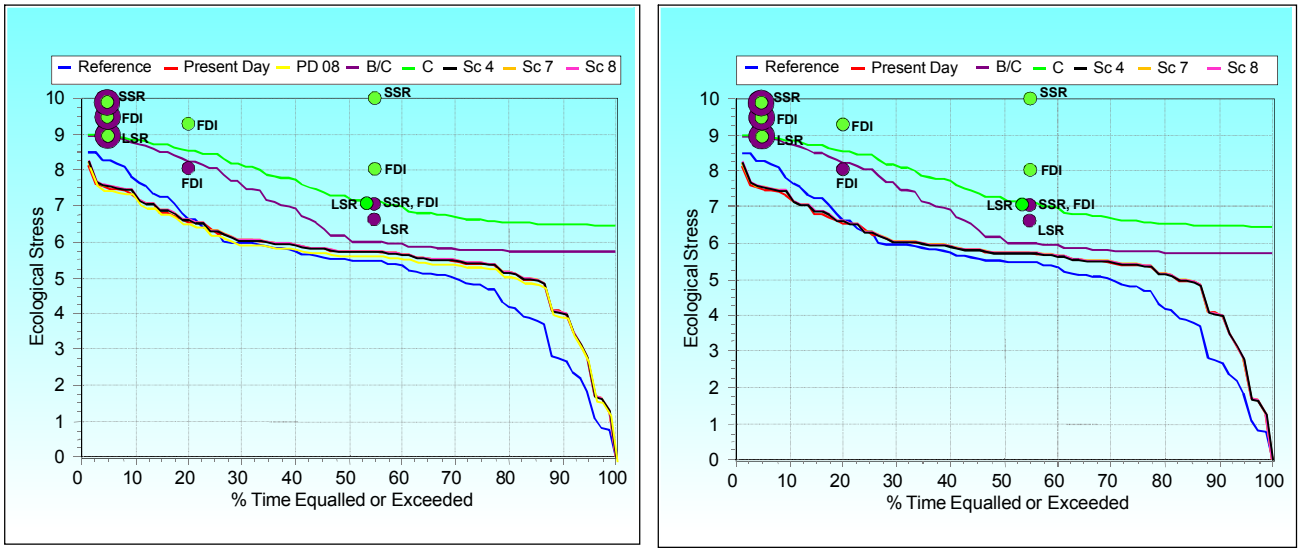


Figure 10.1 Stress duration for EWR 6: Dry and Wet season, Sc 4, 7, 9

10.2 ECOLOGICAL CONSEQUENCES: SCENARIO 4, 7, AND 8

The assessment of the components indicated that these scenarios were similar to the PES and REC.

10.3 IMPACT OF SCENARIO 5 AND 6

The stress and flow duration graphs indicated that the 2020 development scenarios, Sc 5 and Sc 6 were sufficiently similar to be addressed as one. Scenario 5 is represented by the light blue curve in Figure 10.2 and Sc 6 by the dark green curve. Stress requirements for Sc 5 are similar to the PES requirements up to 25% exceedence, after which the stress increases relative to the PES up to 60% exceedence in the dry season. Sc 6 is similar to the PES and both Sc 5 and 6 represent conditions that are more stressed than PD. During wet season Sc 5 and Sc 6 are very similar with stresses similar to PD and improving after 15% exceedence.

DRY SEASON **WET SEASON**

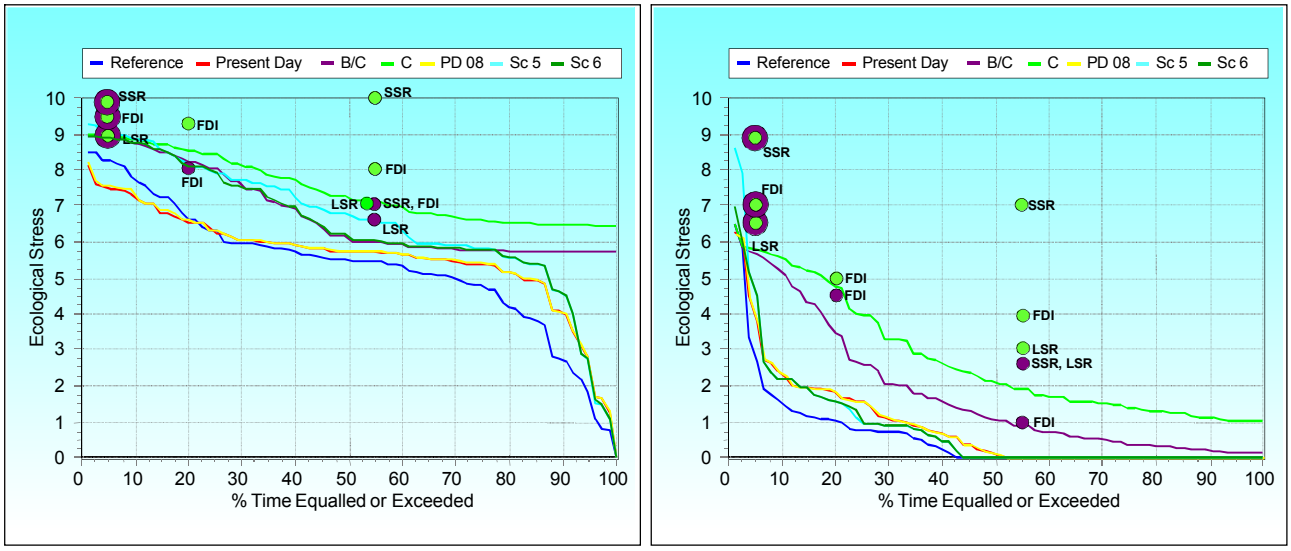


Figure 10.2 Stress duration for EWR 6: Dry and Wet season, Sc 5 and 6

10.4 ECOLOGICAL CONSEQUENCES: SCENARIO 5 AND 6

10.4.1 Driver components

EC			ECOLOGICAL CONSEQUENCES	
PES and REC	AEC→	Sc 5, 6	DRY SEASON	WET SEASON
PHYSICAL-CHEMICAL VARIABLES				
B/C	B	B/C	The only consequences of these scenarios are that there could be less flow in the winter and with a result slightly higher salinity. The summer flows and water quality issues would be the same as per present day with turbidity slightly increased.	
GEOMORPHOLOGY				
B	C	B	Small to moderate decreases in base flows and possibly some minor seasonal accumulations of fines in the channel.	Small increases in base flows with no change in moderate or large floods. Possibly some minor seasonal accumulations of fines in the channel, but the maintenance of the floods will ensure sediment flushing.
The site is maintained by large floods that are necessary to activate and scour the cobble bed of the river. The small changes in base flow will not result in a category change in the EC for geomorphology, since floods are not affected by the scenarios.				

10.4.2 Biotic responses

EC			ECOLOGICAL CONSEQUENCES	
PES and REC	AEC→	Sc 5, 6	DRY SEASON	WET SEASON
RIPARIAN VEGETATION				
B/C	C	B/C	Slightly more water stress as flows are generally slightly less, but not sufficient to cause any changes to riparian vegetation distribution, composition or function.	Slightly less water stress as flows tend towards natural conditions, but changes are too small to illicit a response from vegetation.
Overall, there is improved seasonal differences i.e. greater range between dry and wet season base flows. Dry season base flows being drier and wet season base flows being wetter and high flows are generally wetter. Changes to plant distribution along a hydraulic gradient are insignificant. This together with the fact that most of the impacts at the site were not related to flow modification, means that no changes are expected under either scenario. The EC remains a B/C at 78.7%.				

EC			ECOLOGICAL CONSEQUENCES	
PES and REC	AEC→	Sc 5, 6	DRY SEASON	WET SEASON
FISH				
B	C	A/B	Removal of zero flows will improve conditions. Habitat suitability is overall slightly better than under PES-REC flows (improvement related to improved droughts flows). A slight improvement from PES can therefore be expected under this scenario.	
The overall trends in the LSR guild indicate improvement in the EC from PES, with most significant improvement being associated with the wet season. The fish assemblage is expected to improve from a category B (84.6%) to A/B (89.6%). In general Sc 6 is very similar in terms of fish stresses to SC 5, and will therefore have a similar impact. Dry season conditions are slightly lower than under Sc 5, but still better than the PES and REC. An overall improvement from the PES similar than under Sc 6 can be expected.				
MACROINVERTEBRATES				
B	C	B	No Change from PES (MIRAI 86.5%) is expected.	
ECOSTATUS				
B/C	C	B	Most of the components are similar to the PES and REC. However Sc 5 and 6 results in an improvement of fish to an A/B EC, resulting in improved instream condition and an Ecostatus that improves from the PES and REC.	

10.5 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 6 are provided in Table 10.1.

Table 10.1 Ecological consequences of operational flow scenarios at EWR 6

Driver Components	PES and REC	Sc 4, 7, 8	Sc 5, 6
WATER QUALITY	B/C	B/C	B/C
GEOMORPHOLOGY	B	B	B
Response Components	**PES and REC**	**Sc 4, 7, 8**	**Sc 5, 6**
FISH	B	B	A/B
MACROINVERTEBRATES	B	B	B
INSTREAM	B	B	A/B
RIPARIAN VEGETATION	B/C	B/C	B/C
ECOSTATUS	B/C	B/C	B

Scenario 4, 7, and 8 resulted in conditions similar to the PES-REC. Scenario 5 and 6 resulted in improved conditions for fish and an improvement of the REC EcoStatus. The degree to which each scenario at EWR 6 meets the REC is summarised in Figure 10.3 below.

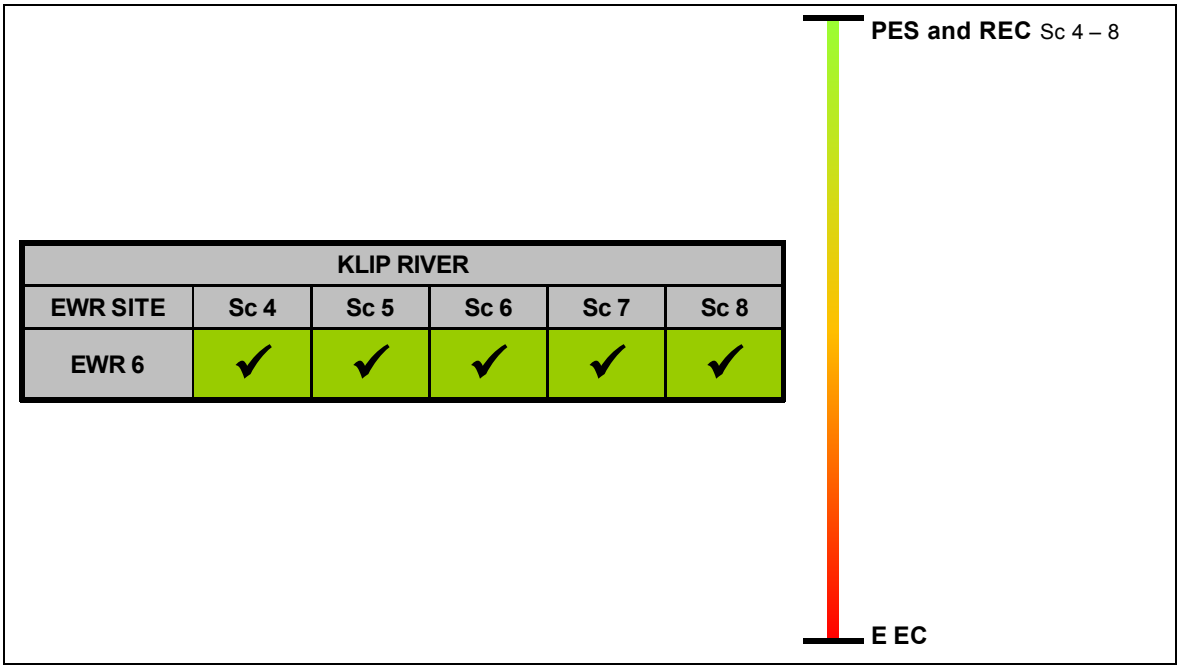


Figure 10.3 Summary of the impacts of operational flow scenarios at EWR 6

11 EWR 8: BAVARIA (WILGE RIVER) - ECOLOGICAL CONSEQUENCES

Sterkfontein Dam is situated in the headwaters of the Wilge River and the flow at EWR 8 includes the natural spills and releases made from Sterkfontein Dam in support of Vaal Dam. Owing to the high evaporation losses that are experienced at Vaal Dam, inter-reservoir operating rules have been developed for the operation of the Sterkfontein and Vaal dams to minimize these losses. To this end, water is thus stored in Sterkfontein Dam until needed and is only released to maintain a minimum operating level of 1471.96 MCM (storage of 476.72 million m^3) in Vaal Dam.

Furthermore, transfers are also made from Woodstock Dam in the Thukela River to Sterkfontein Dam in the Vaal River catchment via the Drakensberg Pumped Storage Scheme (PSS). The Thukela-Vaal transfer rule adopted for the analysis of Scenarios 7 and 8 was to transfer only enough water from Woodstock Dam to maintain Sterkfontein Dam at its Full Supply Capacity (FSC). For the modelling of the EWR at EWR 8 it was assumed that the EWR could be supplied by releases from Sterkfontein Dam during low flow months where the EWR could not be fully supplied from incremental runoff alone.

It is important to note that the water from Sterkfontein Dam has not been released into the Wilge River since the mid 1990's due to the Vaal Dam getting water from the Katse Dam and the high rainfall over the past decade and a half. Scenarios 4 – 8 were assessed and discussed in Section 11.1 – 11.5.

11.1 IMPACT OF SCENARIO 4

Scenario 4 is illustrated by the black curve in Figure 11.1. The PES and REC (C EC) is represented by the green curve, the B/C (AEC up) by the purple curve and the AEC down (D EC) by the brown curve in this figure. During dry season drought conditions Sc 4 has similar stress requirements than the B/C requirements and lies between the C and B/C requirements for the rest of the time. Stress conditions under Sc 4 are more than PD (red curve) but less than the modelled 2008 PD (yellow curve). Wet season stress is similar to PD and modelled 08 PD.

DRY SEASON **WET SEASON**

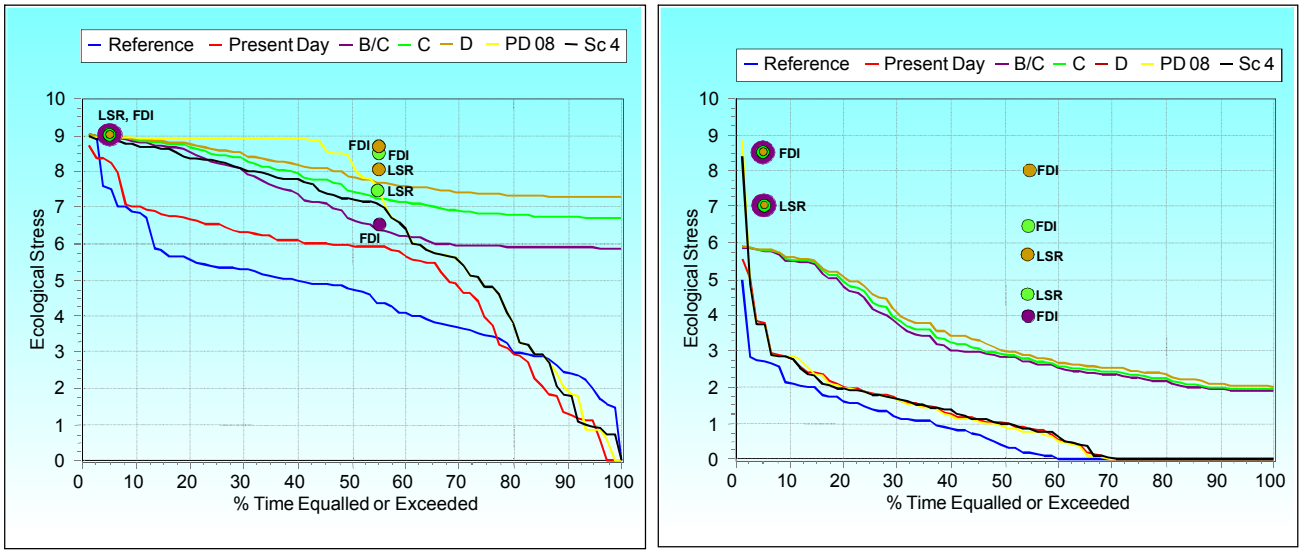


Figure 11.1 Stress duration for EWR 8: Dry and Wet season, Sc 4

11.2 ECOLOGICAL CONSEQUENCES: SCENARIO 4

11.2.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 4	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B/C	C/D	B/C	In the dry season there will be an improvement in nutrients and salinity concentrations. The releases from the dam could cause increased turbidity and release colder water temperatures.	No releases from Sterkfontein Dam and flows supplied from incremental runoff alone. Firstly runoff will deteriorate water quality but there after the higher flows will be used to dilute the impacts from upstream point sources.
GEOMORPHOLOGY					
C	C+	C/D	C	During dry season there are elevated base flows and drought flows and no change to higher flows. Wet season conditions are similar to PD. These flow changes will not have an impact on geomorphology and the EC remains at PES.	

11.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 4	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B/C	D	C	Dry season base flows are better than PD at times and closer to natural. Marginal zone sedge cover will be slightly reduced by increased winter base flows and this is an improvement towards reference:	Wet season base flows are similar to PD so no vegetation response is expected.
The PES will remain in a C although due to the improvement in the marginal zone the vegetation improves to a VEGRAI score of 66.6%					
FISH					
C	B	D	C	The overall trend in the LSR guild indicate improved habitat suitability compared to those under PES flows, with the improvement being especially due to better conditions during the wet season. It is estimated that the LSR guild is presently close to optimal condition, and therefore improved flows will not result in notable improvement of this guild. The primary impact at the site is associated with especially the presence of alien predatory fish on smaller species, and the improved habitat is not expected to improve conditions and the EC for fish (as calculated by the FRAI) will most probably remain in a category C (76.1%).	
MACROINVERTEBRATES					
C/D	C	D	C	The macroinvertebrate stress for this scenario during low flows is lower than PD flows, and this is likely to improve conditions for taxa that have a preference for moderate flows, such as Leptophlebiidae, Atyidae and Hydroptilidae. The macroinvertebrates are expected to remain in C EC (MIRAI 65.3%).	
ECOSTATUS					
C	B/C	D	C	This scenario results in an improvement in water quality as well as a slight improvement in riparian vegetation and aquatic macroinvertebrates within the PES EC. The EcoStatus is improved within the C EC.	

11.3 IMPACT OF SCENARIO 5 - 8

The stress and flow duration graphs indicated that the 2020 development scenarios (Sc 5 and Sc 6) and the future development scenarios (Sc 7 and Sc 8) had the same impact at EWR 8. Scenario 5 is represented by the light blue curve in Figure 11.2 and Sc 6 by the dark green curve. These scenarios represent a significant increase in base flows during both dry and wet season as well as moderate floods. These increases are more than reference condition.

DRY SEASON **WET SEASON**

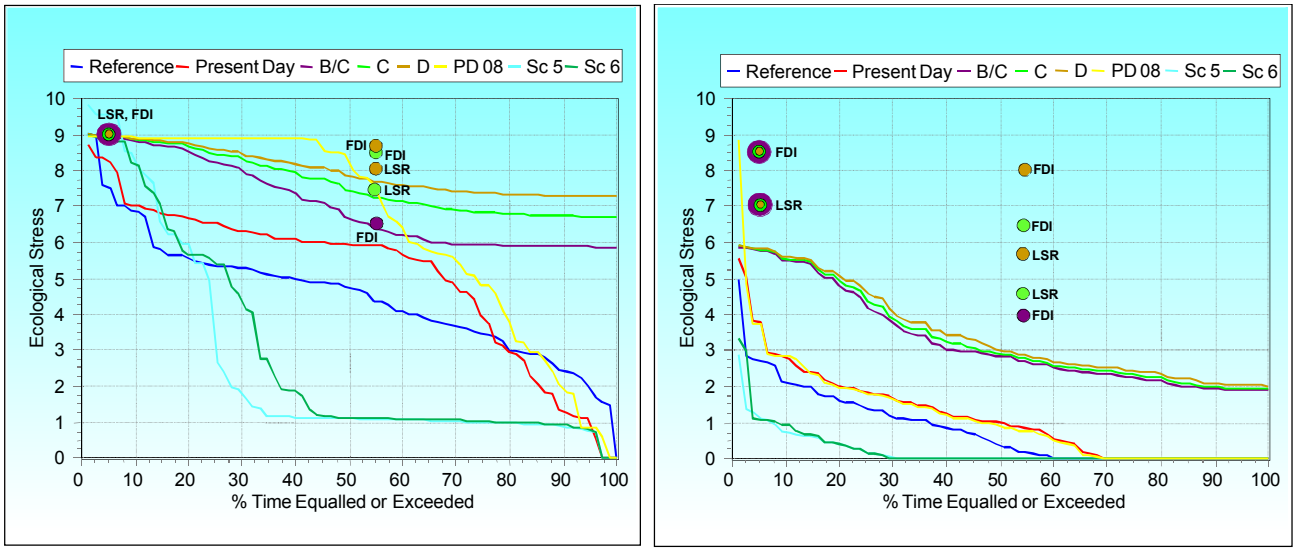


Figure 11.2 Stress duration for EWR 8: Dry and Wet season, Sc 5 - 6

Figure 11.3 illustrates Sc 7 and Sc 8, represented by the orange and pink curves respectively. Compared to Sc 5 and 6 illustrated in Figure 10.2, these scenarios are very similar. Scenario 7 and 8 during dry season drought are similar to the EWR scenarios for a greater length (0 – 15% exceedence compared to 0 – 5% exceedence under Sc 5 and 6) while wet season is very similar. The consequences of Sc 5 – 8 were therefore the same and are discussed in Section 11.3.

DRY SEASON **WET SEASON**

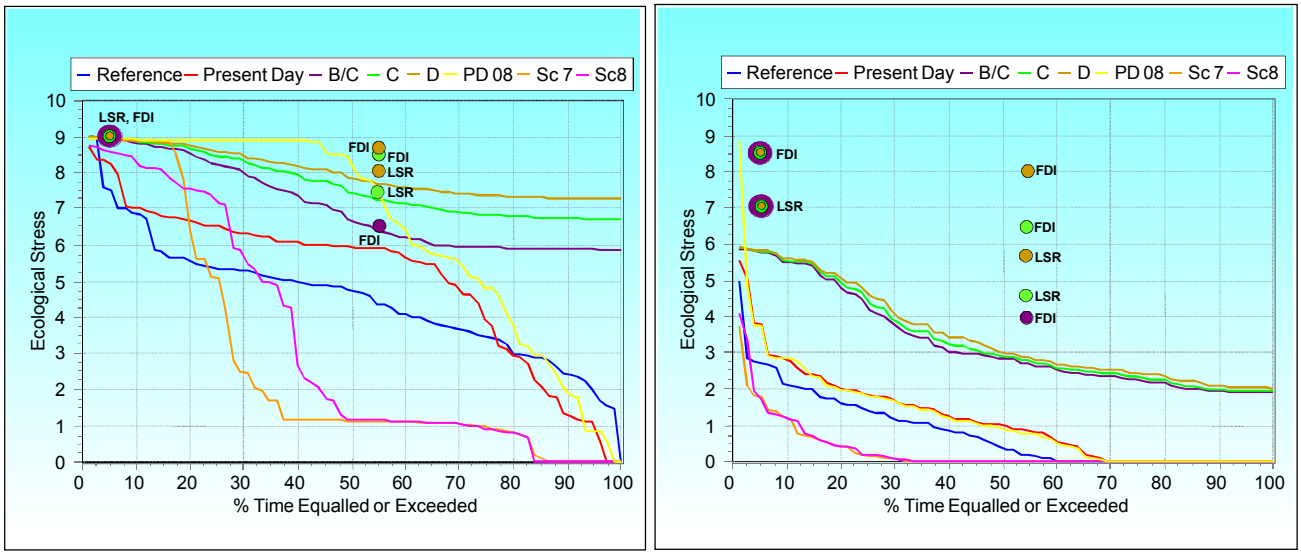


Figure 11.3 Stress duration for EWR 8: Dry and Wet season, Sc 7 and 8

11.4 ECOLOGICAL CONSEQUENCES: SCENARIO 5 – 8

11.4.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 5 - 8	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B/C	C/D	C	In the dry season there will be an improvement in nutrients and salinity concentrations. The releases from the dam could cause increased turbidity and release colder water temperatures. Conversably there could be an increased point source pollution contribution due the increased development and return flows from the WWTWs and urban areas.	Runoff will deteriorate water quality but there after the higher flows will be used to dilute the impacts from upstream point sources and agriculture.
GEOMORPHOLOGY					
C	C+	C/D	D/E	There is significant increase in base flows (20 – 60 times higher) as well as small floods. Major scour of the bed, banks and marginal zones will occur and widespread incision and bank cutting is expected.	Increased base flows (2 – 5 times higher. Major scour of the bed, banks and marginal zones will occur and widespread incision and bank cutting is expected.
The geomorphology of the site is maintained by large annual and inter-annual floods. These scenarios will not affect delivery of these largest flood events, but the enormous increased base flows and the increased moderate floods will cause widespread erosion and rapidly degrade the EC. Base flows would, under these scenarios, exceed the current intra-annual floods.					

11.4.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 5 - 8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	B/C	D	D	Scenarios 5 – 8 are similar to each other except at very low flows. All scenarios are significantly wetter than PD and Natural.	All scenarios wetter than PD and Natural. Floods higher than PD for Sc 5 and 6 and similar to PD for Sc 7 and 8.
There is an extreme increase in inundation stress, especially during dry season base flows (but also wet season base flows) and will result in senescence of marginal zone riparian vegetation with 60 to 100% loss of the current marginal zone. Portions of the current lower zone will become the new marginal zone, with increased vegetation (especially sedge) cover and density. Loss of sediment will occur as high velocity flows scour the active channel and also result in vegetation loss. The EC drops from C (63.5%) to D (47.1%).					
FISH					
C	B	D	D	Drought conditions will be more severe than natural, as well as PD and PES conditions. Maintenance flows will be radically higher than natural, as well as PD and PES flows, resulting in significant deterioration in habitat suitability (especially for small semi-rheophilic and limnophilic species). Radical loss of slow habitats as well as marginal vegetation (especially on islands and bars) due to scouring and erosion will have a significant impact on the fish assemblage, resulting in deterioration in the PES.	Generally flows will be higher than natural, PD and PES, especially in the drought range. Again this will result in loss of natural habitat diversity for especially limnophilic fish species, and therefore overall decrease in habitat suitability for fish (although the semi-rheophilic species may be favored by these conditions). An overall deterioration in the fish assemblage is therefore expected under this scenario in the wet season.
The significant higher flows (especially during dry season) will result in extensive bank erosion, loss of islands, loss of marginal/overhanging vegetation, increased velocities, and hence loss of slow habitats, decreasing habitat suitability for especially limnophilic and small semi-rheophilic species. The entire fish assemblage (including large semi-rheophilic species) will however be impacted negatively due to alteration of natural and present habitat compositions, and the PES is expected to be reduced from a C (76.1%) to a D (55.8%). Wet season may be slightly better under Sc 7 and 8, but the dry season impact is worse and therefore the same response can be expected in the fish due to similar impacts in terms of geomorphology (scouring, bank erosion), vegetation (loss of marginal zone, overhanging vegetation) and loss of natural habitat diversity (especially slow habitat) will be similar for all these scenarios.					
MACROINVERTEBRATES					
C/D	C	D	D	Scenarios 5 - 8 have greatly elevated dry season low flows, and this is expected to cause die-off of marginal vegetation. This could have negative impacts for macroinvertebrates found in the marginal vegetation, such as shrimps (Atyidae) and Hydroptilidae. Seasonal variation in low flows is greatly reduced, and this is	

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↑	AEC↓	Sc 5 - 8	DRY SEASON	WET SEASON
				expected to reduce the diversity of macroinvertebrates. Taxa that prefer high flows are expected to proliferate. Elevated dry season flows are typically associated with outbreaks of pest blackflies. These changes are expected to result in a deterioration of the macroinvertebrates from a present day MIRAI score of 60.8% to 51.9% (Category D).	
ECOSTATUS					
C	B/C	D	D	The significant increase in base flows during dry and wet season has an adverse effect on this site. Although water quality stays stable the geomorphology deteriorates. Riparian vegetation deteriorates due to inundation stress and loss of the marginal zone. This leads to significant loss of important habitat for fish and aquatic macroinvertebrates and therefore the instream condition and the EcoStatus deteriorates to a D EC.	

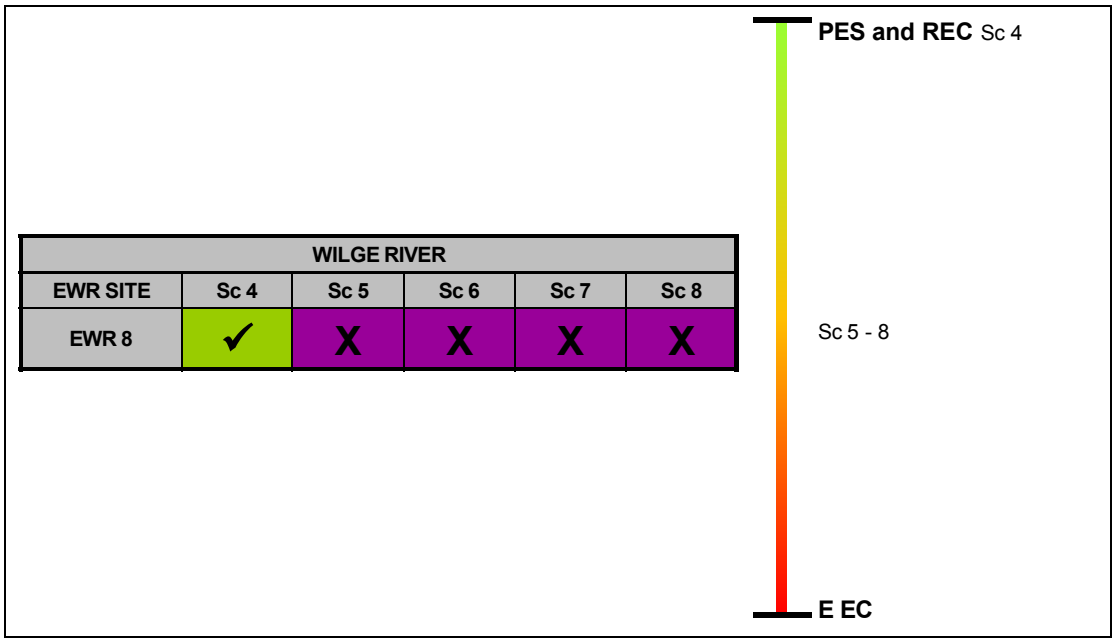
11.5 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 8 are provided in Table 11.1.

Table 11.1 Ecological consequences of operational flow scenarios at EWR 8

Driver Components	PES and REC	Sc 4	Sc 5, 6, 7, 8
WATER QUALITY	C	B/C	C
GEOMORPHOLOGY	C	C	D/E
Response Components	**PES and REC**	**Sc 4**	**Sc 5, 6, 7, 8**
FISH	C	C	D
MACROINVERTEBRATES	C/D	C	D
INSTREAM	C	C	D
RIPARIAN VEGETATION	C	C	D
ECOSTATUS	C	C	D

Scenario 4 meets the requirements of the PES-REC and is a slight improvement within the C EcoStatus as macroinvertebrates improve. The impact of Sc 5 – 8 was similar, and these scenarios result in the deterioration of the PES-REC. The significant increase in base flows during dry and wet season has an adverse effect on this site. Although water quality stays stable the geomorphology deteriorates. Riparian vegetation deteriorates due to inundation stress and loss of the marginal zone. This leads to significant loss of important habitat for fish and aquatic macroinvertebrates and therefore the instream condition and the EcoStatus deteriorates to a D EC. The degree to which each scenario at EWR 8 meets the REC is summarised in Figure 11.4 below.



WILGE RIVER					
EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
EWR 8	✓	X	X	X	X

Figure 11.4 Summary of the impacts of operational flow scenarios at EWR 8

12 EWR 9: SUIKERBOS US (SUIKERBOSRAND RIVER) - ECOLOGICAL CONSEQUENCES

EWR 9 is located downstream of the Balfour and Petrus Haarhoff dams which are situated on the main stem of the river. These two dams supply water to the Balfour Local Municipality. It was assumed that the dam is capable of releasing the required EWR high flows. Scenarios 4 – 8 were assessed and discussed in Section 12.1 – 12.7.

12.1 IMPACT OF SCENARIO 4, 6, AND 8

The stress and flow duration graphs indicated that the 2008, 2020 and full utilization development scenarios (Sc 4, 6 and 8) which included the EWR had the same impact on the EWR 9. Figure 12.1 illustrates the stress requirements and stress points required for a C PES and B/C REC (green and purple curves respectively). The red curve illustrates the original Present Day flow that was provided during the study while the yellow curve is the new present day (PD) flow based on 2008 hydrology. Scenario 4 (black curve), Sc 6 (dark green curve) and Sc 8 (pink curve) are very similar and Sc 6 and Sc 8 curves are lying beneath Sc 4 for most of the time in the dry season while Sc 8 is beneath Sc 4 in the wet season. These scenarios represent decreased stress during the dry season drought season and similar stress to the REC at maintenance periods. During wet season stress is similar to PD 08 for Sc 4 and 8 while Sc 6 is an improvement of PD and PD 08 conditions.

DRY SEASON **WET SEASON**

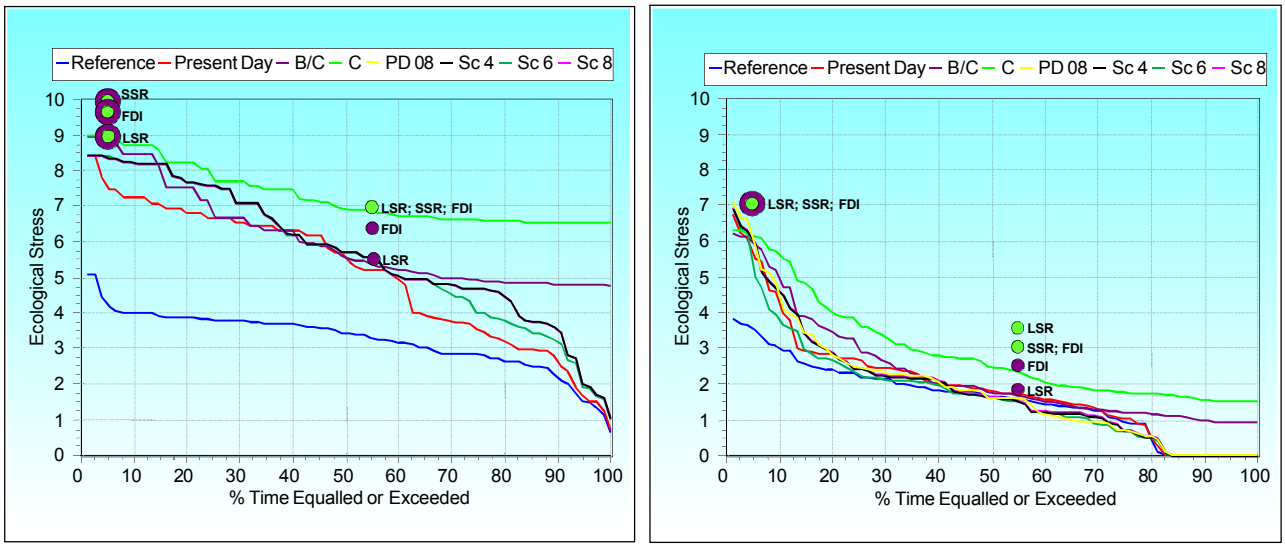


Figure 12.1 Stress duration for EWR 9: Dry and Wet season, Sc 4, 6, 8

12.2 ECOLOGICAL CONSEQUENCES: SCENARIO 4, 6, AND 8

12.2.1 Driver components

EC			ECOLOGICAL CONSEQUENCES	
PES	REC	Sc 4, 6, 8	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL				
C/D	C	C	This scenario has slightly higher winter base flows. The releases from the Haarhoff and Balfour dams would improve the winter water quality slightly. Water temperatures released from these dams could be slightly higher than natural or PD. There could be slightly increased turbidity in the winter due to higher base flows.	Summer flows will be similar to PD flows and hence the water quality would also be similar.
GEOMORPHOLOGY				
B/C	B	B/C	Minor increases in the drought and sometimes lower base flows of the dry season. No change in morphology anticipated.	No change in wet season base flows or floods proposed under this scenario.
The geomorphology of the site is maintained by large annual and inter-annual floods. These scenarios will not affect delivery of these largest flood events, so no change in the EC of the geomorphology is expected.				

12.2.2 Biotic responses

EC			ECOLOGICAL CONSEQUENCES	
PES	REC	Sc 4, 6, 8	DRY SEASON	WET SEASON
RIPARIAN VEGETATION				
B/C	B	B	All scenarios (Sc 4 – 8) similar to or wetter than PD.	All scenarios (Sc 4 – 8) similar and close to PD. Floods do not differ from PD.
Increased dry season base flows will result in additional marginal zone cover, and will favour sedge (*C. marginatus*) growth and keep marginal zone woody species (*G. virgatum*) in check. The EC improves to a B at 82.4%.				
FISH				
D	C	C	The ECs for both wet and dry season, as well as overall will be similar to that of the REC (C) for these scenarios.	
MACROINVERTEBRATES				
D	C	C	This scenario is likely to improve habitat availability for flow dependent taxa. Key taxa expected at the site with improved base flows include Hydropsychidae > 2 sp, Heptageniidae, Coenagrionidae, Corixidae and Leptophlebiidae and Baetidae >2sp. This scenario results in the condition similar to the REC with the MIRAI of 76.6%.	
ECOSTATUS				
C	B/C	B/C	Conditions are similar to REC conditions and all the components improve except geomorphology which remains stable as these scenarios do not affect big floods. The resulting EcoStatus is similar to the REC and an improvement of the PES.	

12.3 IMPACT OF SCENARIO 5

Scenario 5 is represented by the light blue line in Figure 12.2 and represents stress similar to PD 08 in dry season drought. From 15% exceedence the stress decreases from PD 08 and at maintenance the stress is similar to PES. During wet season stress is less than all the EWR scenarios, PD and PD 08 during drought conditions and from 30% exceedence stress is similar to reference conditions.

DRY SEASON **WET SEASON**

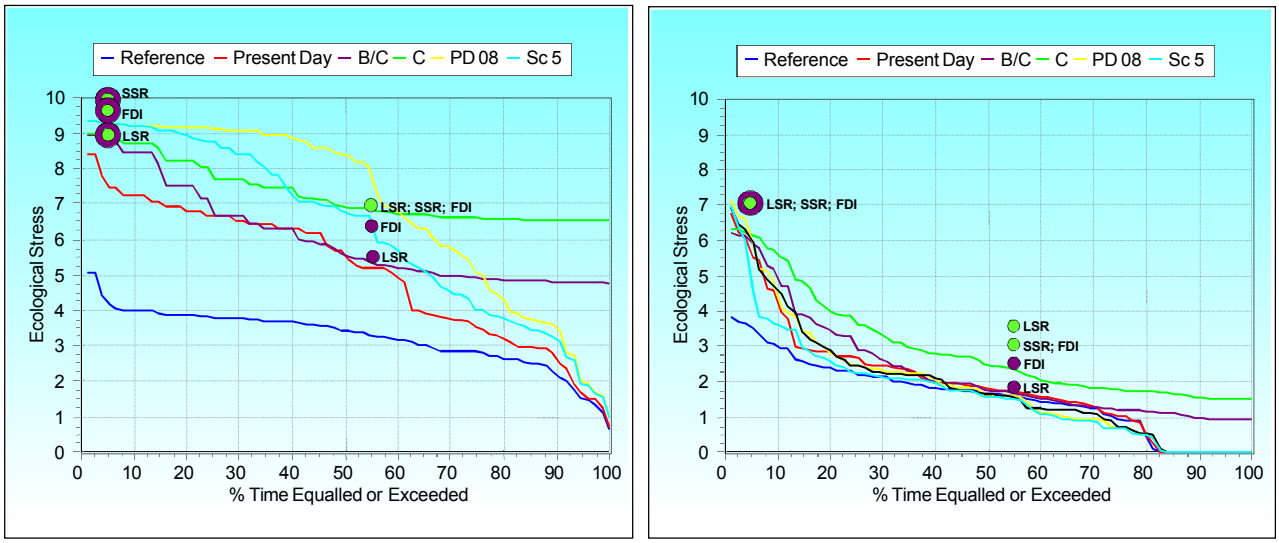


Figure 12.2 Stress duration for EWR 9: Dry and Wet season, Sc 5

12.4 ECOLOGICAL CONSEQUENCES: SCENARIO 5

12.4.1 Driver components

EC			ECOLOGICAL CONSEQUENCES	
PES	REC	Sc 5	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL				
C/D	C	C/D	This scenario has slightly higher winter base flows. The releases from the Haarhoff and Balfour dams would improve the winter water quality slightly. Water temperatures released from these dams could be slightly higher than natural or PD. There could be slightly increased turbidity in the winter due to higher base flows. This scenario included the 2020 development and as a consequence there would be expected to be a worsening of water quality due to upstream urbanisation and increased impervious areas.	Summer flows will be similar to the PD flows and hence the water quality would also be similar.
GEOMORPHOLOGY				
B/C	B	B/C	This scenario is the same as for Sc 4, 6 and 8.	

12.4.2 Biotic responses

EC			ECOLOGICAL CONSEQUENCES	
PES	REC	Sc 5	DRY SEASON	WET SEASON
RIPARIAN VEGETATION				
B/C	B	B	This scenario is the same as for Sc 4, 6 and 8.	
FISH				
D	C	C/D	The conditions will remain similar to PES during the dry season, but an improvement is expected in the wet season. An overall improvement is therefore expected from the PES of D (53.3%) to a C/D (58.8%).	
MACROINVERTEBRATES				
D	C	C	The macroinvertebrate stress profile during the dry season fits the REC category C, except that drought flows are slightly higher. The higher dry season drought is likely to provide slightly improved flow conditions for flow dependent taxa, such as Tricorythidae and Heptageniidae. During the wet season this scenario exceeds the requirements for a category C. These changes result in an improvement of the macroinvertebrates from a present day MIRAI score of 50.4% (Category D) to 76.6% (Category C).	

EC			ECOLOGICAL CONSEQUENCES	
PES	REC	Sc 5	DRY SEASON	WET SEASON
ECOSTATUS				
C	B/C	C	The improvements in macroinvertebrates and riparian vegetation are similar to the REC while fish improve a half a category from the PES. The consequence is an improvement in instream conditions from the PES, but overall the EcoStatus improves within the PES EC.	

12.5 IMPACT OF SCENARIO 7

Scenario 7 is represented by the orange curve in Figure 12.3 and is very similar to PD 08 in dry and wet season. This scenario implies increased stress during the dry season from PES while less stress is expected during wet season.

DRY SEASON **WET SEASON**

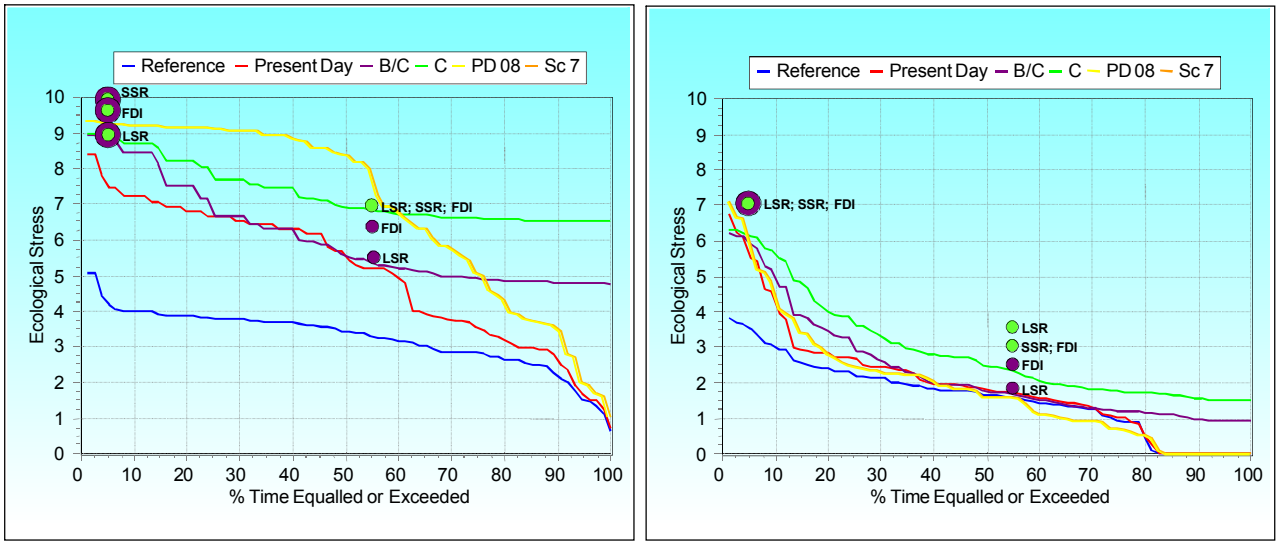


Figure 12.3 Stress duration for EWR 9: Dry and Wet season, Sc 7

12.6 ECOLOGICAL CONSEQUENCES: SCENARIO 7

The assessment of Sc 7 indicated conditions similar to the PES for all the components.

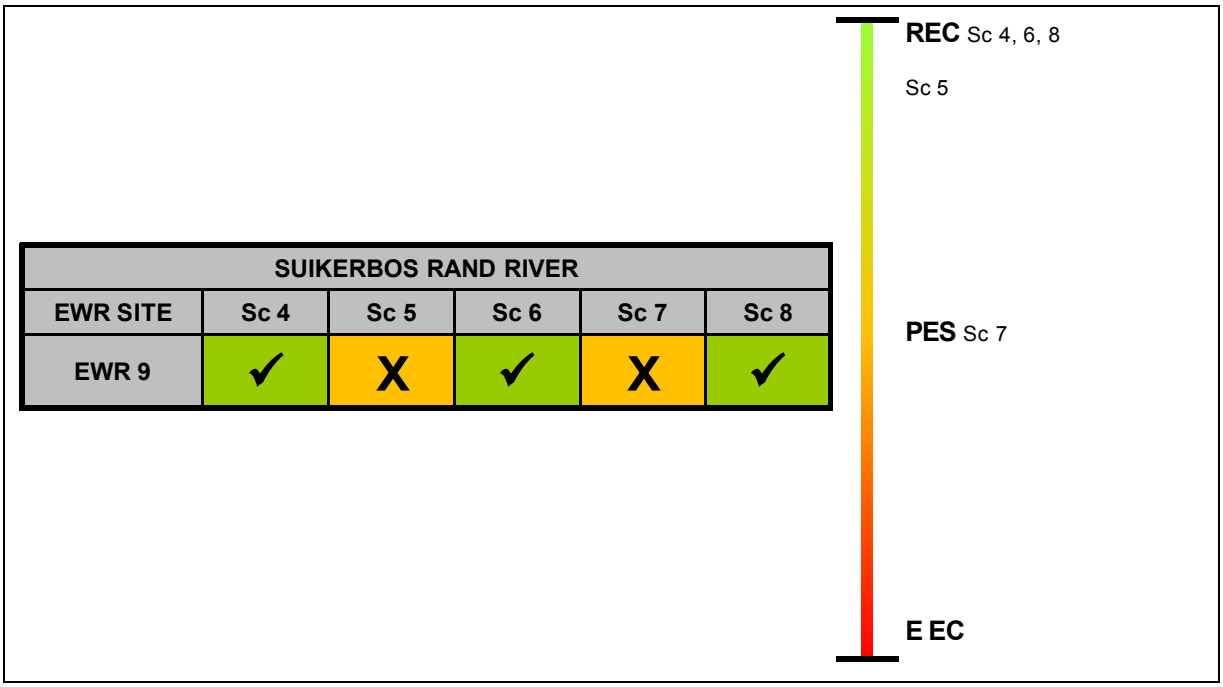
12.7 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 9 are provided in Table 12.1.

Table 12.1 Ecological consequences of operational flow scenarios at EWR 9

Driver Components	PES	REC	Sc 4, 6, 8	Sc 5	Sc 7=PES
WATER QUALITY	C/D	C	C	C/D	C/D
GEOMORPHOLOGY	B/C	B	B/C	B/C	B/C
Response Components	**PES**	**REC**	**Sc 4, 6, 8**	**Sc 5**	**Sc 7**
FISH	D	C	C	C/D	D
MACROINVERTEBRATES	D	C	C	C	D
INSTREAM	D	C	C	C	D
RIPARIAN VEGETATION	B/C	B	B	B	B/C
ECOSTATUS	C	B/C	B/C	C	C

Scenario 4, 6, and 8 resulted in conditions similar to the REC with only geomorphology not improving, and therefore this scenario is an improvement from the PES and achieves the REC. Scenario 5 results in drivers remaining stable and macroinvertebrates, instream and riparian vegetation improving similar to the REC. Fish improves a half a category from the PES and as a consequence there is an improvement in instream conditions from the PES, but overall the EcoStatus improves within the PES EcoStatus. Scenario 7 is virtually the same as modelled 2008 hydrology and results in no change from the PES. The degree to which each scenario at EWR 9 meets the REC is summarised in Figure 12.4 below.



SUIKERBOS RAND RIVER					
EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
EWR 9	✓	X	✓	X	✓

Figure 12.4 Summary of the impacts of operational flow scenarios at EWR 9

13 EWR 10: SUIKERBOS DS (SUIKERBOSRAND RIVER) - ECOLOGICAL CONSEQUENCES

Scenarios 4 – 8 were evaluated and are discussed in Section 13.1 - 13.4. During EWR scenario determination (Step 4 of the Ecological Reserve process) (DWA, 2009b) the following issues regarding hydrology were identified:

- Both the Suikerbosrand River (EWR 10) and the Blesbokspruit River (EWR 11) had significantly MORE flow under present conditions than under natural conditions.
- PES: The present hydrology resulted in the PES of a C/D. The borders of this PES band, representing more and less flow than the present hydrology, were identified. This band therefore consisted of a scenario where flows could be increased and decreased.
- AEC up (Improved PES): Improvement is only possible by REMOVING water (i.e. increasing the stress towards natural). Improvement is also only possible if water quality problems do not deteriorate when water is removed. If water quality problems are not addressed in conjunction with the removal of flow, then a decreased flow will not achieve an improvement. Stress values provided for the REC of a C represents the border between the C and the B EC.
- AEC down (EC lower than the PES): This will be achieved by INCREASING the flows. Based on the assumption that the increase will be constant during the year, stress values are provided for increased flows where the PES changes from a C/D to a D EC.

13.1 IMPACT OF SCENARIO 5 AND 6

The stress and flow duration graphs indicated that Sc 5, and 6 were very similar and therefore Sc 5 represent these two scenarios. Figure 13.1 illustrates the stress requirements and stress points required for a C/D PES, C REC (green and purple curves respectively) and D AEC down. The red curve illustrates the original PD flow that was provided during the study and the blue curve represents Natural. Scenario 5 and 6 (light blue curve) represent decreased stress from the PD both during wet and dry season for drought and maintenance periods as large (approximately 0.4 to 1.0 m^3/s) increases in base flow is proposed.

DRY SEASON **WET SEASON**

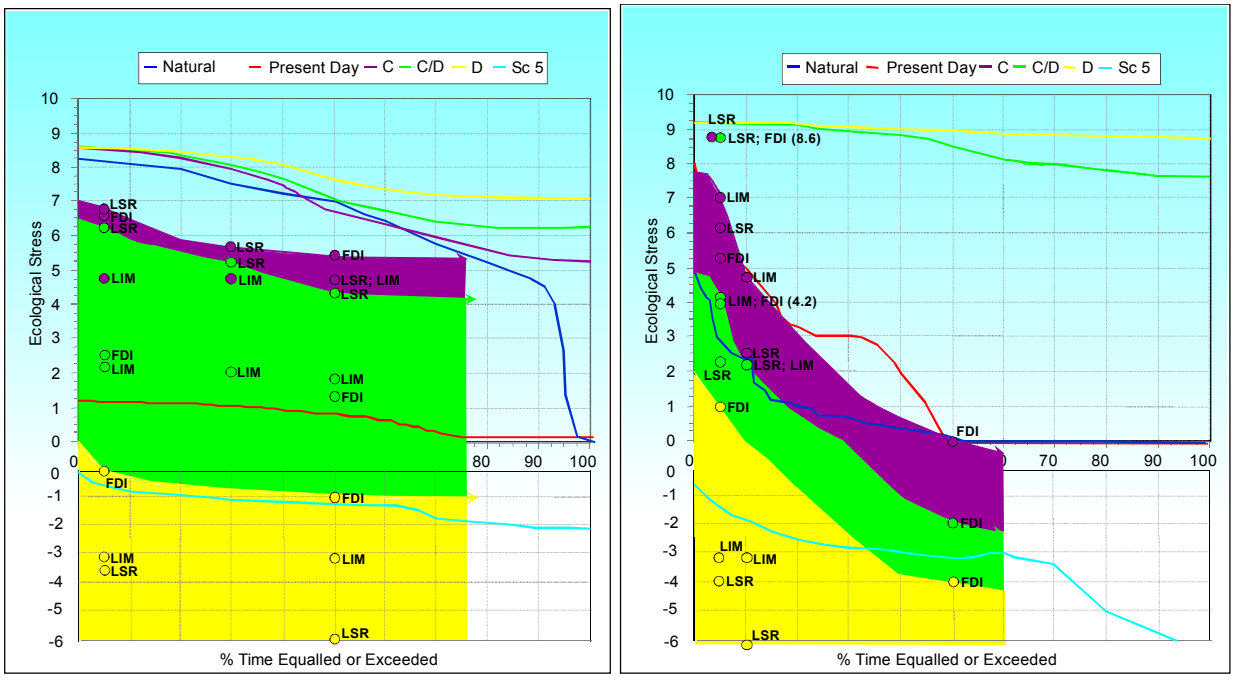


Figure 13.1 Stress duration for EWR 10: Dry and Wet season, Sc 5 and 6

13.2 ECOLOGICAL CONSEQUENCES: SCENARIO 5 AND 6

13.2.1 Driver components

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↓	AEC↑	Sc 5, 6	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL VARIABLES					
D/E	D/E	D	D/E	The water quality status of this site is driven by urban runoff, urban effluent discharges and mine dewatering activities which occur in the Blesbokspruit catchment as the site is below the confluence with the Blesbokspruit River. Included in these scenarios is the proposed re-use of mine water which should improve the salt and metal point source discharge into the Blesbokspruit. There is an increase in base flows during both seasons which would result in increased nutrient loads (WWTW) Industrial point and source discharges from industries such as SAPPI are expected to stay the same. An overall deterioration within the D/E EC is expected as anthropogenic activities increase.	
GEOMORPHOLOGY					
C	-C	C	C/D	Bed scouring and increased bank erosion is expected during both seasons.	
Floods are relatively natural within the reach, but base flows are elevated by 50 to 70% due to the impact of mine dewatering in upstream Blesbokspruit catchment. At the site the banks are largely natural, although some erosion is occurring in places (likely due to the elevated base flows). Erosion in the catchment and along the banks has increased the fines load of the river. The scenarios will continue to promote erosion and incision of the channel, especially within some of the more sensitive alluvial reaches. This will be ameliorated by the bedrock control and cobble armour in many sections of the reach however overall deterioration is expected.					

13.2.2 Biotic responses

EC				ECOLOGICAL CONSEQUENCES	
PES and REC	AEC↓	AEC↑	Sc 5, 6	DRY SEASON	WET SEASON
RIPARIAN VEGETATION					
C	D	C	D	Both scenarios have higher dry season base flows than PD and are significantly higher than natural. *C. marginatus* inundation increases during the dry season, and height above water level drops for *M. junceus*.	There is a slight increase in wet season base flows with increased inundation stress.
Generally there is a further reduction in seasonal differences, with wetter conditions during dry and wet season base flows, but more so during the dry season. This will reduce both woody and non-woody cover in the current marginal zone (which is already constrained and partly lost due to elevated PD flows) as higher levels of dry season inundation is likely to cause senescence. Vegetation cover and density in the lower zone will however increase as a greater portion of the lower zone begins to function as marginal. Wet season changes are unlikely to have as much influence as changes are smaller and riparian plants are able to withstand wetter environments during their growing periods. The EC changes from 62.4% to 56.9% (D).					
FISH					
C/D	D	C	C/D	Dry season flows higher than natural as well as PD modeled hydrology. Habitat suitability and fish stress are however not significantly different from the PES status, and no change in EC is expected in the dry season.	Although flows will be slightly higher than natural and PD during the wet season, adequate habitat suitability presence of all flow-depth categories will be present to maintain in PES.
The conditions will remain similar to PES during both seasons.					
MACROINVERTEBRATES					
C/D	D	C	D	These flows are likely to be detrimental to taxa that prefer slow-flowing water, such as Leptophlebiidae, Sphaeriidae, Pleidae and Caenidae. The overall diversity of macroinvertebrates is expected to drop. These changes result in a deterioration of the macroinvertebrates from a present day MIRAI score of 59.3% (Category C/D) to 55.1% (Category D).	
ECOSTATUS					
C/D	D	C	D	Increased base flows lead to deterioration in geomorphology, riparian vegetation and macroinvertebrates while water quality deteriorates within the PES-REC EC. Instream condition will deteriorate due to a further decrease in habitat availability and the EcoStatus deteriorates to a D which does not meet the requirements of the PES-REC.	

13.3 IMPACT OF SCENARIO 4, 7, AND 8

The stress and flow duration graphs indicated that Sc 4, 7 and 8 was sufficiently similar to be assessed as one and were very similar to PD. Scenario 4 and 8 dry season flows were similar to PD while wet season base flows increased from PD and floods were slightly reduced. Scenario 7 was very similar to PD.

No change is expected in any of the driver and biotic responses under these scenarios. These scenarios therefore meet the requirements of the PES and REC requirements.

13.4 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 10 are provided in Table 13.1.

Table 13.1 Ecological consequences of operational flow scenarios at EWR 10

Driver Components	PES and REC	Sc 4, 7, 8	Sc 5, 6
WATER QUALITY	D/E	D/E	D/E
GEOMORPHOLOGY	C	C	C/D
Response Components	**PES and REC**	**Sc 4, 7, 8**	**Sc 5, 6**
FISH	C/D	C/D	C/D
MACROINVERTEBRATES	C/D	C/D	D
INSTREAM	C/D	C/D	D
RIPARIAN VEGETATION	C	C	D
ECOSTATUS	C/D	C/D	D

Scenario 4, 7 and 8 are very similar to PD and therefore the requirements of the PES-REC are met at EWR 10. Scenario 5 and 6 results in the deterioration of the PES for most components. These scenarios therefore do not meet the requirements of the PES-REC. The degree to which each scenario at EWR 10 meets the REC is summarised in Figure 13.2 below.

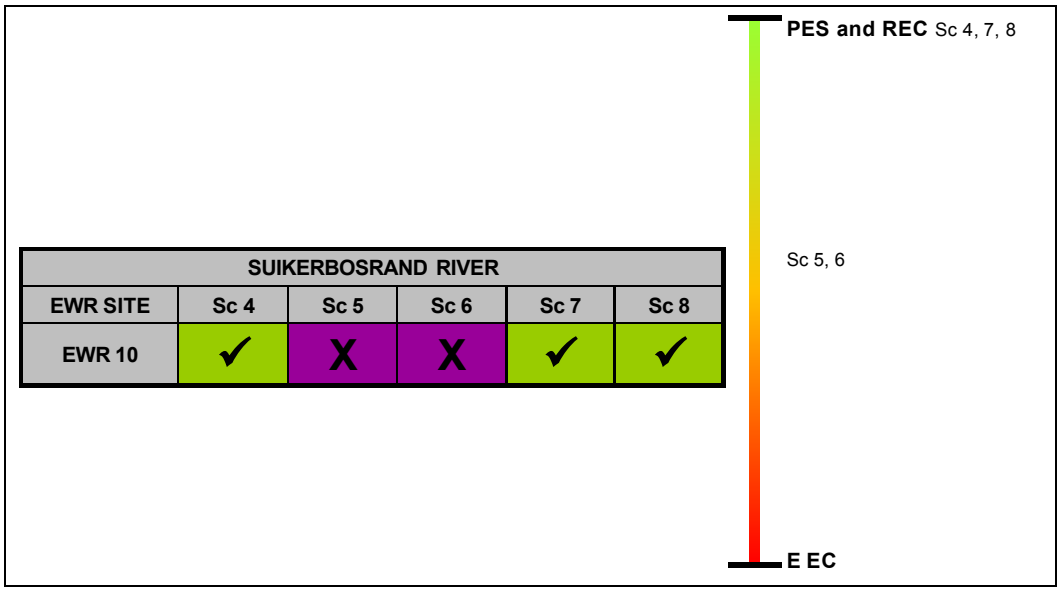


Figure 13.2 Summary of the impacts of operational flow scenarios at EWR 10

14 EWR 11: BLESBOKSPRUIT (BLESBOKSPRUIT RIVER) - ECOLOGICAL CONSEQUENCES

The Blesbokspruit sub-system is characterized by Present Day runoff which is significantly higher than the natural runoff from the catchment. This flow regime of this river system has been significantly influenced by catchment development activities which include the following:

- Increased urban runoff resulting from impervious urbanized areas;
- Urban effluent discharges;
- Industrial discharges; and
- Discharges from mines in the Eastern Mining Basin.

Scenarios 4 – 8 were evaluated and are discussed in Section 14.1 - 14.4.

PES: Identification of the band around the present hydrology which would maintain the PES. This band therefore consisted of a scenario where flows could be increased or decreased. As only an improvement of the PES was considered as the Instream PES was already in a D/E EC, only the band between the PES and the improved category (REC) was described.

14.1 IMPACT OF SCENARIO 5 AND 6

The stress and flow duration graphs indicated that Sc 5, and 6 were very similar and therefore Sc 5 represents these two scenarios. Figure 14.1 illustrates the stress requirements and stress points required for a D INSTREAM PES, and D INSREAM REC (green and purple curves respectively). The red curve illustrates the original PD flow that was provided during the study and the blue curve represents Natural. Scenario 5 and 6 (light blue curve) represent decreased stress from the PD both during wet and dry season for drought and maintenance periods as large (approximately 0.2 to 0.8 m^3/s) increases in base flow proposed.

DRY SEASON **WET SEASON**

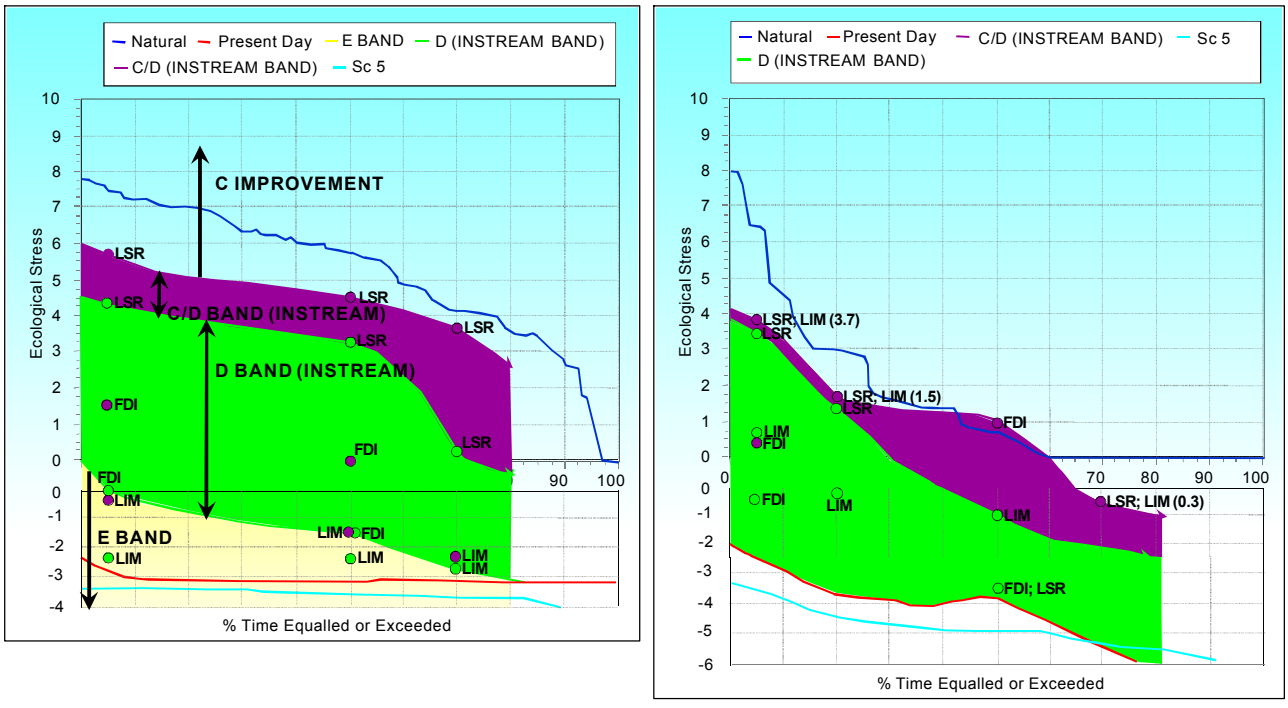


Figure 14.1 Stress duration for EWR 11: Dry and Wet season, Sc 5 and 6

14.2 ECOLOGICAL CONSEQUENCES: SCENARIO 5 AND 6

14.2.1 Driver components

EC			ECOLOGICAL CONSEQUENCES	
PES	REC	Sc 5, 6	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL VARIABLES				
D/E	D	E	The water quality status of this site is driven by urban runoff, urban effluent discharges and mine dewatering activities which occur in the Blesbokspruit catchment. Included in these scenarios is the proposed re-use of mine water which should improve the salt and metal point source discharge into the Blesbokspruit. There is an increase in base flows during both seasons which would result in increased nutrient loads (WWTW) Industrial point and source discharges from industries such as SAPPI are expected to stay the same. An overall deterioration within the D/E EC is expected as anthropogenic activities increase.	
GEOMORPHOLOGY				
C	C	D	Bed scouring and increased bank erosion is expected during both seasons.	
The floods are relatively natural but base flows are strongly elevated due to the impact of mine dewatering in upstream catchment. Present day flow variability within months and across the hydrological year is much reduced relative to natural. The very large increases in base flows have caused the active channel banks to cut, increasing the competence of the channel. Erosion, especially along the banks, has increased the fines load of the river. Water quality is impacting the marginal vegetation, and this may further destabilise the banks as the vegetation dies off. The scenarios will continue to promote erosion and incision of the channel, especially within some of the more sensitive alluvial reaches, causing a decline in EC.				

14.2.2 Biotic responses

EC			ECOLOGICAL CONSEQUENCES	
PES	REC	Sc 5, 6	DRY SEASON	WET SEASON
RIPARIAN VEGETATION				
D	D	D/E	Both scenarios have higher dry season base flows than PD and are significantly higher than natural. *Persicaria lapathifolia* inundation increases during the dry season, and height above water level drops for *Crinum bulbispermum.*	Similarly, there are slight increased wet season base flows with increased inundation stress.
Generally there is a further reduction in seasonal differences, with wetter conditions during dry and wet season base flows, but more so during the dry season. This will reduce both woody and non-woody cover in the current marginal zone (which is already constrained and partly lost due to elevated PD flows) as higher levels of dry season inundation is likely to cause senescence. Vegetation cover and density in the lower zone will however increase as a greater portion of the lower zone begins to function as marginal. Wet season changes are unlikely to have as much influence as changes are smaller and riparian plants are able to withstand wetter environments during their growing periods. The EC changes from 45.6% to 41.5% (D/E).				
FISH				
D	C	E	Dry season flows extensively higher than natural and slightly higher than PD modelled hydrology. Habitat suitability and fish stress are however not significantly different from the PES status, and should fall in same EC than during the PES.	Wet season flows are extensively higher than natural and slightly higher than PD modelled hydrology. Habitat suitability and fish stress will be significantly lower than present and a deterioration can be expected.
Drought and maintenance flows seasonality are similar to PD hydrology. The conditions will largely remain similar to the PES during the dry season but deteriorate during the wet season (especially critical impact on limnophilic species). Due to the alteration in flows, together with the deterioration in water quality, geomorphology as well as loss of vegetation as cover the fish assemblage will deteriorate from the PES of a D (FRAI = 44.8%) to an E (FRAI = 35.1%).				
MACROINVERTEBRATES				
D/E	D	D/E	These flows are detrimental to taxa that prefer slow-flowing water, such as Leptophlebiidae, Sphaeriidae, Gomphidae, Corbiculidae, Hydroptilidae and Caenidae. The overall diversity and abundance of macroinvertebrates is not expected to differ significantly from present conditions. The macroinvertebrate MIRAI is expected to remain unchanged at 39.8% (Category D/E).	
ECOSTATUS				
D	D	D/E	Increased base flows lead to deterioration in driver components and the riparian and fish biotic response is severe to the resulting inundation stress and deteriorated habitat suitability under these scenarios. The EcoStatus deteriorates	

EC			ECOLOGICAL CONSEQUENCES	
PES	REC	Sc 5, 6	DRY SEASON	WET SEASON
			to a D/E EC which do not meet the requirements of the PES or REC.	

14.3 IMPACT OF SCENARIO 4, 7, AND 8

The stress and flow duration graphs indicated that Sc 4, 7 and 8 was sufficiently similar to be assessed as one and were very similar to PD.

No change is expected in any of the driver and biotic responses under these scenarios. These scenarios therefore meet the requirements of the instream PES but not the instream REC. Overall EcoStatus of a D (PES and REC) is maintained.

14.4 SUMMARY OF ECOLOGICAL CONSEQUENCES

The ecological consequences of the operational flow scenarios at EWR 11 are provided in Table 14.1.

Table 14.1 Ecological consequences of operational flow scenarios at EWR 11

Driver Components	PES	REC	Sc 4, 7, 8	Sc 5, 6
WATER QUALITY	D/E	D	D/E	E
GEOMORPHOLOGY	C	C	C	D
Response Components	**PES**	**REC**	**Sc 4, 7, 8**	**Sc 5, 6**
FISH	D	C	D	E
MACROINVERTEBRATES	D/E	D	D/E	D/E
INSTREAM	D/E	C/D	D/E	D/E
RIPARIAN VEGETATION	D	D	D	D/E
ECOSTATUS	D	D	D	D/E

Scenario 4, 7 and 8 are very similar to PD and therefore maintains the PES. Scenario 5 and 6 result in deterioration of the driver components and the fish and riparian vegetation deteriorate due to the inundation stress and decreased habitat suitability (especially limnophilic species) caused by increased base flows. The PES and REC requirements are not met and the EcoStatus under Sc 5 and 6 deteriorate to a D/E EC. The degree to which each scenario at EWR 11 meets the REC is summarised in Figure 14.2 below.

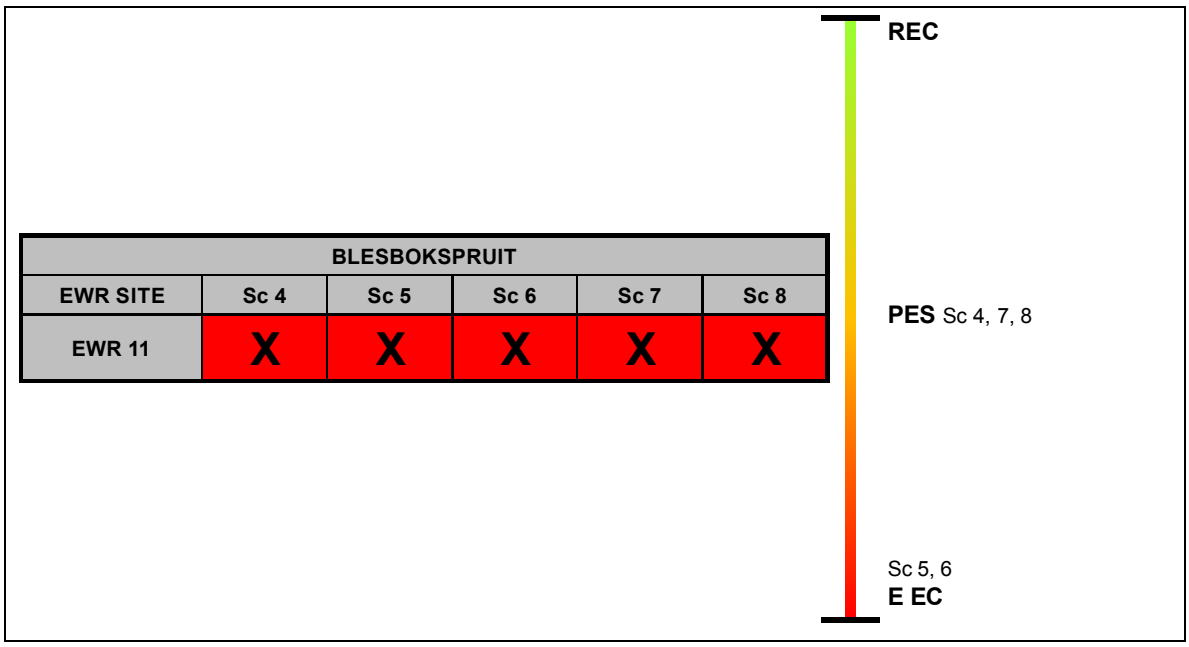


Figure 14.2 Summary of the impacts of operational flow scenarios at EWR 11

15 RESULTS AND CONCLUSIONS: ECOLOGICAL CONSEQUENCES

15.1 SUMMARY OF RESULTS

15.1.1 Ecological consequences of operational scenarios

The ecological consequences were evaluated and ranked at each EWR site according to whether the scenario meets the ecological objectives (in terms of the REC). These summaries were individually provided per EWR site and compared separately for the Vaal River main stem and the tributaries (Figure 15.1 and 15.2). The ranking is provided according to traffic diagrams where the REC is at the top of the ranking – in the green area of the traffic diagram. The REC represents the ecological objectives which should be met and if a scenario meets the ecological objective, it is placed next to the REC heading. Where PES-REC is used instead of just REC, this means that the PES and REC is the same. If the PES is placed in the middle of the traffic diagram, it infers that the REC requires an improvement of the PES. The bottom of the scale is pegged by an EC of E (in the red area of the traffic diagram) as an undesirable state. If any of the evaluated scenarios resulted in an E EcoStatus, it was placed in the red section of the traffic diagram. In cases (which did not occur in the Upper Vaal River system), where the PES is in an E EcoStatus, the PES label would be moved to the E EC level, i.e. at the bottom of the ranking scale. Where scenarios result in an EC which does not quite achieve the REC or falls below the PES, it would be placed on the ranking scale accordingly. As an example, using Figure 15.1, Sc 7 at EWR 1 resulted in an ecological state which is slightly worse than the PES.

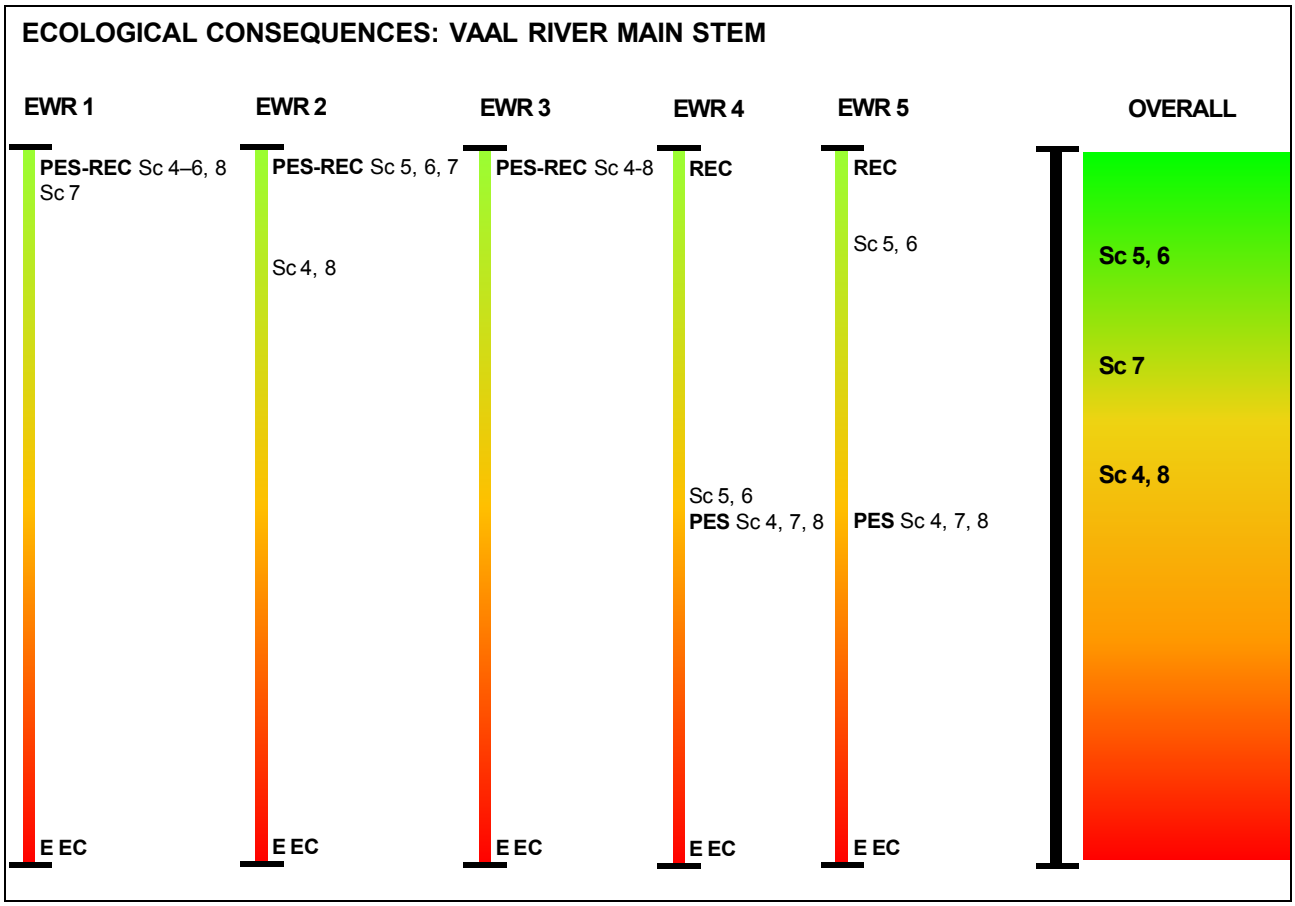


Figure 15.1 Comparison of EWR sites and the success of the scenarios in meeting or achieving the EWR objectives at the EWR sites in the main Vaal River

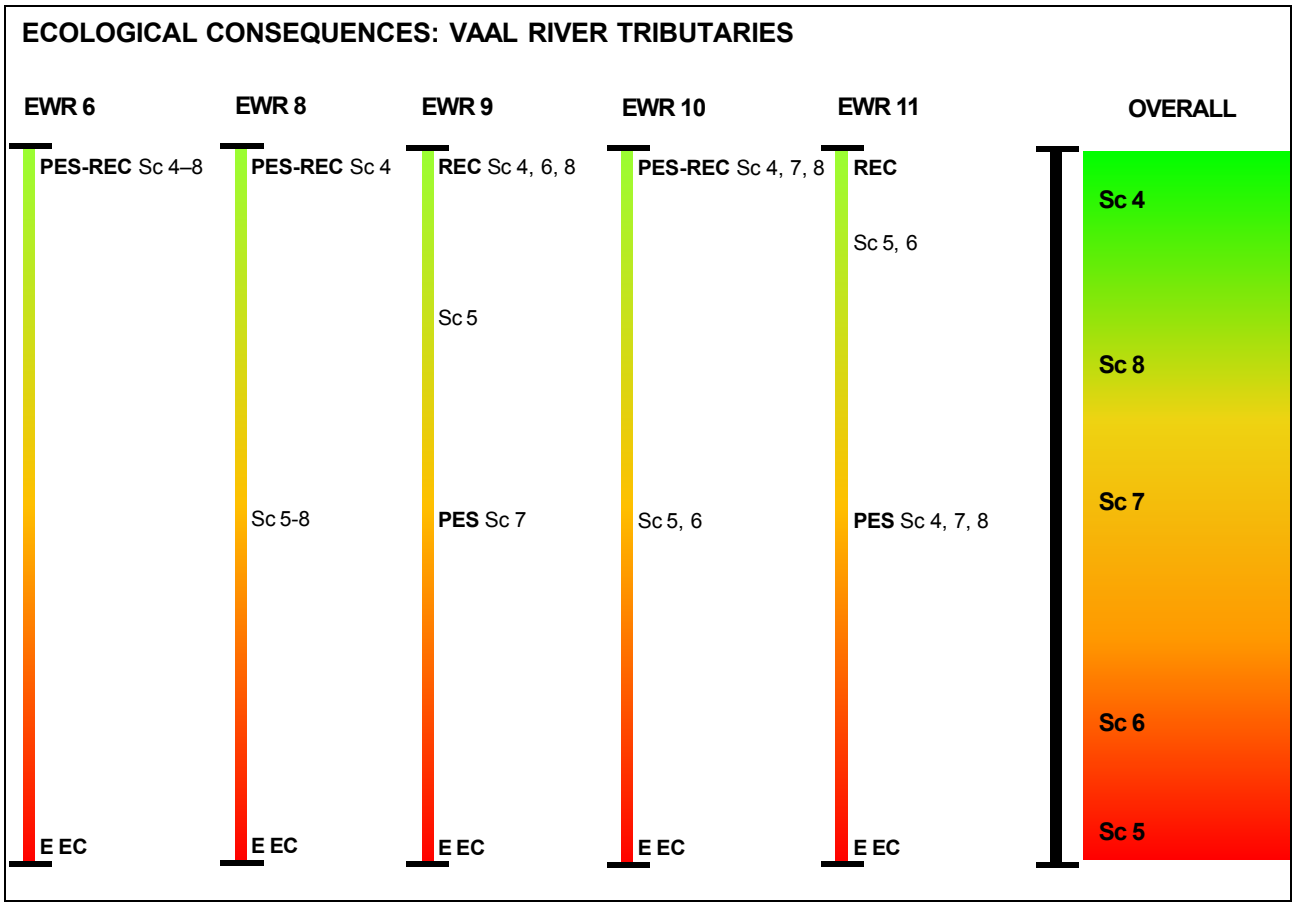


Figure 15.2 Comparison of EWR sites and the success of the scenarios in meeting or achieving the EWR objectives at the EWR sites in the main Vaal River

These traffic diagrams led to a summary table (Table 15.1) which listed the number of EWR sites which is meeting the ecological objectives for each scenario. The key to the table is on the fold-out A3 page (last page in this Chapter and Section 2.7). An overall assessment was undertaken for the Vaal River system to compare the scenarios developed by WRP (DWA, 2010).

Table 15.1 Summary of the consequences of the operational scenarios (Sc 4 - 8) at each EWR site

VAAL RIVER					
EWR SITE	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
EWR 1	✓	✓	✓	✓	✓
EWR 2	✓	✓	✓	✓	✓
EWR 3	✓	✓	✓	✓	✓
EWR 4	X	X	X	X	X
EWR 5	X	✓	✓	X	X
KLIP RIVER					
EWR 6	✓	✓	✓	✓	✓
WILGE RIVER					
EWR 8	✓	X	X	X	X
SUIKERBOSRAND					
EWR 9	✓	X	✓	X	✓
EWR 10	✓	X	X	✓	✓
BLESBOKSPRUIT					
EWR 11	X	X	X	X	X
KLEIN VAAL					
RE-EWR 1	✓	✓	✓	✓	✓
MOOI RIVER					
RE-EWR 2	X	X	X	X	X

A simplified version of this table is provided in Table 15.2. There are three codes used in the table and indicate the following:

✓ EWR objectives (REC) are met.

X EWR objectives (REC) are not met. The PES is also not being maintained (see below).

X(PES) EWR objectives (REC) are not met but the PES is still being maintained. This is relevant for sites where the REC is an improvement of the PES. The improvement cannot be met, but the PES is still maintained.

Table 15.2 Summary of where the EWR objectives are met/achieved in the Upper Vaal River System

Site	PES	REC	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
VAAL RIVER MAIN STEM							
EWR 1	**B/C**	**B/C**	√	√	√	X	√
EWR 2	**C**	**C**	X	√	√	√	X
EWR 3	**C**	**C**	√	√	√	√	√
EWR 4	**C**	**B/C**	X (PES)	X (PES)	X (PES)	X (PES)	X (PES)
EWR 5	**C/D**	**C**	X (PES)	√	√	X (PES)	X (PES)
VAAL RIVER TRIBUTARIES							
EWR 6 (Klip River)	**B/C**	**B/C**	√	√	√	√	√
EWR 8 (Wilge River)	**C**	**C**	√	X	X	X	X
EWR 9 (Suikerbosrand River)	**C**	**B/C**	√	√	√	PES	√
EWR 10 (Suikerbosrand River)	**C/D**	**C/D**	√	X	X	√	√
EWR 11 (Blesbokspruit River)	**D**	**D**	X (PES)	X	X	X (PES)	X (PES)

Table 15.1 and 15.2 is however a comparison of all the sites within the Upper Vaal system. However, this approach is probably not correct as some of the tributaries can be operated independently without influencing the main stem. For decision making purposes it was also necessary to take into consideration the relative Ecological Importance and Sensitivity (EIS) of the different EWR sites. Therefore the EWR sites were grouped according to their EIS score e.g. High, Moderate or Low. The sites within these groupings e.g. sites with a HIGH EIS score, were then ranked according to the number of individual EIS metrics that scored high. For example, an EWR site with 5 metrics which scored high (≥2.5) would be ranked higher than one with 4 HIGH metrics and a lot higher than one with 2 metrics. The results are supplied in Figure 15.3. This figure indicates that the EWR sites in the main river (EWR numbers in red in Figure 15.3) are overall of more importance than the tributaries. The exception was EWR 9 situated in the upper Suikerbosrand River.

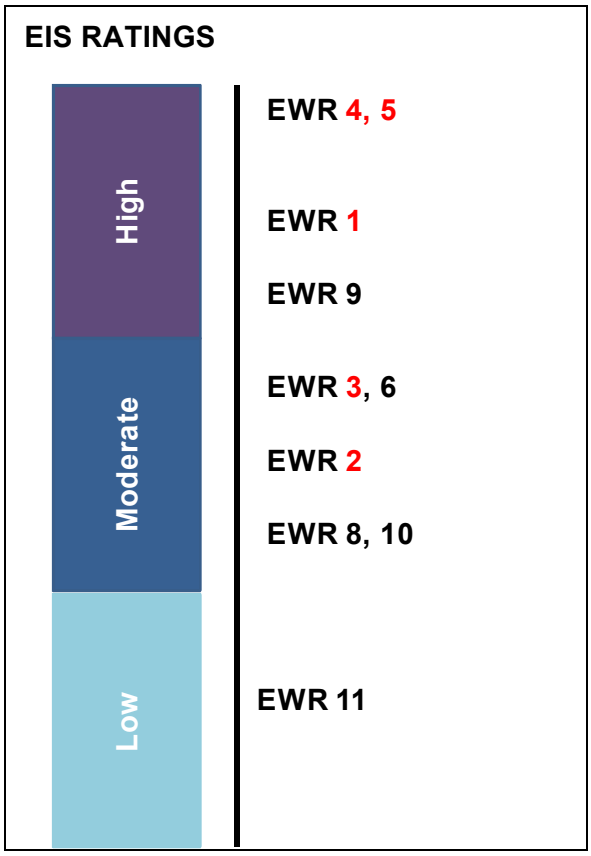


Figure 15.3 Comparison of the Relative importance of the EWR sites within the Upper Vaal Water Management Area

Evaluations therefore were based firstly on a comparison of consequences on the MAIN RIVER and then compared to the consequences on the tributaries of the Vaal River.

The scenarios were also grouped and compared separately. The grouping is according to the same situation WITH and WITHOUT the EWRs as follows:

- Scenario 4 (current situation WITH EWR) – compared against the current situation and resulting PES.
- Scenario 6 (future development scenario WITH EWR) – compared against Scenario 5 which represents the future development scenario WITHOUT EWR).
- Scenario 8 (full utilisation scenario WITH EWR) – compared against Scenario 7 which represents the full utilisation scenario WITHOUT EWR).

These comparisons led to the final traffic diagrams and conclusions discussed in Section 15.2.

15.2 CONCLUSIONS

15.2.1 Consequences of supplying the EWR under current conditions (Sc 4)

The results are summarised in a traffic diagram for the main river and an evaluation of the tributaries in Figure 15.4.

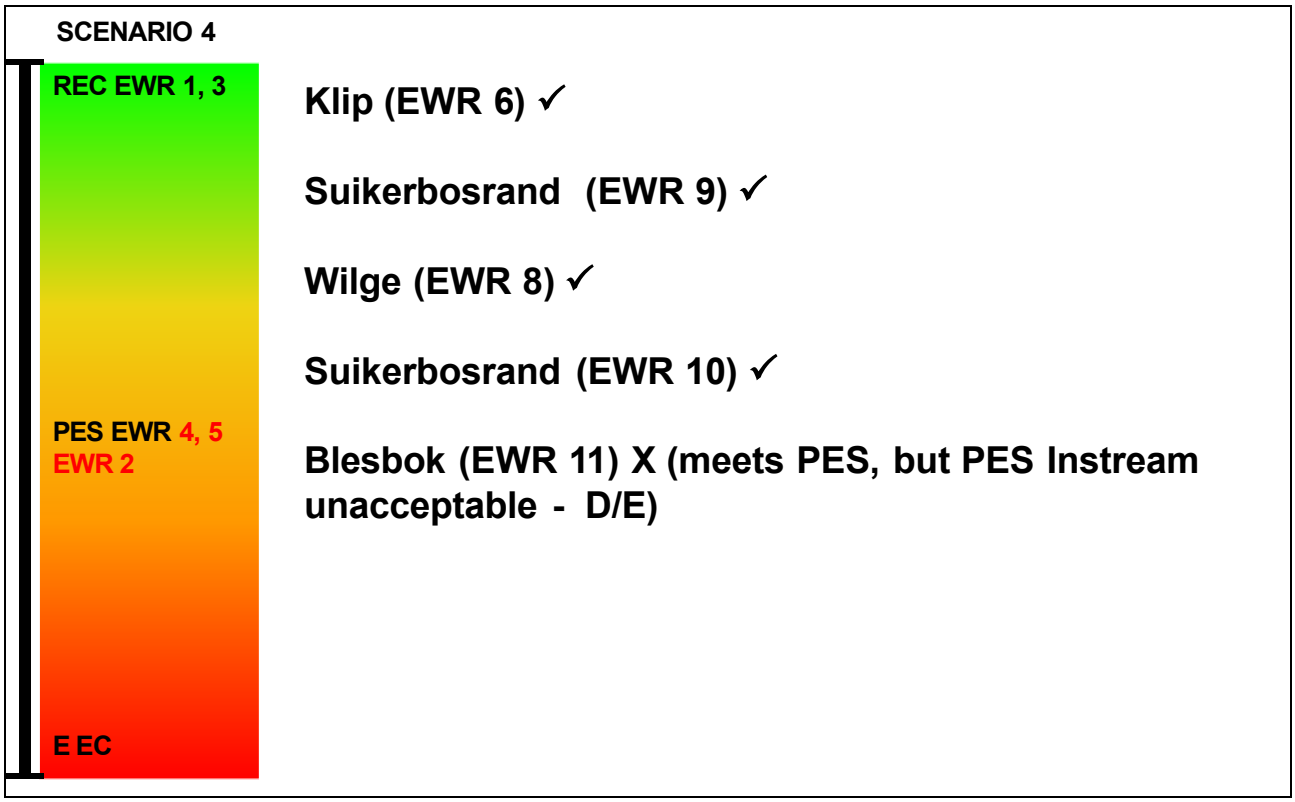


Figure 15.4 Ecological consequences of Sc 4

The conclusions are summarised as follows:

- Scenario 4 fails to meet the REC at EWR 4 and 5. Meeting the REC at EWR 4 is unlikely due to operational constraints and the significant demand on the Vaal Dam. To meet the REC at EWR 4, higher flows in summer is required and lower flows in winter.
- Scenario 4 does not meet the PES-REC at EWR 2 and the reason is probably that this scenario over-supplies EWR 2 to meet the requirements of EWR 3. However, Scenario 4 results in higher flows than required at EWR 3, which is possibly a result of the way in which the configuration model is set up and could be due to operational rules other than for the EWR. This requires further investigation.
- Scenario 4 does not meet the objectives at the Blesbokspruit River (EWR 11). This is not surprising as the Blesbokspruit River has significant water quality problems as well as to MUCH water. Decreasing flows could exacerbate the water quality problems, and this river actually requires a specific management plan which addresses its problems with the focus on water quality as first priority.

In conclusion, there is no significant advantage in supplying the EWR under current conditions as there are no improvements. The current operation of the system meets the PES-REC at most sites.

15.2.2 Consequences of supplying the EWR under future 2020 development conditions (Sc 6)

The results are summarised in a traffic diagram for the main river and an evaluation of the tributaries in Figure 15.5.

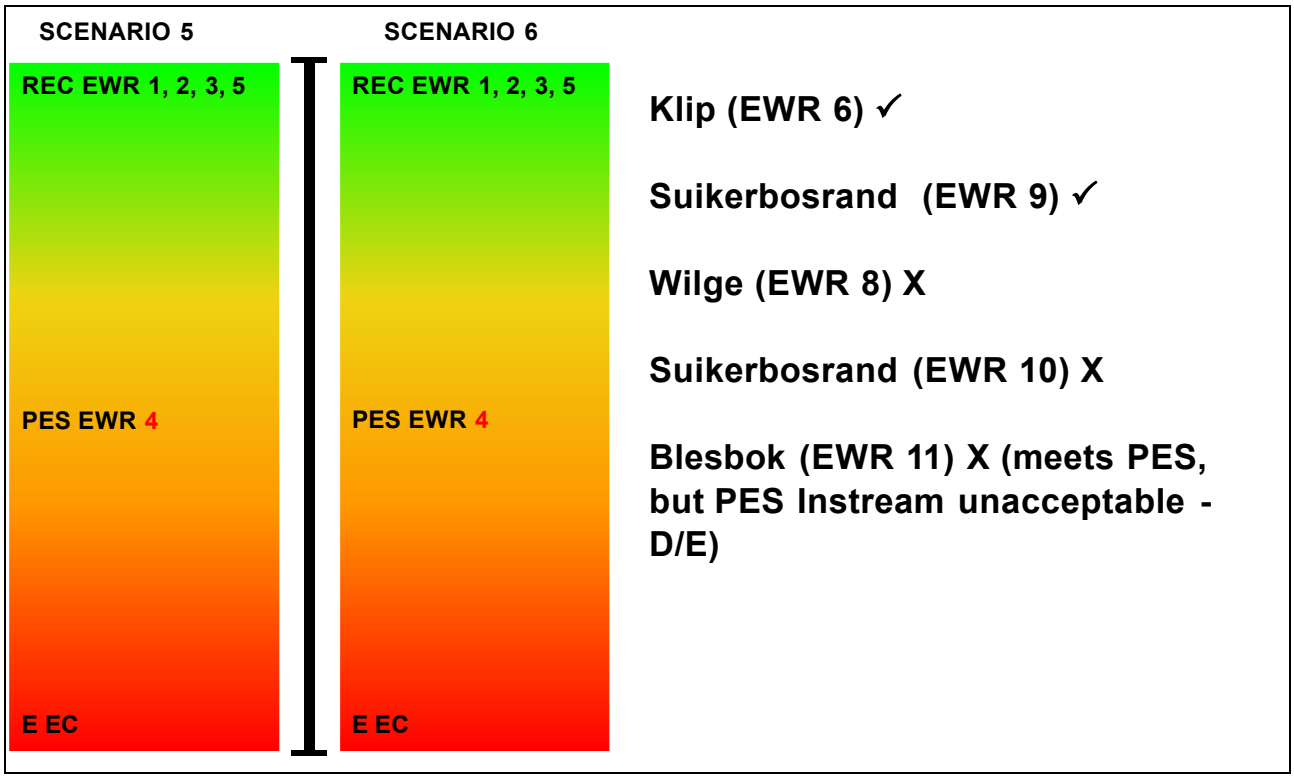


Figure 15.5 Ecological consequences of Sc 5 and 6

The conclusions are summarised as follows:

- There are no differences between Sc 5 and Sc 6.
- Scenario 5 and 6 fail to meet the REC at EWR 4. Meeting the REC at EWR 4 is unlikely due to operational constraints and the significant demand on the Vaal Dam. To meet the REC at EWR 4, higher flows in summer is required and lower flows in winter.
- Scenario 5 and 6 does not meet the EWR objectives at the Wilge River (EWR 8). This is due to the increased supply from Sterkfontein Dam which results in flows much higher than natural during the dry season (e.g. 15 m^3/s during the driest month at 50% exceedence instream of the 2 m^3/s which occurs during natural flows).
- Scenario 5 and 6 does not meet the objectives at the EWR 11 and the lower Suikerbosrand, EWR 10. This is not surprising as the Blesbokspruit has significant water quality problems as well as to MUCH water. Decreasing flows could exacerbate the water quality problems, and this river actually requires a specific management plan which addresses its problems with the focus on water quality as first priority.

In conclusion, there is no advantage in supplying the EWR under 2020 conditions as Sc 5 has the same ecological consequences as Sc 6.

15.2.3 Consequences of supplying the EWR under full utilisation conditions (Sc 8)

The results are summarised in a traffic diagram for the main river and an evaluation of the tributaries in Figure 15.6.

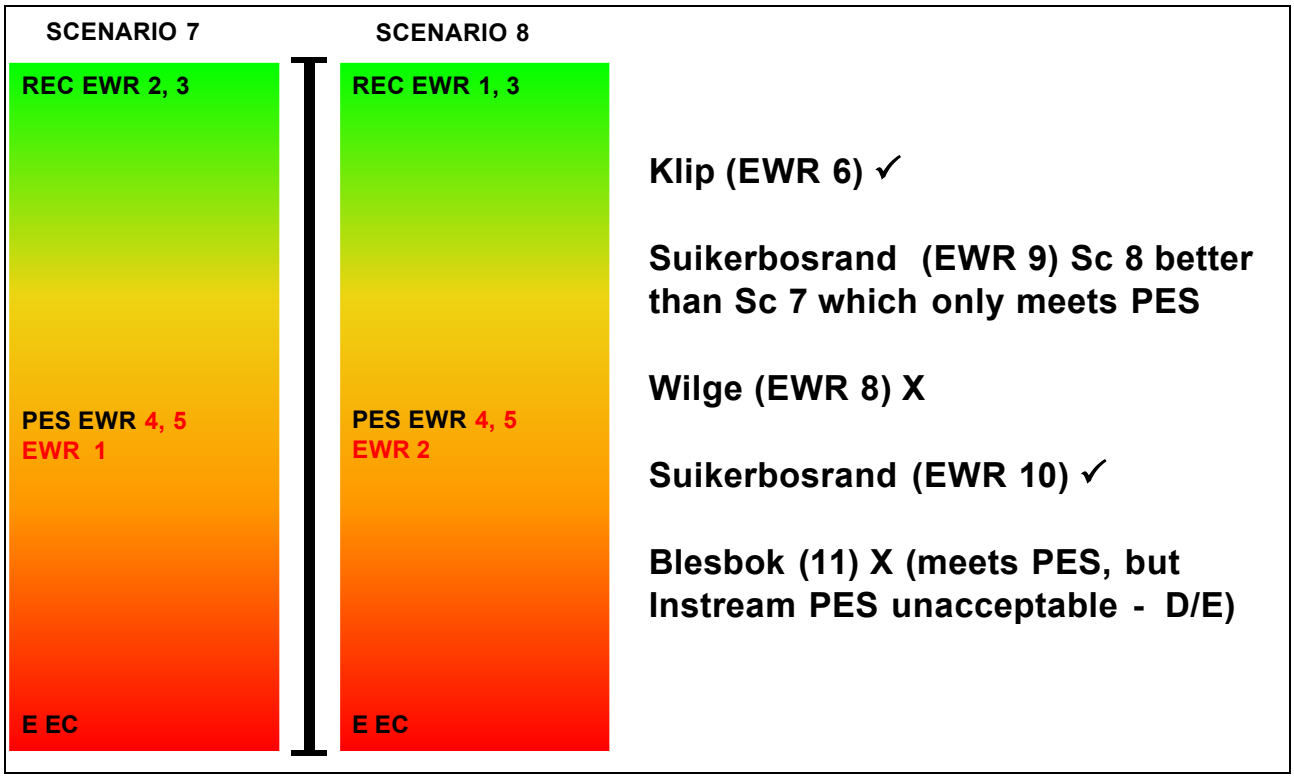


Figure 15.6 Ecological consequences of Sc 7 and 8

The conclusions are summarised as follows:

- There are minor differences between Sc 7 and Sc 8 as Sc 7 meets the objectives at EWR 2 and not at EWR 1 and Sc 8 meet the objectives at EWR 1 and not at EWR 2.
- Scenario 7 and 8 fails to meet the REC at EWR 4 and 5. Meeting the REC at EWR 4 is unlikely due to operational constraints and the significant demand on the Vaal Dam. To meet the REC at EWR 4, higher flows in summer is required and lower flows in winter.
- Scenario 7 and 8 does not meet the EWR objectives at the Wilge River (EWR 8). This is due to the increased supply from Sterkfontein Dam which results in flows much higher than natural during the dry season (e.g. 15 m^3/s during the driest month at 50% exceedence instream of the 2 m^3/s which occurs during natural flows).
- Scenario 7 and 8 does not meet the objectives at the Blesbokspruit EWR site 10. This is not surprising as the Blesbokspruit has significant water quality problems as well as to MUCH water. Decreasing flows could exacerbate the water quality problems, and this river actually requires a specific management plan which addresses its problems with the focus on water quality as first priority.

In conclusion, there is no advantage in supplying the EWR under full utilisation as Sc 7 has the basically the same ecological consequences as Sc 8.

15.2.4 Comparison of Sc 4, 6 and 8

When comparing the 3 relevant traffic diagrams (Figure 15.7), that for the main Vaal River, the Sc 5 related to the 2020 future development is the most desired. This is based on the fact that it achieves the REC at EWR 5 which is situated in the Vredefort Dome which is a World Heritage site. However, one must remember that this statement is based on the evaluation of the scenario provided by WRP and as there is no guarantee that in the interim, the operation could change from what WRP provided, or that there could actually be various possible scenarios, this statement could not hold true. Additionally, it is also the only scenario that achieves the EWR objectives at

both EWR 1 and 2. It must be noted however that Scenario 7 does not meet the PES at EWR 1 only because fish drops with half a category. Taking into account the uncertainty coupled to the hydrological modelling and ecological interpretation, this can be evaluated as meeting the PES.

The tributaries are better off under current conditions, however, most of the tributaries can be addressed separately and further refinement of the Planning model rules could address some of the problems.

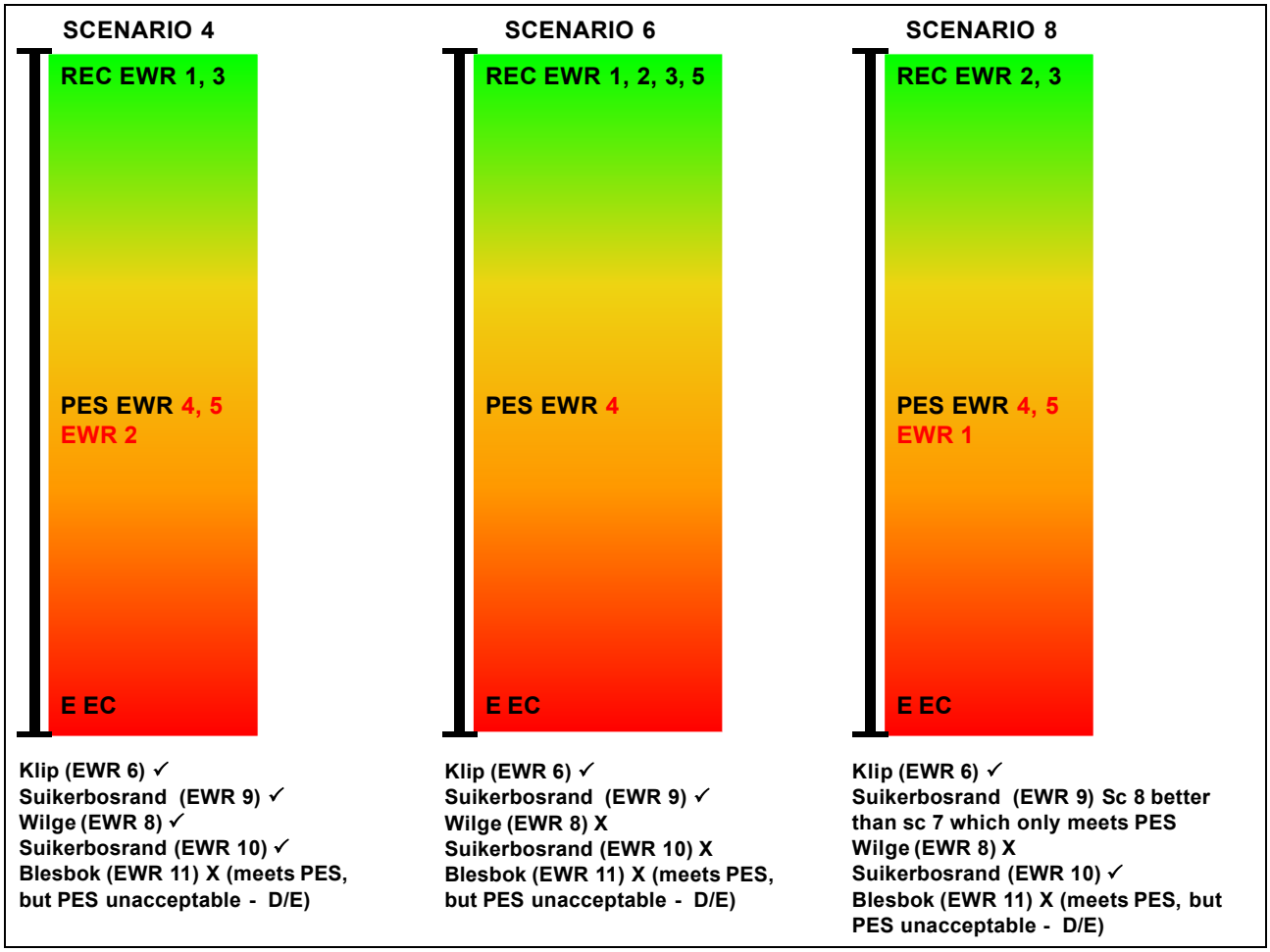


Figure 15.7 Comparison of Sc 4, 6 and 8

The following coding is used (A3 fold-out page as well as in Section 2) and an example is provided in Table 2.2.

✓ REC EcoStatus or REC instream IS met.
X REC EcoStatus or REC instream is NOT met.

Light green with black ✓:	Meets REC EcoStatus including all components.
Dark Green with black ✓:	Meets the REC EcoStatus, but not all the components.
Orange with X:	The scenario does not meet REC requirements but meets the PES.
Purple with X:	The scenario results in an EC below the PES; D EC.
Red with X:	The results are below a D EC.

16 RESULTS AND CONCLUSIONS: GOODS AND SERVICES

The specialists involved analyzed each of the sites as per the scenarios. In all instances Scenario1 acts as the present day situation so all goods and services are scored as the base of 1 (one). Results are summarized in the sub-sections below.

16.1 RESULTS FOR EWR 1: UITKOMS

For EWR 1 the examination of the scenarios considered came to the following conclusions:

Scenario 4 has a marginally positive impact on the abundance of largemouth yellow fish (LKIM) (a score of 1.2) indicating roughly 20% increase) and as a result on recreational fishing (Score of 1.2). It has no other noticeable impacts.

Scenario 5 is similar to Scenario 4 in that it has a marginally positive impact on the abundance of LKIM (20%) and as a result on recreational fishing. It has no other noticeable impacts.

Scenario 6 has a negative impact on the abundance of LKIM (a score of 0.9) indicating roughly 10% decrease). A decrease of 10% is also predicted for the mudfish. These impacts translate into a 10% decrease in both recreational and subsistence fishing.

Scenario 7: For this scenario a 20% increase in the abundance of sedges is predicted as reduced dry season base flows, more towards natural, will facilitate increase in sedge cover. The ability of the river to accommodated waste in terms of both assimilation and dilution will decrease by a predicted 30%. Likewise the development of pathogens and potentially cholera is predicted to increase by about 30%, as this is a dis-service and therefore a cost the impact is negative. Fish abundance for the species smallmouth yellow fish and mudfish are predicted to decrease by 10%. Again this translates into a 10% decrease in both recreational and subsistence fishing.

Scenario 8: For this scenario, as with Scenario 7, a 20% increase in the abundance of sedges is predicted as reduced dry season base flows, more towards natural, will facilitate increase in sedge cover. Fish abundance for the species smallmouth yellow fish and mudfish are predicted to decrease by 10%. Again this translates into a 10% decrease in both recreational and subsistence fishing.

Overall Scenario 7 appears to be the worst for EWR 1 with Scenarios 4 and 5 marginally positive.

16.2 RESULTS FOR EWR 2 GROOTDRAAI

For EWR 2 the examination of the scenarios considered came to the following conclusions:

Scenario 4 has a marginally positive impact on the abundance of grazing grass (10% increase) but a 20% decrease in sedges is predicted. This is because the dry season base flows will be wetter than present day and will reduce marginal sedge cover and promote sedge density in lower zone. Reduced floods and increased wet season base flows will promote the same. Both wet and dry season drought stress is greater than present day and significantly greater than natural which will counter the trend toward increased sedge cover and density. Current marginal zone will recede and merging of marginal and lower zones will be more apparent. For the vlei lily (important for

local medical purposes) a 20% decrease is predicted as increased inundation will result in mortality.

Scenario 5 is similar to Scenario 4 in that it has a marginally positive impact on the abundance of grazing grass (10% increase) but a 20% decrease in sedges is predicted – for the same reasons as given for Scenario 4. Unlike Scenario 4 however the abundance of the water lily is predicted to increase by 10%. The ability of the river to accommodated waste in terms of both assimilation and dilution will increase by a predicted 40%. Likewise the development of pathogens and potentially cholera is predicted to decrease by about 40%.

Scenario 6 is similar to Scenario 5 in that it has a marginally positive impact on the abundance of grazing grass (10% increase) but a 20% decrease in sedges is predicted – for the same reasons as given for Scenario 4.

Scenario 7: For this scenario the ability of the river to accommodated waste in terms of both assimilation and dilution will decrease by a predicted 30%. Likewise the development of pathogens and potentially cholera is predicted to increase by about 30%.

Scenario 8: As with Scenario 7 the ability of the river to accommodate waste in terms of both assimilation and dilution will decrease by a predicted 30%. Likewise the development of pathogens and potentially cholera is predicted to increase by about 30%. This scenario has a marginally positive impact on the abundance of grazing grass (10% increase) but a 50% decrease in sedges is predicted. This is because of a natural wet season, with increased base flows and floods, but the dry season is unnaturally wet as well. This will cause a [further] reduction or total loss of current marginal zone. For the vlei lily a 40% decrease is predicted as increased inundation will result in mortality.

Overall Scenario 7 appears to be the worst for EWR 1 along with Scenario 8.

16.3 RESULTS FOR EWR 3 GLADDEDRIFT

For EWR 3 the examination of the scenarios considered came to the following conclusions:

Scenario 4 has a marginally positive impact on the abundance of grazing grass sedges and the water lily (10% increase). This is because although flows are higher in general, changes are relatively small inside a wide incised channel and therefore make only small differences in terms of vegetation inundation. The scenario is predicted to have a marginally positive impact on the abundance of largemouth yellow fish (20%) and as a result on recreational fishing. It has no other noticeable impacts.

Scenarios 5, 6, and 7 also have a marginally positive impact on the abundance of grazing grass sedges and the water lily (10% increase). The scenario is predicted to have a marginally positive impact on the abundance of largemouth yellow fish (10%) and as a result on recreational fishing. It has no other noticeable impacts.

Scenario 8 also has a marginally positive impact on the abundance of grazing grass sedges and the water lily (20% increase). This is similar to the other scenarios, but with some additional water availability as well as floods. Improved flooding results in an improved abundance because vegetation on the upper parts of the lower zone is maintained. The scenario is predicted to have a

marginally positive impact on the abundance of largemouth yellow fish (20%) and as a result on recreational fishing. It has no other noticeable impacts.

Overall all scenarios are marginally positive.

16.4 RESULTS FOR EWR 4 DE NEYS

Scenario 4 has a marginally positive impact on the abundance of grazing grass sedges and the water lily (10% increase) as the marginal zone remains inundated during summer and winter during base flows. Flood disturbance is generally reduced which means that the lower zone continues to function as the marginal zone and vegetation cover and density will remain high. Trees in the riparian zone have a similar positive reaction of about 10%. The scenario is predicted to have a marginally positive impact on the abundance of mudfish (20%) and as a result on subsistence fishing. It has no other noticeable impacts.

Scenarios 5 and 6 have similar impacts. Sedges are predicted to decrease by about 10% as seasonal difference is improved. Currently riparian vegetation cover in the marginal zone is reduced due to increased dry season inundation. However marginal and lower zone tree that can tolerate inundation is likely to increase in cover on the lower zone by about 20%. The scenario is predicted to have a marginally positive impact on the abundance of mudfish (20%) and as a result on subsistence fishing. It has no other noticeable impacts.

Scenario 7 has no noticeable impacts.

Scenario 8 is similar to Scenario 4 in that it has a marginally positive impact on the abundance of grazing grass, sedges and the water lily (10% increase). Trees in the riparian zone have a similar positive reaction of about 10%. The scenario is also predicted to have a marginally positive impact on the abundance of mudfish (20%) and as a result on subsistence fishing. It has no other noticeable impacts.

The impacts of all scenarios are either neutral or marginally positive.

16.5 RESULTS FOR EWR 5 SCANDINAVIA

For Scenario 4 the sedges and reeds are predicted to decrease by between 10 and 20%. This is because the marginal zone remains in a poor condition as a result of inundation during the dry season. Existing marginal and lower zone populations are completely inundated during wet season which, together with seasonal difference increases, will improve fecundity for some species such as the vlei lily. This is expected to increase in abundance by about 20% Lower zone woody species will have improved recruitment opportunities, improve in cover and abundance and possibly reduce exotic species cover. It has no other noticeable impacts.

Scenarios 5 and 6 are predicted to have a marginally positive impact on the abundance of Mudfish (10%) and as a result on subsistence fishing. For Scenario 5 the sedges and reeds are predicted to decrease by about 20%. As with Scenario 4 existing marginal and lower zone populations are completely inundated during wet season which, together with seasonal difference increases, will improve fecundity for some species such as the vlei lily. This is expected to increase in abundance by about 20% Lower zone woody species will have improved recruitment opportunities, improve in cover and abundance and possibly reduce exotic species cover. It has no other noticeable impacts.

Scenarios 7 and 8 have very similar impacts predicated as those for Scenario 4.

Overall impacts are predicted to be negative for some riparian vegetation but in other respects marginally positive.

16.6 RESULTS FOR EWR 6 KLIP

Overall the impacts are negligible under all scenarios for this EWR. There is a marginally positive impact on the grazing (10%) as well as the yellow fish (10%) under scenarios 5 and 6. Otherwise no significant impacts are predicted.

16.7 RESULTS FOR EWR 8 BAVARIA

Scenario 4. Under this scenario sedges would decrease by about 20% as marginal zone sedge cover will be slightly reduced by increased winter base flows. This is an improvement towards the reference condition. Waste assimilation and dilution is expected to increase by about 30% as a result of increased winter flows from Sterkfontein Dam to supply EWR requirements. During dry season, there will be an improvement in nutrients and salinity concentrations. The releases from the dam could cause increased turbidity and release colder water temperatures.

Scenarios 5, 6, 7 and 8 are expected to have very similar impacts. Sedges will be negatively impacted by about 20%. Reeds and grazing grasses will also be negatively affected. This is a result of extreme increase in inundation stress, especially during dry season base flows (but also wet season base flows) that will result in senescence of marginal zone riparian vegetation with 60 to 100% loss of the current marginal zone. Portions of the current lower zone will become the new marginal zone, with increased vegetation (especially sedge) cover and density. Loss of sediment as high velocity flows scour the active channel will also result in vegetation loss. Most fish species used for subsistence and recreational fishing would also suffer a 10 to 20% decline.

At this EWR scenario 4 is potentially positive but 5, 6, 7, and 8 are negative.

16.8 RESULTS FOR EWR 9 SUIKERBOS US

Scenario 4. Here slightly higher winter base flows and releases from Haarhoff and Balfour dams would improve the winter water quality slightly. Water temperatures released from these dams could be slightly higher than natural or present day. There could be slightly increased turbidity's in the winter due to higher base flows. Fish abundance for the species largemouth yellow fish and Mudfish are predicted to decrease by 20%. Again this translates into a 20% decrease in both recreational and subsistence fishing.

For Scenario 5 the sedges and reeds are predicted to increase by between 10 and 20%. As increased dry season base flows will result in additional marginal zone cover, will favour sedge growth and will keep marginal zone woody species in check.

Scenarios 6 and 7 as well as 8 have similar impacts to Scenario 4. Waste assimilation and dilution is expected to increase by about 30%. Fish abundance for the species largemouth yellow fish and mudfish are predicted to decrease by 20%. Again this translates into a 20% decrease in both recreational and subsistence fishing.

16.9 RESULTS FOR EWR 10 SUIKERBOS DS

Overall the impacts are negligible under all scenarios for this EWR. Under Scenarios 5 and 6 there is a negative impact on the sedges (50%) loss and on reeds (20%) lost. Generally there is a further reduction in seasonal differences, with wetter conditions during dry and wet season base flows, but more so during the dry season. This will reduce both woody and non-woody cover in the current marginal zone (which is already constrained and partly lost due to elevated current flows) as higher levels of dry season inundation is likely to cause senescence. Vegetation cover and density in the lower zone will however increase as a greater portion of the lower zone begins to function as marginal. Wet season changes are unlikely to have as much influence as changes are smaller and riparian plants are able to withstand wetter environments during their growing periods. Otherwise no significant impacts are predicted.

16.10 RESULTS FOR EWR 11 BLESBOKSPRUIT

Under Scenarios 4, 7 and 8 no significant impacts are predicted.

Under Scenarios 5 and 6 there are potentially a number of significant impacts. Sedges are predicted to decline by about 50% and reeds by about 30% as generally there is a further reduction in seasonal differences, with wetter conditions during dry and wet season base flows, but more so during the dry season. This will reduce both woody and non-woody cover in the current marginal zone as higher levels of dry season inundation is likely to cause senescence. Vegetation cover and density in the lower zone will however increase as a greater portion of the lower zone begins to function as marginal. Wet season changes are unlikely to have as much influence as changes are smaller and riparian plants are able to withstand wetter environments during their growing periods. In addition waste assimilation and dilution is predicted to decline by about 20%. This is because water quality in winter is driven by Suikerbosrand and Blesbokspruit Rivers. Point source discharges from waste water treatment works. These treatment works infrastructure are currently under capacitated and the final effluent discharged rarely meets the discharges requirements. Increased population in the 2020 development scenarios will increase the nutrient loads. Higher base flows due to higher surface area of impervious surfaces could increase the return of effluents from waste water treatment works. Smallmouth yellow fish, carp and barbel are also expected to decline by about 10% to 20%.

Scenarios 5 and 6 are largely negative with Scenarios 4, 7 and 8 virtually neutral.

16.11 SUMMARY OF SCENARIOS AND IMPACTS

Table 16.1 below sets out a schematic summary of the impacts by scenario and EWR. Where shading is green the impact is positive. Darker green is more positive that light green. Yellow indicates neutral or results so mixed as to render a judgment of the impacts virtually impossible. Red indicates negative impact. Again darker red is a more sever negative impact than lighter red.

Table 16.1 Consequences of the Operational scenarios on Goods and Services in the Upper Vaal

EWR site	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
1					
2					
3					
4					
5					
6					
8					
9					
10					
11					

Overall only two scenarios at EWR 2 and 11 could be said to be problematically negative from the perspective of goods and services.

17 RECOMMENDATIONS

Recommendations of further work required to confirm the results provided are described in the Table 17.1. The issues regarding each site which must be considered during any further development specifically around ad hoc monitoring is also provided in the table.

Table 17.1 Identified issues to be addressed and further work needed in future

Site	Further work	Issues
EWR 1 Vaal	Yield modelling: Determine why there is a difference in hydrology under Sc 7 which results in fish dropping half an EC.	Unresolved water quality issues at this site that could be responsible for fish kills and the bad condition of fish. This site is critical (due to the unique and critical habitat) in this MRU in the Upper Vaal and monitoring is required which should also focus on identifying the cause of the problems regarding fish..
EWR 2 Vaal	Yield modelling: Determine why there is more water than required at both EWR 2 and 3.	There is currently too little flow at EWR 2 and 3. These two sites both consist of critical habitat in the stretch between Grootdraai and Vaal Dam. Any licenses that would require less flows must be tested to determine whether the EWR will be met.
EWR 3 Vaal	See above.	See above.
EWR 4 Vaal		This site is situated immediately below Vaal Dam in the short stretch of river available between the Vaal Dam and the Vaal Barrage and Lethabo Weir. EWR 4 requires an improvement under current conditions to meet the REC. It is acknowledged that the flow conditions are unlikely to be met. However, as this is the only stretch that still maintains viable breeding areas for the fish and therefore maintains the fish population in this stretch as well as acting as a refuge for tributaries, it is vital that there is no further degradation at the site. Monitoring is therefore required and any changes in the Vaal Dam's operation which exacerbates the current 'unfriendly' operating rules must be carefully considered.
EWR 5 Vaal	-	EWR 5 represents the stretch of river below the Vaal Barrage and upstream of the Mooi River confluence. This stretch runs through the Vredefort Dome and taking into account the importance of this world heritage site, no further degradation should be allowed. It is vital that non-flow related measures be considered that could improve this situation. No changes in flow operations that could be detrimental to this site should be considered. Monitoring is essential.
EWR 6 Klip	Although not part of this study, the hydrology regarding the present use must be updated. There are serious concerns on the illegal abstractions and it is highly likely that the modelled present day flows do not reflect reality. An update in hydrology for this site is important.	The biota seems to still be in good condition. However it is possible that they have not yet fully reacted to the obvious increase in abstractions and farm dams. Almost zero flow conditions were experienced during 2 field visits. There is also a very important wetland in the upper Klip River. Any licences that require further abstraction in flows should not be considered based on these results due to the uncertainty in the hydrology. A re-assessment would be required of the EWR once the updated hydrology is available. Monitoring is essential.
EWR 8 Wilge	Determine whether the operating rules associated with Sc 5 and 7 can be modified to accommodate the EWR. Test the EWR to determine whether any changes improve the situation. There is also uncertainty in the present hydrology as this does not reflect the extremely low flow conditions observed in the field. There is also potential of illegal abstractions.	The current problems at this site include too little flow and at times the river literally stops flowing. However, the fish species are mostly semi-rheophilic which means they can survive in pools and the macroinvertebrates could probably re-establish themselves after no-flow conditions. However, any licenses that further decrease flows must be carefully considered, taking into account the uncertainty regarding the hydrology.
EWR 9 Suikerbos-rand	Certain assumptions regarding the release capability of Balfour Dam has been made in the planning model. No	The current problems at this site include too little flow and almost zero flow conditions at times. The present hydrology did not reflect this during the EWR assessment. Any license

Site	Further work	Issues
	information is presently available to determine whether actual releases can be made. The evaluation of scenarios based on this assumption must be confirmed.	application that implies abstraction of flows must only be considered once more information on Balfour Dam is available. Balfour Dam (and Haarhoff) should be providing an EWR currently which it is not. Any decisions made on the basis of the evaluations of the scenarios must also be treated with care as these are based on an assumption that Balfour Dam can (and will) provide an EWR.
EWR10 Suikerbos-rand; EWR 11 Blesbok-spruit		Water quality issues with reference to urban run-off, mining and SAPPI are dominant at this site. Specific management plans that would probably not influence the main Vaal River are required to address the unacceptable PES in the Blesbokspruit.

The Upper Vaal River system has very high demands imposed on it by the irrigation sector, as well as industrial and domestic sectors and forms the backbone of the economic hub of South Africa.

No specific Ecological Reserve Monitoring has been initiated in this river system apart from the RHP monitoring conducted at EWR 9, 10, 11 and RE-EWR 2[5]. Immediate monitoring is necessary as the surveys undertaken during the Reserve study represent the baseline against which change is measured. These surveys were undertaken during 2007 and 2008 and it can already (pending changes in the catchments), not be applicable. The longer monitoring is delayed, the bigger the chance is that the baseline surveys will have to be repeated because of outdated data.

The main recommendation is that effective monitoring is started as soon as possible due to the economic importance of the Upper Vaal River and the presence of the Vredefort Dome Heritage site that falls within this study area below the Vaal River Barrage. The Upper Vaal River is exposed to regular water quality related impacts due to industrial activities that are not monitored as well as a failing municipal infrastructure that leads to pollution levels that lead to fish kills and the recreational activities being banned by the Department of Health, especially in the reaches below the Vaal Dam.

[5] According to Ms Hermien Roux and Mr Piet Muller, River Health Champions for the North West and Gauteng Provinces respectively (*Pers. Comm.*, 2010).

18 REFERENCES

Department of Water Affairs and Forestry, South Africa (DWAF). 1999 Resource Directed Measures for Protection of Water Resources: Volume 3: River Ecosystems Version 1.0. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry, South Africa (DWAF). 2004. Upper Vaal Water Management Area: Internal Strategic Perspective. Prepared by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 on behalf of the Directorate: National Water Resource Planning. DWAF Report No P WMA 08/000/00/0304.

Department of Water Affairs and Forestry (DWAF), 2008. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Resource unit Report. Report no: RDM/WMA8C00001/CON/0208.

Department of Water Affairs (DWA), 2009a. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoClassification Report. Report no: RDM/WMA8C000/01/CON/0109.

Department of Water Affairs (DWA), 2009b. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EWR Scenario Report. Report no: RDM/WMA8C000/01/CON/0209.

Department of Water Affairs (DWA), 2010a. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Water Resource Modelling Report. Report produced by DMM Development Consultants/Hydrosol/WRP Consulting Engineers. Report no: RDM/ C000/01/CON/0607.

Department of Water Affairs (DWA), 2010b. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Electronic information. Report no: RDM/WMA8C000 01/CON/0710.

Department of Water Affairs (DWA), 2010c. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Socio Economic Consequences of Various Operational Scenarios. Report no: RDM/WMA8C000 01/CON/0210.