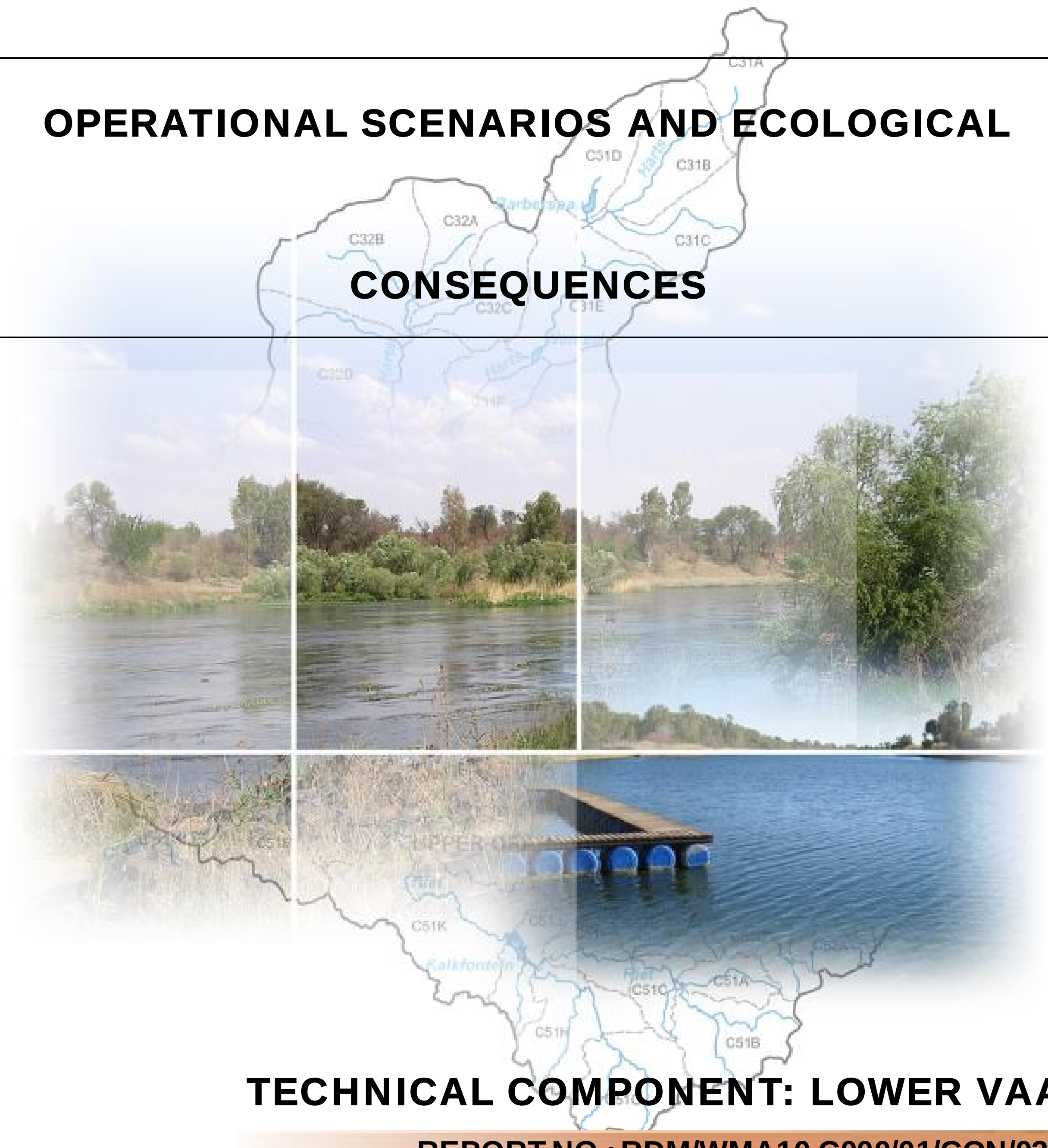
COMPREHENSIVE RESERVE DETERMINATION

INTEGRATED VAAL RIVER SYSTEM

SURFACE WATER

OPERATIONAL SCENARIOS AND ECOLOGICAL CONSEQUENCES



TECHNICAL COMPONENT: LOWER VAAL

REPORT NO.: RDM/WMA10 C000/01/CON/0310
PROJECT NO.: 8829/1

water & forestry
Department:
Water Affairs & Forestry
REPUBLIC OF SOUTH AFRICA

Department of Water Affairs
Private Bag X313
PRETORIA, 0001
Republic of South Africa

Tel: (012) 336 7500/ +27 12 336 7500
Fax: (012) 336 / +27 12 336

This report should be cited as:

> Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study for the integrated Vaal River System, Lower Vaal Water Management Area. Operational scenarios and ecological consequences Report. Report no: RDM/ WMA10C000/ 01/CON/ 0310. Pretoria, South Africa.

Report produced and authored by:

Golder Associates Africa (Pty) Ltd

Golder Associates Africa (Pty) Ltd
Reg. No. 2002/007104/07

PO Box 6002 Halfway House 1685
South Africa
Thandanani Park, Matuka Close
Halfway Gardens, Midrand
Tel + (27) (0)11 254-4901
Fax + (27) (0)11 805-2100

DOCUMENT INDEX

Reports as part of this project:

Bold type indicates this report.

REPORT INDEX	REPORT NUMBER	REPORT TITLE
1.1	RDM/ WMA10C000/01/CON/0107	Lower Vaal Comprehensive Reserve determination: Surface Water Inception report
1.2	RDM/ WMA10C000/01/CON/ 0207	Lower Vaal Comprehensive Reserve determination: Surface Water Desktop EcoClassification report
1.3	RDM/ WMA10C000/ 01/CON/ 0108	Lower Vaal Comprehensive Reserve determination: Surface Water Basic Human Needs Reserve report
1.4	RDM/ WMA10C000/ 01/CON/ 0109	Lower Vaal Comprehensive Reserve determination: Surface Water Resource Units report
1.5	RDM/ WMA09/10C000/ 01/CON/ 0209	Lower and Lower Vaal Comprehensive Reserve determination: Surface Water Wetland/Pans Assessment report
1.6	RDM/ WMA10C000/ 01/CON/ 0110	Lower Vaal Comprehensive Reserve determination: Surface Water EcoClassification report
1.7	RDM/ WMA10C000/ 01/CON/ 0210	Lower Vaal Comprehensive Reserve determination: Surface Water Ecological Water Requirements report
1.8	**RDM/ WMA10C000/ 01/CON/ 0310**	**Lower Vaal Comprehensive Reserve determination: Surface Water Operational scenarios and ecological consequences report**
1.9	RDM/ WMA09/10C000/ 01/CON/ 0410	Lower Vaal Comprehensive Reserve determination: Surface Water Socio Economic consequences of operational scenarios report
1.10	RDM/ WMA10C000/ 01/CON/ 0510	Lower Vaal Comprehensive Reserve determination: Surface Water Ecospecs and monitoring report
1.11	RDM/ WMA10C000/ 01/CON/ 0610	Lower Vaal Comprehensive Reserve determination: Surface Water Main integration report
1.12	RDM/ WMA10C000/01/CON/ 0710	Lower Vaal Comprehensive Reserve determination: Surface Water Electronic information

APPROVAL

TITLE:	Resource Directed Measures: Comprehensive Reserve determination study for the integrated Vaal River System, Lower Vaal Water Management Area. Operational scenarios and ecological consequences Report.
DATE:	November 2010
AUTHORS:	R Heath, P Kimberg, A Koning, A Hudson, M Rountree
REVIEWERS:	R Stassen
LEAD CONSULTANT:	Golder Consultants
FORMAT:	MSWord and PDF
WEB ADDRESS:	www.dwaf.gov.za

Approved for Golder Associates Africa (Pty) Ltd:

Dr Ralph Heath
Study Leader and Manager

Approved for the Department of Water Affairs by:

Ms R Stassen
Project Manager (PSP Project Management Team)

Ms B Weston

Project Manager: Resource Directed Measures.

ACKNOWLEDGEMENTS

The following individuals are thanked for their contributions to the document:

Project Management Committee

Barbara Weston	Department of Water Affairs	Project Manager
Daniel Masemola	Department of Water Affairs	Assistant Project Manager
Retha Stassen	Blue Science Consulting	PSP Management team Leader
Owen Wilson	Arcus Gibb Consulting	Assistant PSP Project Manager
Ralph Heath	Golder Associates Africa	PSP Technical Study Leader and Manager

Study Team

Ralph Heath	Golder Associates Africa	Technical Project Leader and Manager
Trevor Coleman	Golder Associates Africa	Water Quality Specialist
Danie Otto	Golder Associates Africa	Pans/Wetlands Specialist
Anton Linstom	Golder Associates Africa	Pans/Wetlands Specialist
Angelina Jordanova	Golder Associates Africa	Hydraulics engineer
Peter Kimburg	Golder Associates Africa	Fish
Alvar Koning	Golder Associates Africa	Macroinvertebrate
Adrian Hudson	Golder Associates Africa	Riparian vegetation
Anelle Odendaal	Zitholele Consulting	Stakeholder awareness
Jennifer Molwantwa	Zitholele Consulting	Water Quality trainee
Rene Ford	Zitholele Consulting	Socio-economic
Justin du Toit	Golder Associates Africa	Trainee socio-economist
Ken Haumann	PD Naidoo and Associates	Spatsim and hydrology
Mark Rountree	Private Consultant	Geomorphologist
Lindo Hlongwane	Fluvial Environmental Consultants	Trainee geomorphologist
Mushoni Makatu	PD Naidoo and Associates	Spatsim and hydrology

Members of Project Steering Committee

Harrison Pienaar	Chief Directorate: Resource Directed Measures
Barbara Weston	Chief Directorate: Resource Directed Measures
Nancy Motebe	Chief Directorate: Resource Directed Measures
Wendy Ralekoa	Chief Directorate: Resource Directed Measures
Bonani Madekezela	Directorate: Resource Quality Services
Mamogale Kadiaka	Directorate: Water Abstraction and In-stream Use (Environment & Recreation)
Seef Rademeyer	Directorate: National Water Resources Planning
Niel van Wyk	Directorate: National Water Resources Planning
Jurgo van Wyk	Directorate: Water Resource Planning Systems
Peter Pyke	Directorate: Option Analysis
Churchill Mkwalo	Directorate: Stream flow Reduction
Marius Keet	Gauteng Regional Office
Delia Mare	Gauteng Regional Office
Walther van der Westhuizen	Gauteng Regional Office
Riana Munnik	Directorate: Resource Protection and Waste
Dawie Koekemoer	Gauteng Regional Office
Hanke Du Toit	Northern Cape Regional Office
Willem Grobler	Free State Regional Office
Retha Stassen	ARCUS GIBB/ Blue Science Consulting Project Management team

EXECUTIVE SUMMARY

Chapter 3 of the National Water Act (NWA) (Act No. 36, 1998) provides for the protection of water resources of the country through the implementation of Resource Directed Measures (RDM), based on the guiding principles of sustainability and equity. In terms of the Act, before any authorization to utilise a particular water resource can be granted, it is necessary to determine the Reserve for the relevant ecological component of the resource that will be impacted by the proposed water use. The Reserve can be defined as, 'the quantity, quality and reliability of water needed to sustain both basic human needs and aquatic ecosystems.

The Chief Directorate: Resource Directed Measures (CD:RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses in terms of the Act, are determined before any new water uses are authorised. The Reserve requirements must be met, before the requirements for economic development or water uses are satisfied so as to ensure that the long-term integrity of ecosystems are not comprised or severely impacted upon.

The CD: RDM initiated the Comprehensive Reserve Determination Study for the Lower Vaal Water Management Area (WMA), North West Province. The purpose of the Comprehensive Reserve Determination Study for the selected water resources of the Lower Vaal WMA is to determine the ecological and basic human needs water quantity and quality Reserve at a comprehensive level of detail. The results of the Comprehensive Reserve determination study will assist the DWA to make more informed decisions regarding the authorization of future water uses, operation and management of the system and the evaluation of the magnitude of the impacts of the present and proposed developments.

The Lower Vaal WMA forms part of the integrated Vaal River System, and falls within the C drainage region of South Africa. The Lower Vaal WMA is one of the three cascading WMAs in the Vaal River System catchment, which includes the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers.

The study area for the Comprehensive Reserve determination of the Lower Vaal River is the Vaal catchment within the Lower Vaal and Upper Orange WMAs (part of WMA 10 and 13). These catchment areas form part of the integrated Vaal River System, as they fall within the C drainage region of South Africa. The Lower Vaal WMA is the last of the three cascading WMAs in the Vaal River System catchment, which includes the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers.

The Lower Vaal WMA is situated in the north-western part of the country and forms part of the Orange River watercourse. It covers a catchment area of 133 354 km^2, and includes parts of the Northern Cape and North-West Provinces, and a small part of the Free State Province. The Vaal River is the only major river in the WMA, as it flows in a westerly direction from Bloemhof Dam to the confluence with the Orange River. The largest part of the WMA falls within the catchment of the Molopo River, a tributary of the Orange River. The Molopo, Nossob and Kuruman rivers drain the remainder of the WMA but due to the very low rainfall in the WMA, the contribution of flow from these rivers are insignificant. The WMA consists of the D41 (excluding D41A), parts of D42C and D42D, parts of D73A and D73C, C31, C32, C33, C91, and C92 tertiary catchments. For the purpose of this study only the C drainage region is of relevance as it forms part of the Vaal River System, which includes the Harts River catchment, the Modder/Riet catchments and the Vaal River catchment.

The Modder/Riet system forms part of the upper Orange River catchment and consists of tertiary catchments C51 and C52. The Orange River confluences with the Vaal River near the downstream outlet of the Lower Vaal WMA. Virtually all the surface flow of the Vaal River, the main source of water in the Lower Vaal WMA, originates from the Upper and Middle Vaal WMAs. Very little surface run-off originates within the WMA itself due to the low rainfall, flat topography and sandy soils. The groundwater resource is more substantial, supplying an estimated 128 million m^3/annum. The Vaal River is fed by the only tributary, the Harts River which drains a catchment area of 31 000km^2, with the Dry Harts being the major tributary of the Harts River joining it just downstream of Taung. The only lake and wetlands of note are at Barberspan in the Upper Harts River catchment which has been given Ramsar status as a wildlife conservation area.

This report provides the results of the Ecological consequences of proposed operational flows in the rivers of the Lower Vaal catchment area. The Ecological Water Requirement (quantity) scenarios developed are as sets of possible flows to achieve different river states (or Ecological Categories) for each EWR. This process did not consider whether these flows could be supplied or managed. To provide decision makers with more comprehensive information, it is necessary to examine each of the scenarios and their full range of implications. Thereafter, a process was followed to devise an optimised scenario (if necessary) that would have the least overall impact on the users and the ecology. All these operational scenarios were tested to determine the resulting state of the river, and the water quality consequences of each flow scenario were supplied.

The objectives of this task were to develop a range of operational scenarios that result in different impacts on different users. The impacts of incorporating the EWR on the ecology, system yield, services and overall economic activities could then be assessed.

The purpose of this step (step 5) in the 8 step Reserve process is to predict the driver and biotic responses to each operational scenario, including natural and present day hydrology and derive the ecological categories for each EWR site. All information generated during steps 3 (ecoclassification) and step 4 (determination of Ecological Water Requirement) is used during this step.

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

- The operational scenarios (DWA, 2010a) were modelled using the WRPM 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 specialists.

- The impacts of these time series of the operational scenarios were analysed by the physico chemical and geomorphology specialists by completion of the Physico-chemical Assessment Index (PAI) and Geomorphology Assessment Index (GAI) models to predict the driver ecological category.

- The riparian vegetation specialist then assessed the response on the marginal and other riparian zones and supplied this information to the instream biotic specialists (macroinvertebrates and fish).

- Where required, the riparian vegetation specialist ran the Vegetation Response Assessment Index (VEGRAI) model to predict the ecological category for each operational scenario.

The following instream biotic assessment was then undertaken:

- Each time series was converted into a stress duration table and provided on a graph for the same months as evaluated during the EWR workshop.

- 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 the various ecological categories.

- If it was not obvious what the resulting category 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 ecological category.

- The VEGRAI, MIRAI and FRAI results were then used as input to the Ecostatus model to determine the resulting ecological category per operational scenario.

Table A provides a summary of the operational scenarios that were modelled using the WRPM. Detailed information regarding the operational scenarios is documented in report RDM/C000/00/CON/0607.

Table A: Summary of the operational scenarios evaluated

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 were noted and reasoning was provided.
4	2008	Included	Based on Scenario 1. 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.	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 operation 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	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,

Sc No	Dev Level	EWR Status	Scenario description	Reasoning
			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.	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.

Ecological and water quality consequences of the various operational scenarios were assessed and are described in the sections below. The ecological evaluation is based on an assessment of the impact on the status or ECs recommended for each component. Information on the water quality assessment as a key driver is provided below, followed by the overall assessment.

A summary of the scenario consequences are shown in Table B.

Table B: Scenario consequence

Main Stem	**Sc 1 PD REC**	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
16 Bloemhof	**E**	**E**	**E**	**E**	**E**	**E**
18 Schimdtsdrift	**C/D**	**C**	**C/D**	**C**	**C/D**	**C**
Tributaries						
17 Harts	**D**	**D**	**D**	**D**	**D**	**D**
19 Riet	**D**	**C**	**D**	**C**	**D**	**C**

A summary of the ecological consequences per scenario for the main stem of the Vaal EWR (Figure A) and for the tributaries are indicated in Figure B. In summary the following are conclusions (Figure C):

- Negative economic impacts (in terms of GDP and employment) may occur as a consequence of applying the Ecological Reserve in the Renoster, Vals and Vet Rivers
- Main stem of Vaal all scenario's meet PES and REC
- Tributaries Scenarios, 4, 7 and 8 meet PES and REC
- Water quality driver and management plans for nutrients and salts – aquatic ecosystem adapted
- Extra flows but main stem altered for many years
- Tributaries less water and water quality issues

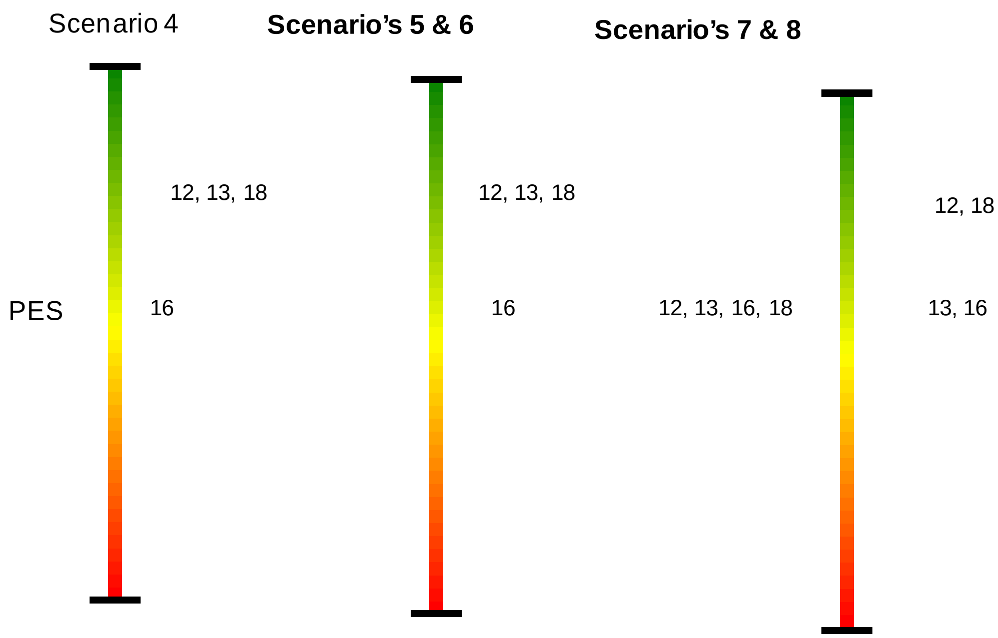


Figure A: Summary of ecological consequences per scenario for the main stem of the Vaal EWR sites

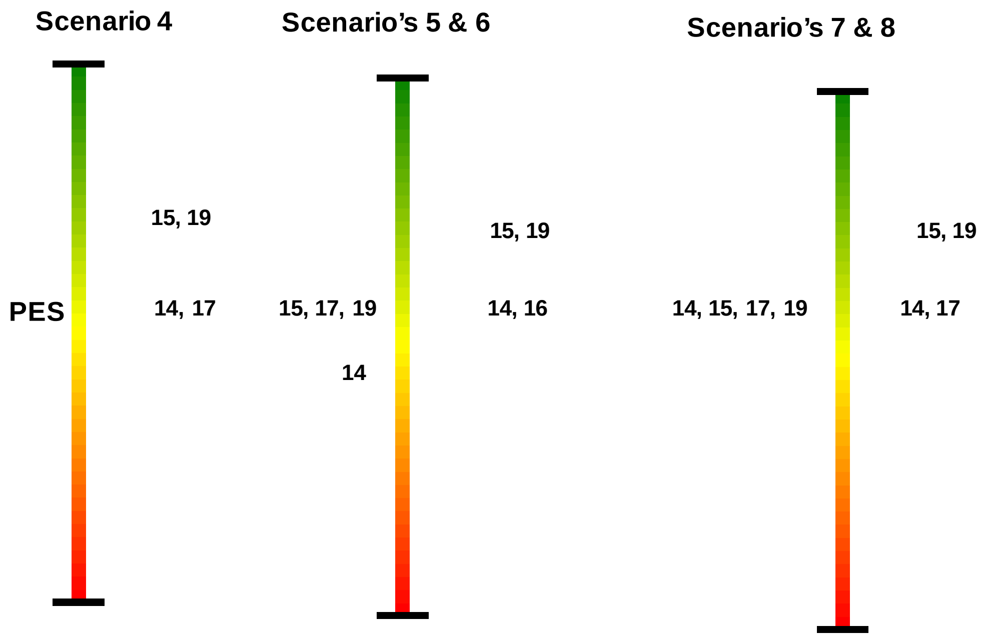


Figure B: Summary of ecological consequences per scenario for the tributaries of the Vaal EWR sites

The following final recommendations for the future management of the Middle Vaal (Table C) have been approved.

Table C: Final recommendations per EWR site

EWR site	Recommendation
16 Vaal (Bloemhof)	Sign off for instream REC=D as the current overall PES=E due to non-flow related impacts. Conditions to improve the Riparian Zone should be included.
17 Harts	Sign off for PES=REC=D
18 Vaal (Schmitsdrift)	Sign off for REC=C/D
19 Riet	Sign off for REC=D with a recommendation that the flow measurements at the gauging weir must be improved.

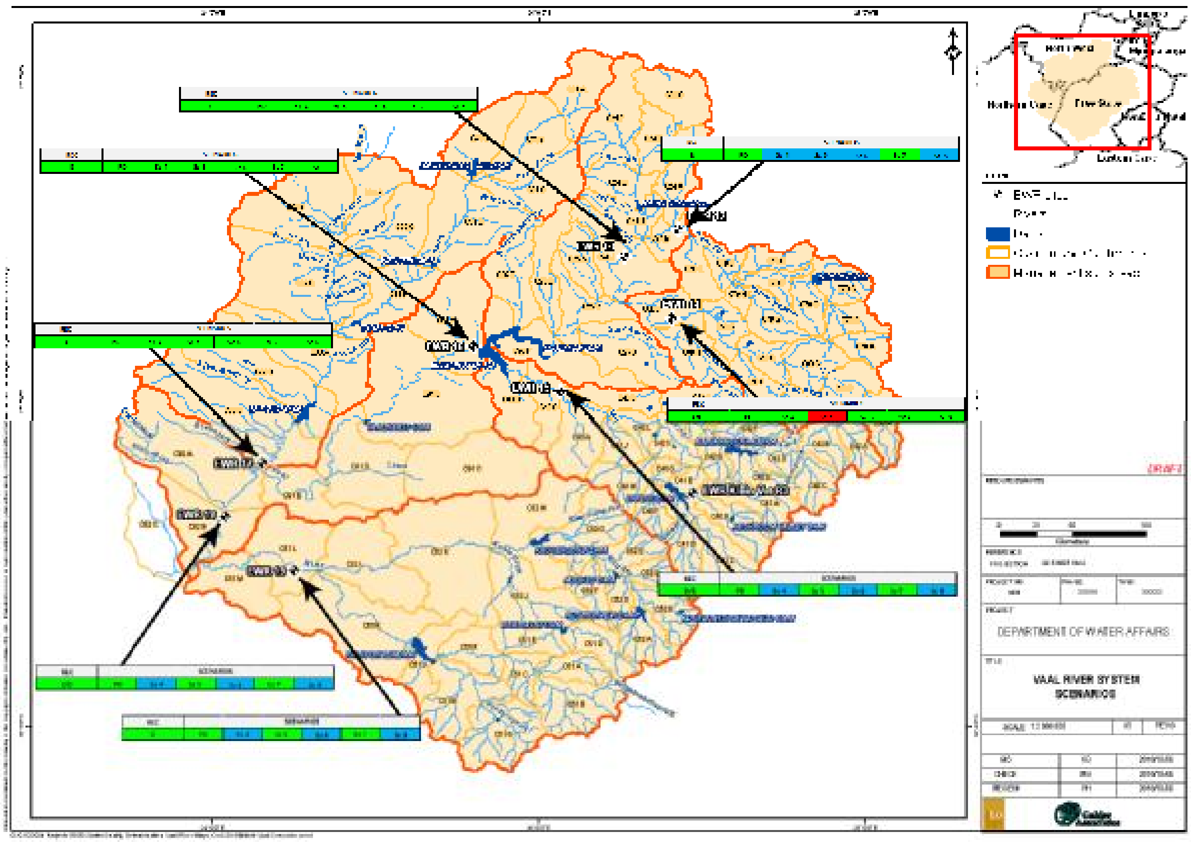


Figure C: Summary of the Ecological Consequences for the Lower Vaal Catchment

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRYNOMS

CD: RDM	Chief Directorate: Resource Directed Measures
D: NWRP	Directorate: National Water Resource Planning
D: RQS	Directorate: Resource Quality Services
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
GDP	Gross Domestic Product
GGP	Gross Geographic Product
IHI	Index of Habitat Integrity
NWA	National Water Act
PES	Present Ecological State
QHI	Quick Habitat Integrity
REC	Recommended Ecological Category
RU	Resource Unit
SCI	Socio Cultural Importance
ToR	Terms of Reference
WMA	Water Management Area

GLOSSARY

DROUGHT FLOW	The minimum flow required facilitating the survival of the riverine ecosystem in a particular condition and over short, infrequent periods, when users are subject to water restrictions. Drought flows in the Vaal River will be defined as low-flows that occur less than x % of the time under natural conditions for each month.
ECOLOGICAL CATEGORY	A category indicating the potential management target for a river. Values range from Category A (unmodified, natural) to Category D (largely modified). This term replaces former terms used, namely: Ecological Reserve Category (ERC), Desired Future State (DFS) and Ecological Management Class (EMC). The reasons for these changes are explained in the proceedings of a workshop to clarify the terminology used in Reserve determinations (DWAF 2003). It should be noted that a distinction is made between Management Classes, which form part of the National Classification System, and Ecological Categories, which forms part of the Ecological Water Requirement assessment.
ECOSPECS	Clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity) that defines the Ecological Category. The purpose of Ecospecs is to establish clear goals relating to resource quality (Kleynhans 2003).
ECOSTATUS	An overall assessment of the Ecological Category (A-F), based on rule-based integration of specialist indices (water quality, fish, etc). EcoStatus refers to the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services" (Iversen *et al.* 2000, *In* IWR Environmental 2003).
ECOLOGICAL WATER REQUIREMENTS (EWR)	The flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.

INSTREAM FLOW REQUIREMENTS (IFR)	The flow patterns (magnitude, timing and duration) needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to the quantity component only of Ecological Water Requirements.
MAINTENANCE FLOW	The flow required to meet the requirements of the riverine ecosystem at a particular site and maintain the resource base in a particular condition during "normal" climatic years. The distinction between "normal" and "drought" was based on an examination of monthly flow duration curves
PRESENT ECOLOGICAL STATE (PES)	The degree to which ecological conditions of an area have been modified from natural (reference) conditions. The measure is based on water quality variables, biotic indicators and habitat information collected 1 to 3 years prior to the assessment. Results are classified on a 6-poin scale, from Category A (***Largely Natural***) to Category F (***Critically Modified***).
REFERENCE CONDITION	Natural ecological conditions, prior to human development.
RESERVE	The quantity and quality of water required (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and (b) to protect aquatic ecosystems under the National Water Act, 1998 (Act No. 36 of 1998) in order to secure ecologically sustainable development and use of the relevant water resource. The Reserve refers to the modified Ecological Water Requirement, where operational limitations, and stakeholder consultation are taken into account.
RESOURCE QUALITY OBJECTIVE	Quantitative and auditable statements about water quantity, water quality, habitat integrity and biotic integrity that specify the requirements (goals) needed to ensure a particular level of resource protection. This term takes into account the management *classes* and the

	requirements of other users. These components are not addressed in this project
RESOURCE UNIT	Stretches of river that are sufficiently ecologically distinct to warrant their own specification of Ecological Water Requirements, and that can be practically managed as a single unit.

1 INTRODUCTION

1.1 Background

Chapter 3 of the National Water Act (NWA) (Act No. 36, 1998) provides for the protection of water resources of the country through the implementation of Resource Directed Measures (RDM), based on the guiding principles of sustainability and equity. In terms of the Act, before any authorization to utilise a particular water resource can be granted, it is necessary to determine the Reserve for the relevant ecological component of the resource that will be impacted by the proposed water use. The Reserve can be defined as, 'the quantity, quality and reliability of water needed to sustain both basic human needs and aquatic ecosystems.

The Chief Directorate: Resource Directed Measures (CD:RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses in terms of the Act, are determined before any new water uses are authorised. The Reserve requirements must be met, before the requirements for economic development or water uses are satisfied so as to ensure that the long-term integrity of ecosystems are not comprised or severely impacted upon'. As the Department of Water Affairs (DWA) is the custodian of the nation's water resources, it is their responsibility to ensure the adequate protection and effective management of these resources.

The CD: RDM initiated the Comprehensive Reserve Determination Study for the water resources of the Middle Vaal Water Management Area (WMA) that forms part of the overall comprehensive Reserve determination of the integrated Vaal River System. The purpose of this Reserve Determination Study is to determine the ecological and basic human needs water quantity and quality Reserve at a comprehensive level of detail.

The results of the Comprehensive Reserve determination study will assist the DWA to make more informed decisions regarding the authorisation of future water uses, operation and management of the system and the evaluation of the magnitude of the impacts of the present and proposed developments.

This report provides the ecological consequences as part of step 5 of the 8-step Reserve determination process (see Figure 1.1) on a comprehensive level of detail for the rivers of the Lower Vaal and the Modder-Riet rivers catchment areas.

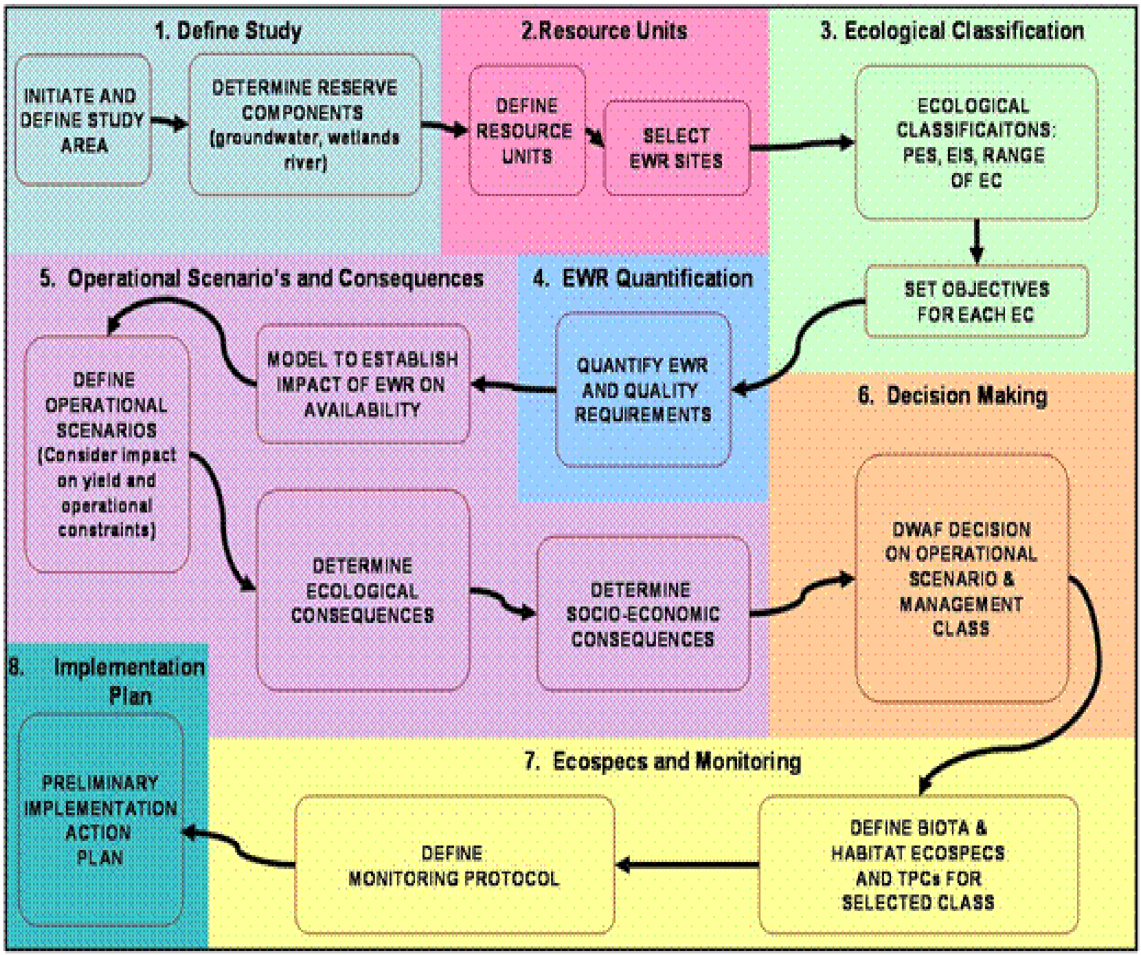


Figure 1.1: Generic procedure for the determination of the ecological Reserve

1.2 Study area

The study area for the Comprehensive Reserve determination of the Lower Vaal River is the Vaal catchment within the Lower Vaal and Upper Orange WMAs (part of WMA 10 and 13) (see Figure 1.2). These catchment areas form part of the integrated Vaal River System, as they fall within the C drainage region of South Africa. The Lower Vaal WMA is the last of the three cascading WMAs in the Vaal River System catchment, which includes the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers.

The Lower Vaal WMA is situated in the north-western part of the country and forms part of the Orange River watercourse. It covers a catchment area of 133 354 km^2, and includes parts of the Northern Cape and North-West Provinces, and a small part of the Free State Province. The Vaal River is the only major river in the WMA, as it flows in a westerly direction from Bloemhof Dam to the confluence with the Orange River. The largest part of the WMA falls within the catchment of the Molopo River, a tributary of the Orange River. The Molopo, Nossob and Kuruman rivers drain the remainder of the WMA but due to the very low rainfall in the WMA, the contribution of flow from these rivers are insignificant. The WMA consists of the D41 (excluding D41A), parts of D42C and D42D, parts of D73A and D73C, C31, C32, C33, C91, and C92 tertiary catchments. For the purpose of this study only the C drainage region is of relevance as it forms part of the Vaal River System, which includes the Harts River catchment, the Modder/Riet catchments and the Vaal River catchment.

The Modder/Riet system forms part of the upper Orange River catchment and consists of tertiary catchments C51 and C52. The Orange River confluences with the Vaal River near the downstream outlet of the Lower Vaal WMA. The C drainage region of the Lower WMA comprises four sub-catchments and the Upper Orange one catchment as listed in Table 1.1.

Table 1.1: Sub-catchments and related quaternary drainage regions within the C Drainage region within the Lower Vaal WMA and Upper Orange WMA (DWAF, 2006)

PRIMARY CATCHMENT	SUB-CATCHMENT	QUARTENARY CATCHMENTS	AVERAGE GROSS AREA (km^2)
C	Dry Harts	C32A-D	10 205
	Harts	C31A-F	11 023
	Vaalharts	C33A-C	9843
	Vaal downstream Bloemhof	C91A-E, C92A-C	22 427
	Modder/Riet	C51A-M, C52A-L	34 795

Virtually all the surface flow of the Vaal River, the main source of water in the Lower Vaal WMA, originates from the Upper and Middle Vaal WMAs. Very little surface run-off originates within the WMA itself due to the low rainfall, flat topography and sandy soils. The groundwater resource is more substantial, supplying an estimated 128 million m^3/annum. The Vaal River is fed by the only tributary, the Harts River which drains a catchment area of 31 000km^2, with the Dry Harts being the major tributary of the Harts River joining it just downstream of Taung. The only lake and wetlands of note are at Barberspan in the Upper Harts River catchment which has been given Ramsar status as a wildlife conservation area.

Selected Ecological Water Requirement (EWR) sites are indicated in Table 1.2 and in Figure 1.2.

Table 1.2: Selected EWR sites for the Lower Vaal catchment

EWR Site number	EWR16	EWR17	EWR18	EWR19
EWR site name	Downstream Bloemhof Dam	Lloyds weir on Harts River	Schmidtsdrift	Lilydale Lodge
River	Vaal	Harts	Vaal	Riet
National RHP site	-	C3HART-DELPO	C9VAAL-SCHMI	-
Coordinates	S27.65541; E25.59564	S28.37694; E24.30305	S28.7048; E24.07601	S29.03842; E24.50283
Ecoregion (Level II)	11.08; 29.02	29.02; 30.01	29.02; 30.01	29.02
Geomorphic zone	E: Lower Foothills	E: Lower Foothills	E: Lower Foothills	E: Lower Foothills
Altitude (m)	1211	1114	1239	1107
RU	Vaal K	Harts C	Vaal O	Riet D

Quartenary catchment	C91A	C33C	C92B	C51L
Hydrological Gauge	C9H021	C3H016	C9H024	C5H048

1.3 Purpose of this report

The activities and tasks for step 5 of the Reserve determination process were undertaken in accordance with the appropriate approaches and methodologies for rivers as prescribed by the CD: RDM of DWA. The report summarises the ecological consequences of a range of operational scenarios based on the output from the planning model (WRP, RDM/C000/01/CON/0607; DWA, 2010a).

1.4 Report structure

This report is structured into the following sections:

Section 1: Introduction
Section 2: Approach to ecological consequences - provides the approach followed to obtain the ecological consequences.
Section 3: Operational scenarios analysed – summary of operational scenarios
Section 4: Determination of ecological consequences – results of the various operational scenarios for the ecological components per EWR site in the Lower Vaal and Modder/Riet catchments.
Section 5: Recommendations

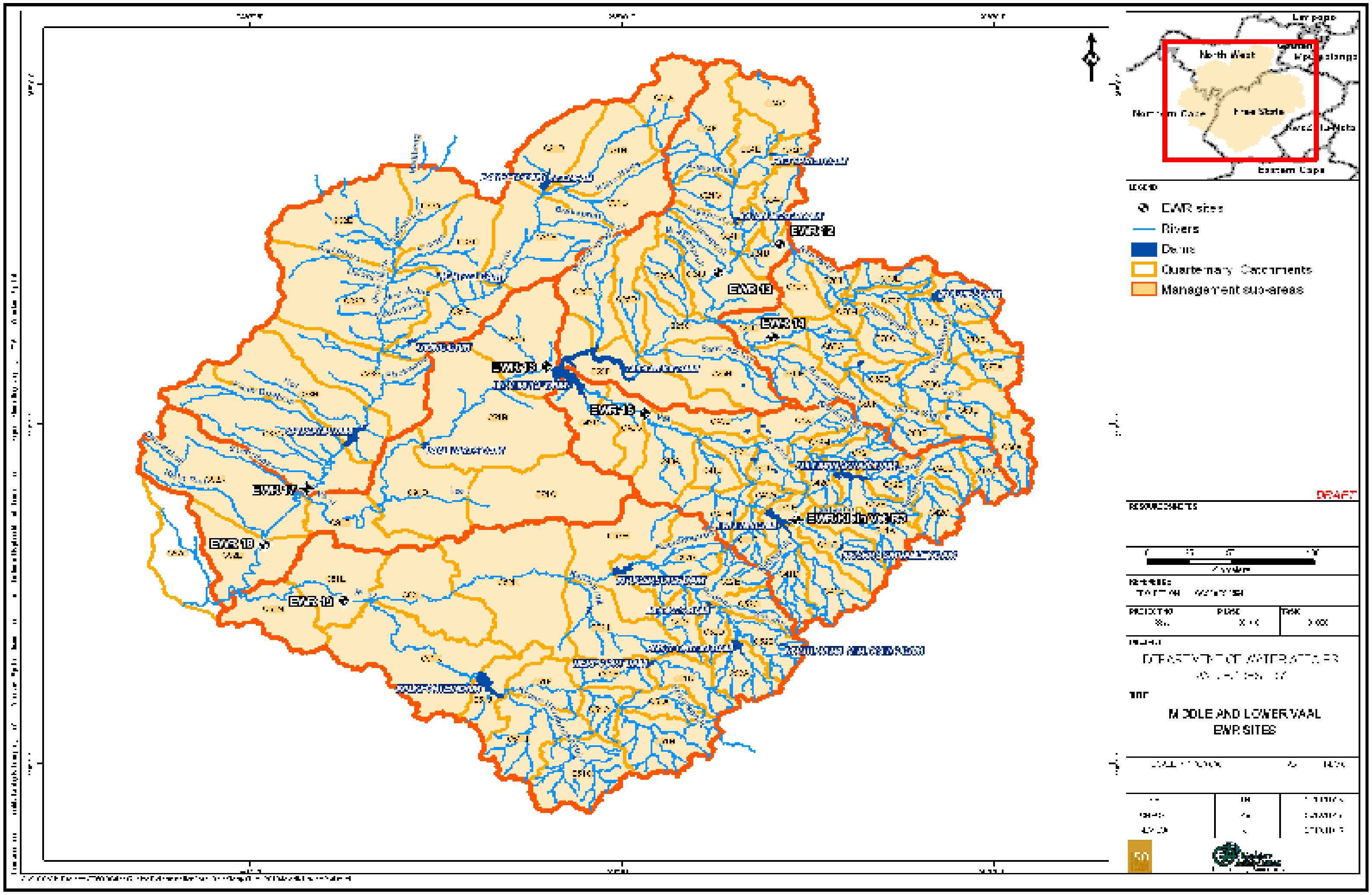


Figure 1.2: Resource Units and selected EWR sites for the Lower Vaal

2 APPROACH TO ECOLOGICAL CONSEQUENCES

Operational flow scenarios were identified during two meetings and analysed using the Water Resources Planning Model (WRPM). During the evaluation of these scenarios to determine the ecological consequences, ecological as well as other aspects were considered. This will assist the DWA during the decision-making process regarding impacts of the various flow scenarios. This process will form part of the Water Resources Classification System in future.

Step 5 of the 8 step Reserve process is to determine the ecological, goods and services and socio-economic consequences of the operational scenarios. This report summarises the ecological consequences. The goods and services and socio-economic consequences are provided in separate reports.

2.1 Approach followed

The purpose of this step (step 5) in the 8 step Reserve process is to predict the driver and biotic responses to each operational scenario, including natural and present day hydrology and derive the ecological categories for each EWR site. All information generated during steps 3 (ecoclassification) and step 4 (determination of Ecological Water Requirements) is used during this step.

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

- The operational scenarios (DWA, 2010a) were modelled using the WRPM 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 specialists.
- The impacts of these time series of the operational scenarios were analysed by the physico chemical and geomorphology specialists by completion of the Physico-chemical Assessment Index (PAI) and Geomorphology Assessment Index (GAI) models to predict the driver ecological category.
- The riparian vegetation specialist then assessed the response on the marginal and other riparian zones and supplied this information to the instream biotic specialists (macroinvertebrates and fish).
- Where required, the riparian vegetation specialist ran the Vegetation Response Assessment Index (VEGRAI) model to predict the ecological category for each operational scenario.

The following instream biotic assessment was then undertaken:

- Each time series was converted into a stress duration table and provided on a graph for the same months as evaluated during the EWR workshop.
- 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 the various ecological categories.
- If it was not obvious what the resulting category 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 ecological category.

- The VEGRAI, MIRAI and FRAI results were then used as input to the Ecostatus model to determine the resulting ecological category per operational scenario.

2.2 Phyisico chemical

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.
- Information describing the present state for water quality at each EWR 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.
- 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.

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 biotic specialists. Final adjustments to the model were highlighted, and notes included.

2.3 Geomorphology

The following steps were undertaken by the geomorphologist to determine the ecological consequences per operational scenarios:

- Monthly volumes and flow duration curves provided a guideline for estimating the size and frequency of floods under each of the operational scenarios and allowed to determine the consequences for high flows at the EWR sites under each of the operational scenarios.
- A qualitative description of the changes in geomorphology and riparian vegetation of each operational scenario per EWR site was provided to the instream biotic 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.

2.4 Riparian vegetation

The riparian vegetation specialist undertook the following activities to determine the ecological consequences of the operational scenarios and to provide information to the instream biotic specialists:

- Flow duration curves of each operational 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) with surveyed vegetation points on the profile and the levels of inundation of each species or guild, a quantitative description was provided for present day and natural drought and maintenance flows (wet and dry seasons). The same was then done for each operational 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 EWR site was provided to the instream biotic specialists to indicate changes in availability and quality of different instream habitats.
- Floods: Total volumes of the specified 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 to qualitatively assess changes. If changes to floods were likely to result in changes to riparian vegetation metrics, then this was also incorporated into VEGRAI.
- The VEGRAI was then adjusted based on the data and descriptions from the above comparisons. A VEGRAI was compiled for each scenario and adjustments were made to applicable metrics in applicable zones with motivations for each adjustment. The Ecological Category per operational scenario was recorded and the ecological consequences were documented.

2.5 Instream biota

The two months assessed during the determination of the ecological water requirements step were used during the determination of the instream biotic consequences of the operational scenarios.

Macroinvertebrates

- The descriptions of stress indices and recommendations for EWRs as generated during step 4 were 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 an ecological category change.
- The MIRAI for the PES used during the EcoClassification determination, was adjusted and these adjustments to the different metrics were highlighted in the model.
- The resulting change in ecological category was described qualitatively and provided in this report.

Fish

- During the EWR determination, the Fish Flow Habitat Assessment (FFHA) model was used to determine the fish HFSR requirement.
- The same model was used to assess the operational scenarios.
- The flow duration table for each operational scenario 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 used during the EcoClassification determination, was adjusted and these adjustments to the different metrics were highlighted in the model.
- The resulting change in ecological category was described qualitatively and provided in this report.

3 OPERATIONAL SCENARIOS EVALUATED

Table 3.1 provides a summary of the operational scenarios that were modelled using the WRPM. Detailed information regarding the operational scenarios is documented in report RDM/C000/00/CON/0607.

Table 3.1: Summary of the operational scenarios evaluated

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 were noted and reasoning was provided.
4	2008	Included	Based on Scenario 1. 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.	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 operation 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	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.

Sc No	Dev Level	EWR Status	Scenario description	Reasoning
			Crocodile catchment.	
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.

4 DETERMINATION OF ECOLOGICAL CONSEQUENCES PER EWR SITE

4.1 EWR 16: DOWNSTREAM BLOEMHOF DAM (VAAL RIVER)

4.1.1 Catchment development and impacts

EWR 16 is below Bloemhof Dam and according to the available data, baseflows across all seasons have been reduced, and it is expected that small and moderate floods have been seriously reduced from natural due to the upstream Bloemhof Dam. Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Hartz system) which has been operational since the late 1930’s.

Extra water is released from the Vaal Dam in winter and this is used for the dilution of salts in the middle and lower Vaal. Increased winter flow results in increased winter turbidity. The salinity and nutrient impacts from the Vaal Barrage (Klip, Riet and Suikerbosrand Rivers) are combined with mine water decants from Witwatersrand and Mooi River (Wonderfonteinspruit). Furthermore gold mining around the KOSH area results in increased inputs into the Koekermoerspruit and Schoonspruit catchments.

4.1.2 Graphs of flow scenarios

Error! Reference source not found. illustrates the stress requirements and stress points required for the REC, present day and the operational scenarios analysed for the wet dry season at EWR site 16.

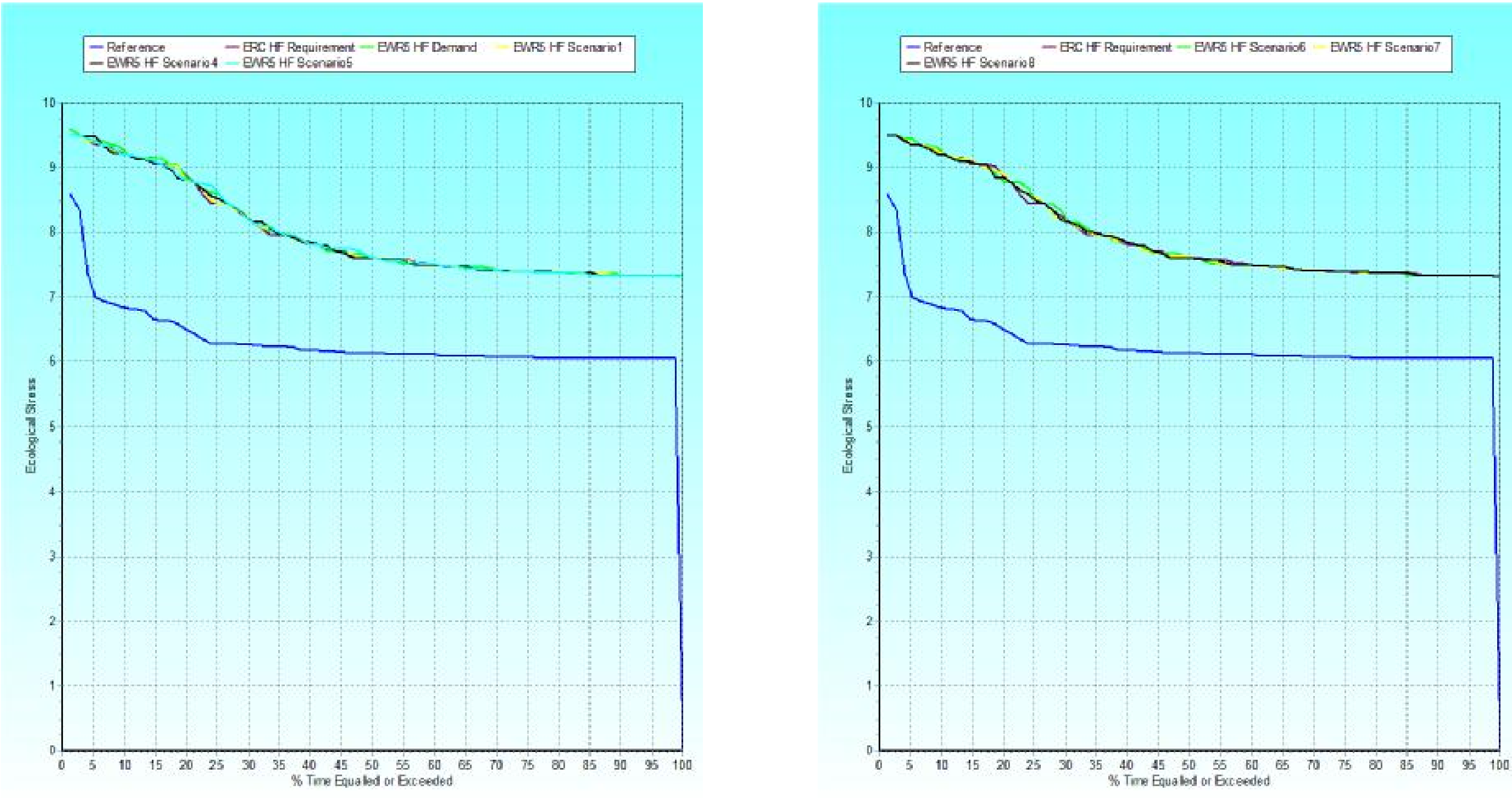
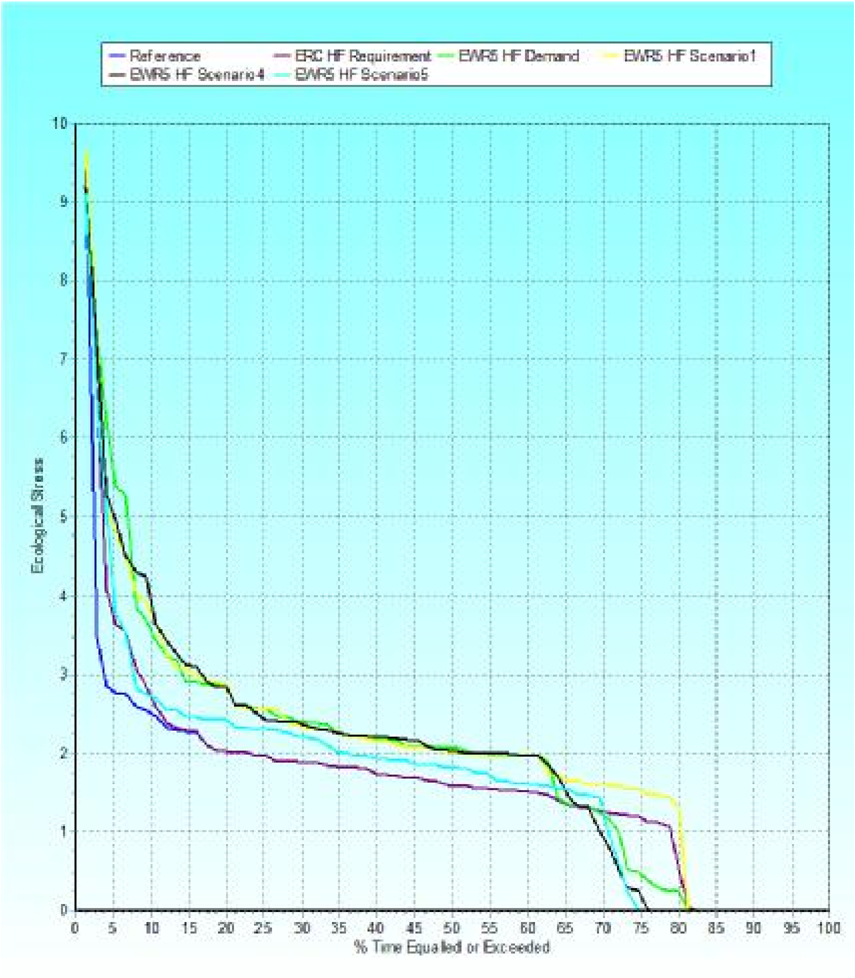


Figure 4.1: Stress curves for the dry season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 16



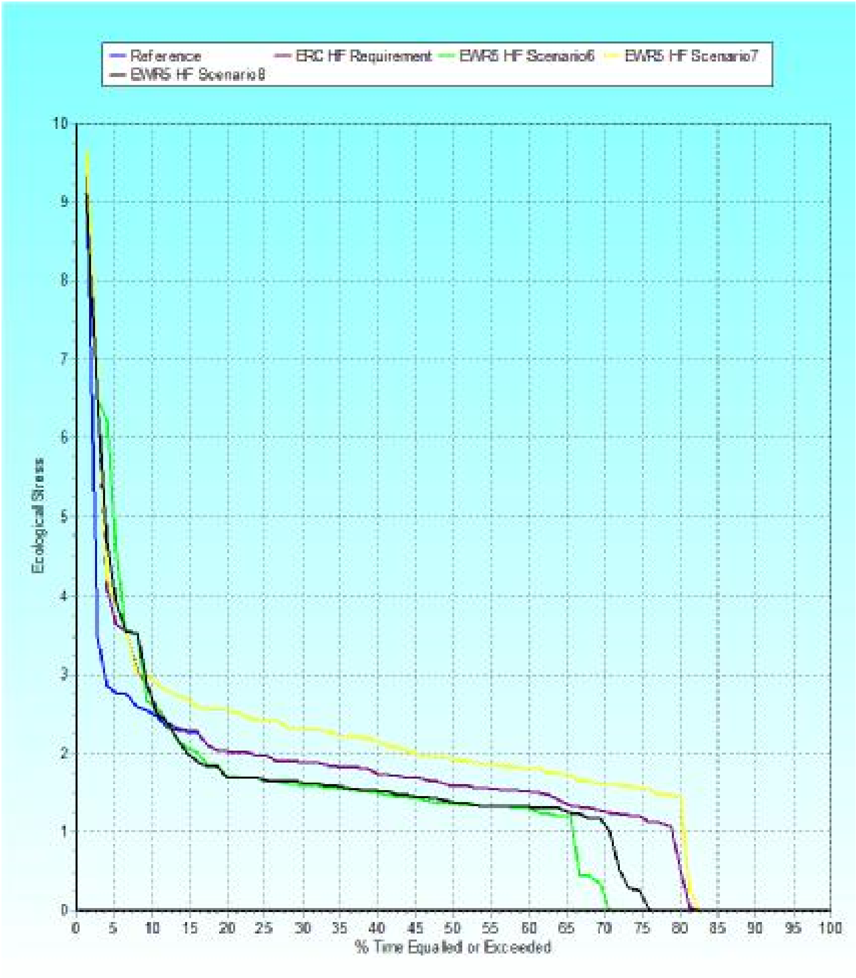


Figure 4.2: Stress curves for the wet season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 16

4.1.3 Ecological consequences

The ecological consequences for the driver components (geomorphology and physic chemical) and response variables (riparian vegetation, macroinvertebrates and fish) are discussed below for present day and the operational scenarios.

Geomorphology

According to the available data, baseflows across all seasons have been reduced, and it is expected that small and moderate floods have been seriously reduced from natural due to the upstream Bloemhof Dam. The critical reduction of flows has degraded the in-channel condition through reduced scour and bed activation events, and the riparian zone due to reduced activation and inundation events. The PES is in a D/E.

Scenario 1

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 1**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
D/E	D	-	D/E	Reduced flows	Seriously reduced baseflows and small floods have reduced scour and thus caused fining of the channel bed and a lack of bed scour or bank inundation.
The site and reach are moderately bedrock influenced –there are a few bedrock riffles downstream and some small islands created by bedrock outcrops. Since the 1950's there has been some slight narrowing of the active channel. This reduction in channel size over the reach may be due to reduced flows, but at the site this is due to the development of a deeper, narrower channel due to the releases of clean, "sediment hungry" waters from the dam which cause net erosion downstream. At the site, both banks are cut – tree roots are being exposed due to the scour of the lower banks. The PES is thus in a D/E due the impacts of the large Bleomhof Dam on sediment availability as well as the highly altered hydrology. The channel is incising and there are no alternative opportunities for replenishment of the sediment which is trapped in the dam and thus little opportunity for improvement with flows in the zone immediately downstream of the dam. The infrequent (1:3 year) 500m^3/s flood was identified as the critical flow to scour the bed and flush accumulated fines in order to maintain fish habitat. Although this will cause further erosion at our site (in the zone immediately downstream of the dam).					

Scenario 4 and 8

Scenarios 4 and 8 propose very minor increased in wet season baseflows and slight reductions in dry season baseflows. These minor flow changes will not have any significant impact on the geomorphology or cause any change from the present EC. These scenarios have not been evaluated further since no changes from the PES are expected.

Scenario 5 and 6

Scenarios 5 and 6 both propose reduced baseflows in the dry season and increased baseflows and small floods in the wet season. These changes tend towards a more natural flow pattern, and these scenarios have been evaluated together. This will result in an increase to a D category.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5, 6	DRY SEASON	WET SEASON
Specialist inputs					
D/E			D	Reduced dry season baseflows.	Increased baseflows and small floods should increase scour of the bed and inhibit some of the fines deposition.
The larger volumes of water available in the wet season under these two scenarios should provide for larger, more regular floods relative to the PD conditions. Additionally, the higher wet season baseflows and increased small floods should prevent deposition of fines, resulting in a small improvement in the in-channel condition. This will, however, also cause more rapid erosion/cutting of the lower banks, and thus the lower riparian zone is likely to degrade whilst the channel bed is scoured.					

Scenario 7

Scenario 7 proposed no major changes from the present day flow patterns. This scenario has not been evaluated further since no changes from the PES are expected.

Physico chemical

As these scenarios do not supply EWR 16 with extra water the results of this scenario are similar to the present day below Bloemhof Dam.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
E	D	D	C/D	Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Harts system) Winter flows and concentrations of salts similar for these scenarios Winter salt concentrations only 10% higher than the summer concentrations despite the 8.7 times lower	Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Harts system Summer flows and concentrations of salts similar for these scenarios Summer salt concentrations only 10% lower than the winter concentrations due to 8.7 times higher flows.

				flows. Extra water is released from the Vaal Dam in winter and this is used for the dilution of salts in the middle and lower Vaal. Increases winter flows results in increased winter turbidity. The salinity and nutrient impacts from the Vaal Barrage (Klip, Riet and Suikerbosrand Rivers) are combined with mine water decants from Witwatersrand and Mooi River (Wonderfonteinspruit). Furthermore gold mining around the KOSH area results in increased inputs into the Koekermoerspruit and Schoonspruit catchments. The winter increased salt load is dues to diffuse salts from the mines in the Witwatersrand, Mooi River (Wonderfonteinspruit) and Koekermoerspruit and Schoonspruit catchments. Increasing trend in phosphate concentrations. Potential for algal blooms increasing. High nutrients due to waste water treatment work discharges and informal settlement runoff. Potential for algal growth – rooted macrophytes, filamentous, exotic floating macropytes (Water hyacinth) and single cell blooms. Chlorophyll-*a* seasonal variability. High ammonia values due to waste water (treated and untreated) being released from the Vaal Barrage, Mooi River (Potchefstroom) and Schoonspruit (Klerksdorp, Orkney and Stilfontein). Occasional high metal values from mine water discharges and industrial discharges (Sasol). Diffuse runoff from un-sewered areas leads to seasonally high microbiological contamination. Occasional low dissolved oxygen values that result in fish kills as result from treated and untreated sewage effluent entering and being released from the Vaal Barrage.	Extra water is released from the Vaal Dam to dilute the salt concentrations of the middle and lower Vaal. Increases summer flows results in increased turbidity. The salinity impacts from the Vaal Barrage (Klip, Riet and Suikerbosrand) as well as the Mooi River (Wonderfonteinspruit) also add to the salt concentrations. The KOSH area results in increased inputs into the Koekermoerspruit and Schoonspruit catchments. The summer concentrations of salts are 15 to 20% lower than the winter values due to the dilution effects of more than 8 times the flows in summer. There is also an increase in nutrients (potential for increased algal blooms) due to diffuse waste water treatment work discharges and informal settlement runoff. High ammonia values due to waste water (treated and untreated) being released from the Vaal Barrage and Mooi River (Wonderfonteinspruit) and Koekermoerspruit and Schoonspruit catchments. Occasional high metal values from mine water discharges. Diffuse runoff from un-sewered areas leads to seasonally high microbiological contamination. The potential for algal blooms increases due to summer temperatures but this is masked by the higher turbidity's.
As these scenarios do not supply EWR 16 with extra water the results of this scenario are similar to the present day 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.

Scenarios 5 and 6

The water quality and flows of Scenario's 5 and 6 are similar.

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AECa**	**Sc 5,6**	**DRY SEASON**	**WET SEASON**
PHYSICO-CHEMICAL					
C	B	D	D	Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Harts system) Winter flows and concentrations of salts similar for these scenarios The winter flows are similar for all the scenario's studied. Winter salt concentrations only 11% higher than the summer concentrations despite the 10 times lower flows. The salts concentrations for these scenarios in winter are 16% lower than the present day scenario, Extra water is released from the Vaal Dam in winter and this is used for the dilution of salts in the middle and lower Vaal. Slightly increased winter flows results in increased winter turbidity. The salinity impacts from the Vaal Barrage (Klip, Riet and Suikerbosrand) as well as the Mooi River (Wonderfonteinspruit) also add to the salt concentrations. The KOSH area results in increased inputs into the Koekermoerspruit and Schoonspruit catchments. This increased salt load is dues to diffuse salts from the mines in the Witwatersrand. These scenario's includes proposed re-use of mine	Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Harts system) Summer flows and concentrations of salts similar for these scenarios Summer salt concentrations only 11% lower than the winter concentrations due to 10 times higher flows. The salts concentrations for these scenarios in summer are 16% lower than the present day scenario Extra water is released from the Vaal Dam to dilute the salt concentrations of the middle and lower Vaal. Increases summer flows results in increased turbidity. The salinity impacts from the Vaal Barrage (Klip, Riet and Suikerbosrand) as well as the Mooi River (Wonderfonteinspruit) also add to the salt concentrations. The KOSH area results in increased inputs into the Koekermoerspruit and Schoonspruit catchments. This increased salt load is dues to diffuse salts from the mines in the Witwatersrand. These scenario's includes proposed re-use of mine water. Scenario 5 includes projected possible transfer

				water. Scenario 5 includes projected possible transfer to the Crocodile catchment which would reduce the nutrients and salt into the Vaal Barrage. The winter salt concentrations are about 15 to 20% lower than the other scenarios despite similar flows. This is due to mine water reuse and the transfer of the Johannesburg southern waste water treatment works effluent to the Crocodile West catchment. The diffuse origin of salts will not be impacted by this reuse strategy. Transfer to the Crocodile catchment which would reduce the nutrients and salt into the Vaal Barrage. Increasing trend in phosphate concentrations. Potential for algal blooms increasing. High nutrients due to waste water treatment work discharges and informal settlement runoff. Potential for algal growth – rooted macrophytes, filamentous, exotic floating macropytes (Water hyacinth) and single cell blooms. Chlorophyll-*a* seasonal variability. Occasional high metal values from mine water discharges. Diffuse runoff from un-sewered areas leads to seasonally high microbiological contamination	to the Crocodile catchment which would reduce the nutrients and salt into the Vaal Barrage. The summer concentrations of salts are about 20% lower than the other scenarios due to 20% increased summer flows. High ammonia values due to waste water (treated and untreated) being released from the Vaal Barrage and Mooi River (Wonderfonteinspruit) and Koekermoerspruit and Schoonspruit catchments. There is also an increase in nutrients (potential for increased algal blooms) due to diffuse waste water treatment work discharges and informal settlement runoff. Occasional high metal values from mine water discharges. Diffuse runoff from un-sewered areas leads to seasonally high microbiological contamination. The potential for algal blooms increases due to summer temperatures but this is masked by the higher turbidity's. The potential for algal blooms increases due to summer temperatures as well as the future 2020 development conditions (greater nutrients).
These scenarios include the proposed re-use of mine water which would decrease the salts originating from the point discharges from the mines. These scenarios result in a lower salt concentration summer with more water being reused from the mines as well as increased flows. These scenario's Include the projected possible transfer to the Crocodile catchment which will further reduce the salt and nutrient loads at EWR 13. There will be a continued 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.					

Riparian vegetation

The site downstream of Bloemhof Dam on the Vaal River consists of a relatively broad area of flow with shallow sloping banks, on which vegetation could easily colonise and recruit. The site selection at this site is, however, not ideal as the vegetation in the area has been disturbed by construction of weirs and bridges as well as the fact that the riparian vegetation has been completely transformed by anthropogenic disturbances and is not representative of the vegetation along this reach of the Vaal River. The riparian vegetation has been transformed in order to create recreational areas and a number of exotic tree species have been planted along the edge of the river, possibly to control erosion. Land use in the area is predominantly urban settlement, agricultural and pastoral farming and recreation.

The marginal zone at Site EWR 16 is dominated by graminoid and cyperoid species including *Cyperus denudatus*, *Phragmites australis*,*Cyperus longus* and *Pennisetum clandestinum.* The lower non-marginal zone is dominated by mainly by exotic graminoids and herbaceous species such as *Pennisetum clandestinum*, *Cirsium vulgare* with some individuals of the woody species *Acacia karroo.* The upper non-marginal zone is dominated by exotic tree species, mainly *Eucalyptus* spp, with some *Acacia karroo* and *Salix mucronata* present.

Current status: The area is currently highly degraded due to the removal of indigenous species and transformation of the riparian vegetation by the introduction of a number of exotic species. The exotic species in the area, in fact, contribute to a total of over 70% of the total number of species identified during the surveys.

Trajectory of change: Due to the factors mentioned above under the section “Current Status” and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
F	F	F	F	The flows anticipated for scenario 1 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 12. The flows anticipated for scenario 1 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 1 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 12. The flows anticipated for scenario 1 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Scenario 4

EC	ECOLOGICAL CONSEQUENCES

PES	REC	AECa	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
F	F	F	F	Due to the heavily impacted nature of the site it is unlikely that the flows expected in this scenario will in any way change the PES of the site	Due to the heavily impacted nature of the site it is unlikely that the flows expected in this scenario will in any way change the PES of the site

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
F	F	F	F	Due to the heavily impacted nature of the site it is unlikely that the flows expected in this scenario will in any way change the PES of the site	Due to the heavily impacted nature of the site it is unlikely that the flows expected in this scenario will in any way change the PES of the site

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
F	F	F	F	Due to the heavily impacted nature of the site it is unlikely that the flows expected in this scenario will in any way change the PES of the site	Due to the heavily impacted nature of the site it is unlikely that the flows expected in this scenario will in any way change the PES of the site

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					

F	F	F	F	Due to the heavily impacted nature of the site it is unlikely that the flows expected in this scenario will in any way change the PES of the site	Due to the heavily impacted nature of the site it is unlikely that the flows expected in this scenario will in any way change the PES of the site

Scenario 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 8	DRY SEASON	WET SEASON
Specialist inputs					
F	F	F	F	Due to the heavily impacted nature of the site it is unlikely that the flows expected in this scenario will in any way change the PES of the site	Due to the heavily impacted nature of the site it is unlikely that the flows expected in this scenario will in any way change the PES of the site

Macroinvertebrates

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
D/C	C	D	D/C	Habitat covered in algae. Initial summer flush to open up the necessary habitat.	Habitat covered in algae. Initial summer flush to open up the necessary habitat.

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
D/C	C	D	D/C	Habitat covered in algae. Initial summer flush to open up the necessary habitat.	Habitat covered in algae. Initial summer flush to open up the necessary habitat.

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
D/C	C	D	D/C	Mostly same as PES.	Higher flow during the wet part of the wet season. Bigger floods and slight improvement of water quality.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
D/C	C	D	D/C	Mostly same as PES.	Higher flows than scenario 5. Wetter part of the wet season which will result in better flows and improved water quality.

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
D/C	C	D	D/C	Habitat covered in algae. Initial summer flush to open up the necessary habitat.	Habitat covered in algae. Initial summer flush to open up the necessary habitat.
Same as the Present Day.					

Scenario 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 8	DRY SEASON	WET SEASON
Specialist inputs					
D/C	C	D	C/D	Same as the Present Day.	Better flow during the dry part of the wet season during the whole wet season.

Fish

Scenarios 1, 4, 7 and 8

Eleven fish species may historically have occurred at this site in varying frequencies of occurrence and abundances (Kleynhans *et al.,* 2007).

Nine fish species would historically have occurred at the site in moderate abundance. A further 2 species *L. kimberleyensis* and *B. paludinosus* would have been expected at the site at lower abundances. *A. sclateri* may have occurred at specific sites in the vicinity where suitable habitat occurred for it at moderate abundances. Eight of the expected fish species have a high level of preference for either slow deep or slow shallow habitats suggesting that these would historically have been the predominant velocity depth classes at this site. Two of the expected fish species namely *Labeobarbus aeneus* and *Austroglanis sclateri* have a high level of preference for fast shallow habitats. *Labeobarbus kimberleyensis* has a high level of preference for fast deep habitats. Seven of the expected fish species are either moderately tolerant or tolerant of reduced flow levels. Four fish species are moderately intolerant of a lack of flow, indicating that these species would require periods of flow at some stage in their lifecycle. The expected fish assemblage show high levels of preference for a wide range of cover types. Ten of the expected fish species are either moderately tolerant or tolerant of modified water quality indicating that water quality at this site would fluctuate naturally along with seasonal flow patterns. *L. kimberleyensis* is moderately intolerant of modified water quality. Five species have a requirement for movement between reaches/ fish habitat segments. These are the species that are most likely to be impacted upon by the construction of dams and weirs that impede fish migration.

Six of the expected fish species were recorded at the site during the 2 Reserve determination surveys. The Present Ecological State (PES) of the site was rated as a Class E. Along with the indigenous fish species 3 exotic fish species were recorded at the site namely: *Gambusia affinis* (Mosquitofish), *Cyprinus carpio* (Carp) and *Ctenopharyngodon idella* (Grass carp).

None of the scenarios are expected to result in any change of PES for site EWR16.

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 1,4,7,8**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
E	D	D	E	Slight decrease in salt loads	Salt increase in salt loads
A PES of E was recorded at site EWR16. The low PES score can be attributed to the absence of 5 of the expected indigenous fish species, the lower than reference frequency of occurrence of the observed species, the presence and high abundance of 3 exotic fish species and the presence of a large migration barrier (Bloemhof Dam) directly upstream of the site.					

4.1.4 Summary of ecological consequences

The summary of the ecological categories for the operational scenarios at EWR 16 are provided in Table 4.1.

Table 4.1: Summary of ecological categories for operational scenarios at EWR site 16

Driver	**Sc 1 PD**	**Sc 4**	**Sc 5**	**Sc6**	**Sc 7**	**Sc 8**
Water quality	C/D	C/D	C	C	C/D	C/D
Geomorphology	D/E	D/E	D	D	D/E	D/E
Response components						
Fish	E	E	E	E	E	E
Aquatic invertebrates	C/D	C/D	C	C	C/D	C/D
Instream	D	D	D	D	D	D
Riparian vegetation	F	F	F	F	F	F
Ecostatus*	**E**	**E**	**E**	**E**	**E**	**E**

* Mainly due to non-flow related impacts on riparian vegetation

4.2 EWR 17: LLOYDS WEIR (HARTS RIVER)

4.2.1 Catchment development and impacts

The drivers at EWR 17 on the Harts River has changed due the large increases in the baseflows across all seasons and slight reductions in floods due to the upstream Spitskop Dam. Water is released into the Harts catchment from the Vaal at the Vaal-Harts Weir for the Vaal Hartz irrigation scheme. This irrigation scheme has been operational since 1939.

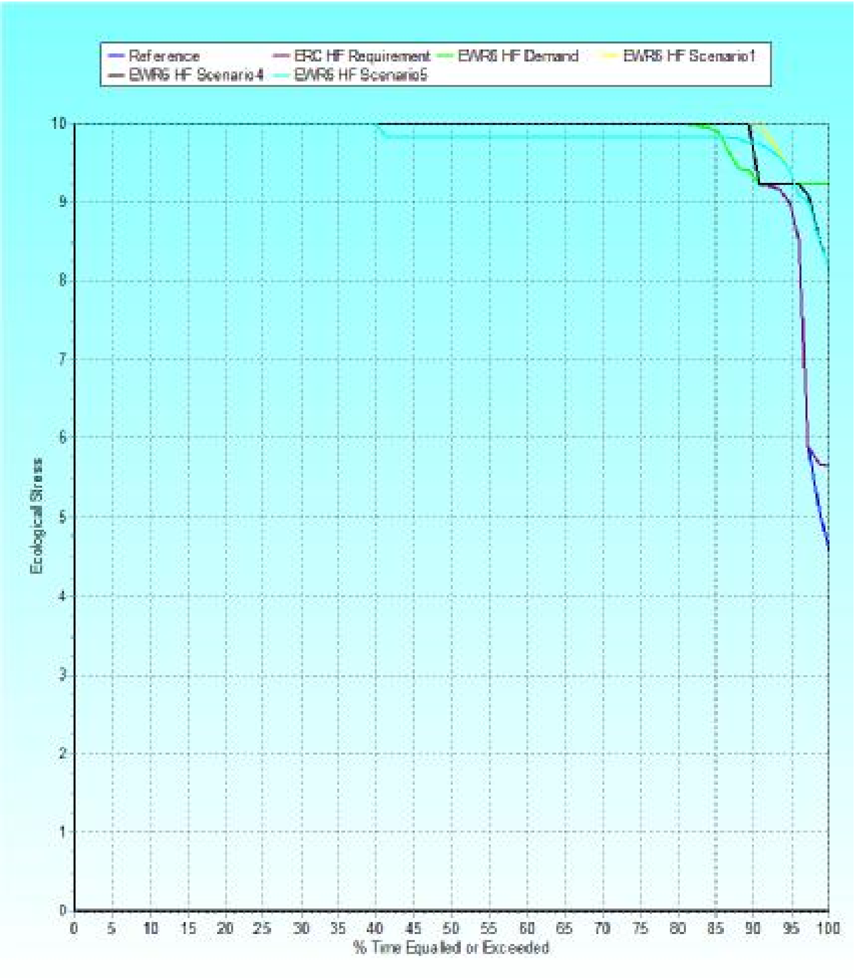
There are also three dams upstream that have effects on the flows and water quality. The Taung Dam is used mainly for domestic water supply. It was shown that it was not feasible to have an EWR site downstream of Wentzel Damcritical sites were available and the introduction of an EWR release from the dam will impact negatively on the yield of the dam as the full yield will be used for the EWR. Releases for the irrigation water use downstream of Spitskop Dam impacts on the flow and water quality of the Harts River downstream of the dam. The maximum discharge capability of the outlet works of Spitskop Dam is dependent on the storage level within the dam. This limitation was taken into account during the planning analysis, thus the full required EWR could not be released for the Harts River.

The water quality drivers are due to the following:

- Poor water quality due to Vaal Hartz irrigation return flows
- High use of pesticides and know toxicology effects
- Small scale alluvial diamond mining into the river beds causes high turbidity levels
- Poor water quality in the Spitskop Dam is released for downstream irrigation and this contributes to the salts in the Lower Harts River
- High salts in winter due to low flows and return flows from irrigation and mining
- Winter salts concentrations are double the summer concentrations with 35 times less flow
- High nutrients (agricultural return flows). There's dams upstream used for irrigation (trapping the nutrients and salts). But most nutrients measured are due to diffuse pollution rather than point source
- High nutrients due to return flows from intensive 70 year irrigation system
- The high turbidity (sand mining and other land use) at this site reduces the algal growth opportunities in winter but macrophytes still clog the river in winter.

4.2.2 Graphs of flow scenarios

Error! Reference source not found. illustrates the stress requirements and stress points required for the REC, present day (demand) and the operational scenarios analysed for the wet and dry season at EWR site 17.



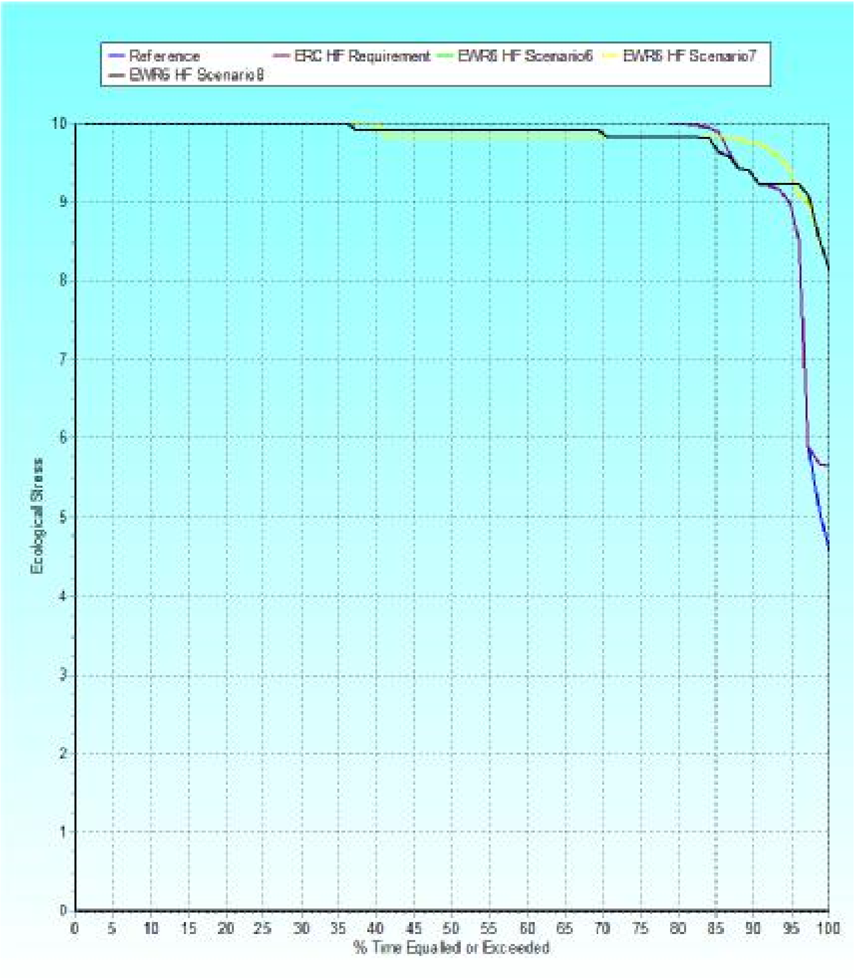
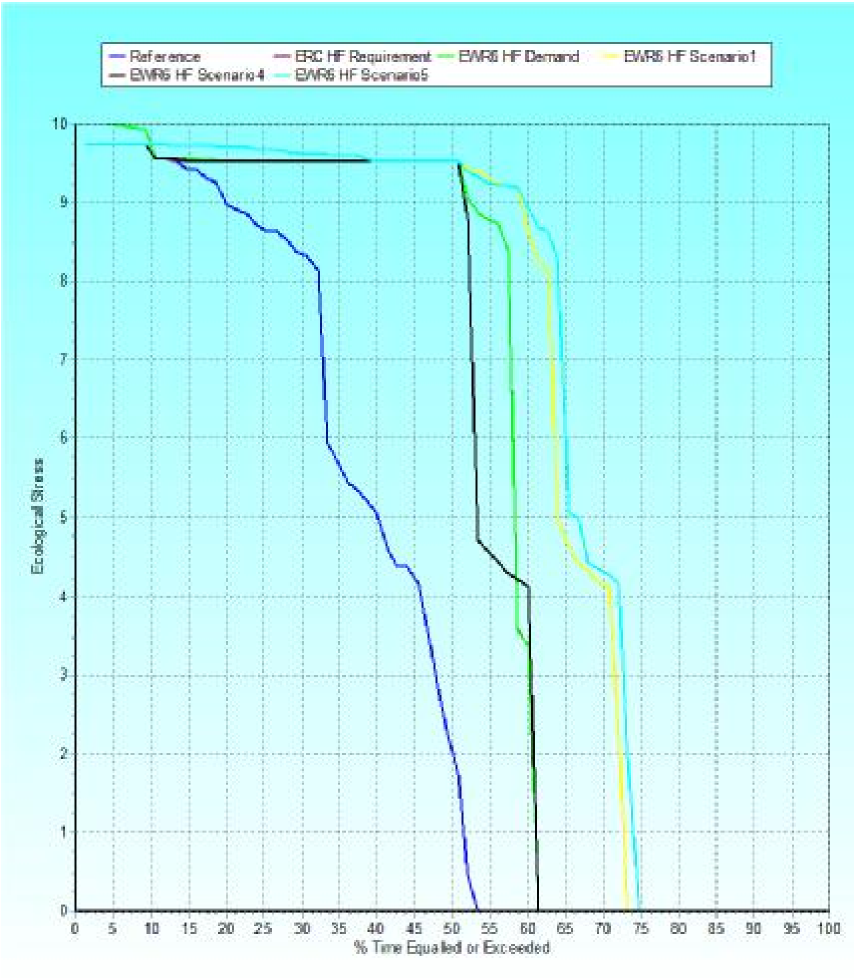


Figure 4.3: Stress curves for the dry season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 17



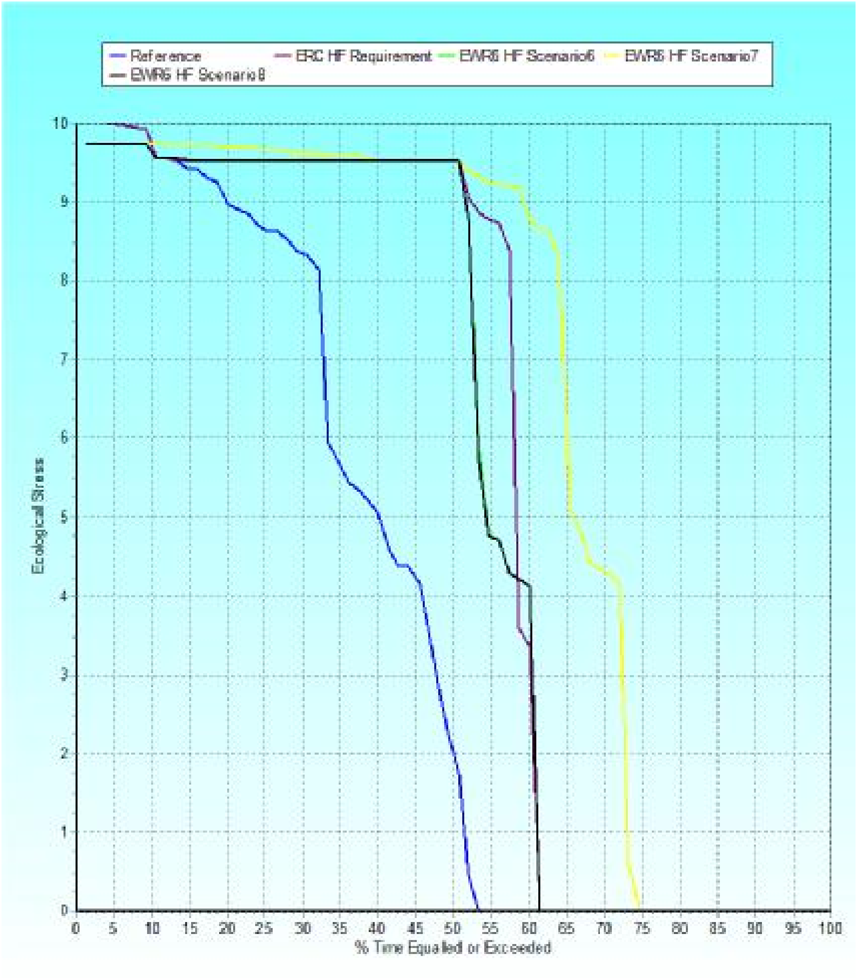


Figure 4.4: Stress curves for the wet season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 17

4.2.3 Ecological consequences

The ecological consequences for the driver components (geomorphology and physic chemical) and response variables (riparian vegetation, macroinvertebrates and fish) are discussed below for present day and the operational scenarios.

Geomorphology

According to the available hydrological data, on the Harts River there have been large increases in the baseflows across all seasons at this site and slight reductions in floods due to a basin transfer from the Vaal into the irrigation scheme.

The EWR site is located on the lower Harts River, within the backup zone of the Vaal River. High flow hydraulics is therefore not reliable and similarly the sediment characteristics at the site are not representative of the reach. Confidence is therefore extremely low in the EWR flows for geomorphology, and consequently the ability to assess the consequences of scenarios based on this site information is very poor.

PES is in a D condition due to widespread cut banks along this reach; grazing and trampling disturbance on the upper and lower banks. Additionally, the upstream bridge has caused some localised erosion.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
D	D	-	D	Increased baseflows	Increased baseflows but a slight reduction in small flood peaks which may have slightly reduced sediment transport, increasing deposition and decreasing flushing of fines and scour.
The provision of small and moderate intra-annual floods of 2 m^3/s (three per year) and 10 m^3/s (two per year) should be sufficient to flush fines from the fast-flowing reaches. Larger inter-annual floods may be required to activate the coarser sediment, but due to the location of the site and consequent constraints and data limitations (as discussed above); these larger floods could not be identified.					

Scenario 5 and 7

These scenarios propose no major changes from the present day flow patterns. They have not been evaluated further since no changes from the PES are expected.

Scenario 4, 6 and 8

Increased baseflows; especially in the wet season, and an increase in small floods will reinstate some of the reduced flows. These small floods, combined with higher baseflows should improve the in-channel habitat. This will change the PES from a low D to a slightly higher D, but will not change the EC.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 4, 6, 8	DRY SEASON	WET SEASON
Specialist inputs					
D			D	Increased baseflows	Increased baseflows and slight increase in small floods.
The provision of small and moderate floods will maintain the PES at this site, allowing for some removal of fines to improve in-channel habitat.					

Physico chemical

The Taung Dam is used mainly for domestic water supply. It was shown that it was not feasible to have an EWR site downstream of Wentzel Dam. Releases for the irrigation water use downstream of Spitskop Dam. The maximum discharge capability of the outlet works of Spitskop Dam is dependent on the storage level within the dam. Based on the median storage level observed in Spitskop Dam the maximum release capability was set to be 7.6 m^3/s. The EWR rule data provided for March (month during which freshets and flood releases were required) were subsequently adjusted to represent a maximum requirement of 7.6 m^3/s.

Scenarios present day, 5 and 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 5,7	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B	D	D/E	Poor water quality due to Vaal Hartz irrigation system Salts high High use of pesticides and know toxicology effects Small scale alluvial diamond mining into the river beds causes high turbidity levels Water is released into the Harts catchment from the	Poor water quality in the Spitskop Dam is released for downstream irrigation and this contributes to the salts in the Lower Harts River. Lower salt concentrations in summer due dilution from rainfall. Diffuse runoff from irrigation and mining. Winter salts concentrations are half the winter concentrations due to 35 times more flow. High nutrients due to diffuse agricultural runoff from intensive fertilizer use. High nutrients due to return flows from intensive 70 year irrigation system The high turbidity (sand mining and other land use) at

				Vaal Hartz irrigation system in the Vaal River. This irrigation system has been operational since 1939 and this is a transfer of salts from the Lower Vaal. Poor water quality in the Spitskop Dam is released for downstream irrigation and this contributes to the salts in the Lower Harts River. High salts in winter due to low flows and return flows from irrigation and mining. Winter salts concentrations are double the summer concentrations with 35 times less flow. High nutrients (agricultural return flows). There's dams upstream used for irrigation (trapping the nutrients and salts). But most nutrients measured are due to diffuse pollution rather than point source. High nutrients due to return flows from intensive 70 year irrigation system The high turbidity (sand mining and other land use) at this site reduces the algal growth opportunities in winter but macrophytes still clog the river in winter.	this site reduces the algal growth opportunities in summer but macrophytes still clog the river when the flows are reduced or runoff captured in the upstream dams.

Scenarios 4, 6 and 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4,6,8	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B	D	C/D	These scenarios include the EWR requirements as well as the 2020 development and include proposed re-use of mine water. Water is released into the Harts catchment from the Vaal Hartz irrigation system in the Vaal River. This irrigation system has been operational since 1939 and this is a transfer of salts from the Lower Vaal. Poor water quality in the Spitskop Dam is released for downstream irrigation and this contributes to the salts in the Lower Harts River. High salts in winter due to low flows and return flows from irrigation and mining. Winter salts concentrations are double the summer concentrations with 35 times less flow. The return flows from irrigation will increase due to the 2020 development scenario (Scenario 4, 6 and 8) and these scenario's have slight improvement in salt concentrations in winter.	Poor water quality in the Spitskop Dam is released for downstream irrigation and this contributes to the salts in the Lower Harts River. Lower salt concentrations in summer due dilution from rainfall. Diffuse runoff from irrigation and mining. Winter salts concentrations are half the winter concentrations due to 35 times more flow. High nutrients due to diffuse agricultural runoff from intensive fertilizer use. High nutrients due to return flows from intensive 70 year irrigation system The high turbidity (sand mining and other land use) at this site reduces the algal growth opportunities in summer but macrophytes still clog the river when the flows are reduced or runoff captured in the upstream dams. These scenarios include the EWR requirements as well as the 2020 development and include proposed re-use of mine water which has a small improvement of the

				High nutrients (agricultural return flows). There's dams upstream used for irrigation (trapping the nutrients and salts). But most nutrients measured are due to diffuse pollution rather than point source. High nutrients due to return flows from intensive 70 year irrigation system The high turbidity (sand mining and other land use) at this site reduces the algal growth opportunities in winter but macrophytes still clog the river in winter.	salt concentrations on summer. The return flows from irrigation will increase due to the 2020 development scenario (Scenario 4, 6 and 8).

Riparian vegetation

The site at Lloyds Weir on the Harts River consists of a relatively broad area of flow with steep sloping banks, on which vegetation would not easily colonise and recruit. Erosion is also visible on the banks and much of the area has be degraded by the construction of infrastructure such as bridges and weirs. Although the site selection at this site is not ideal as the vegetation in the area has been disturbed by the construction of the bridge, it is representative of much of the vegetation along this reach of the Harts River as land use in the area is predominantly agricultural and pastoral farming with some mining activities also occurring in the area.

The marginal zone at Site EWR 17 is dominated by aquatic, graminoid and cyperoid species including *Phragmites australis, Cynodon dactylon* and *Myriophyllum spicatum* while the lower non-marginal zone is dominated by mainly by graminoids and herbaceous species such as *Cynodon dactylon*, *Pennisetum clandestinum, Cirsium vulgare* and *Rorripa nasturtium-aquaticum.* The upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Diospyros lycoides, Melianthus comosus* and *Asparagus sauveolens.*

Current status: The area is currently considerably degraded due to the construction and mining activities that have disturbed much of the riparian vegetation and the introduction of a number of exotic species. The exotic species in the area contribute to a significant number of the total number of species identified during the surveys as well as a considerable percentage approximately 30% of the abundance recorded during the survey. The most significant reason for the low PES at this site is due to the degradation of the site as well as the invasion of the site by exotic species.

Trajectory of change: Due to the factors mentioned above under the section "Current Status" and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

EC				**ECOLOGICAL CONSEQUENCES**	
PES	**REC**	**AECa**	**Sc 1 PD**	**DRY SEASON**	**WET SEASON**
Specialist inputs					

D	D	D/E	D	The flows anticipated for scenario 1 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 14. The flows anticipated for scenario 1 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 1 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 14. The flows anticipated for scenario 1 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
D	D	D/E	D	Higher flow rates will cause increased growth and propagation of plants in the marginal zone during the dry season, thereby increasing the size and stability of the marginal zone. However, it is unlikely that the changes occurring will increase the PES significantly to move it into a higher class	Higher flow rates and better seasonality during the wet season will cause increased inundation of the marginal zone and reduce terrestrial encroachment of the lower non marginal zone. However, it is unlikely that the changes occurring will increase the PES significantly to move it into a higher class

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
D	D	D/E	D	There will be decrease in flows for this scenario, however, although causing slight changes in the marginal zone, the changes will not be sufficient to change the PES	There will be a decrease in flows for this scenario, however, although causing slight changes in the marginal zone, the changes will not be sufficient to change the PES

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
D	D	D/E	D	Higher flow rates will cause increased growth and propagation of plants in the marginal zone during the dry season, thereby increasing the size and stability of the marginal zone. However, it is unlikely that the changes occurring will increase the PES significantly to move it into	Higher flow rates and better seasonality during the wet season will cause increased inundation of the marginal zone and reduce terrestrial encroachment of the lower non marginal zone. However, it is unlikely that the changes occurring will

				a higher class	increase the PES significantly to move it into a higher class

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
D	D	D/E	D	The flows anticipated for scenario 1 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 14. The flows anticipated for scenario 7 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 1 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 14. The flows anticipated for scenario 7 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Scenario 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 8	DRY SEASON	WET SEASON
Specialist inputs					
D	D	D/E	D	Higher flow rates will cause increased growth and propagation of plants in the marginal zone during the dry season, thereby increasing the size and stability of the marginal zone. However, it is unlikely that the changes occurring will increase the PES significantly to move it into a higher class	Higher flow rates and better seasonality during the wet season will cause increased inundation of the marginal zone and reduce terrestrial encroachment of the lower non marginal zone. However, it is unlikely that the changes occurring will increase the PES significantly to move it into a higher class

Macroinvertebrates

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Water quality has a detrimental effect on taxa that have a high and moderate preference for good water quality. Very high floods resulted in washing away taxa that is associated with fast flowing waters.	Water quality has a detrimental effect on taxa that have a high and moderate preference for good water quality. Very high floods resulted in washing away taxa that is associated with fast flowing waters.

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Habitat covered in algae. Initial summer flush to open up the necessary habitat.	Habitat covered in algae. Initial summer flush to open up the necessary habitat.

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Water quality has a detrimental effect on taxa that have a high and moderate preference for good water quality. Very high floods resulted in washing away taxa that is associated with fast flowing waters.	Water quality has a detrimental effect on taxa that have a high and moderate preference for good water quality. Very high floods resulted in washing away taxa that is associated with fast flowing waters.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Habitat covered in algae. Initial summer flush to open up the necessary habitat. Higher base flows during the winter months will improve water quality.	Habitat covered in algae. Initial summer flush to open up the necessary habitat. Higher flows in the wet months, will flush algae

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Water quality has a detrimental effect on taxa that have a high and moderate preference for good water quality.	Water quality has a detrimental effect on taxa that have a high and moderate preference for good water quality.

				Very high floods resulted in washing away taxa that is associated with fast flowing waters.	Very high floods resulted in washing away taxa that is associated with fast flowing waters.
Same as the Present Day.					

Scenario 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 8	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Habitat covered in algae. Initial summer flush to open up the necessary habitat.	Habitat covered in algae. Initial summer flush to open up the necessary habitat.

Fish

Scenarios 1, 5 and 7

Eleven fish species may historically have occurred at the site (Kleynhans *et al*., 2007). Under reference conditions, 8 fish species would have occurred at the site in moderate abundance (Kleynhans *et al*., 2007). *Barbus paludinosus*, *Labeobarbus kimberleyensis* may occasionally have been present at the site in a low abundance (Kleynhans *et al*., 2007). *Clarias gariepinus* would always have occurred at the site in low abundance (Kleynhans *et al*., 2007). *Austroglanis sclateri* may sporadically have been present at the site in low abundance (Kleynhans *et al*., 2007).

Eight of the expected fish species have a high level of preference for either slow deep or slow shallow habitats suggesting that these would historically have been the predominant velocity depth classes at this site. Two fish species namely *Labeobarbus aeneus* and *Austroglanis sclateri* have a high level of preference for fast shallow habitats. *Labeobarbus kimberleyensis* has a high level of preference for fast deep habitats. Seven of the expected fish species are either moderately tolerant or tolerant of reduced flow levels. Four fish species are moderately intolerant of a lack of flow, indicating that these species would require periods of flow at some stage in their lifecycle. The expected fish assemblage show high levels of preference for a wide range of cover types. Ten of the expected fish species are either moderately tolerant or tolerant of modified water quality indicating that water quality at this site would fluctuate naturally along with seasonal flow patterns. *L. kimberleyensis* is moderately intolerant of modified water quality. Five species have a requirement for movement between reaches/ fish habitat segments. These are the species that are most likely to be impacted upon by the construction of dams and weirs that impede fish migration.

Eight of the expected fish species were recorded at the site during the 2 Reserve determination surveys. The PES of the site was rated as a Class C. Along with the indigenous fish species 1 exotic fish species was recorded at the site namely: *Gambusia affinis* (Mosquitofish). Another exotic fish species *Cyprinus carpio*

(Carp) has been recorded in this section of the Harts River (Kleynhans *et al*., 2007), but wasn't recorded during either of the Reserve Determination surveys.

Eight of the 11 expected fish species were recorded during the 2 Reserve Determination surveys resulting in a PES of D.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1,5,7	DRY SEASON	WET SEASON
Specialist inputs					
D	C	C	D	Eight fish species were recorded at the site during the dry season survey	Seven fish species were recorded at the site during the wet season survey
A PES of D was recorded at site EWR17					

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Austroglanis sclateri	1	0
Barbus anoplus	4	0
Barbus paludinosus	2	1
Barbus trimaculatus	3	1
Labeobarbus aeneus	3	3
Labeobarbus kimberleyensis	2	0
Clarias gariepinus	4	3
Labeo capensis	3	3
Labeo umbratus	3	1
Pseudocrenilabrus philander	4	2
Tilapia sparrmanii	3	1

Scenarios 4, 6 and 8

Scenarios 4, 6 and 8 are very similar. These scenarios are associated with increased base flows during the wet and dry seasons and increased floods. These scenarios result in a slight improvement in water quality, especially decreased salt loads.

Increased flow levels may result in improved habitat availability for *B. trimaculatus* and *B. anoplus*. Both of these species have a very high level of preference for overhanging vegetation. Increased flow levels may result in increased availability of this habitat type, potentially leading to an increased abundance of this species. The potential for re-colonisation of this site by species such as *L. kimberleyensis* and *A. sclateri* is limited by the extensive flow regulation, nutrient enrichment, migration barriers and growth of aquatic macrophytes in this reach.

The improved abundance of *B. anoplus* and *B. trimaculatus* at this site results in an improvement in the PES from a Class D to a Class C/D.

EC				**ECOLOGICAL CONSEQUENCES**	
PES	**REC**	**AEC a**	**Sc 4,6,8**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
D	C	C	C/D	Increased base flow levels resulting in decreased salt loads and improved habitat for species such as *B. anoplus* and *B. trimaculatus*	Increased base flow levels resulting in decreased salt loads and improved habitat for species such as *B. anoplus* and *B. trimaculatus*
Increased abundance of B. anoplus and B. trimaculatus results in an increase in the PES of the site from a D to a C/D					

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Austroglanis sclateri	1	0
Barbus anoplus	4	2
Barbus paludinosus	2	1
Barbus trimaculatus	3	2
Labeobarbus aeneus	3	3
Labeobarbus kimberleyensis	2	0
Clarias gariepinus	4	3
Labeo capensis	3	3

Labeo umbratus	3	1
Pseudocrenilabrus philander	4	2
Tilapia sparrmanii	3	1

4.2.4 Summary of ecological consequences

The summary of the ecological categories for the operational scenarios at EWR 17 are provided in Table 4.2.

Table 4.2: Summary of ecological categories for operational scenarios at EWR site 17

Driver	**Sc 1 PD**	**Sc 4**	**Sc 5**	**Sc6**	**Sc 7**	**Sc 8**
Water quality	E	E	E	E	E	E
Geomorphology	D	D	D	D	D	D
Response components						
Fish	D	D	D	D	D	D
Aquatic invertebrates	C/D	C/D	C/D	C/D	C/D	C/D
Instream	D	D	D	D	D	D
Riparian vegetation	D	D	D	D	D	D
Ecostatus	**D**	**D**	**D**	**D**	**D**	**D**

4.3 EWR 18: SCHMIDTSDRIFT (VAAL RIVER)

4.3.1 Catchment development and impacts

Flows at this site have been critically reduced relative to the natural condition – wet season baseflows have dropped by almost two orders of magnitude. The very large reduction of flows has degraded the in-channel condition through reduced scour and bed activation events, the riparian zone due to reduced inundation events, and overall the entire river ecosystem due to the frequent extreme low flow conditions. The in-channel habitat is chocked by the excessive algal growth.

The water quality drivers at this site are as follows:

- High salts concentrations (EC and SO_4) from return flows of agriculture and diamond mining

- Low to moderate nutrients (moderate to high ammonia from degrading algal matter)
- Eutrophication due to the intensive irrigated Vaal Hartz irrigation scheme return flows that enters the system above the EWR site
- Winter flows and concentrations of salts similar for all the scenarios and higher concentrations than those of the summer.
- There is a settling of salts in Bloemhof Dam on the Vaal River as well as Spitskop Dam in the Harts River
- Increasing trend in nutrients concentrations. Potential for algal blooms increasing. High nutrients due to waste water treatment work discharges upstream as well as return flows from fertilizers being used in the Vaal Hartz irrigation scheme. The observed algal growth – rooted macrophytes, filamentous, exotic floating macropytes (Water hyacinth) and single cell blooms.

4.3.2 Graphs of flow scenarios

Error! Reference source not found. illustrates the stress requirements and stress points required for the REC, present day (demand) and the operational scenarios analysed for the wet and dry seasons at EWR site 18.

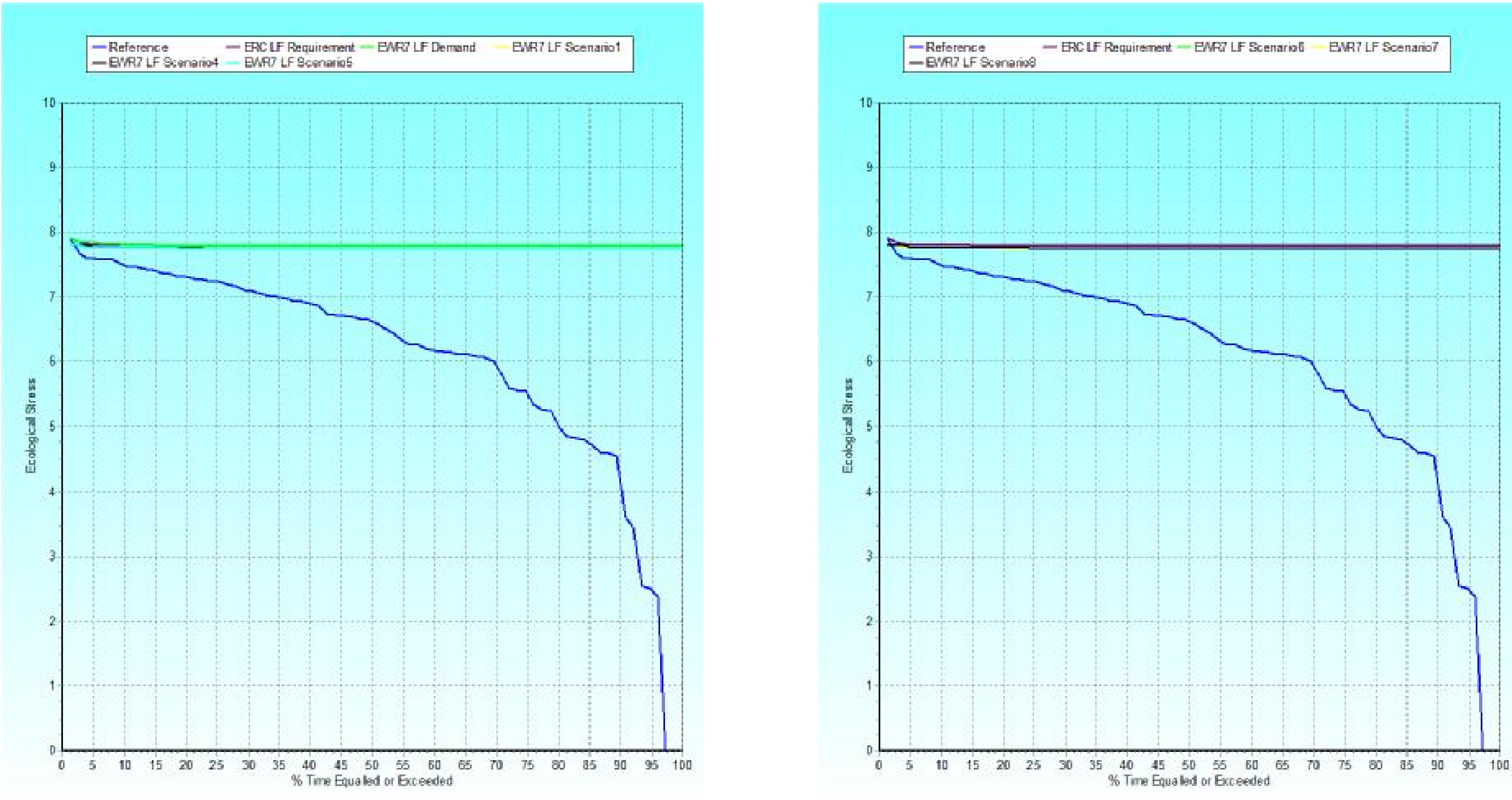
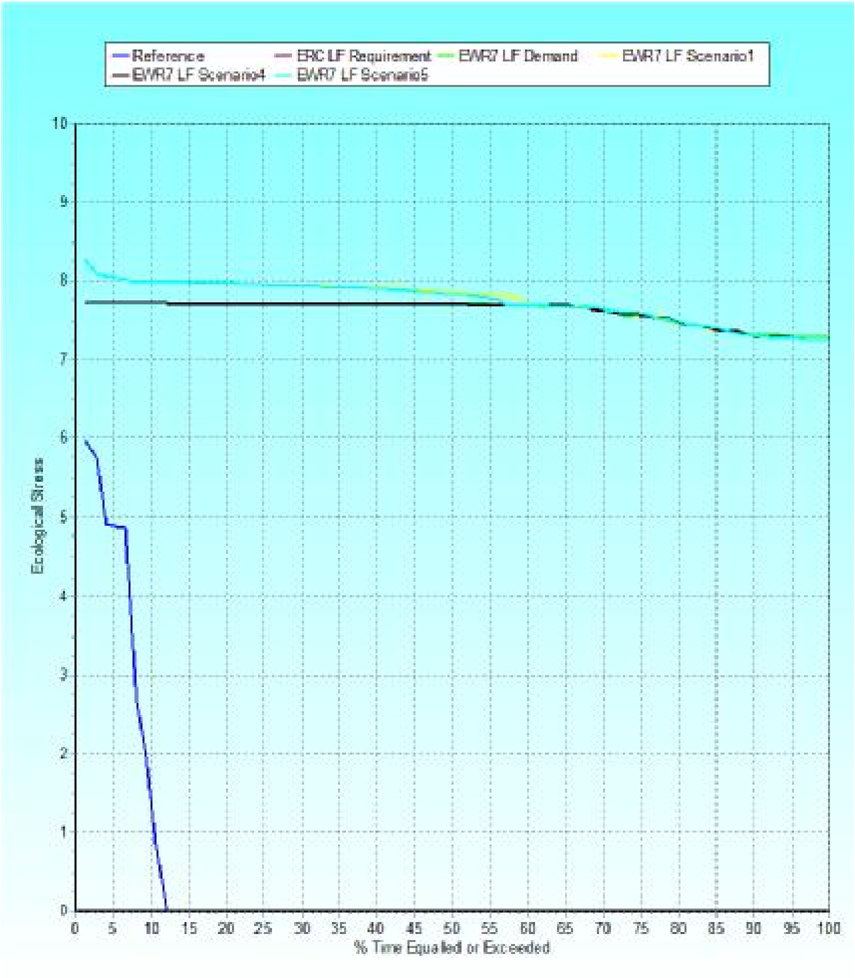


Figure 4.5: Stress curves for the dry season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 18



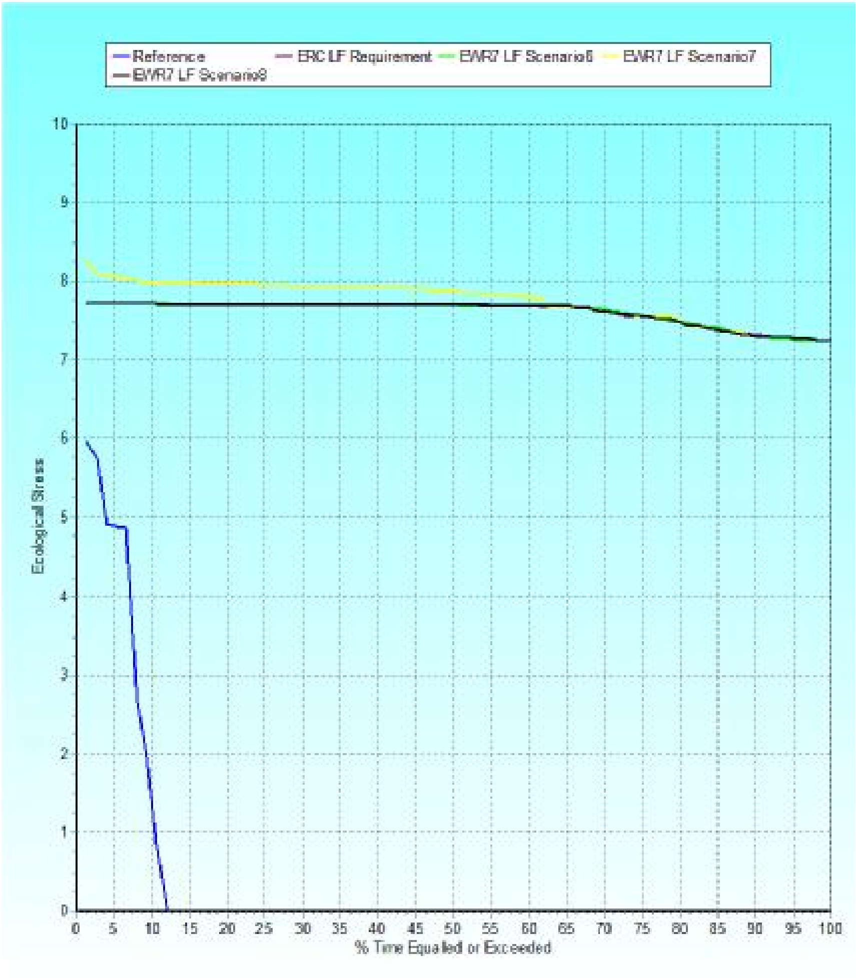


Figure 4.6: Stress curves for the wet season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 18

4.3.3 Ecological consequences

The ecological consequences for the driver components (geomorphology and physic chemical) and response variables (riparian vegetation, macroinvertebrates and fish) are discussed below for present day and the operational scenarios.

Geomorphology

Flows at this site have been critically reduced relative to the natural condition – wet season baseflows have dropped by almost two orders of magnitude. The very large reduction of flows has degraded the in-channel condition through reduced scour and bed activation events, the riparian zone due to reduced inundation events, and overall the entire river ecosystem due to the frequent extreme low flow conditions. The in-channel habitat is chocked by the excessive algal growth.

Thus although the impacts of the upstream dams on sediment reduction are lessened due to the ameliorating effects of the larger tributaries, the flows in the river in this reach have dropped so much that the PES is now in a C/D.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Reduced flows	Critically reduced baseflows and removal of almost all small and moderate floods, so there is now very reduced sediment transport resulting in enhanced deposition of fines and associated large increases in algal growth.
More flows generally, and provision of floods specifically, can quickly improve the PES of this site. Floods of 120 (1:1) and 560 (1:2) were identified to achieve the REC of a C, since this could scour the fines and remove some of the algal growth.					

Scenario 5 and 7

These scenarios propose no major changes from the present day flow patterns. They have not been evaluated further since no changes from the PES are expected.

Scenario 4 and 8

Scenarios 4 and 8 propose increased wet season baseflows. These minor flow changes are insufficient to achieve much in the way of scour and will thus not have any significant impact on the geomorphology or cause any change from the present EC. These scenarios have not been evaluated further since no changes from the PES are expected.

Scenario 6

Scenario 6 proposes increased baseflows and the provision of large floods in the wet season. These changes tend towards a more natural flow pattern, and the magnitude of the increased flows and floods is expected to be sufficient to achieve some in-channel habitat improvement. This will result in an increase to a C category.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5, 6	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C	No change from Present Day.	Increased baseflows and the provision of some floods should be sufficient to scour the bed and remove some of the excessive algal growth.
The larger volumes of water available in the wet season will provide for larger, more regular floods relative to the PD conditions. These higher wet season flows and in particular the increased floods will scour the bed removing some of the accumulated fines and scour the algal growth in the channel.					

Physico chemical

Scenarios present day, 5 and 7

High salts concentrations (EC and SO_4) return from agriculture and diamond mining impacts. There are irrigation drainage channels which collect and discharge into the river. Low to moderate nutrients (moderate to high ammonia from degrading algal matter).

Eutrophication is a problem (there are three dams upstream of the system). Increased flows might flush though the salts and nutrients sediment in the dam into the system –worse.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1,5,7	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B	D	D/E	Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Harts system). High salts concentrations (EC and SO_4) return from agriculture and diamond mining impacts mainly in the Harts River released from the Spitskop Dam. There are irrigation drainage channel which collects and	Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Harts system). High salts concentrations (EC and SO_4) return from agriculture and diamond mining impacts mainly in the Harts River released from the Spitskop Dam. There are irrigation drainage channel which collects and

				discharges into the river.	discharges into the river.
				Low to moderate nutrients (moderate to high ammonia from degrading algal matter)	Low to moderate nutrients (moderate to high ammonia from degrading algal matter)
				Eutrophication (there are three dams upstream of the system) as well as the intensive irrigated Vaal Hartz irrigation system.	Eutrophication (there are three dams upstream of the system) as well as the intensive irrigated Vaal Hartz irrigation system.
				Winter flows and concentrations of salts similar for the scenarios and higher concentrations than those of the summer.	Summer flows and concentrations of salts similar for the scenarios and lower concentrations than those of the winter.
				The winter flows are similar for all the scenarios studied.	The summer flows vary between the scenarios studied.
				Winter salt concentrations only 9 % higher than the summer concentrations despite the 30 times lower flows.	Summer salt concentrations only 9 % lower than the winter concentrations due to dilutions by the 30 times higher summer flows.
				Extra water is released from the Vaal Dam in winter and this is used for the dilution of salts in the middle and lower Vaal. Slightly increased winter flows results in increased winter turbidity.	Extra water is released from the Vaal Dam in winter and this is used for the dilution of salts in the middle and lower Vaal. Increased summer flows results in increased winter turbidity as well as increased diffuse runoff from irrigation and mining.
				There is a settling of salts in Bloemhof Dam as well as Spitskop Dam in the Harts River.	The operational releases from Bloemhof Dam as well as Spitskop Dam in the Harts River are greater in summer and poor water quality is released to this site.
				The mine water reuse and the transfer of the Johannesburg southern waste water treatment works effluent to the Crocodile West catchment have small reduction in nutrients and salts at this site. Localised impacts from the Vaal Harts irrigation system are more influential.	The mine water reuse and the transfer of the Johannesburg southern waste water treatment works effluent to the Crocodile West catchment have small reduction in nutrients and salts at this site. Localised impacts from the Vaal Harts irrigation system are more influential.
				Increasing trend in nutrients concentrations. Potential for algal blooms increasing. High nutrients due to waste water treatment work discharges upstream as well as return flows from fertilzers being used in the Vaal Hartz irrigation scheme. The observed algal growth – rooted macrophytes, filamentous, exotic floating macropytes (Water hyacinth) and single cell blooms.	Increasing trend in nutrients concentrations. Potential for algal blooms increasing. High nutrients due to waste water treatment work discharges upstream as well as return flows from fertilzers being used in the Vaal Hartz irrigation scheme. The observed algal growth – rooted macrophytes, filamentous, exotic floating macropytes (Water hyacinth) and single cell

				Chlorophyll-*a* seasonal variability.	blooms. Chlorophyll-*a* seasonal variability. The potential for algal blooms increases due to summer temperatures but this is masked by the higher turbidity's. The potential for algal blooms increases due to summer temperatures as well as the future 2020 development conditions (greater nutrients).
These scenarios include the proposed re-use of mine water which would decrease the salts originating from the point discharges from the mines. Bloemhof and Spitskop dams play a regulatory role for this site. These scenarios result in a lower salt concentration summer due to extra flow releases. These scenario's Include the projected possible transfer to the Crocodile catchment which will further reduce the salt and nutrient loads at EWR 18 but localised impacts from the Vaal Hartz scheme override the upstream management. There will be a continued potentially worsening nutrient levels due to upstream urbanisation and the use of fertilizers in the Vaal Hartz irrigation scheme. It is important to note that nutrients and salts are the driving force at this site and other variables such as microbiology and metals that are not measured are also variables of concern.					

Scenarios 4 and 8

EC				**ECOLOGICAL CONSEQUENCES**	
PES	**REC**	**AEC a**	**Sc 4,8**	**DRY SEASON**	**WET SEASON**
PHYSICO-CHEMICAL					
C	B	D	D/E	Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Harts system) as well as EWR releases. High salts concentrations (EC and SO_4) return from agriculture and diamond mining impacts mainly in the Harts River released from the Spitskop Dam. There are irrigation drainage channel which collects and discharges into the river. Low to moderate nutrients (moderate to high ammonia from degrading algal matter) Eutrophication (there are three dams upstream of the system) as well as the intensive irrigated Vaal Hartz	Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Harts system) as well as EWR releases. High salts concentrations (EC and SO_4) return from agriculture and diamond mining impacts mainly in the Harts River released from the Spitskop Dam. There are irrigation drainage channel which collects and discharges into the river. Low to moderate nutrients (moderate to high ammonia from degrading algal matter) Eutrophication (there are three dams upstream of the system) as well as the intensive irrigated Vaal Hartz

				irrigation system. Winter flows and concentrations of salts similar for the scenarios and higher concentrations than those of the summer. The winter flows are similar for all the scenario's studied. Winter salt concentrations are 35 % higher than the summer concentrations due to 30 times lower flows. Extra water is released from the Vaal Dam in winter and this is used for the dilution of salts in the middle and lower Vaal. Slightly increased winter flows results in increased winter turbidity. There is a settling of salts in Bloemhof Dam as well as Spitskop Dam in the Harts River. The mine water reuse and the transfer of the Johannesburg southern waste water treatment works effluent to the Crocodile West catchment have small reduction in nutrients and salts at this site. Localised impacts from the Vaal Harts irrigation system are more influential. Increasing trend in nutrients concentrations. Potential for algal blooms increasing. High nutrients due to waste water treatment work discharges upstream as well as return flows from fertilzers being used in the Vaal Hartz irrigation scheme. The observed algal growth – rooted macrophytes, filamentous, exotic floating macropytes (Water hyacinth) and single cell blooms. Chlorophyll-*a* seasonal variability.	irrigation system. Summer flows and concentrations of salts similar for the scenarios and lower concentrations than those of the winter. The summer flows vary between the scenario's studied. Summer salt concentrations 35 % lower than the winter concentrations due to dilutions by the 30 times higher summer flows. Extra water is released from the Vaal Dam in winter and this is used for the dilution of salts in the middle and lower Vaal. Increased summer flows results in increased winter turbidity as well as increased diffuse runoff from irrigation and mining. The operational releases from Bloemhof Dam as well as Spitskop Dam in the Harts River are greater in summer and poor water quality is released to this site. The mine water reuse and the transfer of the Johannesburg southern waste water treatment works effluent to the Crocodile West catchment have small reduction in nutrients and salts at this site. Localised impacts from the Vaal Harts irrigation system are more influential. Increasing trend in nutrients concentrations. Potential for algal blooms increasing. High nutrients due to waste water treatment work discharges upstream as well as return flows from fertilzers being used in the Vaal Hartz irrigation scheme. The observed algal growth – rooted macrophytes, filamentous, exotic floating macropytes (Water hyacinth) and single cell blooms. Chlorophyll-*a* seasonal variability. The potential for algal blooms increases due to summer temperatures but this is masked by the higher turbidity's. The potential for algal blooms increases due to summer temperatures as well as the future 2020 development

					conditions (greater nutrients).

These scenarios include the proposed re-use of mine water which would decrease the salts originating from the point discharges from the mines. Bloemhof and Spitskop dams play a regulatory role for this site. These scenarios result in a lower salt concentration summer due to extra flow releases.

These scenario's Include the projected possible transfer to the Crocodile catchment which will further reduce the salt and nutrient loads at EWR 18 but localised impacts from the Vaal Hartz scheme override the upstream management. There will be a continued potentially worsening nutrient levels due to upstream urbanisation and the use of fertilizers in the Vaal Hartz irrigation scheme. It is important to note that nutrients and salts are the driving force at this site and other variables such as microbiology and metals that are not measured are also variables of concern.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B	D	D/E	Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Harts system) as well as EWR releases. High salts concentrations (EC and SO_4) return from agriculture and diamond mining impacts mainly in the Harts River released from the Spitskop Dam. There are irrigation drainage channel which collects and discharges into the river. Low to moderate nutrients (moderate to high ammonia from degrading algal matter) Eutrophication (there are three dams upstream of the system) as well as the intensive irrigated Vaal Hartz irrigation system. Winter flows and concentrations of salts similar for the scenarios and higher concentrations than those of the summer. The winter flows are similar for all the scenario's studied. Winter salt concentrations are 40 % higher than the	Water is released from Bloemhof Dam for use in the downstream irrigation (Vaal Harts system) as well as EWR releases. High salts concentrations (EC and SO_4) return from agriculture and diamond mining impacts mainly in the Harts River released from the Spitskop Dam. There are irrigation drainage channel which collects and discharges into the river. Low to moderate nutrients (moderate to high ammonia from degrading algal matter) Eutrophication (there are three dams upstream of the system) as well as the intensive irrigated Vaal Hartz irrigation system. Summer flows and concentrations of salts similar for the scenarios and lower concentrations than those of the winter. The summer flows vary between the scenario's studied. Summer salt concentrations 40 % lower than the winter concentrations due to dilutions by the 30 times higher

				summer concentrations due to 30 times lower flows. Extra water is released from the Vaal Dam in winter and this is used for the dilution of salts in the middle and lower Vaal. Slightly increased winter flows results in increased winter turbidity. There is a settling of salts in Bloemhof Dam as well as Spitskop Dam in the Harts River. The mine water reuse and the transfer of the Johannesburg southern waste water treatment works effluent to the Crocodile West catchment have small reduction in nutrients and salts at this site. Localised impacts from the Vaal Harts irrigation system are more influential. Increasing trend in nutrients concentrations. Potential for algal blooms increasing. High nutrients due to waste water treatment work discharges upstream as well as return flows from fertilzers being used in the Vaal Hartz irrigation scheme. The observed algal growth – rooted macrophytes, filamentous, exotic floating macropytes (Water hyacinth) and single cell blooms. Chlorophyll-*a* seasonal variability.	summer flows. Extra water is released from the Vaal Dam in winter and this is used for the dilution of salts in the middle and lower Vaal. Increased summer flow results in increased winter turbidity as well as increased diffuse runoff from irrigation and mining. The operational releases from Bloemhof Dam as well as Spitskop Dam in the Harts River are greater in summer and poor water quality is released to this site. The mine water reuse and the transfer of the Johannesburg southern waste water treatment works effluent to the Crocodile West catchment have small reduction in nutrients and salts at this site. Localised impacts from the Vaal Harts irrigation system are more influential. Increasing trend in nutrients concentrations. Potential for algal blooms increasing. High nutrients due to waste water treatment work discharges upstream as well as return flows from fertilzers being used in the Vaal Hartz irrigation scheme. The observed algal growth – rooted macrophytes, filamentous, exotic floating macropytes (Water hyacinth) and single cell blooms. Chlorophyll-*a* seasonal variability. The potential for algal blooms increases due to summer temperatures but this is masked by the higher turbidity's. The potential for algal blooms increases due to summer temperatures as well as the future 2020 development conditions (greater nutrients).
These scenarios include the proposed re-use of mine water which would decrease the salts originating from the point discharges from the mines. Bloemhof and Spitskop dams play a regulatory role for this site. These scenarios result in a lower salt concentration summer due to extra flow releases. These scenario's Include the projected possible transfer to the Crocodile catchment which will further reduce the salt and nutrient loads at EWR 18 but localised impacts from the Vaal Hartz scheme override the upstream management. There will be continued potentially worsening nutrient levels due to upstream urbanisation and the use of fertilizers in the Vaal Hartz irrigation scheme. This scenario includes proposed re-use of mine water and possible transfer to the Crocodile catchment.					

It is important to note that nutrients and salts are the driving force at this site and other variables such as microbiology and metals that are not measured are also variables of concern.

Riparian vegetation

The site at Schmidtsdrif on the Vaal River consists of a broad area of flow with moderately sloping banks, on which vegetation would easily colonise and recruit. Vegetated sand banks indicate that few flood events take place in this reach of the river and the creation of patches for the colonisation of species due to floods is seldom encountered. Disturbance in the area is mainly due to anthropogenic impacts such as the utilisation of the vegetation in the area for grazing, fuel and possibly medicinal plant species and mining activities that are widespread along the banks of the river. Erosion is also visible on the banks and much of the area has been degraded due to the mining activities on the banks of the river. Although the site selection at this site is not ideal as the vegetation in the area has been disturbed, it is representative of much of the vegetation along this reach of the Vaal River as land use in the area is predominantly mining with some agricultural and pastoral farming also occurring in the area.

The marginal zone at Site EWR 18 is dominated by graminoid and cyperoid species including *Panicum coloratum, Sporobulus africanus, Phragmites australis* and *Myriophyllum spicatum* while the lower non-marginal zone is dominated by mainly by graminoids and herbaceous species such as *Chloris virgata, Cynodon dactylon, Eragrostis* spp., *Paspalum distichum, Sporobulus africanus, Xanthium strumarium, Sporobulus fimbriatus, Clematis brachiata, Lycium arenicola,* and the upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Diospyros lycoides, Melianthus comosus* and *Rhus pyroides*.

Current status: The area is currently considerably degraded due to the mining activities on the banks of the river resulting in an inflow of silt and the introduction of exotic species in the area. Although the number of exotic species occurring in the area is considerably less than many of the other sites the exotic species only contribute to approximately 20% of the species recorded in the area. The exotic species that appears to be having the greatest impact on the area is the aquatic weed *Myriophyllum spicatum* which has colonised and taken over the aquatic habitat. This species, if it remains unchecked may cause considerable damage in future. Furthermore, the lack of stochastic events, such as flooding may be aiding the colonisation by this species at site EWR 1.

Trajectory of change: Due to the factors mentioned above under the section “Current Status” and the fact that these factors are not being remedied or arrested it must be assumed, in order to comply with cautionary principles, that the trajectory of change is negative.

EC				**ECOLOGICAL CONSEQUENCES**	
PES	**REC**	**AEC a**	**Sc 1**	**DRY SEASON**	**WET SEASON**
Specialist inputs					

C/D	C/D	D	C/D	No significant change from present day status and it is unlikely that this scenario will change the present ecological status of the riparian vegetation at all.	No significant change from present day status and it is unlikely that this scenario will change the present ecological status of the riparian vegetation at all.

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/D	D	C/D	Although base flows are increased the size of the increases are not significant to have any effect on the present ecological status of the riparian vegetation.	Although base flows are increased the size of the increases are not significant to have any effect on the present ecological status of the riparian vegetation.

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/D	D	C/D	No significant change from present day status and it is unlikely that this scenario will change the present ecological status of the riparian vegetation at all.	No significant change from present day status and it is unlikely that this scenario will change the present ecological status of the riparian vegetation at all.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/D	D	C	Slightly less terrestrialisation of the lower non-marginal zone and marginal zone, due to increased water flows. Change is going to be very slight though.	Slightly less terrestrialisation of the lower non-marginal zone and marginal zone, due to increased water flows. Change is going to be very slight though.

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/D	D	C/D	No significant change from present day status and it is unlikely that this scenario will change the present ecological status of the riparian vegetation at all.	No significant change from present day status and it is unlikely that this scenario will change the present ecological status of the riparian vegetation at all.

Scenario 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 8	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/D	D	C/D	Although base flows are increased the size of the increases are not significant to have any effect on the present ecological status of the riparian vegetation.	Although base flows are increased the size of the increases are not significant to have any effect on the present ecological status of the riparian vegetation.

Macroinvertebrates

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Unavailability of fast flowing conditions. Taxa that are water quality sensitive are absent. No real seasonality.	Unavailability of fast flowing conditions. Taxa that are water quality sensitive are absent. No real seasonality.

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C	Same as PES.	Slightly higher base flows in the wet season. With better flow regimes taxa that are flow sensitive will move back.

					Improving the water quality will have a positive effect on the taxa that is sensitive to water quality.

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Unavailability of fast flowing conditions. Taxa that are water quality sensitive are absent.	Unavailability of fast flowing conditions. Taxa that are water quality sensitive are absent.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C	Same as PES.	Slightly higher base flows in the wet season. Higher than scenario 4 and scenario 8. With better flow regimes taxa that are flow sensitive will move back. Improving the water quality will have a positive effect on the taxa that is sensitive to water quality.

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Unavailability of fast flowing conditions. Taxa that are water quality sensitive are absent.	Unavailability of fast flowing conditions. Taxa that are water quality sensitive are absent.
Same as the Present Day.					

Scenario 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 8	DRY SEASON	WET SEASON
Specialist inputs					

C/D	C	D	C	Same as PES.	Slightly higher baseflows in the wet season. With better flow regimes taxa that are flow sensitive will move back. Improving the water quality will have a positive effect on the taxa that is sensitive to water quality.

Fish

Scenarios 1, 5 and 7

Eight fish species would historically have occurred at the site in moderate abundance (Kleynhans *et al*., 2007). *Barbus paludinosus* and *Labeobarbus kimberleyensis* would have occurred at the site in low abundances (Kleynhans *et al*., 2007). *Austroglanis sclateri* may sporadically have been present at the site in moderate abundance (Kleynhans *et al*., 2007). Eight of the expected fish species have a high level of preference for either slow deep or slow shallow habitats suggesting that these would historically have been the predominant velocity depth classes at this site. Two fish species namely *Labeobarbus aeneus* and *Austroglanis sclateri* have a high level of preference for fast shallow habitats. *Labeobarbus kimberleyensis* has a high level of preference for fast deep habitats. Seven of the expected fish species are either moderately tolerant or tolerant of reduced flow levels. Four fish species are moderately intolerant of a lack of flow, indicating that these species would require periods of flow at some stage in their lifecycle. The expected fish assemblage show high levels of preference for a wide range of cover types. Ten of the expected fish species are either moderately tolerant or tolerant of modified water quality indicating that water quality at this site would fluctuate naturally along with seasonal flow patterns. *L. kimberleyensis* is moderately intolerant of modified water quality. Five species have a requirement for movement between reaches/ fish habitat segments. These are the species that are most likely to be impacted upon by the construction of dams and weirs that impede fish migration.

Nine of the expected fish species were recorded at the site during the 2 Reserve Determination surveys. The Present Ecological State (PES) of the site was rated as a Class C. In addition to the indigenous fish species the exotic species *Gambusia affinis* was abundant at the site. The exotic species *Cyprinus carpio* was also recorded at the site.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1,5,7	DRY SEASON	WET SEASON
Specialist inputs					
D	C	C	D	Seven of the expected fish species were recorded at site EWR18 during the dry season survey	Eight of the expected fish species were recorded at site EWR18 during the wet season survey
A PES of D was recorded at site EWR18 during scenario 1 (present day). Nine of the 11 expected fish species were recorded at the site during the 2 Reserve surveys. The observed frequency of occurrence was lower than reference for 5 of the 9 observed species contributing to the PES of D.					

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Austroglanis sclateri	**2.00**	**0.00**
Barbus anoplus	**4.00**	**0.00**
Barbus paludinosus	**4.00**	**1.00**
Barbus trimaculatus	**4.00**	**1.00**
Labeobarbus aeneus	**4.00**	**3.00**
Labeobarbus kimberleyensis	**4.00**	**2.00**
Clarias gariepinus	**4.00**	**3.00**
Labeo capensis	**4.00**	**3.00**
Labeo umbratus	**4.00**	**3.00**
Pseudocrenilabrus philander	**3.00**	**2.00**
Tilapia sparrmanii	**4.00**	**1.00**

Scenarios 4 and 8

Scenarios 4 and 8 are very similar and result in a slight decrease in the duration of wet season flow related stress due to increased flows and a 20 – 30% reduction in salt and nutrient levels. This constitutes a reduction in wet season flow related stress resulting in an increase in the abundance of *B. paludinosus, B. trimaculatus* and *P. philander* that were present at the site in low abundance. This increase in abundance would result in an increase in the PES from a D (current day) to a C/D.

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 4,8**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
C	C	D	D	Unchanged from scenario 1 (current day)	Increased flow levels result in a 20 - 30% reduction in salt load also decreased nutrient levels due to increased dilution.
Increased flow during the wet season results in a 20 – 30% reduction in salt and nutrient levels. This constitutes a reduction in wet season flow related stress resulting in an increase in the abundance of *B. paludinosus, B. trimaculatus* and *P. philander* that were					

present at the site in low abundance. This increase in abundance would result in an increase in the PES from a D to a C/D.

Scenario 6

Scenario 6 results in increased flow levels during the wet season that will flood and flush sediments, algae and aquatic macrophytes from the site. Scenario 6 will also result in improved water quality during the wet season due to reduced salt and nutrient concentrations and may result in increased abundances of all species in line with the expected reference frequency of occurrence. The increased abundances resulted in an improvement in the PES from a D to a C category.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
D	C	C	C	Relatively unchanged from scenario 1 (current day)	Increased flow levels result in flooding and flushing of sediments, algae and aquatic macrophytes from the site. Increased flow levels result in improved water quality due to decreased salt and nutrient levels.
Increased flow levels and improved water quality during the wet season results in an improvement in the PES from a D to a C category					

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Austroglanis sclateri	2	0
Barbus anoplus	4	0
Barbus paludinosus	4	4
Barbus trimaculatus	4	4
Labeobarbus aeneus	4	4
Labeobarbus kimberleyensis	4	3
Clarias gariepinus	4	4

Labeo capensis	4	4
Labeo umbratus	4	4
Pseudocrenilabrus philander	3	2
Tilapia sparrmanii	4	3

4.3.4 Summary of ecological consequences

The summary of the ecological categories for the operational scenarios at EWR 18 are provided in Table 4.3.

Table 4.3: Summary of ecological categories for operational scenarios at EWR site 18

Driver	**Sc 1 PD**	**Sc 4**	**Sc 5**	**Sc6**	**Sc 7**	**Sc 8**
Water quality	D/E	D	D/E	D	D/E	D
Geomorphology	C/D	C/D	C/D	C	C/D	C/D
Response components						
Fish	C	C	C	C	C	C
Aquatic invertebrates	C/D	C/D	C/D	C	C/D	C/D
Instream	C/D	C	C/D	C	C/D	C
Riparian vegetation	C/D	C/D	C/D	C	C/D	C/D
Ecostatus	**C/D**	**C**	**C/D**	**C**	**C/D**	**C**

4.4 EWR 19: LILYDALE LODGE (RIET RIVER)

4.4.1 Catchment development and impacts

Relative to the natural hydrology the Present Day flows at EWR 19 are characterised by reduced floods, reduced wet season baseflows and elevated dry season baseflows.

There are Rustfontein, Krugersdrift, Tierpoort and Kalkfontein dams in the upper catchments and interbasin transfer from the Caledon River in the upper reaches of the catchment.

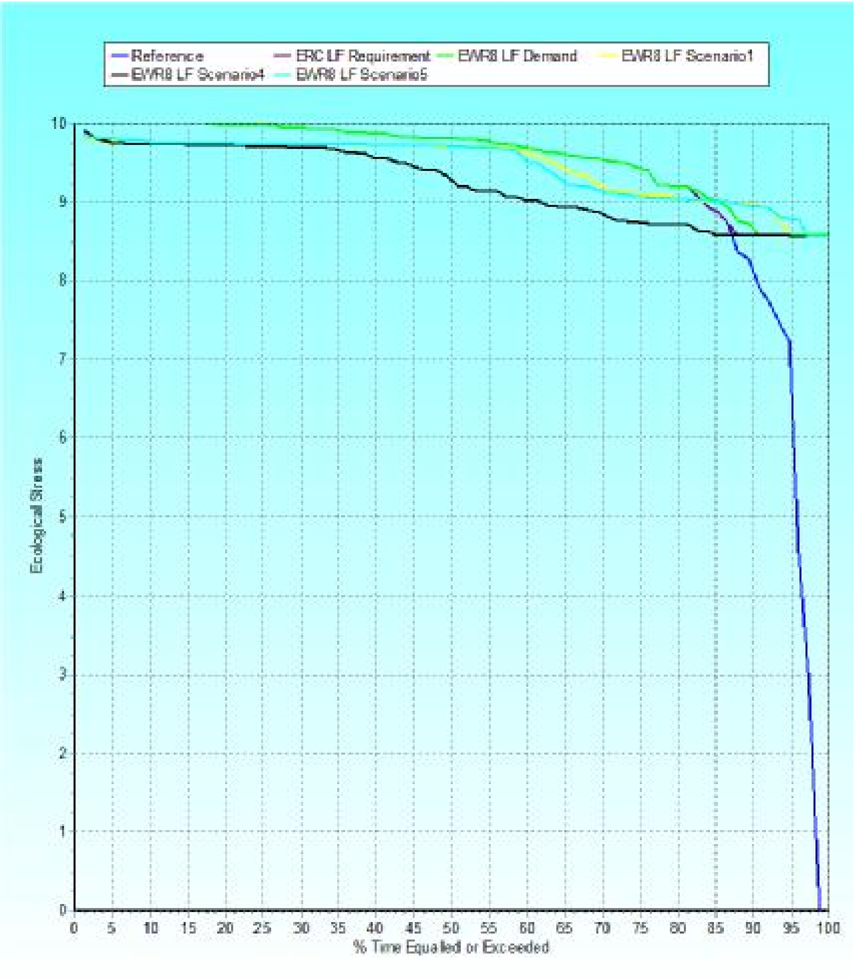
The water quality drivers at this site are as follows:

- High salts in winter due to low flows and return flows from irrigation and mining.

- Moderate to high nutrients (agricultural return flows). There's dams upstream that are used for irrigation (trapping the nutrients and salts) releases. Most nutrients measured are due to diffuse pollution rather than point source.

4.4.2 Graphs of flow scenarios

Error! Reference source not found. illustrates the stress requirements and stress points required for the REC, present day (demand) and the operational scenarios analysed for the wet and dry seasons at EWR site 19.



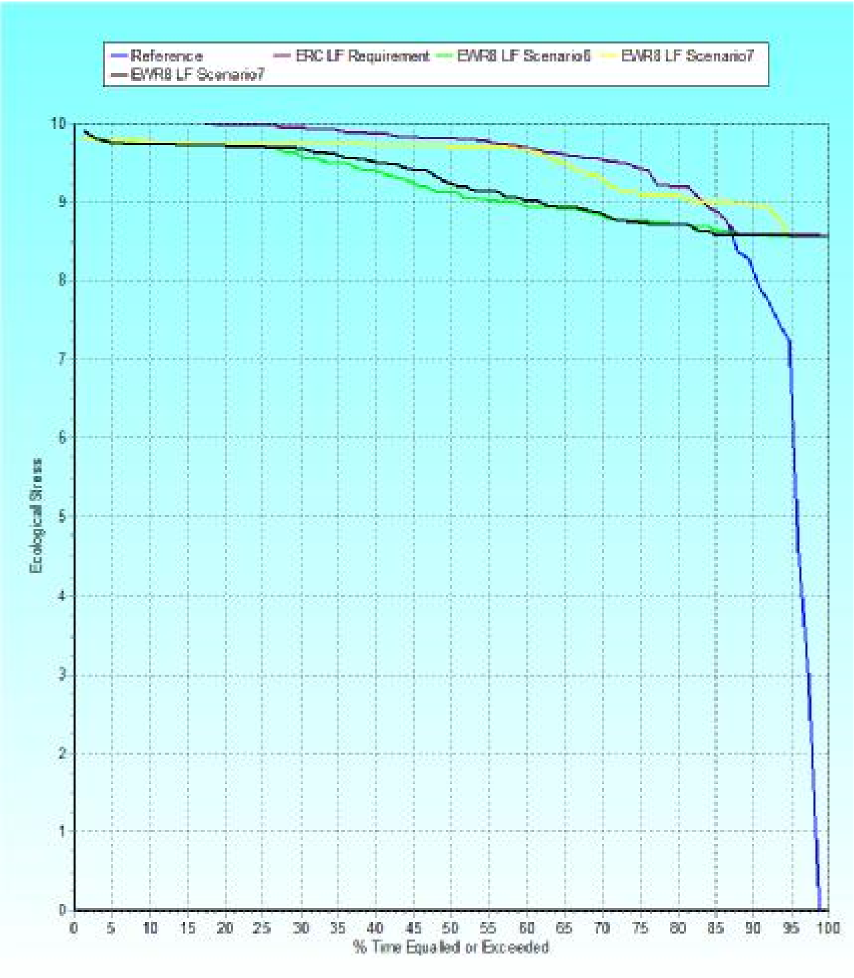


Figure 4.7: Stress curves for the dry season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 19

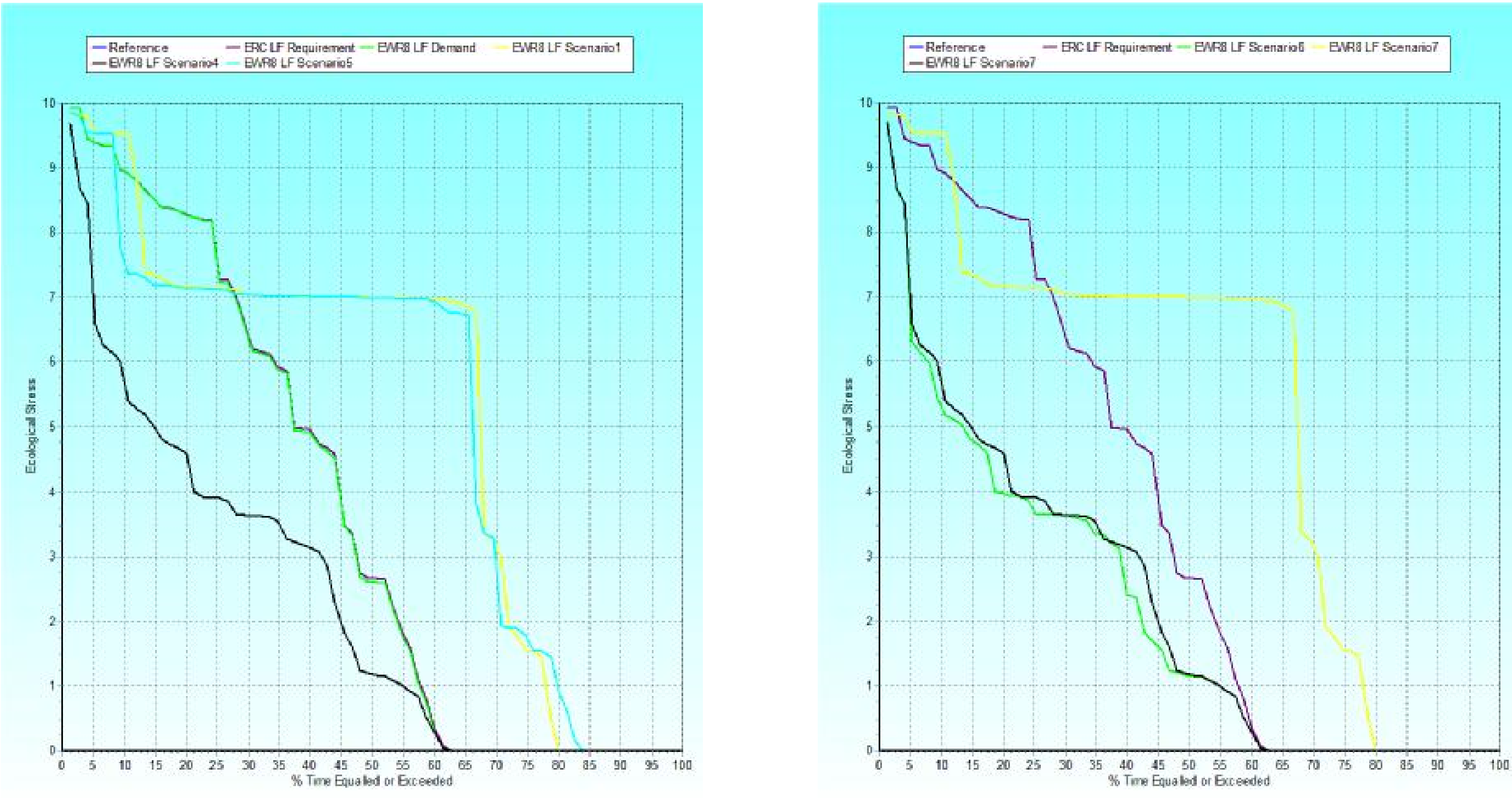


Figure 4.8: Stress curves for the wet season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 19

4.4.3 Ecological consequences

The ecological consequences for the driver components (geomorphology and physic chemical) and response variables (riparian vegetation, macroinvertebrates and fish) are discussed below for present day and the operational scenarios.

Geomorphology

Relative to the natural hydrology the Present Day flows at this site are characterised by reduced floods, reduced wet season baseflows and elevated dry season baseflows.

The EWR site is located in a steep bedrock gorge section of the river. Most of the bed of the active channel here is exposed bedrock (i.e. sediment free), and there is thus is little available sediment in the active channel due to the high energy of the site. There are large dams far upstream and these would have a low impact on sediment trapping, but extreme reductions in floods were identified by the hydrologist in the EcoClassification of the site. Thus although the morphology of the site is relatively resilient to any flow changes, PES for the reach was calculated to be a low C due to the far greater sensitivity of the up- and downstream alluvial reaches to the very reduced floods.

Scenario 1

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 1**	**DRY SEASON**	**WET SEASON**
C	C	D	C	Increased baseflows	Decreased baseflows and a reduction in floods have reduced sediment transport; so flushing of fines and scour is reduced.
The provision of small intra-annual floods of 2 m^3/s (five per year), an annual flood of 20 m^3/s and inter-annual 100 m^3/s (1:2 years) should be sufficient to continue to flush fines from this fast-flowing reach, as well as maintain some coarse in-channel habitat in the alluvial reaches up and downstream. Larger inter-annual floods (230 m^3/s) are also required to activate the coarser sediment, but these may be beyond reasonable manageable flows.					

Scenario 5 and 7

These scenarios propose no major changes from the present day flow patterns. They have not been evaluated further since no changes from the PES are expected.

Scenario 4, 6 and 8

Increased dry season baseflows, large increases in wet season floods and very large increases in the wet season baseflows are proposed for these scenarios. These increased flows will reinstate much of the scouring ability of the river and will improve the in-channel habitat and riparian zone. This will change the PES from a low C to a high C. The site is not very sensitive to morphological adjustment, but the in-channel improvements in habitat condition should be relatively substantial in that there will be more frequent flushing of fines; scouring and activation of the coarser bed sediments as well as more frequent inundation of the marginal and lower riparian vegetation.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4, 6, 8	DRY SEASON	WET SEASON
Specialist inputs					
C	C	D	C+	Increased baseflows	Very large increases in baseflows and increased floods.
The large increases in wet season baseflows and the provision of small and moderate floods will maintain improve in-channel habitat through increased transport and removal fines; increased scour and more frequent activation of the cobble areas.					

Physico chemical

Scenarios present day, 5 and 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1,5,7	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B	D	D	Rustfontein, Krugersdrift, Tierpoort and Kalkfontein dams in the upper catchments and interbasin transfer from the Caledon River. High salts in winter due to low flows and return flows from irrigation and mining. Moderate to high nutrients (agricultural return flows). There's dams upstream used for irrigation (trapping the nutrients and salts). But most nutrients measured are due to diffuse pollution rather than point source. Winter salts concentrations are 3 times higher than the summer concentrations and the flows 18 times less.	Rustfontein, Krugersdrift, Tierpoort and Kalkfontein dams in the upper catchments and interbasin transfer from the Caledon River. Summer salts are 3 times lower than the winter and the flows are 18 times higher than the winter flows. PO_4 stable, other nutrients steady trend overall but have been increasing since 1996. Nutrient levels will increase due to the 2020 development condition. The potential for algal blooms increases due to summer temperatures as well as the future 2020 development conditions (greater nutrients) but this scenario includes

					the EWR requirements. Nutrient levels diluted in summer and the potential for algal blooms increases due to summer temperatures but this is masked by the higher turbidity's.

Scenarios 4, 6 and 8

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AECa**	**Sc 4,6,8**	**DRY SEASON**	**WET SEASON**
PHYSICO-CHEMICAL					
C	B	D	D	Rustfontein, Krugersdrift, Tierpoort and Kalkfontein dams in the upper catchments and interbasin transfer from the Caledon River. These scenarios include the EWR requirements as well as the 2020 development and include proposed re-use of mine water. Higher base flows all year round. High salts in winter due to low flows and return flows from irrigation and mining. Moderate to high nutrients (agricultural return flows). There's dams upstream used for irrigation (trapping the nutrients and salts). But most nutrients measured are due to diffuse pollution rather than point source. Winter salts concentrations are 30 % lower in these scenarios when compared to PD. times higher than the summer. Winter concentrations 3 times higher than summer. These scenarios include the EWR requirements as well as the 2020 development.	Rustfontein, Krugersdrift, Tierpoort and Kalkfontein dams in the upper catchments and interbasin transfer from the Caledon River. These scenarios include the EWR requirements as well as the 2020 development includes proposed re-use of mine water.. Higher base flows all year round. Summer salt concentrations are 40% lower in summer than the PD scenario. Summer salts are 3 times lower than the winter and the flows are 16 times higher than the winter flows. PO_4 stable, other nutrients steady trend overall but have been increasing since 1996 and the 2020 development scenarios would probably lead to a slight increase in nutrients due to upper catchment urbanization. Nutrient levels will increase due to the 2020 development condition. The potential for algal blooms increases due to summer temperatures as well as the future 2020 development conditions (greater nutrients) but this scenario includes the EWR requirements. Nutrient levels diluted in summer and the potential for algal blooms increases due to summer temperatures but this is masked by the higher turbidity's.

Riparian vegetation

The site at Lillydale Lodge on the Riet River consists of a relatively broad area of flow with moderately sloping banks on the western side which are considerably impacted by previous mining activities and the introduction of exotic species. On the eastern bank there is a very small bank with a shallow slope before rising to a steep cliff which would not allow for easy colonisation and recruitment. The site selection at this site is, however, ideal as the vegetation in the area has been disturbed on much of this reach of the river by mining activities and stock grazing in the past. This area has recently been declared a national park, but much degradation is still evident from previous activities. Land use in the area is nature reserve at the moment but was previously pastoral farming and mining.

The marginal zone at Site EWR 19 is dominated by graminoid and cyperoid species including *Cyperus denudatus, Cyperus longus, Panicum coloratum, Cynodon dactylon, Sporobulus fimbriatus, Phragmites australis* and *Myriophyllum spicatum* while the lower non-marginal zone is dominated by mainly by graminoids and woody species mainly *Cynodon dactylon* and *Eucalyptus* spp. *Eragrostis plana, , Xanthium strumarium* and *Nidorella* spp. and the upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Diospyros lycoides, Melianthus comosus* and *Rhus pyroides*.

Current status: The area is currently degraded due to the introduction of a number of exotic species and the previous mining and farming impacts. The exotic species in the area, in fact, contribute to a total of only 20% of the total number of species identified during the surveys, but do make up a considerable amount of the local biomass.

Trajectory of change: Due to the factors mentioned above under the section "Current Status" and the fact that these factors are being remedied or arrested within the reserve area the trajectory of change is stable.

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 1**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
D	D	D/E	D	The flows anticipated for this scenario do not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at the site.	The flows anticipated for this scenario do not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at the site .

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 4**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
D	D	D/E	C/D	Higher flow rates will cause increased growth and propagation of plants in the marginal zone during the dry season, thereby increasing the size and stability of the marginal zone. And arresting terrestrialisation of the lower	Higher flow rates and better seasonality during the wet season will cause increased inundation of the marginal zone and reduce terrestrial encroachment of the lower non marginal

				nonmarginal zone.	zone

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
D	D	D/E	D	The flows anticipated for this scenario do not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at the site.	The flows anticipated for this scenario do not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at the site.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
D	D	D/E	C/D	Higher flow rates will cause increased growth and propagation of plants in the marginal zone during the dry season, thereby increasing the size and stability of the marginal zone. And arresting terrestrialisation of the lower nonmarginal zone.	Higher flow rates and better seasonality during the wet season will cause increased inundation of the marginal zone and reduce terrestrial encroachment of the lower non marginal zone

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
D	D	D/E	D	The flows anticipated for this scenario do not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at the site .	The flows anticipated for this scenario do not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at the site .

Scenario 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 8	DRY SEASON	WET SEASON
Specialist inputs					
D	D	D/E	C/D	Higher flow rates will cause increased growth and propagation of plants in the marginal zone during the dry season, thereby increasing the size and stability of the marginal zone. And arresting terrestrialisation of the lower nonmarginal zone.	Higher flow rates and better seasonality during the wet season will cause increased inundation of the marginal zone and reduce terrestrial encroachment of the lower non marginal zone

Macroinvertebrates

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C	C/B	D	C	Loss of taxa that shows a high requirement for fast and moderately fast flows. Loss of taxa that has a high and moderate requirement for unmodified water quality.	Loss of taxa that shows a high requirement for fast and moderately fast flows. Loss of taxa that has a high and moderate requirement for unmodified water quality.

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
C	C/B	D	C	Significant improvement in the base flows during the dry season months. In terms of morphology here will be an in-channel improvement. There will be an improvement in the salts and the nutrients. Salts will reduce by 30%.	Significant improvement in the base flows during the wet season months. In terms of morphology here will be an in-channel improvement. There will be an improvement in the salts and the nutrients. Salts will reduce by 40%. Floods in the wet season will be large enough to flush the system at least once a year.

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 5	DRY SEASON	WET SEASON

Specialist inputs					
C	C/B	D	C	Loss of taxa that shows a high requirement for fast and moderately fast flows. Loss of taxa that has a high and moderate requirement for unspoilt water quality.	Loss of taxa that shows a high requirement for fast and moderately fast flows. Loss of taxa that has a high and moderate requirement for unspoilt water quality..
Same as present day.					

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
C	C/B	D	C	Significant improvement in the base flows during the dry season months. In terms of morphology here will be an in-channel improvement. There will be an improvement in the salts and the nutrients. Salts will reduce by 30%.	Significant improvement in the base flows during the wet season months. In terms of morphology here will be an in-channel improvement. There will be an improvement in the salts and the nutrients. Salts will reduce by 40%.

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
C	C/B	D	C	Loss of taxa that shows a high requirement for fast and moderately fast flows. Loss of taxa that has a high and moderate requirement for unspoilt water quality.	Loss of taxa that shows a high requirement for fast and moderately fast flows. Loss of taxa that has a high and moderate requirement for unspoilt water quality..
Same as the Present Day.					

Scenario 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 8	DRY SEASON	WET SEASON
Specialist inputs					
C	C/B	D	C	Significant improvement in the base flows during the dry season months. In terms of morphology here will be an in-channel improvement. There will be an improvement in the salts and the nutrients. Salts will	Significant improvement in the base flows during the wet season months. In terms of morphology here will be an in-channel improvement. There will be an improvement in the

				reduce by 30%.	salts and the nutrients. Salts will reduce by 40%.

Fish

Scenarios 1, 5 and 7

Eight fish species would historically have occurred at the site in moderate abundance (Kleynhans *et al*., 2007). *Barbus paludinosus* and *Labeobarbus kimberleyensis* would have occurred at the site in low abundances (Kleynhans *et al*., 2007). *Austroglanis sclateri* may sporadically have been present at the site in moderate abundance (Kleynhans *et al*., 2007). Eight of the expected fish species have a high level of preference for either slow deep or slow shallow habitats suggesting that these would historically have been the predominant velocity depth classes at this site. Two fish species namely *Labeobarbus aeneus* and *Austroglanis sclateri* have a high level of preference for fast shallow habitats. *Labeobarbus kimberleyensis* has a high level of preference for fast deep habitats. Seven of the expected fish species are either moderately tolerant or tolerant of reduced flow levels. Four fish species are moderately intolerant of a lack of flow, indicating that these species would require periods of flow at some stage in their lifecycle. The expected fish assemblage show high levels of preference for a wide range of cover types. Ten of the expected fish species are either moderately tolerant or tolerant of modified water quality indicating that water quality at this site would fluctuate naturally along with seasonal flow patterns. *L. kimberleyensis* is moderately intolerant of modified water quality. Two fish species namely *Clarias gariepinus* (Sharptooth catfish) and *Tilapia sparrmanii* (Banded tilapia) have a requirement for movement between reaches/ fish habitat segments. These are the species that are most likely to be impacted upon by the construction of dams and weirs that impede fish migration. The remaining fish species have a requirement for movement within reaches.

Five of the expected indigenous fish species were recorded at the site during the 2 Reserve Determination surveys. The Present Ecological State (PES) of the site was rated as a Class D. The exotic fish species *Cyprinus carpio* (Carp) was also recorded at the site during the surveys.

EC				**ECOLOGICAL CONSEQUENCES**	
PES	**REC**	**AEC a**	**Sc 1,5,7**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
D	C	C	D	Five of the 8 expected fish species were recorded at site EWR19 during the low flow survey	Four of the eight expected fish species were recorded at site EWR19 during the high flow survey.
A PES of D was recorded at site EWR19					

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Austroglanis sclateri	**3.00**	**0.00**
Labeobarbus aeneus	**1.00**	**2.00**
Labeobarbus kimberleyensis	**1.00**	**0.00**
Clarias gariepinus	**1.00**	**2.00**
Labeo capensis	**1.00**	**2.00**
Labeo umbratus	**3.00**	**0.00**
Pseudocrenilabrus philander	**1.00**	**1.00**
Tilapia sparrmanii	**1.00**	**1.00**

Scenarios 4, 6 and 8

Scenarios 4, 6 and 8 results in large increases in base flow during both wet and dry season. This contributes to a 40% reduction in salt loads during the wet season and a 30% reduction during the dry season. Nutrient levels will also decrease due to dilution associated with increased flows. Increased flow levels and improved water quality may contribute to the increased abundance of *L. kimberleyensis* and *L. umbratus* and results in an increase in the PES from D to B/C.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4,6,8	DRY SEASON	WET SEASON
Specialist inputs					
D	C	C	B/C	Increased flow levels result in a 30% reduction in salt load also decreased nutrient levels due to increased dilution.	Increased base flows result in a 40% reduction in salt loads and decreased nutrient levels.
Increased base flows during both the wet and dry seasons results in improved habitat availability and improved water quality this may result in the increased abundance of two species *L. kimberleyensis* and *L. umbratus* that were absent/ present in low abundances in the study area during the present day.					

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Austroglanis sclateri	**3.00**	**0.00**
Labeobarbus aeneus	**1.00**	**1.00**
Labeobarbus kimberleyensis	**1.00**	**1.00**
Clarias gariepinus	**1.00**	**1.00**
Labeo capensis	**1.00**	**1.00**
Labeo umbratus	**3.00**	**3.00**
Pseudocrenilabrus philander	**1.00**	**1.00**
Tilapia sparrmanii	**1.00**	**1.00**

4.4.4 Summary of ecological consequences

The summary of the ecological categories for the operational scenarios at EWR 19 are provided in Table 4.4.

Table 4.4: Summary of ecological categories for operational scenarios at EWR site 19

Driver	**Sc 1 PD**	**Sc 4**	**Sc 5**	**Sc6**	**Sc 7**	**Sc 8**
Water quality	D/E	D	D/E	D	D/E	D
Geomorphology	C	C	C	C	C	C
Response components						
Fish	D	D	D	D	D	D
Aquatic invertebrates	C	C	C	C	C	C
Instream	D	C	D	C	D	C
Riparian vegetation	C/D	C/D	C/D	C/D	C/D	C/D
Ecostatus	**D**	**C**	**D**	**C**	**D**	**C**

5 SOCIO-ECONOMICS AND GOODS AND SERVICES

The following is a summary of the Socio Economic Present State Evaluation Report (RDM/ WMA09C000/ 01/CON/ 0907). Of the initial eight water allocation scenarios identified by the Project Team, the economic impacts of Scenarios 7 and 8 were modelled for several tributaries of the Vaal. Present day GDP and employment figures per EWR site were calculated using present day water abstraction at each EWR site and economic water multiplier for each economic zone within the Lower Vaal WMAs. The relevant economic zones were:

Lower Vaal WMA

- Vaal River main-stem;
- Harts;
- Modder; and
- Riet.

Water use data were collected for various water users within the Lower Vaal WMAs. Major water users within these WMAs are:

- Irrigated agriculture;
- Mining and manufacturing; and
- Domestic and/or household consumption

Relevant data were collected for each user category and used to estimate water use. These data were then modelled using the SAFRIM and WIM methodology (consistent with the Upper Vaal study) producing baseline economic impacts based on the economic zones identified. The baseline results indicated that irrigated agriculture had a significant economic impact in the Lower Vaal WMA providing R524 million directly to GDP and 7,403 employment opportunities. Irrigated agriculture in the Middle Vaal provided R315 million directly to GDP and 6,027 employment opportunities. While providing similar employment opportunities within the mining sector, the other industries within the Middle Vaal WMA provided significantly more employment opportunities and contributed more to total GDP than other industries within the Lower Vaal WMA.

The results of the socio-economic assessment indicated that significant deviations from present day demand for Scenario 8 were found for EWR R1 (Renoster), 14 (Vals), V1 and V2 (Vet). This implies that potentially significant economic impacts may occur as a consequence of applying the Ecological Reserve in the Renoster, Vals and Vet Rivers which are tributaries of the Vaal River. The results for the main stem showed that Scenario 8 caused more water to be pumped through the VRESAP pipeline and Sterkfontein Dam was operated at lower storage levels. The assurance of supply to users will, however, is not likely to be jeopardised by implementing the EWRs.

n terms of evaluating which Scenario is acceptable from a socio-economic perspective Scenario 8 was the only Scenario evaluated against present day water use. It is recommended that, due to the highly negative socio-economic impacts found in the Renoster, Vals and Vet tributaries, further and more detailed investigations may need to be conducted to more accurately assess the socio-economic costs and benefits of implementing the EWRs in these tributaries. Irrigated agriculture is a major economic activity in these tributaries and the Renoster, Vals and Vet tributaries account for approximately 21 000ha of agricultural production within the Middle Vaal WMA. Much of the annual crop yield is also made up of cereals such as maize and wheat which may negatively affect regional and potentially national food security. Possible further research into this could entail a financial and economic analysis of irrigated agriculture along these tributaries based on water allocation or costs scenarios the aim of which could be to assess the impacts of increasing water cost to irrigators and assessing at what levels costs affect profitability. Necessary trade-offs that could be made could also be identified by such a study. The traffic diagram below (Figure 5.1) provides a graphic representation of the overall socio-economic impacts of Scenario 8 in the Middle and Lower Vaal WMAs. The implementation of the EWRs on the major tributaries will result in limited socio-economics impacts (mainly on irrigation).

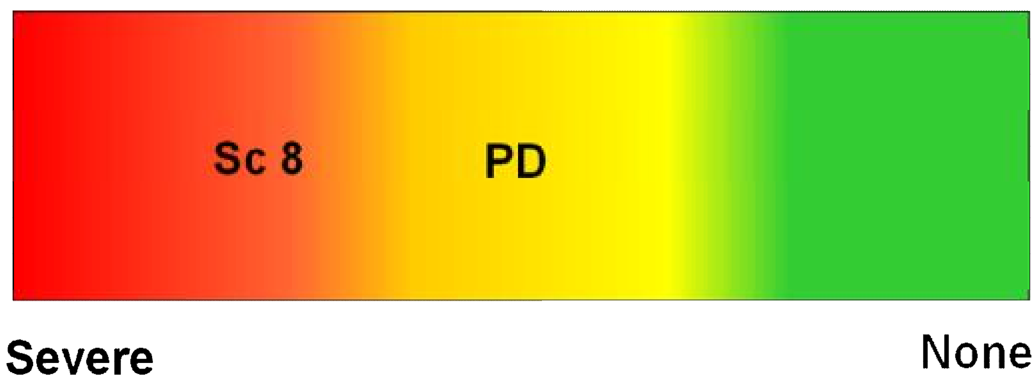


Figure 5.1: Traffic light diagram of overall socio-economic impacts of Scenarios 7 and 8 for the Lower Vaal WMAs

The methodology used to assess the impacts on Ecosystems Goods and Services in this study was consistent with the approach used for the Upper Vaal WMA. Of the eight water allocation Scenarios identified, Scenarios 4, 5, 6, 7 and 8 were evaluated per EWR site (shown in Figure 5.2). The approach investigated the impact of each Scenario on Fish, Riparian Vegetation, Recreation and Water Quality resources per EWR site. Overall it was found that by implementing the ER at each EWR site no negative impacts were found except for Scenario 5 at EWR site 14. These negative impacts were driven by impacts on fish species such as the, Smallmouth yellowfish (*Labeobarbus aeneus*), Orange-Vaal mudfish (*Labeo capensis*) and Moggel, (*Labeo umbratus*) and result from reduced flow levels leading to a decrease or disappearance of species from this reach. Scenario 5 cannot, therefore, be recommended as acceptable from an Ecosystems Goods and Services perspective based on these negative impacts. Scenario 6 had the highest overall score for each resource in both the Middle and Lower Vaal WMAs and on this basis must be recommended as the most acceptable Scenario from an Ecosystems Goods and Services perspective. The traffic diagram below (Figure 5.2) provides a graphic representation of the overall impacts of each Scenario on Ecosystems Goods and Services in the Lower Vaal WMAs.

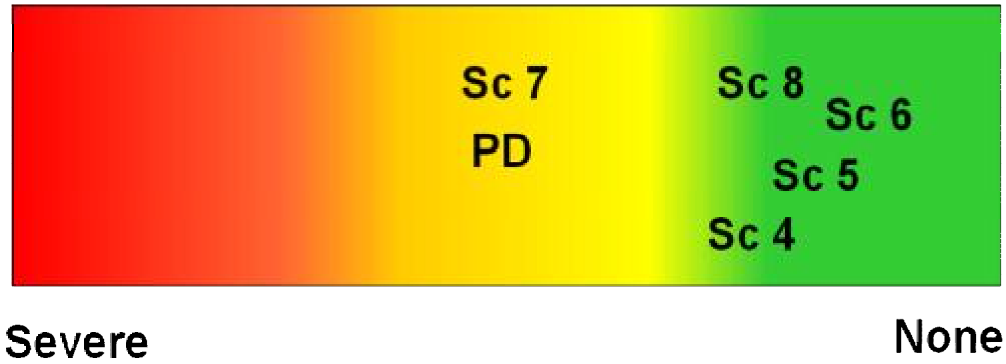


Figure 5.2: Traffic light diagram of overall Ecosystems Goods and Services impacts of Scenarios 4, 5, 6, 7 and 8 for the Lower Vaal WMAs

6 SUMMARY OF ECOLOGICAL CONSEQUENCES

The impacts of the various scenarios at the EWR sites are provided in the Table 6.1 and Figure 7.3 indicate the overall PES for the different scenarios.

There is currently too much flow in the main stem Upper and Middle Vaal. However, the flows are reduced significantly in the Lower Vaal due to irrigation abstractions. The main transfer of irrigation water is from the Vaal to the Harts and Vaal-Harts Weir. This reduced flows leads to water quality impacts, especially in the lower reaches of the river.

The water use on the harts River needs to be controlled, especially the high volumes return flows from the irrigation areas.

Table 6-1: Overall assessment of the PES as derived per scenario for the Lower Vaal

Main Stem	**Sc 1 PD (REC)**	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
16 Bloemhof	**E**	**E**	**E**	**E**	**E**	**E**
18 Schimdtsdrift	**C/D**	**C**	**C/D**	**C**	**C/D**	**C**
Tributaries						
17 Harts	**D**	**D**	**D**	**D**	**D**	**D**
19 Riet	**D**	**C**	**D**	**C**	**D**	**C**

7 CONCLUSIONS AND RECOMMENDATIONS

A summary of the ecological consequences per scenario for the main stem Vaal and the tributaries are indicated in Figure 7.1 and Figure 7.2. These Figures (Figures 7.1 and 7.2) are summaries of the ecological consequences for the Main stem of the Vaal and the tributaries. In these figures EWR 12 to 15 Middle Vaal are also included as a comparison of the different scenarios.

In summary the following are concluded:

- Main stem of Vaal all scenario's meet PES and REC
- Tributaries Scenarios, 4, 7 and 8 meet PES and REC
- Water quality is a driver and management plans for nutrients and salts are required, although the aquatic ecosystem has adapted
- Extreme low flows in the lower part of the Vaal River due to irrigation abstractions and transfer of water to the Harts River catchment for irrigation
- Tributaries less water available and water quality issues

At the presentation to the Department of Water Affairs Management Team on the 7th of October 2010 the following was agreed recommendations for the future management for the Lower Vaal (Table 7.1).

Table 7-1: Final recommendations per EWR site

EWR site	**Recommendation**
16 Vaal (Bloemhof)	Sign off for instream REC=D (instream PES) as the current overall PES=E due to non-flow related impacts. Conditions to improve the Riparian Zone should be included.
17 Harts	Sign off for PES=REC=D
18 Vaal (Schmitsdrift)	Sign off for PES=REC=C/D
19 Riet	Sign off for PES=REC=D with a recommendation that the flow measurements at the gauging weirs must be improved.

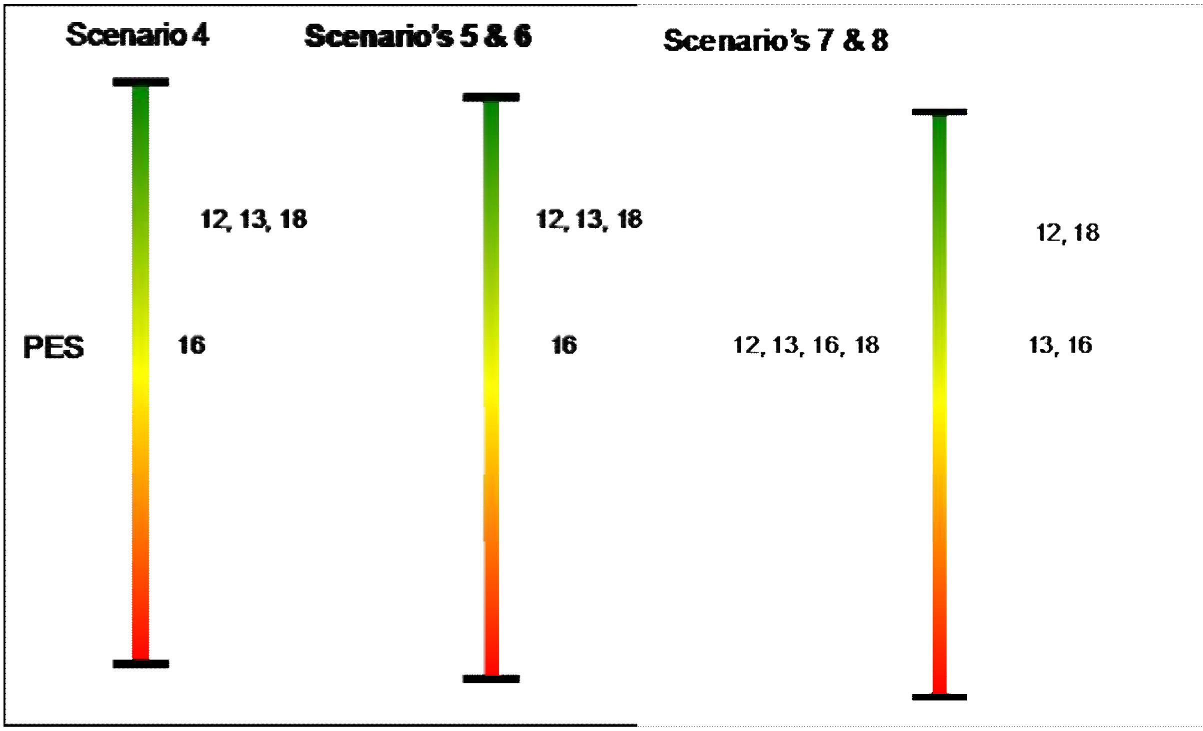


Figure 7.1: Summary of ecological consequences per scenario for the main stem of the Vaal EWR sites

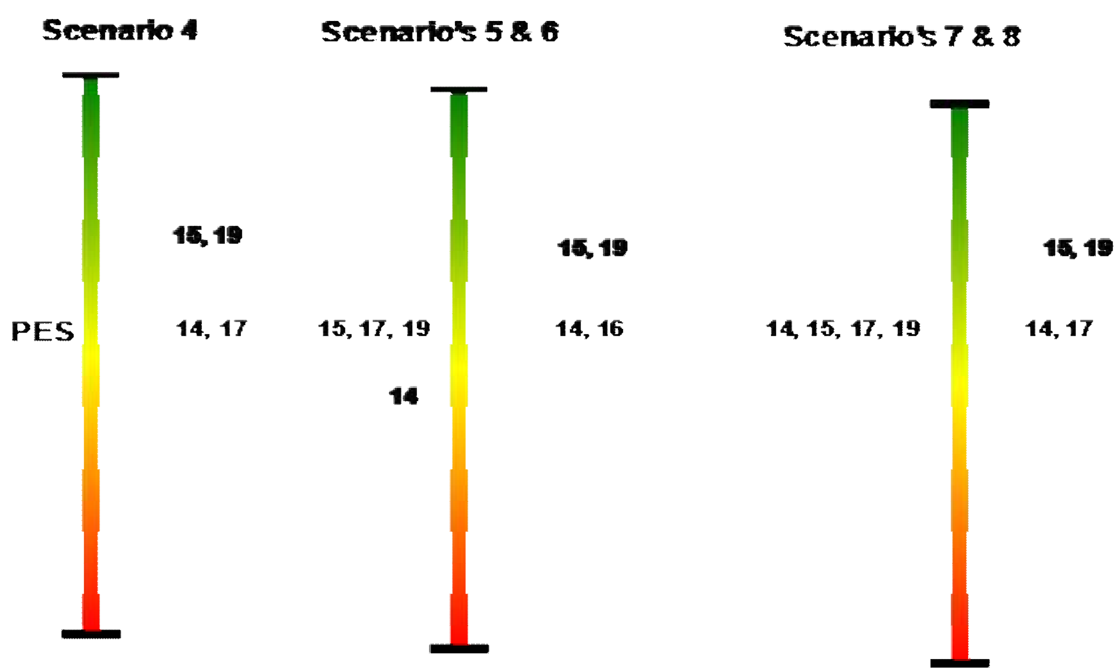


Figure 7.2: Summary of ecological consequences per scenario for the tributaries of the Vaal EWR sites

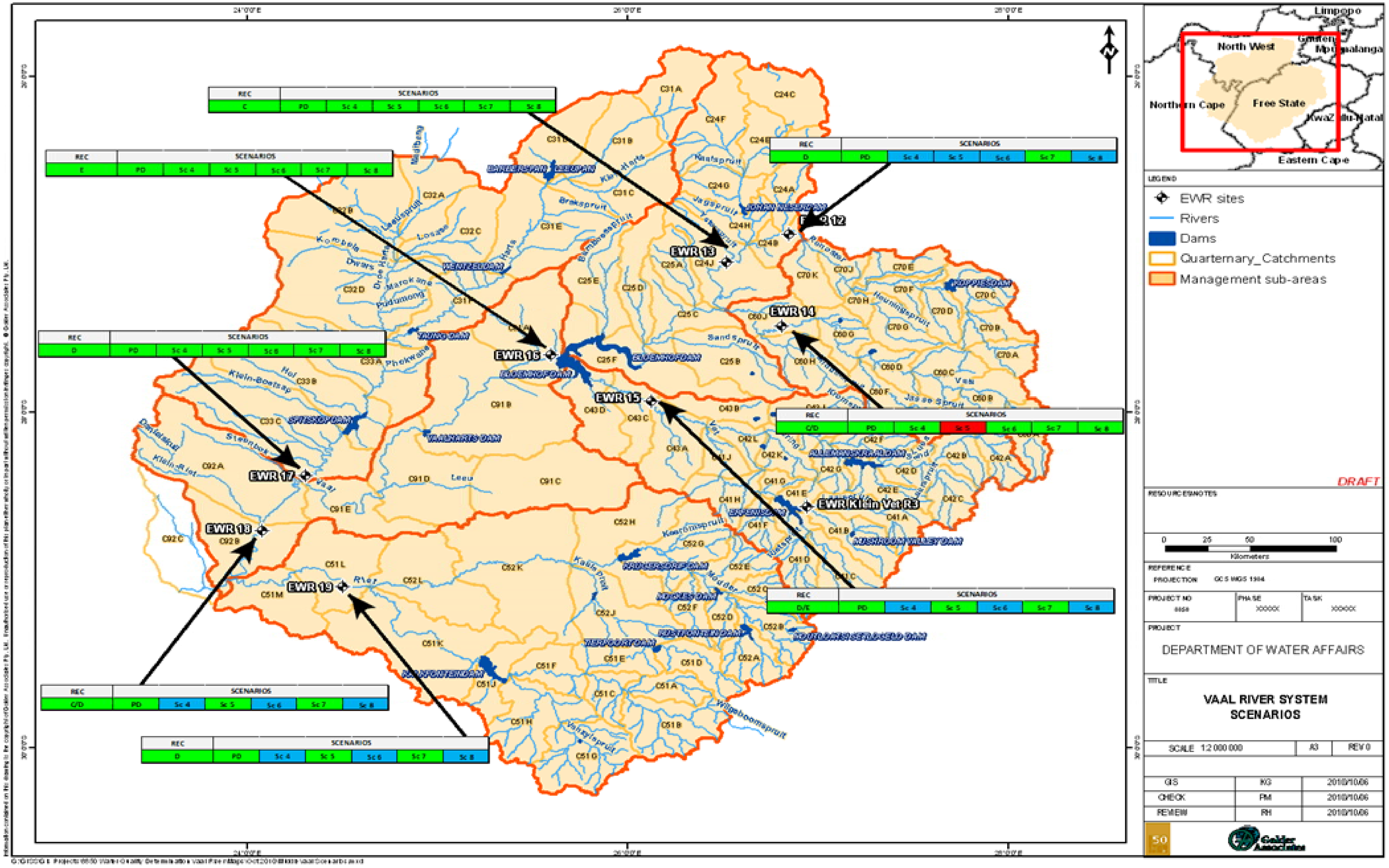


Figure 7.3 Summary of the Ecological assessment of the proposed scenarios for the Lower and Middle Vaal

8 REFERENCES

DWA (2010): Reserve determination study for the integrated Vaal River System, Middle and Lower Vaal Water Management Areas. Socio Economic consequences of operational scenarios report. Report no: RDM/ WMA09/10C000/ 01/CON/ 0410. Pretoria, South Africa.

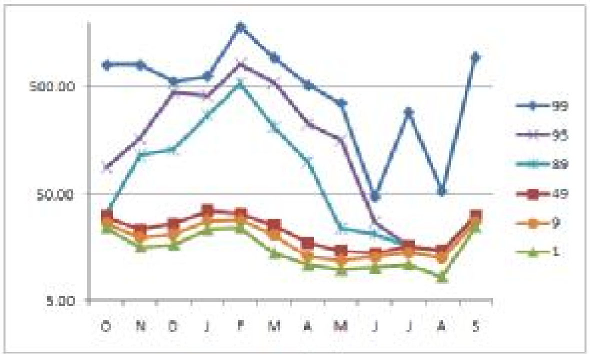
DWA (2010a): Hydrological inputs for the Reserve determination study for selected water resources in the Vaal Water Management Area. Report no: RDM/C000/01/CON/0607. Pretoria, South Africa.

APPENDIX A:

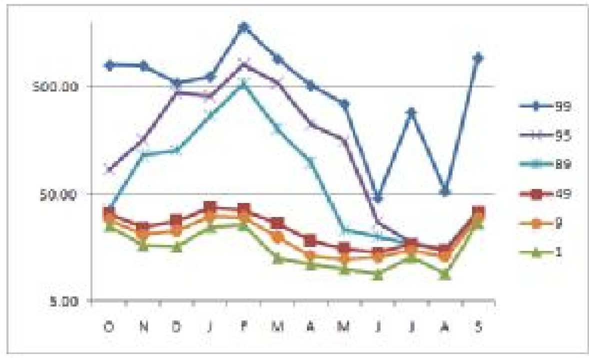
COMPARISON OF OPERATIONAL SCENARIOS ON

FLOWS AT EWR SITES

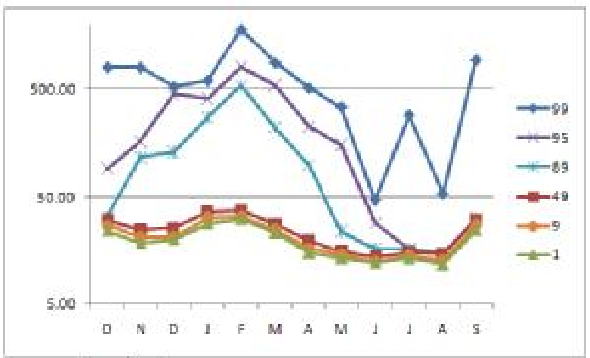
EWR 16, Vaal River at Bloemhof Dam



NEW PRESENT DAY (Sc 1)

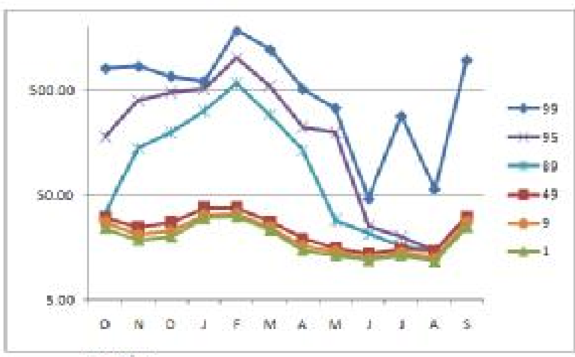


REF

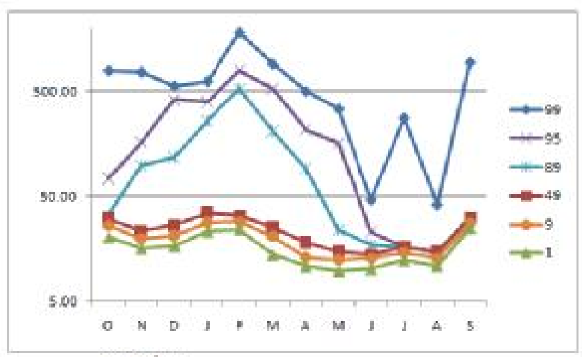


Scenario 4

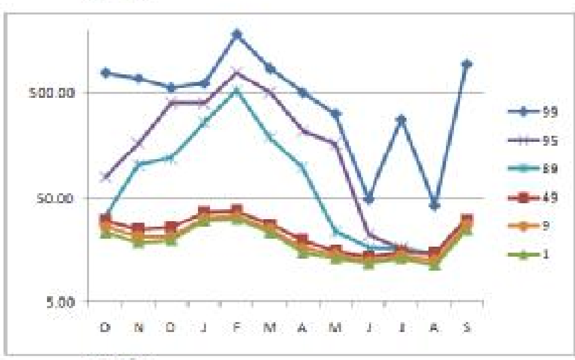
Scenario 5



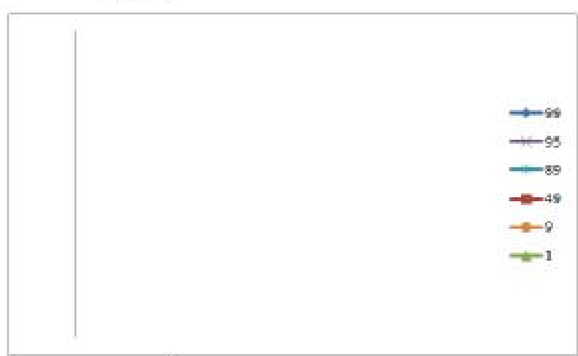
Scenario 6



Scenario 7

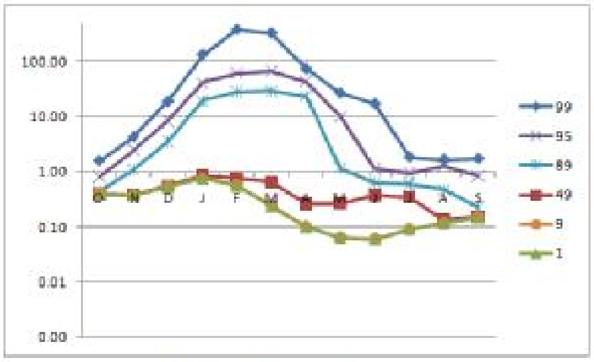


Scenario 8

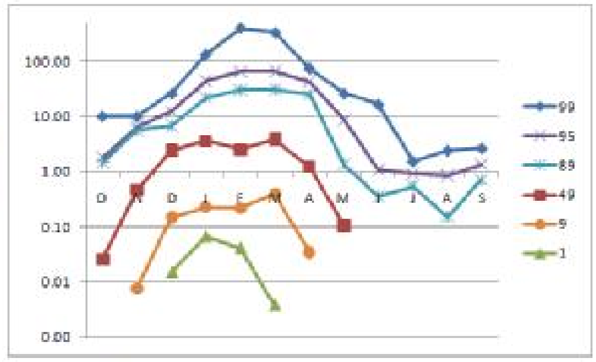


0

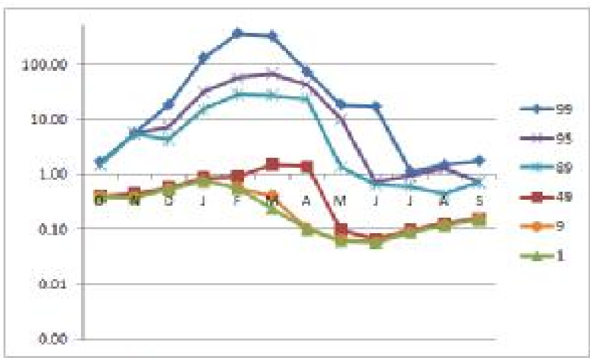
EWR 17, Harts River at Lloyds Weir



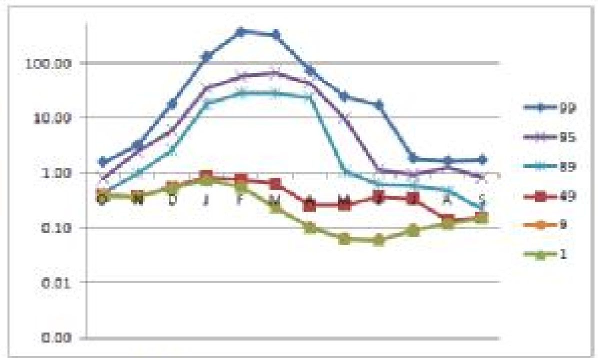
NEW PRESENT DAY (Sc 1)



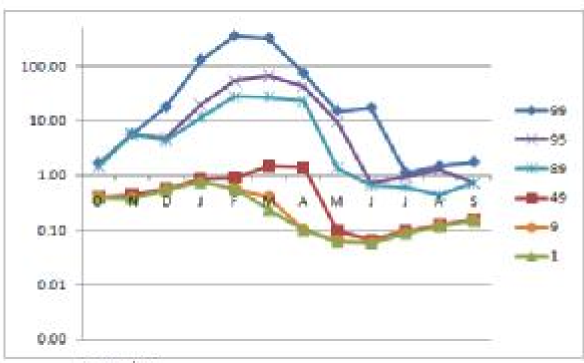
REF



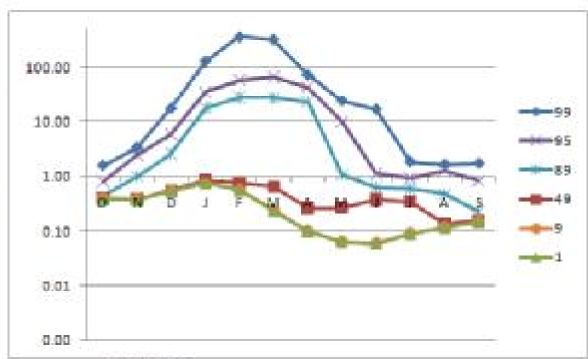
Scenario 4



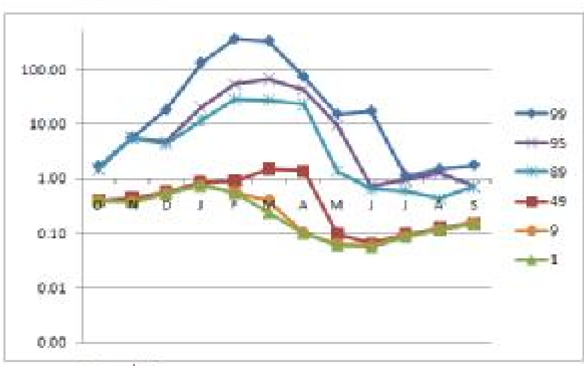
Scenario 5



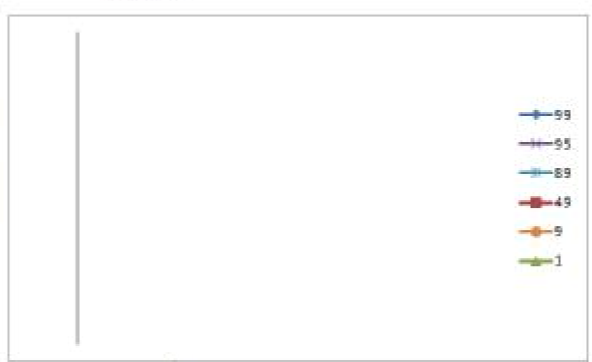
Scenario 6



Scenario 7

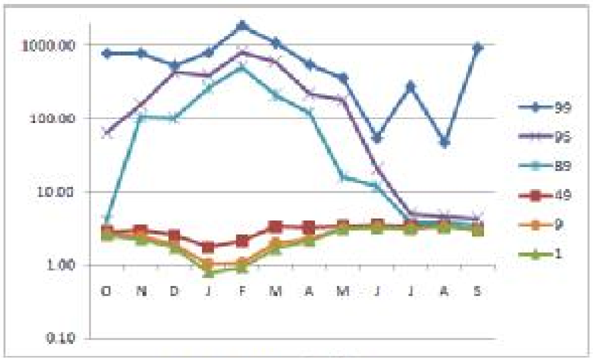


Scenario 8

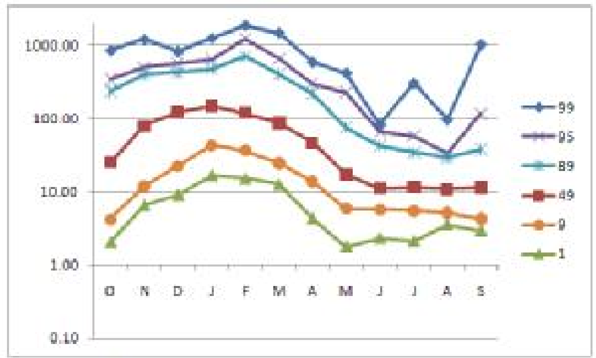


0

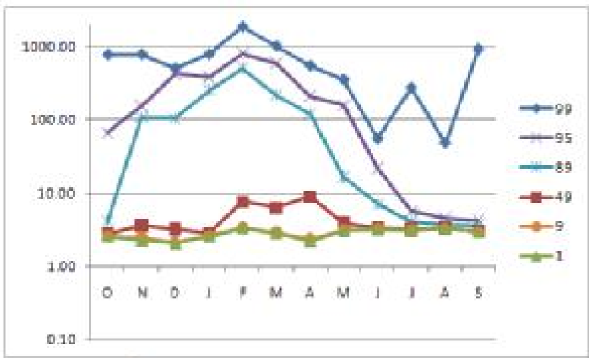
EWR 18, Vaal River at Schmidtsdrift



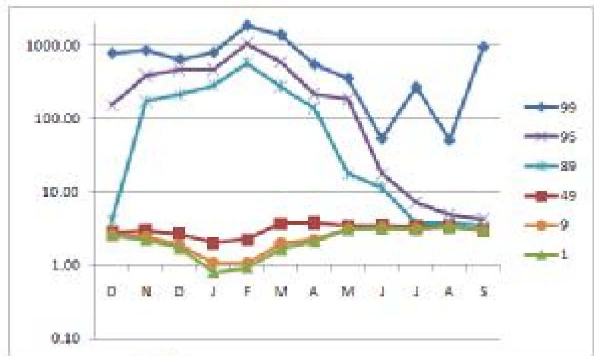
NEW PRESENT DAY (Sc 1)



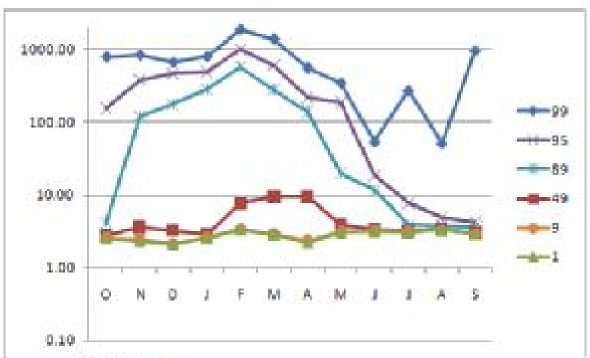
REF



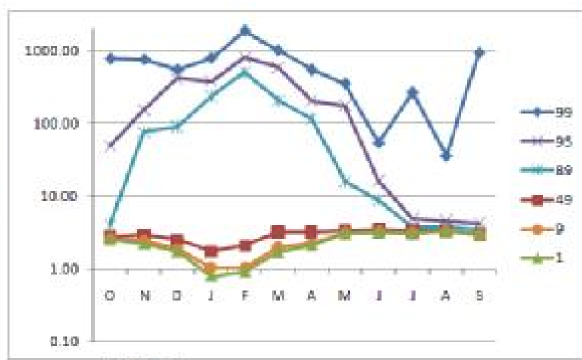
Scenario 4



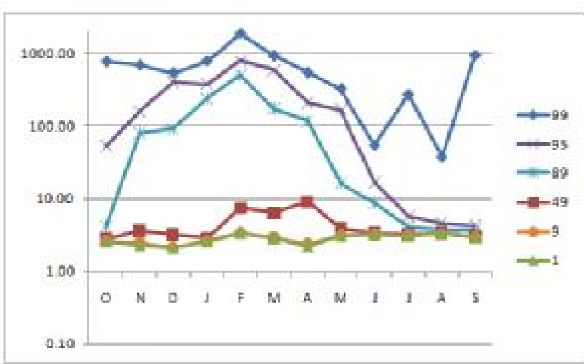
Scenario 5



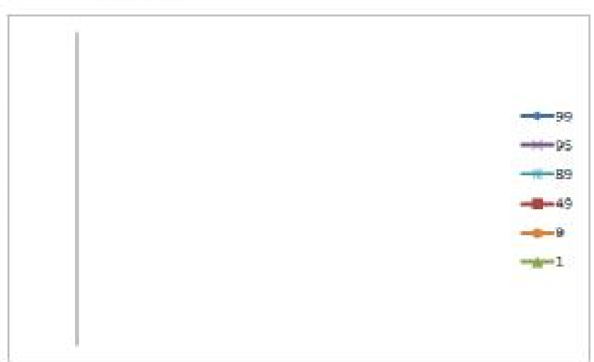
Scenario 6



Scenario 7

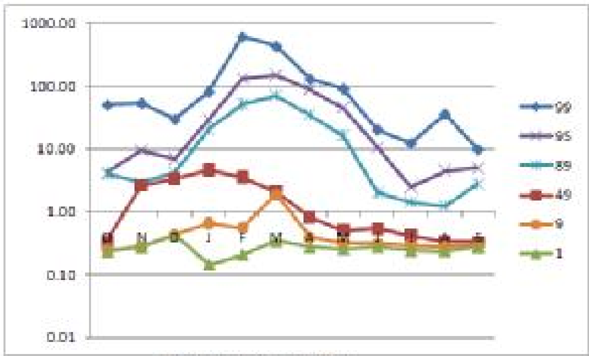


Scenario 8

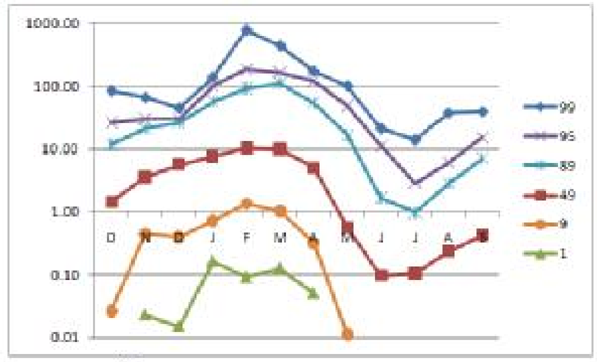


0

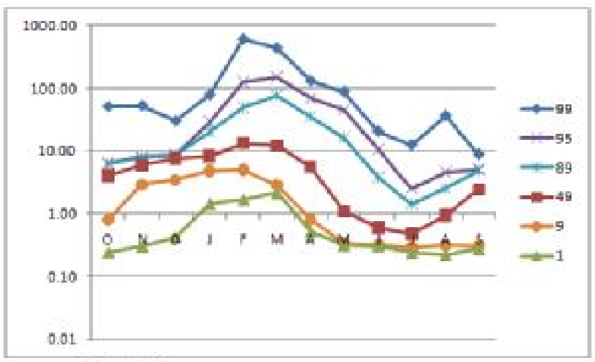
EWR 19, Riet River at Lilydale Lodge



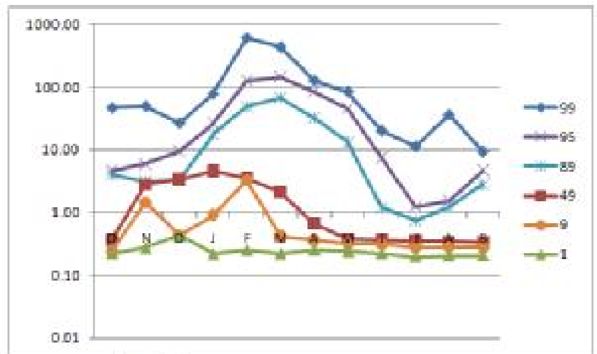
NEW PRESENT DAY (Sc 1)



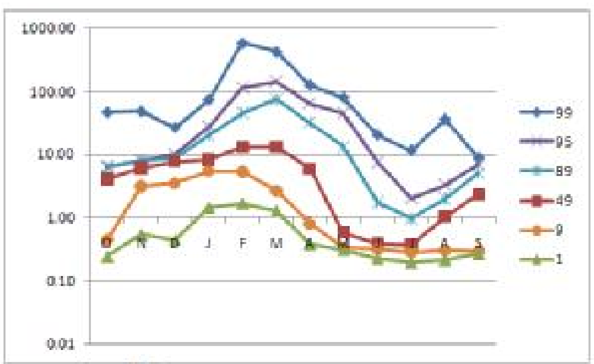
REF



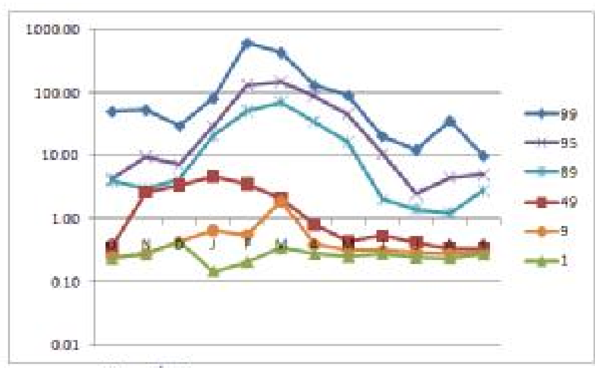
Scenario 4



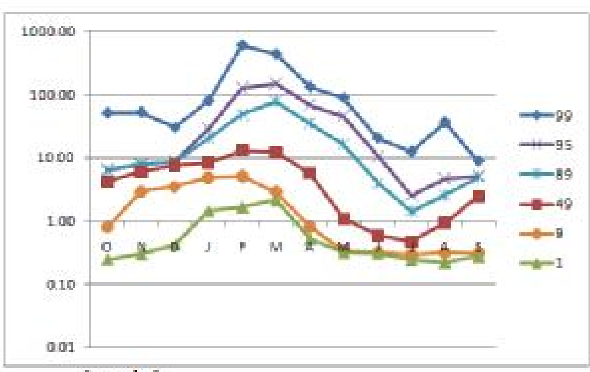
Scenario 5



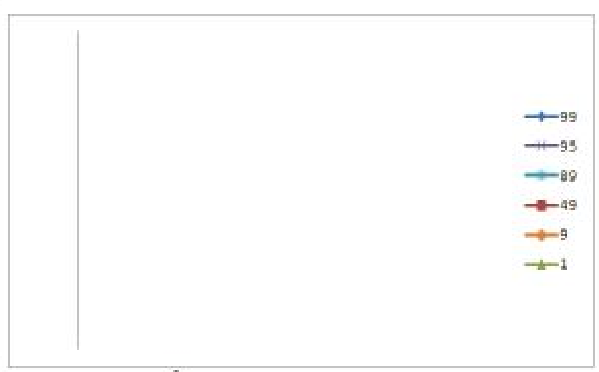
Scenario 6



Scenario 7



Scenario 8



0