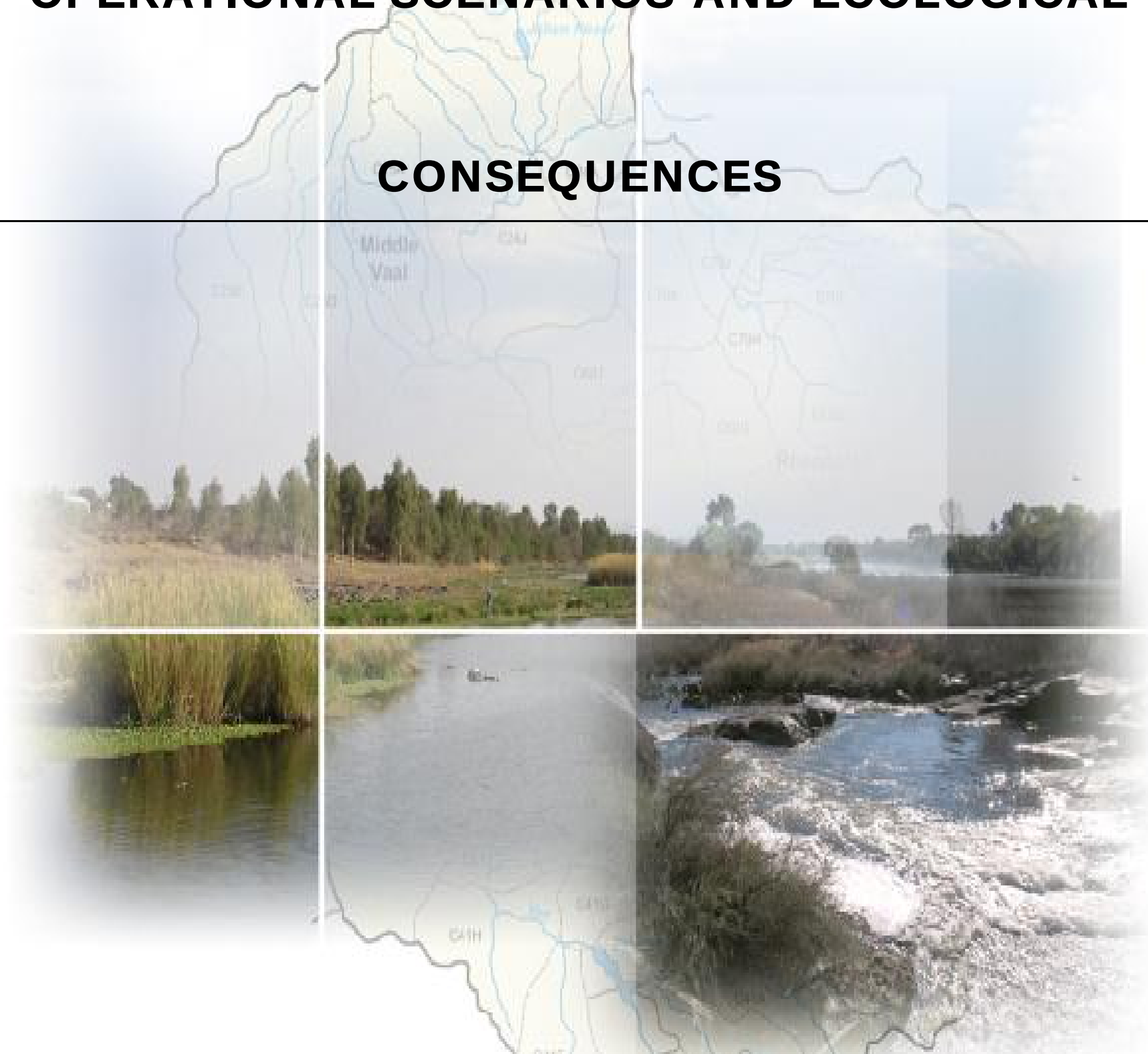
COMPREHENSIVE RESERVE DETERMINATION

INTEGRATED VAAL RIVER SYSTEM

SURFACE WATER

OPERATIONAL SCENARIOS AND ECOLOGICAL CONSEQUENCES



TECHNICAL COMPONENT: MIDDLE VAAL

REPORT NO.: RDM/WMA9 C000/01/CON/0310

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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 Middle Vaal Water Management Area (WMA), North West Province. The purpose of the Comprehensive Reserve Determination Study for the selected water resources of the Middle 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 Middle Vaal WMA forms part of the integrated Vaal River System, and falls within the C drainage region of South Africa. The Middle 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 Middle Vaal WMA covers a catchment area of 52 563 km^2, and includes parts of the Free State and North-West Provinces. It is situated in the north-western part of the country and forms part of the Orange River watercourse. The Vaal River flows in a westerly direction to the Lower Vaal WMA. It is the middle WMA within the Vaal River System, with water being transferred *via* the Vaal River through this WMA to Bloemhof Dam, from the Upper Vaal WMA to the Lower Vaal WMA. The WMA consists of the C24, C25, C41, C42, C43, C60 and C70 tertiary catchments.

The surface flow of the Vaal River, most of which originates in the Upper Vaal WMA, represents the bulk of the surface water in the Middle Vaal WMA. The Vaal River is fed by a number of tributaries of which the most significant are the Renoster, Schoonspruit, Vals and Vet Rivers. Vlei areas occur along the lower Vet River and in the upper Schoonspruit catchment. The surface water flows that originate within the WMA are highly seasonal and intermittent.

This report provides the results of the Ecological consequences of proposed operational flows in the rivers of the Middle 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 Eastern Sub-system. Includes proposed Polihali Dam and conveyance infrastructure. Includes proposed re-use of mine water. Includes projected possible transfer to the Crocodile catchment.	Key scenarios. Includes most likely future developments and illustrates resulting flows at EWR sites. NO EWRs were included as a demand in the system. Basically, this is the WHAT IF scenarios, i.e., what if we manage the system in this manner without providing EWRs – will the EcoStatus change and if so, how much.
6	2020	Included	Based on Sc 5. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 5 and Sc 4.
7	Full utilization (Future development scenario)	Excluded	Scenario representing the full utilization of available water. Based on current infrastructure. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system.	This is also a future scenario, but brings in new developments apart from the VRESSAP pipeline. Full utilisation means that there is allocated water, or water available in dams, which have not been used yet.

Sc No	Dev Level	EWR Status	Scenario description	Reasoning
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 consequences

Main Stem	**Sc 1 PD REC**	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
12 Vermaasdrift	**D**	**C**	**C/D**	**C/D**	**D**	**C**
13 Regina	**C/D**	**C**	**C**	**C**	**C**	**C**
Tributaries						
14 Vals	**C/D**	**C/D**	**D**	**C/D**	**C/D**	**C/D**
15 Vet	**D/E**	**D**	**D/E**	**D**	**D/E**	**D**

Significant deviations between Scenario 7 and 8 were found for EWR R1 (Renoster), 14 (Vals), V1 and V2 (Vet). 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:

- Little impact on Ecosystem goods and services – negative impact at Vals River for Scenario 5
- 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

A summary of ecological consequences per scenario are included for the main stem (Figure A) and the tributaries (Figure B), and an overview for the Lower Vaal EWR sites (Figure C).

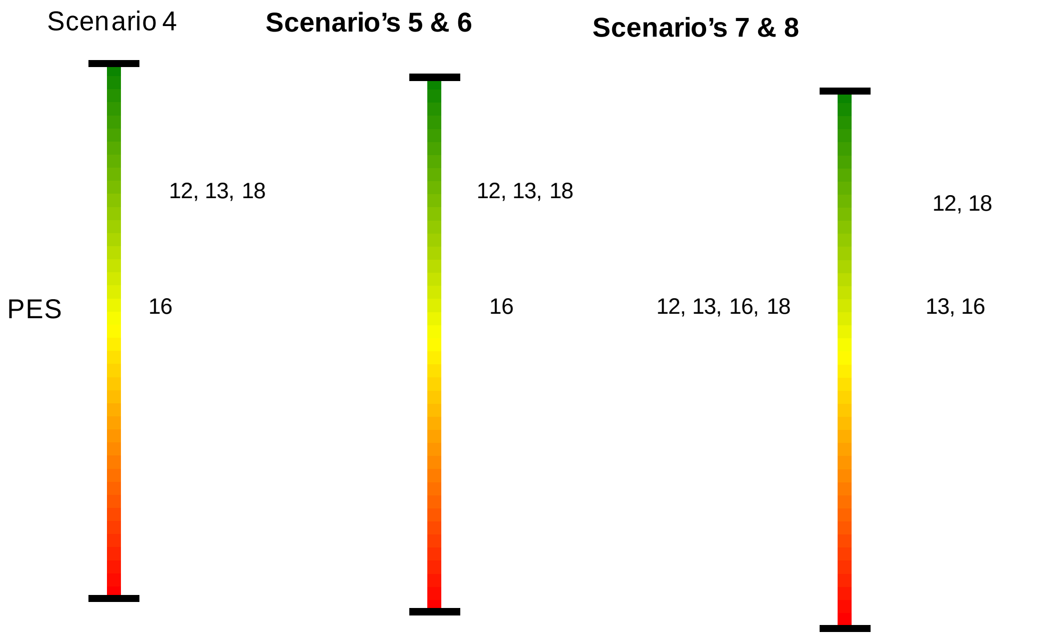

Figure A: Summary of ecological consequences per scenario for the main stem of the Vaal EWR sites

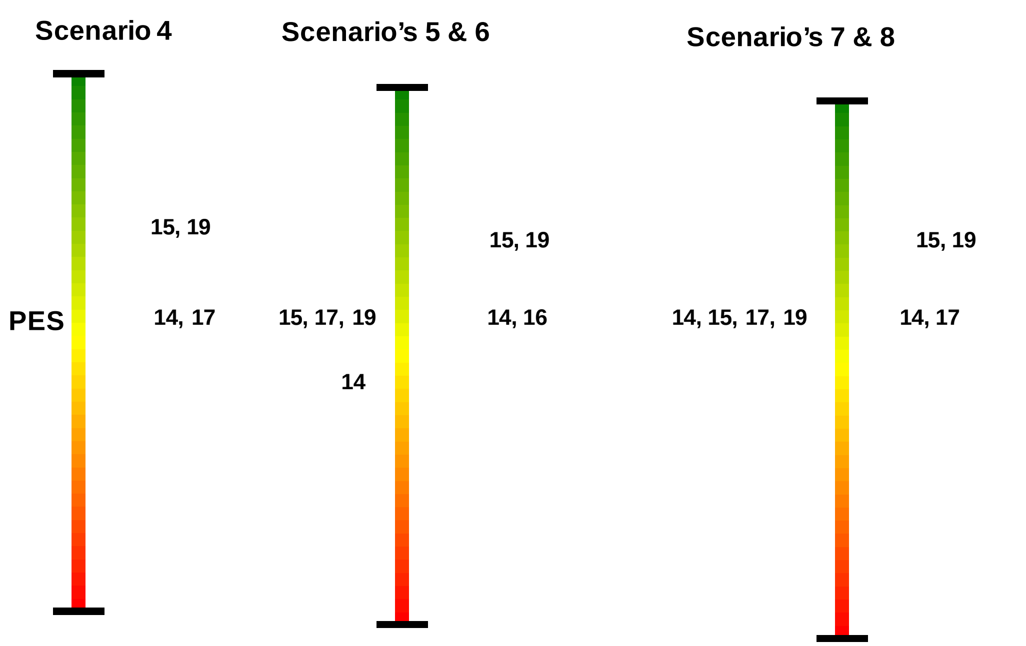

Figure B: Summary of ecological consequences per scenario for the tributaries of the Vaal EWR sites

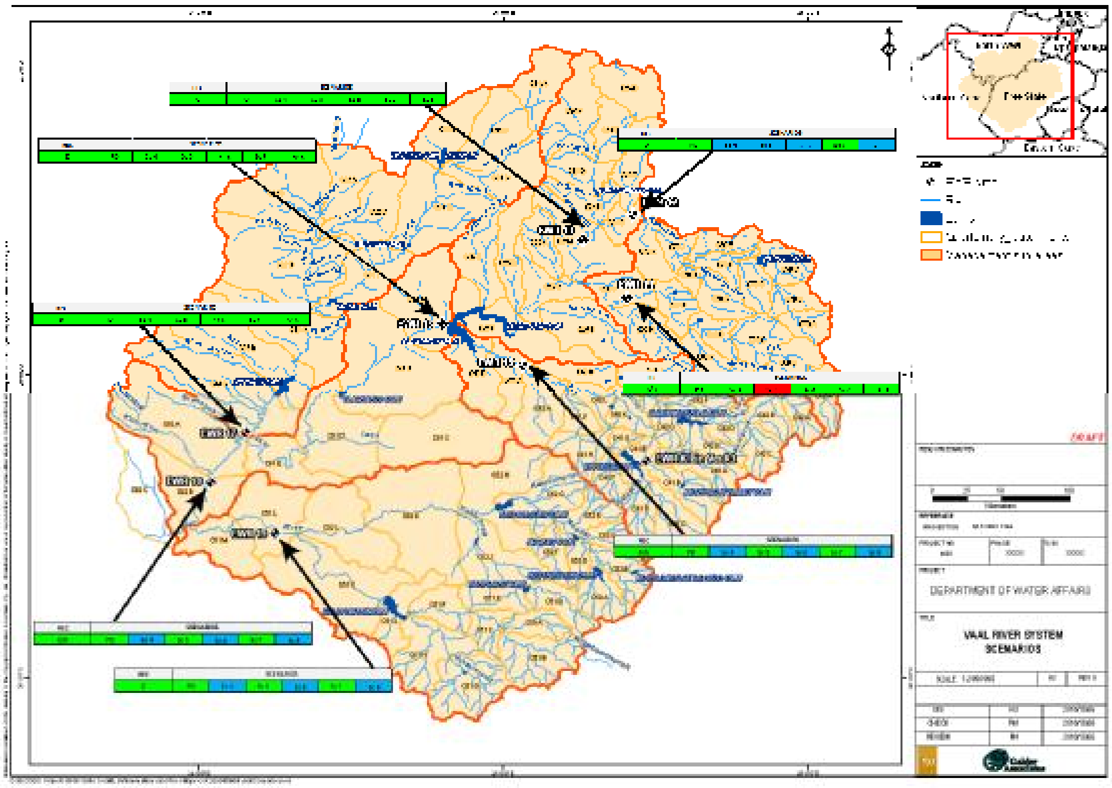

Figure C: Summary of the Ecological Consequences for the Middle Vaal Catchment scenario's.

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
12 Vaal (Regina)	Sign off for PES=REC=D
13 Vaal (Vermaasdrift)	Sign off for PES=REC=C
14 Vals	Sign off for PES=REC=C/D
15 Vet	Sign off for REC=D (instream PES) with recommendation that no more abstractions upstream are allowed as the EWRs below Erfenis and Allemanskraal Dams are currently not being met. It was noted that the Reserve at the sites that were extrapolated by WRP on the Sand and upper Vet River would be unrealistic as this would require 70% reduction in irrigation. The management of this system should be investigated in more detail (e.g if the EWR on the Sand and Vet are not met, how will this affect the main stem, can these requirements be provided by other tributaries? Trade-off options should be explored here.

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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 Middle Vaal catchment area.

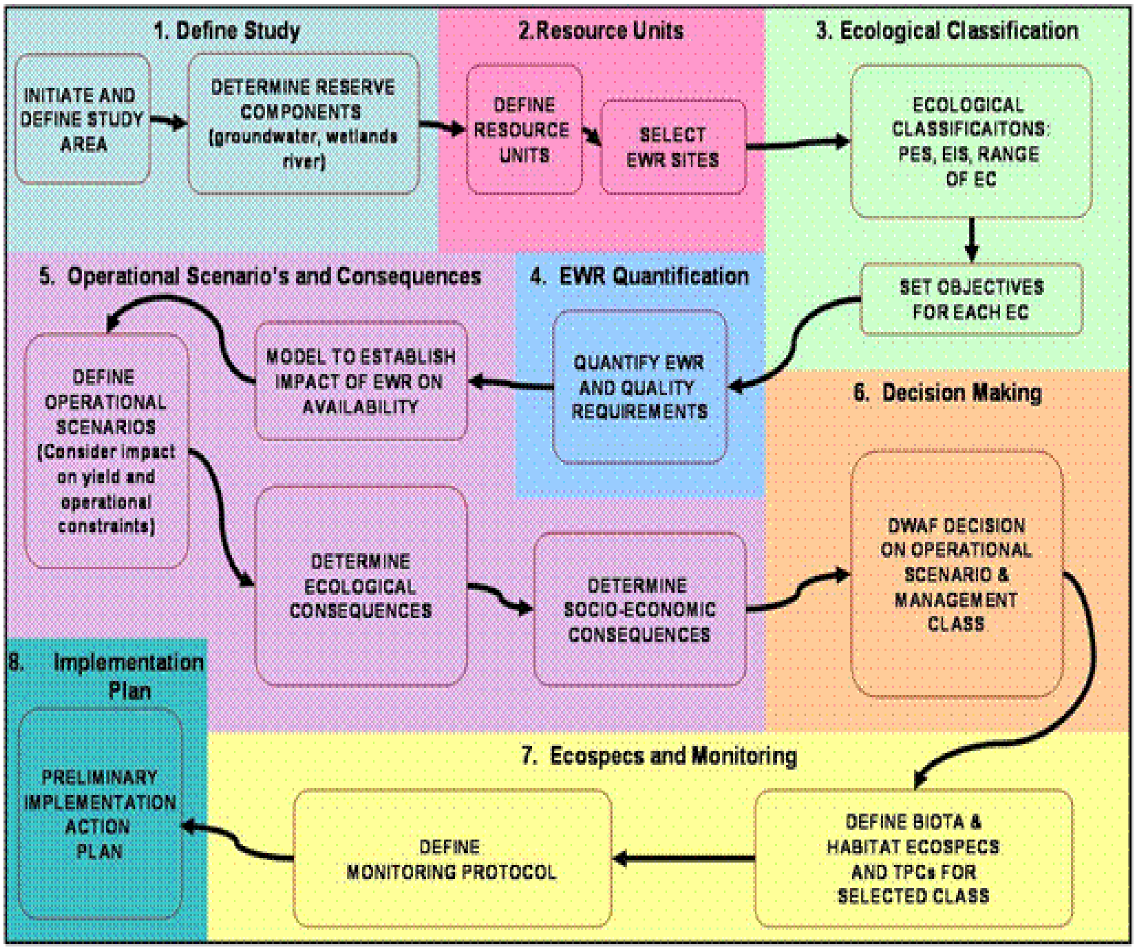


Figure 1.1: Generic procedure for the determination of the ecological Reserve

1.2 Study area

The Middle Vaal WMA forms part of the integrated Vaal River System, and falls within the C drainage region of South Africa. The Middle 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 Middle Vaal WMA covers a catchment area of 52 563 km^2, and includes parts of the Free State and North-West Provinces. It is situated in the north-western part of the country and forms part of the Orange River watercourse. The Vaal River flows in a westerly direction to the Lower Vaal WMA. The WMA consists of the C24, C25, C41, C42, C43, C60 and C70 tertiary catchments.

The surface flow of the Vaal River, most of which originates in the Upper Vaal WMA, represents the bulk of the surface water in the Middle Vaal WMA. The Middle Vaal River is fed by a number of tributaries of which the most significant are the Renoster, Schoonspruit, Vals and Vet Rivers. Vlei areas occur along the lower Vet River and in the upper Schoonspruit catchment. The surface water flows that originate within the WMA are highly seasonal and intermittent.

Selected Ecological Water Requirement (EWR) sites are indicated in Table 1.1 and in Figure 1.2.

Table 1-1: Selected EWR sites for the Middle Vaal catchment

EWR Site number	EWR site name	River	National RHP site	Coordinates	Ecoregion (Level II)	Geomorphic zone	Altitude (m)	RU	Quaternary catchment
EWR12	Vaal River: Vermaasdrift	Vaal	C2-Vaal Orkne	S26.93615 E26.85025	11.01	E: Lower Foothills	1348	MRU Vaal F	C24A
EWR13	Vaal River: Regina bridge	Vaal	C2-Vaal Orkne	S27.10413 E26.52185	11.08	E: Lower Foothills	1285	MRU Vaal G	C24J
EWR14	Vals River: Proklameersdrift	Vals	C6Vals-Prokl	S27.48685 E26.81320	11.07	E: Lower Foothills	1400	MRU Vals B	C60J/C60G
EWR15	Vet River: Fisantkraal	Vet	C4-Vet-Hoops C4-Vet-Erfen	S27.93482 E26.12569	11.08	E: Lower Foothills	1247	MRU Vet C	C43A
RE-EWR3	Klein-Vet, just downstream of Winburg	Klein Vet	C4GVet-V4	S28.564708 E26.943946	11.03	E: Lower Foothills	1367 From Google	MRU Vet A	C41A

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 Middle Vaal.
Section 5: Recommendations

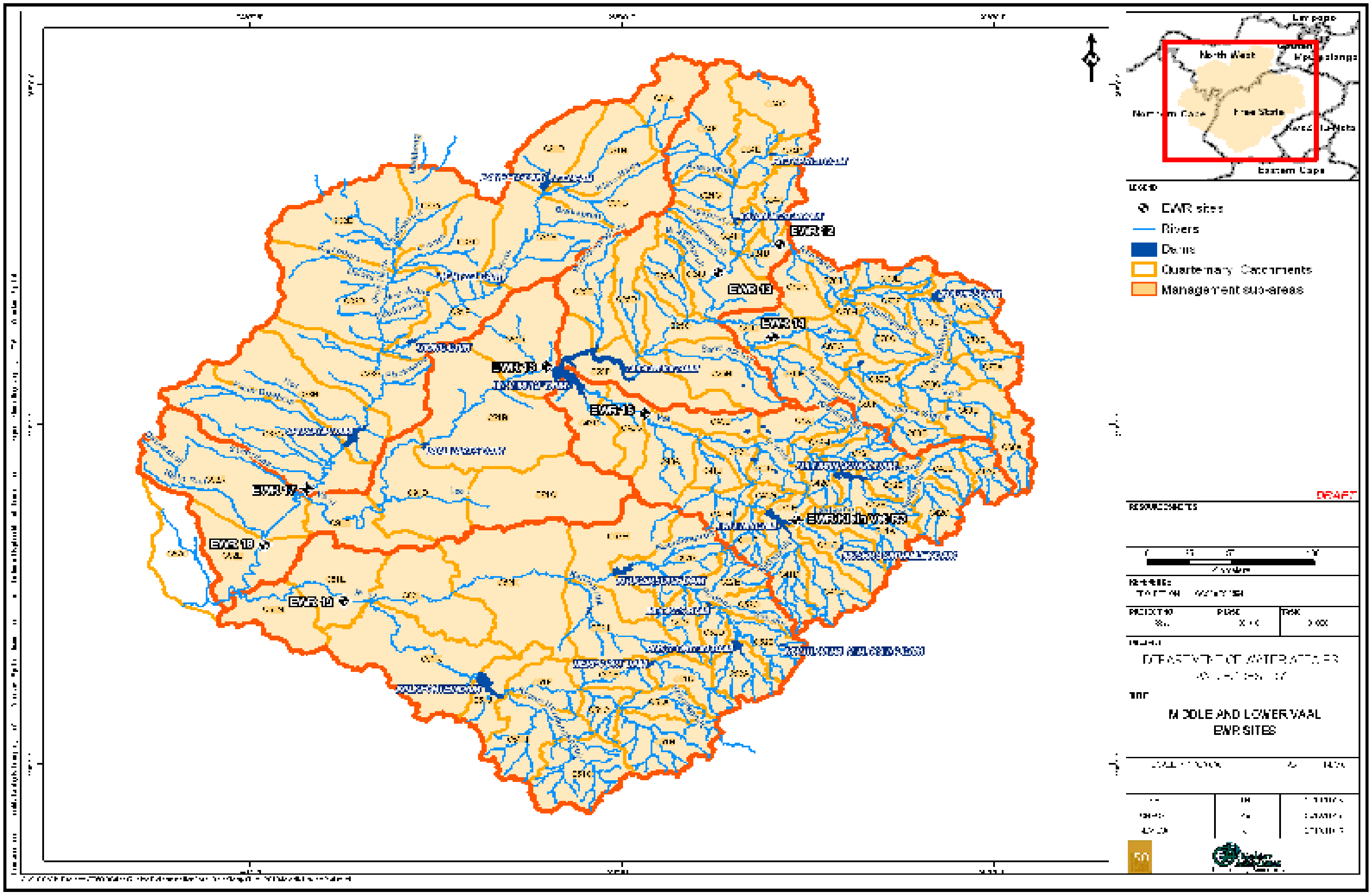


Figure 1.2: Resource Units and selected EWR sites for the Middle Vaal

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 (DWA, RDM/ WMA09/10C000/ 01/CON/0410).

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 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.

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.	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
			Includes proposed re-use of mine water. Includes projected possible transfer to the 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 12: VERMAASDRIFT (VAAL RIVER)

4.1.1 Catchment development and impacts

This site is upstream of the Klerksdorp Orkney Stilfontein and Hartbeesfontein (KOSH) mining area in the Middle Vaal. The flows in this reach of the middle Vaal have been regulated since the Vaal River Barrage was completed in 1919. Since the completion of the Vaal Dam in the 1940's this reach of the river has been further regulated. Currently the Vaal Dam releases extra water in winter and this is used for the dilution of salts in the middle and lower Vaal. Furthermore, this reach's flows are further regulated due to releases of water for the Vaal Harts Irrigation scheme that has been operational since the last 1930's. As a consequence of this regulation, this reach of the Vaal River has increased winter base flows and the summer floods are reduced due to the upstream dams.

The water quality at EWR 12 is impacted by the following:

- The salinity and nutrient impacts from the Klip, Riet and Suikerbosrand and Waterval Rivers are combined in the Vaal Barrage and released downstream to this EWR site.

- High salinity due to mine water decants from Witwatersrand and Mooi River (Wonderfonteinspruit).

- There is an increasing trend in phosphate concentrations. Potential for algal blooms is 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 and Chlorophyll-*a*.

- High ammonia values due to waste water (treated and untreated) being released from the Vaal Barrage and Mooi River.

- 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.

4.1.2 Graphs of flow scenarios

Figure 4.1 and 4.2 illustrates the stress requirements and stress points required for the REC, present day (demand) and the operational scenarios analysed for February (wet season) and August (dry season) at EWR site 12.

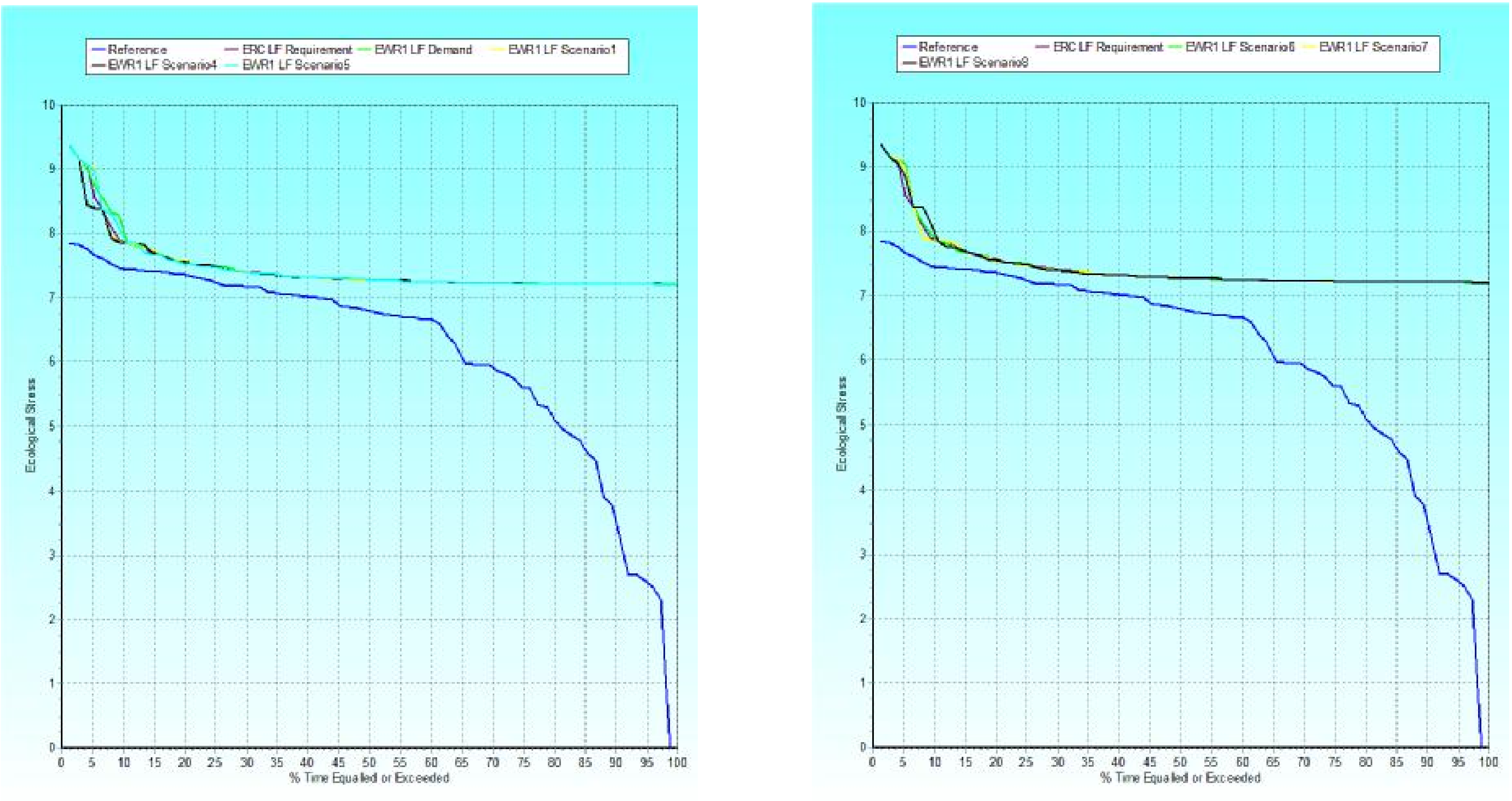
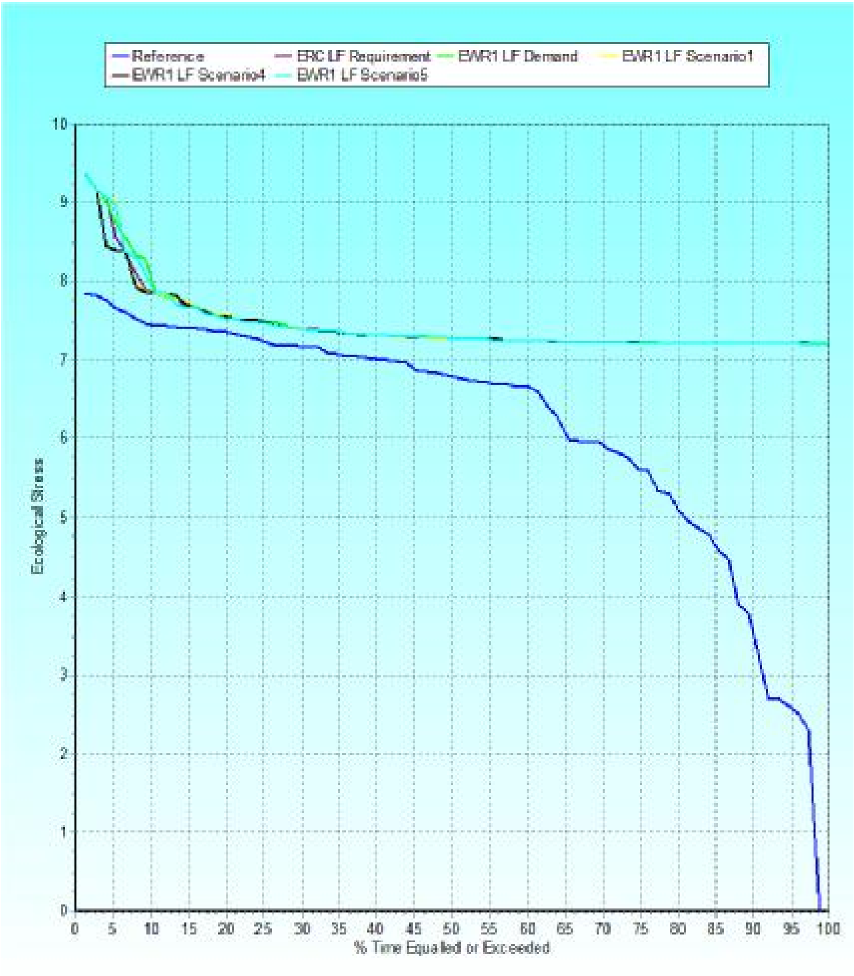


Figure 4.1: Stress curves for the dry season for operational scenarios (1, 4 & 5, and 7 & 8) at EWR site 12



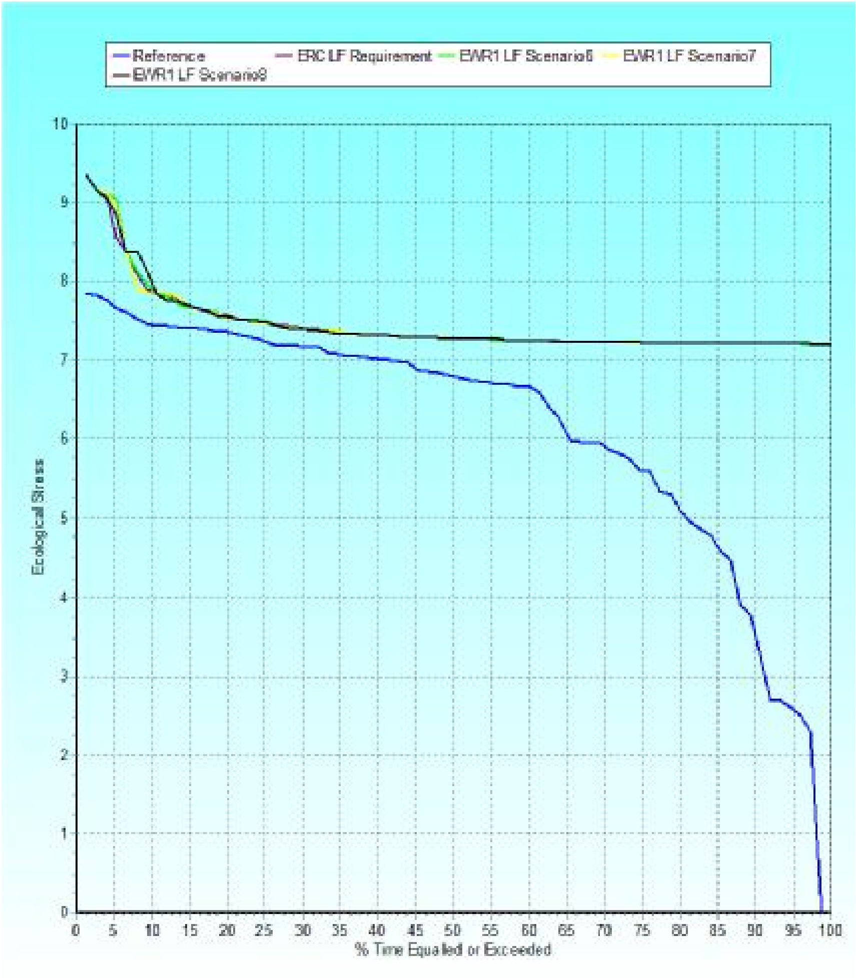


Figure 4.2: Stress curves for the wet season for operational scenarios (1, 4 & 5, and 7 & 8) at EWR site 12

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

The site and reach are bedrock influenced – the upstream islands and riffle areas created by bedrock outcrops (probably dolerite dykes), and the angular boulders and cobbles of the channel bed are largely locally derived (i.e. they are in situ, not transported, bed material). The PES is in a C/D due to reduced sediment supply and transport potential, as well as to a lesser extent system connectivity.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	-	C/D	Elevated baseflows	Reduced floods and baseflows have reduced scour and thus caused fining of the channel bed.
Wet season baseflows and small and moderate floods have been reduced from natural within this reach, whilst dry season baseflows are elevated. This has degraded the in-channel condition of the river through reduced scour and bed activation events. Large dams far upstream have also likely reduced some of the sediment supply, but large tributaries do reinstate some of this. Several intra-annual (50 m^3/s) floods, as well as larger 100 (1:1) and 340 (1:2) m^3/s floods, are required to scour fines and mobilise gravels to maintain the in-channel condition. An increased frequency of these floods will improve the in-channel condition.					

Scenario 4 and 8

Scenario 4 reinstates some of the wet season baseflows, but this is not expected to have a significant impact on the geomorphology or cause any change from the present EC. Scenario 8 proposes reduced wet season floods and increase wet season baseflows. Dry season flows will remain the same as PD.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4, 8	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	-	C/D	No change to dry season baseflows.	Very slight increase in the wet season baseflows.
Very little change in geomorphology is expected under this scenario, since these would only very slightly increase the mobilisation and scouring of					

bed sediments.

Scenario 5 and 6

Scenarios 5 and 6 both propose reduced baseflows in the dry season and increased baseflows (especially scenario 6) and small floods in the wet season. These changes tend towards a more natural flow pattern, and these scenarios have been evaluated together.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 5, 6	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	-	C	Reduced dry season baseflows may allow for some minor seasonal accumulations of fines in the channel.	Increased baseflows and small floods. This should increase maintenance of the channel by ensuring sediment flushing.
The provision of higher baseflows and moderate floods in summer will inundate the lower banks and terraces; scour the channel; deepen pools; activate the gravels and reduce embeddedness.					

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

Present day, scenarios 4, 7 and 8

As these scenarios do not supply EWR 12 with extra water the results of this scenario are similar to the present day.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AECa	Sc 1,4,7,8	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
E	D	D	E	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	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 Klip, Riet and

				impacts from the Klip, Riet and Suikerbosrand River Waterval are combined in the Vaal Barrage and released downstream to this EWR site. High salinity due to mine water decants from Witwatersrand and Mooi River (Wonderfonteinspruit). 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 and Mooi River. 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.	Suikerbosrand River Waterval are combined in the Vaal Barrage and released downstream to this EWR site. Runoff from the Mooi River (Wonderfonteinspruit) also adds to the salt concentrations. The summer concentrations of salts are similar to those of winter despite there being more than 8 times the flows in summer. This increased salt load is dues to diffuse salts from the mines in the Witwatersrand and the Mooi River (Wonderfonteinspruit). 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. 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 12 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

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 5,6**	**DRY SEASON**	**WET SEASON**

PHYSICO-CHEMICAL					
C	B	D	D	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 Klip, Riet and Suikerbosrand River Waterval are combined in the Vaal Barrage and released downstream to this EWR site. High salinity due to mine water decants from Witwatersrand and Mooi River (Wonderfonteinspruit). High salinity due to mine water decants from Witwatersrand but 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 in winter with slightly increased flows. Scenario 5 includes projected possible transfer to the Crocodile catchment which would reduce the nutrients and salt into the Vaal Barrage. The diffuse origin of salts will not be impacted by this reuse strategy. 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	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 Klip, Riet and Suikerbosrand River Waterval are combined in the Vaal Barrage and released downstream to this EWR site. Runoff from the Mooi River (Wonderfonteinspruit) also adds to the salt concentrations. The summer concentrations of salts are similar to those of winter despite there being about 10 times the flows in summer. 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 to the Crocodile catchment which would reduce the nutrients and salt into the Vaal Barrage. These scenarios result in a lower salt concentration in summer with increased flows. 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 in winter and summer with slightly 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 12.

There will be 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 at Vermaasdrif on the Vaal River consists of a relatively broad area of flow with moderately sloping banks, on which vegetation would easily colonise and recruit. The site selection at this site is, however, not ideal as the vegetation in the area has been disturbed by the construction of the bridge at Vermaasdrif and is not representative of the vegetation along this reach of the Vaal River. For this reason the vegetation surveyed for the purposes of this study was the vegetation at the transect site itself as well as vegetation further upstream of the site. Land use in the area is predominantly agricultural and pastoral farming.

The marginal zone at Site EWR 12 is dominated by graminoid and cyperoid species including *Brachiaria marlothii, Cyperus denudatus, Cyperus longus, Echinochloa holubii, Panicum coloratum, Pycreus mundii, Sporobulus africanus, Sporobulus fimbriatus, Azolla filiculoides, Eichhornia crassipes* and *Myriophyllum spicatum* while the lower non-marginal zone is dominated by mainly by graminoids and herbaceous species such as *Agrostis lachnantha, Andropogon eucomus, Chloris virgata, Cynodon dactylon, Phragmites australis, Eragrostis plana, Hemarthria altissima, Imperata cylindrical , Ischaemum fasciculatum, Miscanthus junceus, Paspalum distichum, Andropogon appendiculatus, Brachiaria marlothii, Cyperus denudatus, Cyperus longus, Echinochloa holubii, Eragrostis obtuse, Eragrostis porosa, Fimbristylis ferruginea, Panicum coloratum, Pycreus mundii, Sporobulus africanus, Sporobulus fimbriatus, Urochloa panicoides, Persicaria lapathifolia, Alternanthera sessilis, Barleria macrostegia, Corchorus asplenifolius, Equisetum ramosissimum, Galium capense, Hibiscus pusillus, Lobelia angolensis, Nidorella resedifolia, Persicaria amphibian*and the upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Ziziphus mucronata, Rhus lancea, Gymnosporia buxifolia, Rhus pyroides, Diospyros lycoides, Ehretia rigida, Grewia flava, Asparagus laricinus* and *Asparagus sauveolens.*

Current status: The area is currently considerably degraded due to the introduction of a number of exotic species. The exotic species in the area, in fact, contribute to a total of almost 50% of the total number of species identified during the surveys. Furthermore, the lack of stochastic events, such as fire and flooding, are causing homogenization of the riparian vegetation at site EWR 12.

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.

Scenario 1

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C	C	D	C	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	AEC a	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
C	C	D	C	The flows anticipated for scenario 4 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 4 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 4 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 4 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
C	C	D	C	The flows anticipated for scenario 5 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 5 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 5 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 5 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
C	C	D	C	The flows anticipated for scenario 6 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 6 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 6 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 6 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
C	C	D	C	The flows anticipated for scenario 7 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 7 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 7 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 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					
C	C	D	C	The flows anticipated for scenario 8 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 8 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 8 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 8 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Macroinvertebrates

Present day

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/B	D	C/D	Sufficient Vegetation biotope. Some stones in current. Stones biotope consisted of mostly unmovable rocks.	Flow slightly higher than dry flow season. More vegetation available for habitat. Glow over rocks faster and deeper.

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/B	D	C	Slightly less stress in the dry period of the dry season. In the wetter period of the dry season there is more flow, which will result in less stress. This will also result in better water quality in the dry season.	Less stress in the dry period of the wet season. More flow during the whole wet season which will result in higher velocity, deeper water and better water quality,

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/B	D	C/D	Sufficient Vegetation biotope. Some stones in current. Stones biotope consisted of mostly unmovable rocks.	Flow slightly higher than dry flow season. More vegetation available for habitat. Glow over rocks faster and deeper.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/B	D	C/D	Sufficient Vegetation biotope. Some stones in current. Stones biotope consisted of mostly unmovable rocks.	Flow slightly higher than dry flow season. More vegetation available for habitat. Glow over rocks faster and deeper.

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/B	D	C/D	Sufficient Vegetation biotope. Some stones in current. Stones biotope consisted of mostly unmovable rocks.	Flow slightly higher than dry flow season. More vegetation available for habitat. Glow over rocks faster and deeper.

Scenario 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 8	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C/B	D	C	Slightly less stress in the dry period of the dry season. In the wetter period of the dry season there is more flow, which will result in less stress. This will also result in better water quality in the dry season.	Slightly less stress in the dry period of the wet season. More flow during the whole wet season which will result in higher velocity, deeper water and better water quality,

Fish

The expected fish assemblage is composed of species with a high preference for slow deep and slow shallow velocity-depth classes. The only exception is *Labeobarbus aeneus* (Smallmouth yellowfish) which prefers fast shallow habitats. Three of the expected species (*A. sclateri, L. aeneus* and *L. capensis*) are moderately intolerant of no-flow conditions. The remainder of the expected fish assemblage are either moderately tolerant or tolerant of no-flow conditions. All of the expected fish species show a high level of preference for specific cover elements. Four of the expected species have a high preference for substrate cover. All of the expected fish species are either moderately tolerant or tolerant of modified water quality. The majority of the expected fish species have a requirement for movement within fish habitat segments/ within reaches. Three of the expected species have a requirement for movement between fish habitat segments/ reaches. The likelihood exists that some of the other fish species are still present at the site but at very low abundances.

Of the 9 expected fish species only 4 were recorded during the low flow and high flow surveys. Two alien invasive fish species were recorded at the site namely *Gambusia affinis* and *Cyprinus carpio*. The Present Ecological State (PES) of the site was classified as a Class D. This can be attributed primarily to the absence of 5 of the expected indigenous fish species from the assemblage during both surveys (*A. sclateri, B. anoplus, L. umbratus. T. sparrmanii* and *L. kimberleyensis*). It is possible that these species may still be present at the site and within the reach but in such low abundances that they were not recorded during either of the surveys.

Ecological stress duration curve for scenario 4 matches that of scenario 1 (present day) very closely for both the wet and the dry seasons. Scenario 5 is associated with a slight improvement in water quality however the fish assemblage at site EWR12 is moderately tolerant or tolerant of modified water quality and small decreases in salt loads are unlikely to result in a significant improvement in fish assemblage. No changes are expected in the fish assemblage.

None of the predicted scenarios result in an improvement in PES.

<table>
<tr><th colspan="4">EC</th><th colspan="2">ECOLOGICAL CONSEQUENCES</th></tr>
<tr><th>PES</th><th>REC</th><th>AEC a</th><th>1,4,5</th><th>DRY SEASON</th><th>WET SEASON</th></tr>
<tr><th colspan="6">Specialist inputs</th></tr>
<tr><td>D</td><td>C</td><td>C</td><td>D</td><td>Four of the eight expected fish species were recorded at the site during the dry season.</td><td>Only two of the 8 expected fish species were recorded at the site during the wet season. High flow levels hampered sampling efforts</td></tr>
<tr><td colspan="6">A PES of D was recorded at site EWR12 during scenario 1 (present day). This could be attributed primarily to the absence of 5 of the expected indigenous fish species from the site during both surveys.</td></tr>
</table>

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Austroglanis sclateri	**2.00**	**0.00**
Labeobarbus aeneus	**4.00**	**4.00**
Barbus anoplus	**5.00**	**0.00**
Clarias gariepinus	**4.00**	**4.00**
Labeo capensis	**4.00**	**4.00**
Labeo umbratus	**4.00**	**0.00**
Pseudocrenilabrus philander	**3.00**	**3.00**
Tilapia sparrmanii	**3.00**	**0.00**
Labeobarbus kimberleyensis	**4.00**	**0.00**

4.1.4 Summary of ecological consequences

The summary of the ecological categories for the operational scenarios at EWR 12 are provided in Table 4.1.

Table 4-1: Summary of ecological categories for operational scenarios at EWR site 12

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

The ecostatus and Recommended Ecological Category for EWR site 12 is a D. All the scenarios achieve the PES (and REC) to varying degrees. Scenarios 4, 5, 6 and 8 achieve an improved alternative category. Scenario 7 maintains the PES.

4.2 EWR 13: REGINA BRIDGE (VAAL RIVER)

4.2.1 Catchment development and impacts

This site is downstream of the Klerksdorp Orkney Stilfontein and Hartbeesfontein (KOSH) mining area as well as the Schoonspruit in the Middle Vaal. The flows in this reach of the middle Vaal have been regulated since the Vaal River Barrage was completed in 1919. Since the completion of the Vaal Dam in the 1940's this reach of the river has been further regulated. Currently the Vaal Dam releases extra water in winter and this is used for the dilution of salts in the middle and lower Vaal. Furthermore this reach's flows are further regulated due to releases of water for the Vaal Hartz Irrigation scheme that has been operational since the last 1930's. As a consequence of this regulation this reach of the Vaal River has increased winter base flows and the summer has seriously reduced baseflows and small floods have reduced scour and thus caused fining of the channel bed.

The water quality at EWR 13 is impacted by the following:

- The salinity and nutrient impacts from the Klip, Riet, Schoonspruit, Koekermoerspruit, Suikerbosrand, Waterval and Mooi Rivers (Wonderfonteinspruit) and generally the Vaal Barrage.

- There is an 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 and Chlorophyll-***a*** with seasonal variability.

- High ammonia values due to waste water (treated and untreated) being released from the Vaal Barrage, Mooi River and Schoonspruit.

- Occasional high metal values from mine water discharges.

- 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.

4.2.2 Graphs of flow scenarios

Figure 4.3 and 4.4 illustrates the stress requirements and stress points required for the REC, present day (demand) and the operational scenarios analysed for February (wet season) and August (dry season) at EWR site 13.

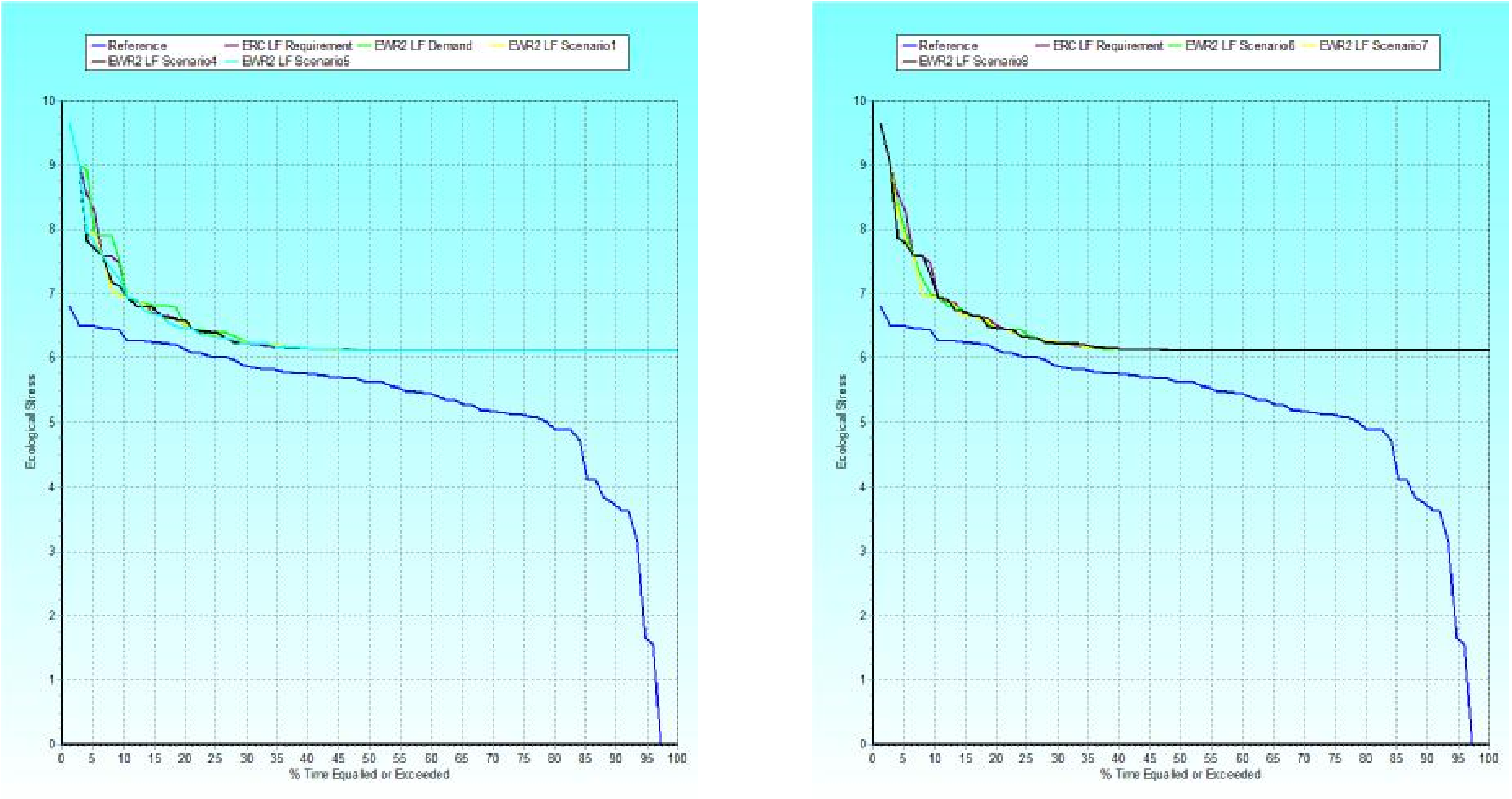


Figure 4.3: Stress curves for the dry season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 13

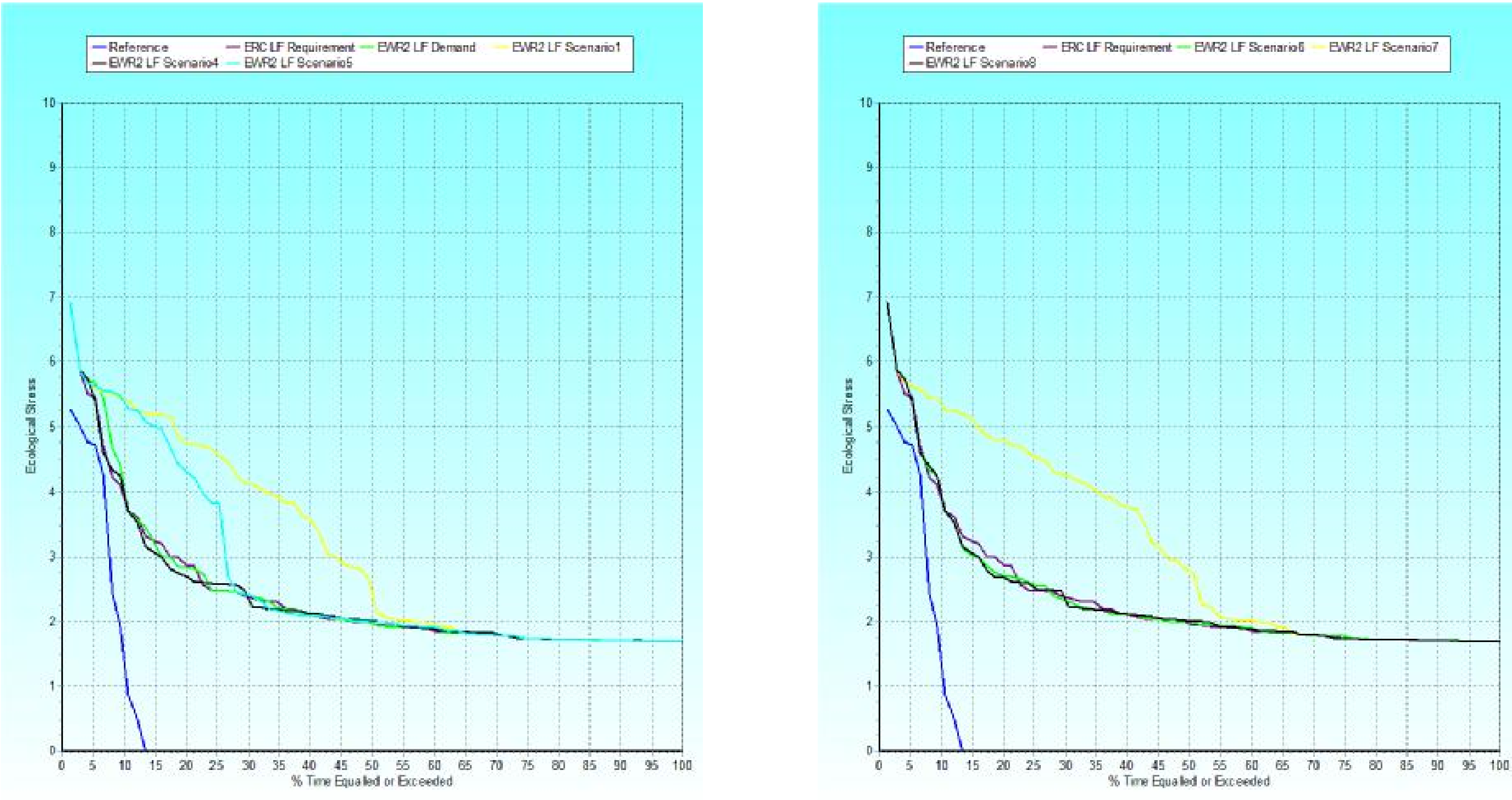


Figure 4.4: Stress curves for the wet season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 13

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

Wet season baseflows and small and moderate floods have been seriously reduced from natural within this reach. Dry season baseflows are elevated. As with the upstream site (EWR 12), the altered flow conditions have degraded the in-channel condition of the river through reduced scour and bed activation events.

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 1**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
C	C	C	C	Elevated baseflows	Seriously reduced baseflows and small floods have reduced scour and thus caused fining of the channel bed.
Due to the low slopes at this site, very large discharges are required to scour the coarse sediment on the bed. The site and reach are moderately bedrock influenced – many of the upstream islands and riffle areas created by bedrock outcrops. Since 1944, the islands have become increasingly vegetated with trees – probably stabilized due to reduced floods as well as increased exotic vegetation. The PES is in a C Ecological Category due to sediment supply and transport potential reductions. Sediment distribution on the bars here is better than at EWR 12, suggesting that tributaries have ameliorated the effects of upstream dams					

Scenario 4 and 8

Scenarios 4 and 8 propose minor increases in some of the baseflows for this site; dry season flows remain as is. These minor flow changes are not expected to have a 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 (especially scenario 6) and small floods in the wet season. These changes tend towards a more natural flow pattern, and these scenarios have been evaluated together.

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 5, 6**	**DRY SEASON**	**WET SEASON**

Specialist inputs					
C	C	C	C+	Reduced dry season baseflows (relative to the elevated PD levels) may allow for some minor seasonal accumulations of fines in the channel.	Increased baseflows and small floods should increase maintenance of the channel by ensuring sediment flushing.
The larger volumes of water available under these 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 and also remove some of the algae which promotes further deposition. Thus an increased frequency of these floods will improve the in-channel condition.					

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 (Scenario 1 and 4) do not supply EWR 13 with extra water the results of this scenario are similar to the present day.

Scenarios 1, 4, 7 and 8

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC â**	**Sc 1,4, 7 & 8**	**DRY SEASON**	**WET SEASON**
PHYSICO-CHEMICAL					
E	D	D	E	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 result 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.	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

				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.	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 13 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

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↑	Sc 5,6	DRY SEASON	WET SEASON
PHYSICO-CHEMICAL					
C	B	D	D	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 flow results in increased winter turbidity. The salinity impacts from the Vaal Barrage (Klip,	Extra water is released from the Vaal Dam to dilute the salt concentrations of the middle and lower Vaal. Increases summer flow results in increased turbidity. The salinity impacts from the Vaal Barrage (Klip, Riet and Suikerbosrand) as well as the Mooi River

				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 include proposed re-use of mine 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	(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 scenarios include proposed re-use of mine water. Scenario 5 includes projected possible transfer 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 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 at Regina Bridge on the Vaal River consists of a relatively broad area of flow with moderately sloping banks on the both banks on which vegetation would easily colonise and recruit. The site selection at this site is ideal as the vegetation in the area of the site is representative of the vegetation of the reach. Land use in the area is predominantly agricultural and pastoral farming and this has impacted on the site with regard to exotic species and possibly increases in nutrient levels in the river itself.

The marginal zone at Site EWR 13 is dominated by graminoid and cyperoid species including *Cyperus denudatus, Cyperus longus, Echinochloa holubii, Panicum coloratum, Sporobulus africanus, Azolla filiculoides* and *Myriophyllum spicatum* while the lower non-marginal zone is dominated by mainly by tree species such as *Salix mucronata, Ziziphus mucronata* and the upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Ziziphus mucronata, Rhus lancea, Gymnosporia buxifolia, Rhus pyroides, Diospyros lycoides, Ehretia rigida, Grewia flava, Asparagus laricinus* and *Asparagus sauveolens.*

Current status: The area is currently degraded due to the introduction of a number of exotic species. The exotic species in the area contribute to a total of almost 30% of the total number of species identified during the surveys, but the exotic species do not make up as significant a percentage of the cover as they do in Site 1. Furthermore, the lack of stochastic events, such as fire and flooding, are causing homogenization of the riparian vegetation at site EWR 13 as well as the colonisation of the islands with more vegetation as well as more exotic species than would usually occur there. It must be noted that the disturbances and the degradation in this area are mostly due to anthropogenic changes that are not directly related to- or due to the flow regime. Therefore, although there may be a certain reduction in the abundance of less firmly rooted exotic species, due to large flood events, a change in flow regime is unlikely to change the ecological status of the reach significantly.

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.

Scenario 1

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C	C	D	C	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 13. 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 13. 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					
C	C	D	C	The flows anticipated for scenario 4 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 13. The flows anticipated for scenario 4 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 4 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 13. The flows anticipated for scenario 4vare, in fact, very similar to that of the flows experienced during the determination of the PES.

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
C	C	D	C	The flows anticipated for scenario 5 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 13. The flows anticipated for scenario 5 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 5 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 13. The flows anticipated for scenario 5 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
C	C	D	C	The flows anticipated for scenario 6 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 13. The flows anticipated for scenario 6 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 6 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 13. The flows anticipated for scenario 6 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
C	C	D	C	The flows anticipated for scenario 7 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 13. 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 7 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 13. 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					
C	C	D	C	The flows anticipated for scenario 8 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 13. The flows anticipated for scenario 8 are, in fact, very similar to that of the flows experienced during the determination of the PES.	The flows anticipated for scenario 8 does not differ significantly enough for the scenario to have an influence on the ecological status of the riparian vegetation at site EWR 13. The flows anticipated for scenario 8 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Macroinvertebrates

Scenario present day (Sc 1)

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C	C/B	C/D	C	Algae fill up habitat between cobbles. Lower, will result in the water quality being impaired.	Higher flow flushes the algae from the cobble habitat. Increased flow will result in better water quality.

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
C	C/B	C/D	C	Algae fill up habitat between cobbles. Lower, will result in the water quality being impaired.	Higher flow flushes the algae from the cobble habitat. Increased flow will result in better water quality.

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
C	C/B	C/D	C	The wet part of the dry season is slightly better with more flow.	Dry period in the wet season the same as present day. Flows at the wet part of the wet season better that will result in a slightly better Ecological Category.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON

Specialist inputs					
C	C/B	C/D	C	The wet part of the dry season is slightly better with more flow.	Dry period in the wet season the same as present day. Flows at the wet part of the wet season better that will result in a slightly higher C class.

Scenario 7

EC				**ECOLOGICAL CONSEQUENCES**	
PES	**REC**	**AEC a**	**Sc 7**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
C	C/B	C/D	C	Algae fill up habitat between cobbles. Lower, will result in the water quality being impaired.	Higher flow flushes the algae from the cobble habitat. Increased flow will result in better water quality.
Same as Present Day.					

Scenario 8

EC				**ECOLOGICAL CONSEQUENCES**	
PES	**REC**	**AEC a**	**Sc 8**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
C	C/B	C/D	C	Algae fill up habitat between cobbles. Lower, will result in the water quality being impaired.	Higher flow flushes the algae from the cobble habitat. Increased flow will result in better water quality.
Same as Present Day.					

Fish

Scenario 1, 4, 7 and 8

Scenarios 1, 4, 7 and 8 are very similar. Eight fish species would historically have occurred at the site at moderate abundances (Kleynhans *et al.,* 2007). A 9th species *Austroglanis sclateri* (Rock catfish) would historically have occurred at the site at low densities (Kleynhans *et al.,* 2007). The expected fish assemblage has a wide range of velocity depth preferences. This is indicative of the wide range of flow levels and habitats that would naturally have occurred at the site in historical times. Five of the eight expected species are either moderately tolerant or tolerant of no flow conditions indicating the seasonal nature of the river under reference conditions. Three of the expected species namely *Labeobarbus aeneus*, *L. kimberleyensis* and *L. umbratus* are moderately intolerant of no flow conditions indicating that these species require flowing water for completion of their lifecycle. The expected fish assemblage show high levels of preference for a wide range of cover types. Seven of the 8 expected fish species are either moderately tolerant or tolerant of modified water quality indicating that the water quality in the river fluctuates naturally along with the seasonal change in flow levels. Three of the expected fish species namely *Barbus anoplus* (Chubbyhead barb), *Clarias gariepinus* (Sharptooth catfish) and *Tilapia sparrmanii* (Banded tilapia) have a requirement for movement between reaches/ fish habitat segments. These species will be impacted upon by the construction of dams and weirs that impede fish migration.

Five of the nine species expected to occur at the site in moderate to high densities were recorded at the site during the Reserve Determination surveys (PES Class D). The PES Class of D can be attributed primarily to the absence of 4 of the expected indigenous fish species from the assemblage during both the wet and dry season surveys (*B. anoplus, L. kimberleyensis, L. umbratus* and *A. sclateri*). These species may be still be present in the reach but at such low abundances that they were not collected during the 2 surveys.

In addition 2 exotic fish species: *Gambusia affinis* (Mosquitofish) and *Cyprinus carpio* (Carp) were recorded at the site in moderate to high abundances.

EC				**ECOLOGICAL CONSEQUENCES**	
PES	**REC**	**AEC a**	**Sc 1,4,7,8**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
D	C	C	D	Four of the eight expected indigenous fish species were recorded at site EWR13 during the dry season survey	Four of the eight expected indigenous fish species were recorded at site EWR13 during the wet season survey.
A PES of D was recorded at site EWR13. This can be attributed primarily to the absence of 4 of the expected fish species during both wet and dry season surveys.					

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Labeobarbus aeneus	**4.00**	**4.00**
Barbus anoplus	**5.00**	**0.00**
Labeobarbus kimberleyensis	**4.00**	**0.00**

Clarias gariepinus	**4.00**	**4.00**
Labeo capensis	**4.00**	**4.00**
Labeo umbratus	**4.00**	**0.00**
Pseudocrenilabrus philander	**3.00**	**4.00**
Tilapia sparrmanii	**3.00**	**3.00**
Austroglanis sclateri	**2.00**	**0.00**

Scenario 5 and 6

Scenarios 5 and 6 result in 25% more flow through the site during the wet season therefore resulting in flushing of sediment and aquatic macrophytes from the site and decreased flow related stress. Scenarios 5 and 6 may result in increased abundance of L. *kimberleyensis* which has a high level of preference for fast deep habitats. Increased flow levels and flushing will result in improved habitat condition due to the clearing of the extensive algal growth which is currently clogging the habitat at the site. This may result in the increased abundance of B. *anoplus* which has a high level of preference for overhanging vegetation and *L. umbratus* which requires substrate cover. These habitat types are currently largely eliminated by the extensive algal and aquatic macrophyte growth. Increased abundance of these species results in an improvement in the PES from a Class D to a Class C.

<table>
<tr><th colspan="4">EC</th><th colspan="2">ECOLOGICAL CONSEQUENCES</th></tr>
<tr><th>PES</th><th>REC</th><th>AEC a</th><th>Sc 5, 6</th><th>DRY SEASON</th><th>WET SEASON</th></tr>
<tr><th colspan="6">Specialist inputs</th></tr>
<tr><td>D</td><td>C</td><td>C</td><td>C</td><td>Increased flow resulting in flushing of sediments and aquatic macrophytes from the site</td><td>Increased flow resulting in flushing of sediments and aquatic macrophytes from the site</td></tr>
<tr><td colspan="6">Increased flow levels will result in improved habitat integrity due to flushing of sediments and aquatic macrophytes. It will also result in improved water quality and increased availability of fast shallow and deep habitats. This may result in improved abundance of species such as B. anoplus, L. umbratus and L. kimberleyensis. The improved abundance of these species will result in an improvement in the PES from a Class D to a Class C.</td></tr>
</table>

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Labeobarbus aeneus	**4.00**	**4.00**

Barbus anoplus	**5.00**	**4.00**
Labeobarbus kimberleyensis	**4.00**	**2.00**
Clarias gariepinus	**4.00**	**4.00**
Labeo capensis	**4.00**	**4.00**
Labeo umbratus	**4.00**	**4.00**
Pseudocrenilabrus philander	**3.00**	**4.00**
Tilapia sparrmanii	**3.00**	**3.00**
Austroglanis sclateri	**2.00**	**0.00**

4.2.4 Summary of ecological consequences

The summary of the ecological categories for the operational scenarios at EWR 13 are provided in Table 4.2.

Table 4-2: Summary of ecological categories for operational scenarios at EWR site 13

Driver	**Sc 1 PD (REC)**	**Sc 4**	**Sc 5**	**Sc6**	**Sc 7**	**Sc 8**
Water quality	**E**	**E**	**D**	**D**	**E**	**E**
Geomorphology	**C**	**C**	**C**	**C**	**C**	**C**
Response components						
Fish	**D**	**D**	**D**	**D**	**D**	**D**
Macroinvertebrates	**C**	**C**	**C**	**C**	**C**	**C**
Instream	**C/D**	**C/D**	**C**	**C**	**C/D**	**C/D**
Riparian vegetation	**B/C**	**B/C**	**B/C**	**B/C**	**B/C**	**B/C**
Ecostatus	**C**	**C**	**C**	**C**	**C**	**C**

4.3 EWR 14 : PROKLAMEERSDRIFT (VALS RIVER)

4.3.1 Catchment development and impacts

The Vals River (EWR 14) has reduced baseflows in summer and winter. Declined small summer floods have reduced sediment transport; so flushing of fines and scour is reduced. There are no large dams to remove sediment or trap large floods. The dominant land use and water usage is due to agriculture upstream.

The water quality is as a result of the following drivers

- High salts in winter due to low flows and return flows from irrigation.
- Low phosphates
- Growth of aquatic macrophytes driven by high nitrogen levels

4.3.2 Graphs of flow scenarios

Figure 4.3 illustrates the stress requirements and stress points required for the REC, present day (demand) and the operational scenarios analysed for February (wet season) and August (dry season) at EWR site 14.

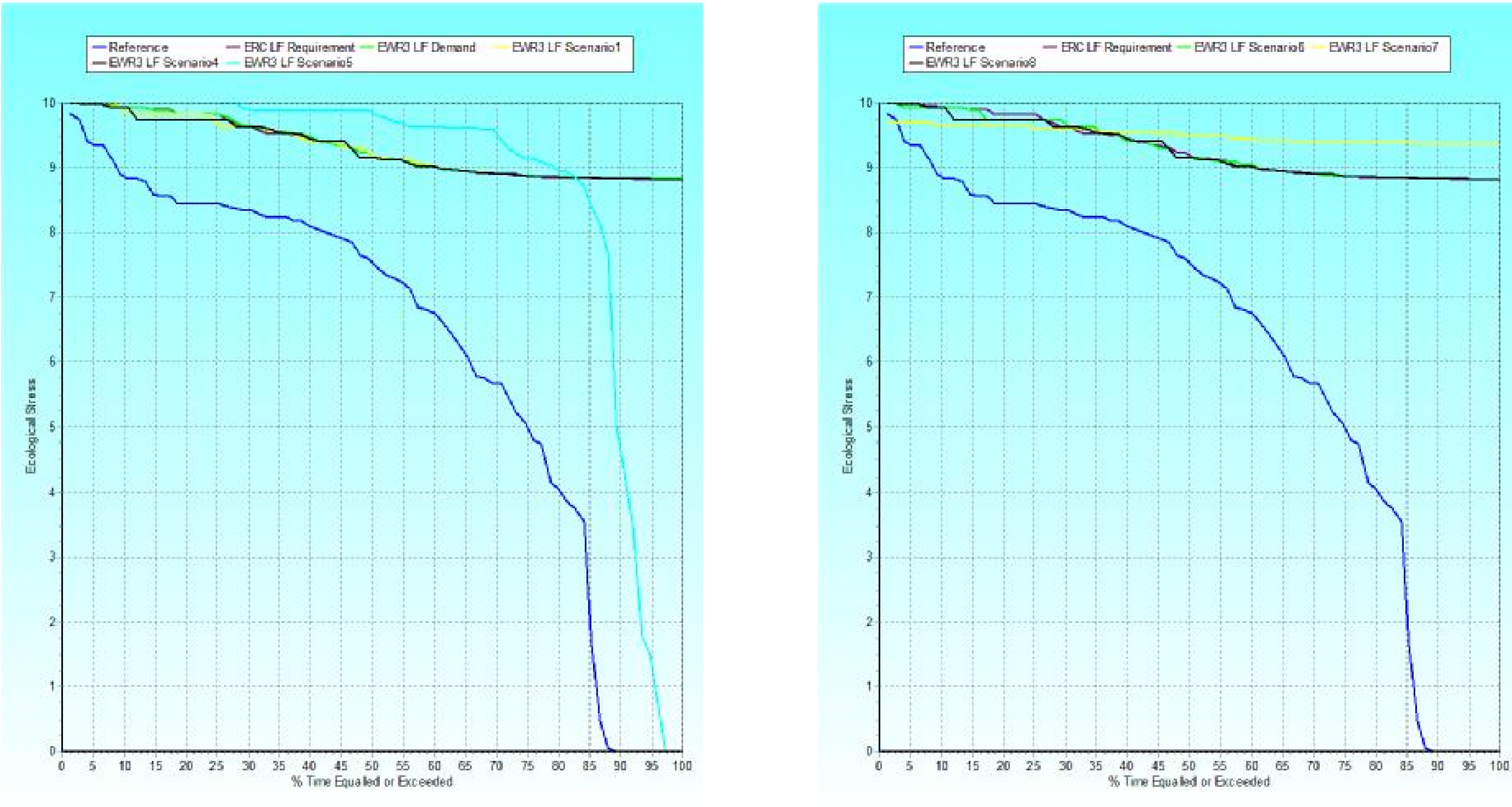
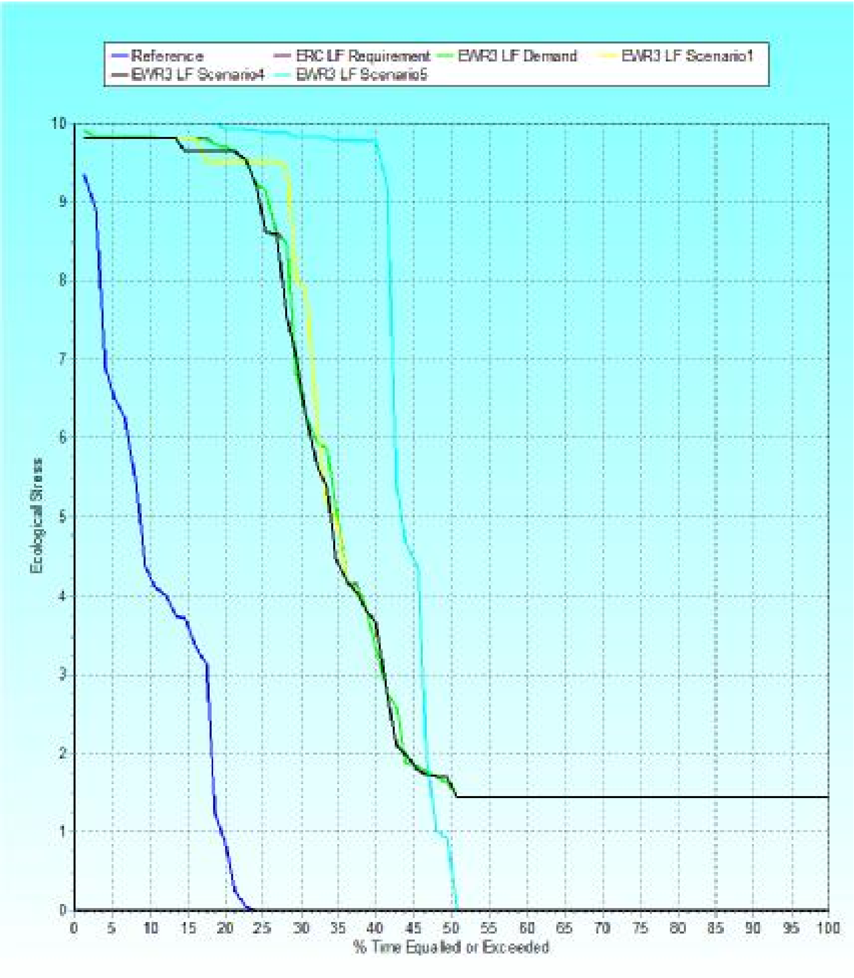


Figure 4.5: Stress curves for the dry season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 14



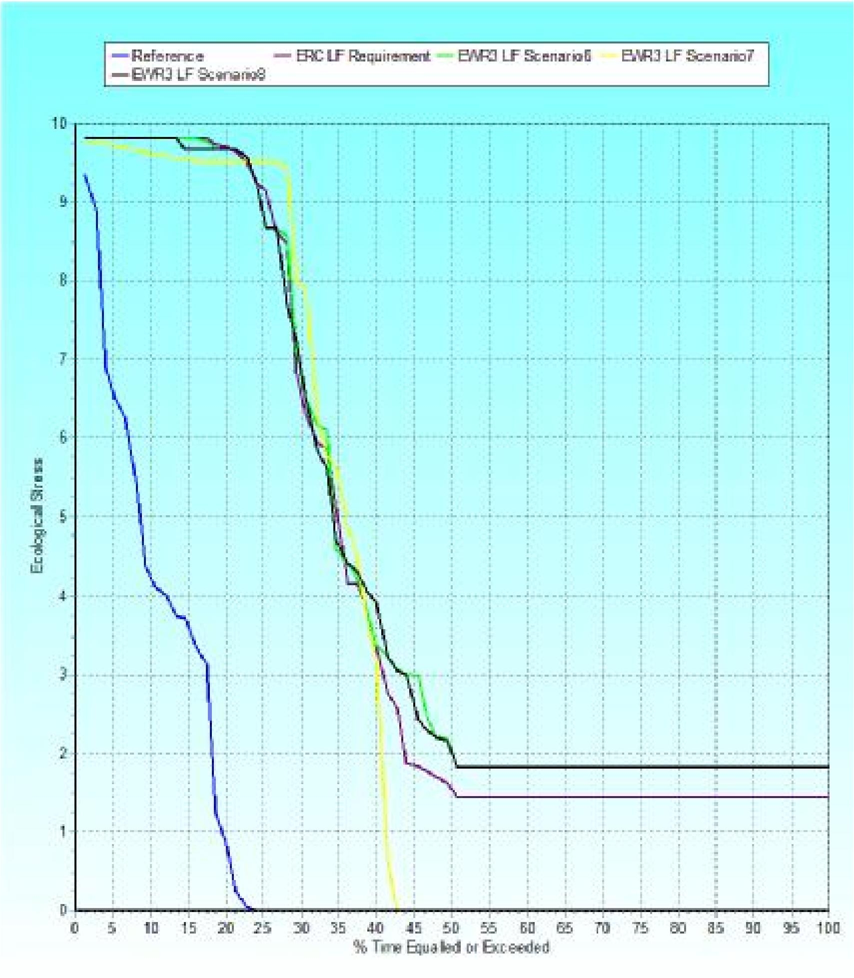


Figure 4.6: Stress curves for the wet season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 14

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

Baseflows on this river (the Vals River) have been reduced relative to the natural condition. PES is in a B/C condition.

Scenario 1

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 1**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
B/C	B/C	C	B/C	Reduced flows	Reduced baseflows and decline in small floods have reduced sediment transport; so flushing of fines and scour is reduced.. There are no very large dams to remove sediment or trap large floods.
The continued provision of small and moderate floods will maintain the PES at this site. Intra-annual floods of 3 m^3/s will scour the fines whilst larger annual 35 m^3/s event will activate the bed and maintain in-channel conditions.					

Scenario 4, 7 and 8

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 5 and 6

Under these scenarios (2020 development in the catchment) there are generally very slight decreases in baseflows; albeit that Scenario 6 also allows for some increased flows to provide the EWR. Change from PD flows is on the order of 100’s of litres per second, and these minor reductions in flow are not sufficient to cause a change of the PES.

Physico chemical

Scenarios present day, 4, 7 and 8

<table>
<tr><th colspan="4">EC</th><th colspan="2">ECOLOGICAL CONSEQUENCES</th></tr>
<tr><th>PES</th><th>REC</th><th>AEC a</th><th>1,4,7,8</th><th>DRY SEASON</th><th>WET SEASON</th></tr>
<tr><th colspan="6">PHYSICO-CHEMICAL</th></tr>
<tr><td>C</td><td>B</td><td>D</td><td>C/D</td><td>High salts in winter due to low flows and return flows from irrigation.
Low nutrients (but high growth of aquatic macrophytes, hence the ammonia higher than the nutrients).
Trajectory of change:
Decreasing nutrients but stable phosphates
Increasing salts</td><td>Summer salts are less than half the winter and the flows are 15 times higher than the winter flows.

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.

The potential for algal blooms increases due to summer temperatures as well as the future 2020 development conditions (greater nutrients).</td></tr>
<tr><td colspan="6">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.</td></tr>
</table>

Scenario 5

<table>
<tr><th colspan="4">EC</th><th colspan="2">ECOLOGICAL CONSEQUENCES</th></tr>
<tr><th>PES</th><th>REC</th><th>AEC a</th><th>Sc 5</th><th>DRY SEASON</th><th>WET SEASON</th></tr>
<tr><th colspan="6">PHYSICO-CHEMICAL</th></tr>
<tr><td>C</td><td>B</td><td>D</td><td>C/D</td><td>High salts in winter due to low flows. Winter salt concentrations are double those of the summer despite the flows being 15 times less.
Winter salts are slightly better than PD
Point sources of nutrients relate to the waste water treatment works associated with Kroonstad and return flows from irrigation will increase due to the 2020 development scenario.
Low nutrients (but high growth of aquatic</td><td>Summer salts are less than half the winter and the flows are 15 times higher than the winter flows.

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.</td></tr>
</table>

				macrophytes, hence the ammonia higher than the nutrients). Decreasing nutrients levels Increasing salts	Diffuse runoff from agriculture increases the potential for nutrients and salts during summer rains. will increase due to the 2020 development scenario. Summer salts similar to PD

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 6**	**DRY SEASON**	**WET SEASON**
PHYSICO-CHEMICAL					
C	B	D	C/D	High salts in winter due to low flows and return flows from irrigation. Low nutrients (but high growth of aquatic macrophytes, hence the ammonia higher than the nutrients). Winter salts are lower better than PD Point sources of nutrients relate to the waste water treatment works associated with Kroonstad and return flows from irrigation will increase due to the 2020 development scenario but this scenario includes the EWR requirements. Trajectory of change: Decreasing nutrients but stable phosphates Increasing salts	Summer salts are 54% lower the winter and the flows are 15 times higher than the winter flows. 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 Proklameersdrif on the Vals River consists of a relatively narrow area of flow with moderately sloping banks, on which vegetation would easily colonise and recruit. This being said, there is a large amount of grass cover on the slopes and, due to the competitiveness of graminoids, recruitment by woody species will be hampered by the high abundance of graminoids. The site selection at this site is very good as this site well represents the riparian vegetation in the area. The fact that few woody species occur in this area, due to the fact that it falls within the grassland biome, does call into question the usefulness of VEGRAI in this specific vegetation type. The only woody species occurring in this area are exotics with few indigenous species and VEGRAI appears to have been developed for areas with significant woody vegetation present in the riparian vegetation. The vegetation at Proklameersdrif, although representative of the vegetation along this reach of the Vals River, has been affected by land use in the surrounding areas. Land use in the area is predominantly agricultural and pastoral farming.

The marginal zone at Site EWR 14 is dominated by graminoid and cyperoid species including *Cyperus denudatus, Cyperus longus, Echinochloa holubii*, *Cyperus denudatus, Cyperus longus, Pycreus mundii* and *Sporobulus fimbriatus* while the lower non-marginal zone is dominated by mainly by graminoids and herbaceous species such as *Agrostis lachnantha, Andropogon eucomus, Chloris virgata, Cynodon dactylon, Phragmites australis, Eragrostis plana, Hemarthria altissima, Ischaemum fasciculatum, Echinochloa holubii, Eragrostis obtuse, Eragrostis porosa, Fimbristylis ferruginea, Panicum coloratum, Pycreus mundii, Sporobulus africanus, Sporobulus fimbriatus, Urochloa panicoides, Persicaria lapathifolia, Alternanthera sessilis, Barleria macrostegia, Corchorus asplenifolius, Equisetum ramosissimum, Galium capense, Hibiscus pusillus, Lobelia angolensis, Nidorella resedifolia, Persicaria amphibian*and the upper non-marginal zone is dominated by graminoid species but sparse woody species include *Acacia karroo, Salix mucronata, Ziziphus mucronata, Rhus lancea, Gymnosporia buxifolia, Grewia flava,* and *Asparagus sauveolens.*

Current status: The area is currently degraded due to the introduction of a number of exotic species. Although not as degraded as the sites along the Vaal River, the Vals River has been impacted upon by surrounding agricultural practices and burning regimes. For this reason, combined with the lack of significant historical data, it was difficult not only to determine the correct reference site conditions, but also the actual current status of this site

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, 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	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 4 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 4 are, in fact, very similar to that of the flows experienced during the determination of the PES.

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	There will be a slight decrease in flow 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 slight decrease in flow for this scenario, however, although causing slight changes in the marginal zone, the changes will not be sufficient to change the PES

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	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 8 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 8 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Macroinvertebrates

Scenario present day (Sc 1)

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.	Lower base flows which will result in the frequency and abundance of taxa being affected.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.	Higher flows will result some taxa moving back into the system.

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.
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	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.	Absence of taxa with a preference for very fast flowing water. Loss of taxa that prefers loose cobbles.
Same as the Present Day.					

Fish

Scenario 1, 4, 7 and 8

Scenarios 1, 4, 7 and 8 are all very similar in terms of flow stress duration. Seven fish species would historically have occurred at this site at low to moderate abundances (Kleynhans *et al*., 2007). A further 2 species *L. kimberleyensis* and *A. sclateri* may occasionally have occurred at the site in low abundances (Kleynhans *et al.*, 2007). Six of the expected species have a preference for either slow deep or slow shallow habitats suggesting that these are the predominant velocity depth classes that occur at this site. Two species: *L. aeneus* and *A. sclateri* have a preference for fast shallow habitat and *L. kimberleyensis* for fast deep habitats. Five of the expected fish species are either moderately tolerant or tolerant of reduced flow. Four fish species have a requirement for flowing water at some stage in their lifecycle. The expected fish assemblage show high levels of preference for a wide range of cover types. Eight of the expected fish species are either moderately tolerant or tolerant of modified water quality indicating that water quality in the Vals River would fluctuate naturally along with seasonal flow patterns. Three species have a requirement for movement between reaches/ fish habitat segments. These species 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 C/D. This PES can be attributed primarily to the absence of *A. sclateri* and *L. umbratus* from the fish assemblage during both surveys and the very low species diversity and abundance recorded during the dry season survey. Water quality impacts originating from Kroonstad have a limiting effect on the fish community in the Vals River during the dry season.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1,4,7,8	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	C	C/D	Very low fish species diversity and abundance was recorded at site EWR14 during the dry season. Water quality impacts originating from Kroonstad have a limiting effect on aquatic biota in the Vals River during the dry season.	Fish species diversity and abundance increased substantially during the wet season with seven of the nine expected indigenous fish species recorded.
A PES of C/D was recorded at site EWR14. The low PES can be attributed to the absence of *A. sclateri* and *L. umbratus* from the fish assemblage during both surveys and the very low fish species diversity and abundance measured at the site during the low flow survey.					

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

Scenario 5

Scenario 5 will result in decreased flow levels throughout the year. This will result in slightly increased nutrient and salt loads in the Vals River. Reduced flow levels may result in the disappearance of species such as *L. aeneus* and *L. capensis* that are moderately intolerant of no flow conditions from this reach of the Vals River. The disappearance of these 2 species will result in a reduction in the PES from a Class C/D to a Class D/E.

<table>
<tr><th colspan="4">EC</th><th colspan="2">ECOLOGICAL CONSEQUENCES</th></tr>
<tr><th>PES</th><th>REC</th><th>AEC a</th><th>Sc 5</th><th>DRY SEASON</th><th>WET SEASON</th></tr>
<tr><th colspan="6">Specialist inputs</th></tr>
<tr><td>C/D</td><td>C</td><td>C</td><td>D/E</td><td>Decreased flows resulting in slightly increased salt and nutrient loads</td><td>Decreased flows resulting in slightly increased salt and nutrient loads</td></tr>
<tr><td colspan="6">Decreased flows and increased salt and nutrient loads may result in a decrease in the abundance of species such as L. aeneus and L. capensis that are moderately intolerant of no flow conditions and that require fast flowing habitats at some point throughout their lifecycle. A decrease in the abundance of these 2 species results in a reduction in the PES from a class C/D to a Class D/E.</td></tr>
</table>

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

Scenario 6

Scenario 6 will result in slightly decreased nutrient loads. Flow duration stress will remain largely unchanged from the current state (Scenario 1) during both seasons. This may result in increased abundance and diversity of fish species during the wet season but is not expected to result in an improvement in the PES Class from the C/D measured in Scenario 1.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	C	C/D	Slightly decreased nutrient and salt loads	Slightly decreased nutrient and salt loads
Scenario 6 will result in slightly decreased salt and nutrient loads during both seasons. This may result in improved fish species diversity and abundance during the dry season but is not expected to result in a significant improvement in PES from the C/D measured in Scenario 1.					

4.3.4 Summary of ecological consequences

The summary of the ecological categories for the operational scenarios at EWR 14 are provided in Table 4.3.

Table 4-3: Summary of ecological categories for operational scenarios at EWR site 14

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

4.4 EWR 15 : FISANTKRAAL (VET RIVER)

4.4.1 Catchment development and impacts

The Vet River at EWR 15 is impacted by irrigated agriculture and the presence of two large dams upstream which supply water for irrigation. Water from Allemanskraal Dam is used for agricultural irrigation as well as to meet the urban water requirements of Virginia Town. Virginia has a fixed allocation of 15.2 million m3/a from Allemanskraal Dam but can also be supplied by Sedibeng Water through their abstractions at

Balkfontein. Erfenis Dam supplies water to irrigation as well as urban water users. However, since the urban water users comprising of Brandfort, Theunissen, Bultfontein and Hoopstad, do not have access to water from alternative water resources, the supply to these towns have priority over the irrigation water use.

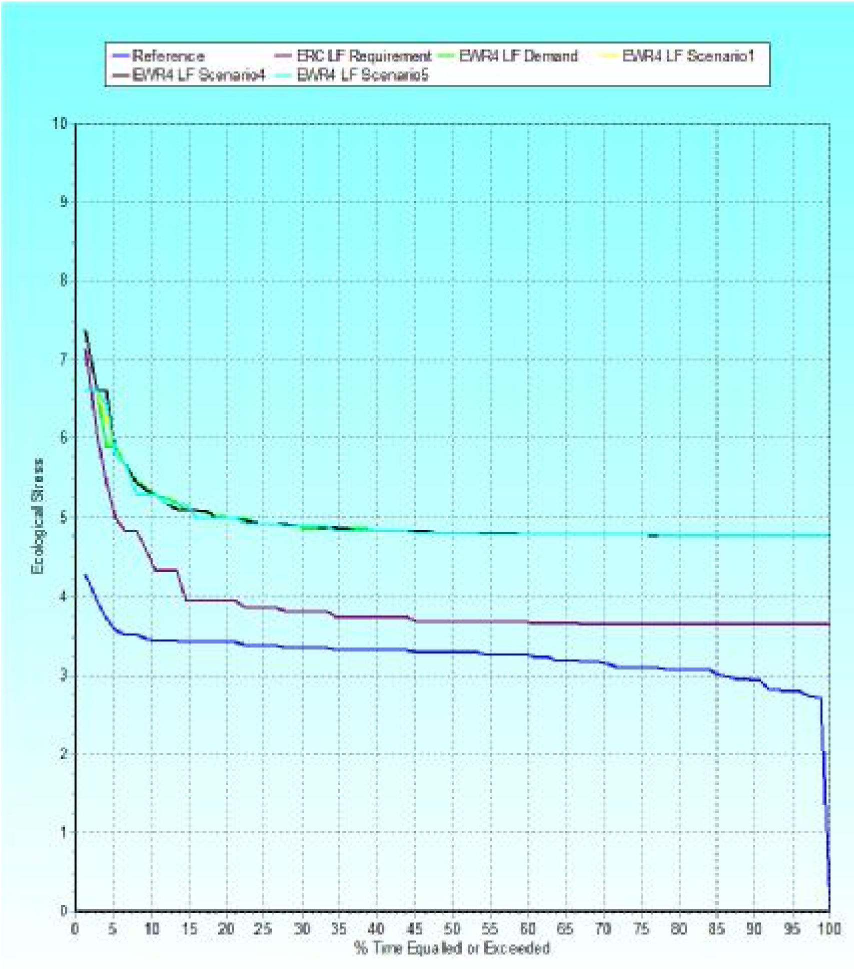
There are reduced base flows in summer and winter. In summer there is a decline in floods which has reduced sediment transport; so flushing of fines and scour is reduced.

The water quality at EWR 15 is driven by:

- High salts in winter due to low flows.
- Point sources of nutrients relate to the waste water treatment works associated with the many small towns and return flows from irrigation.
- Low phosphates (but high growth of aquatic macrophytes driven by nitrogen).
- High turbidity at this site reduces the algal growth opportunities in winter.

4.4.2 Graphs of flow scenarios

Figure 4.4 illustrates the stress requirements and stress points required for the REC, present day (demand) and the operational scenarios analysed for February (wet season) and August (dry season) at EWR site 15.



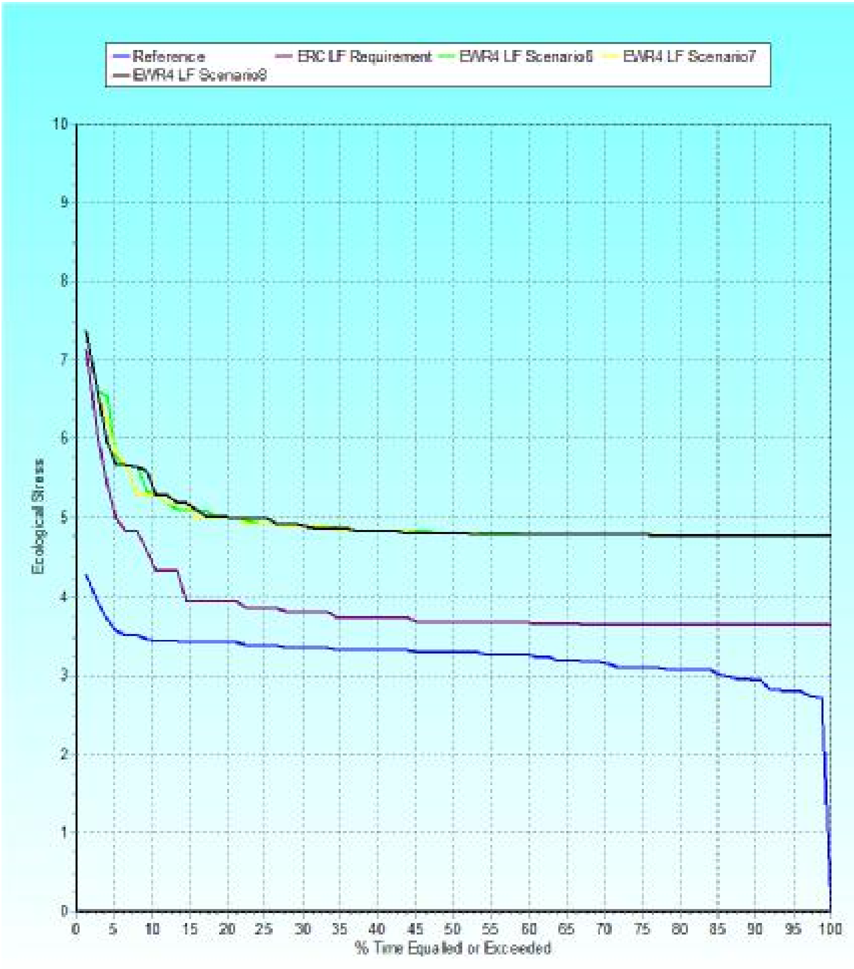


Figure 4.7: Stress curves for the dry season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 15

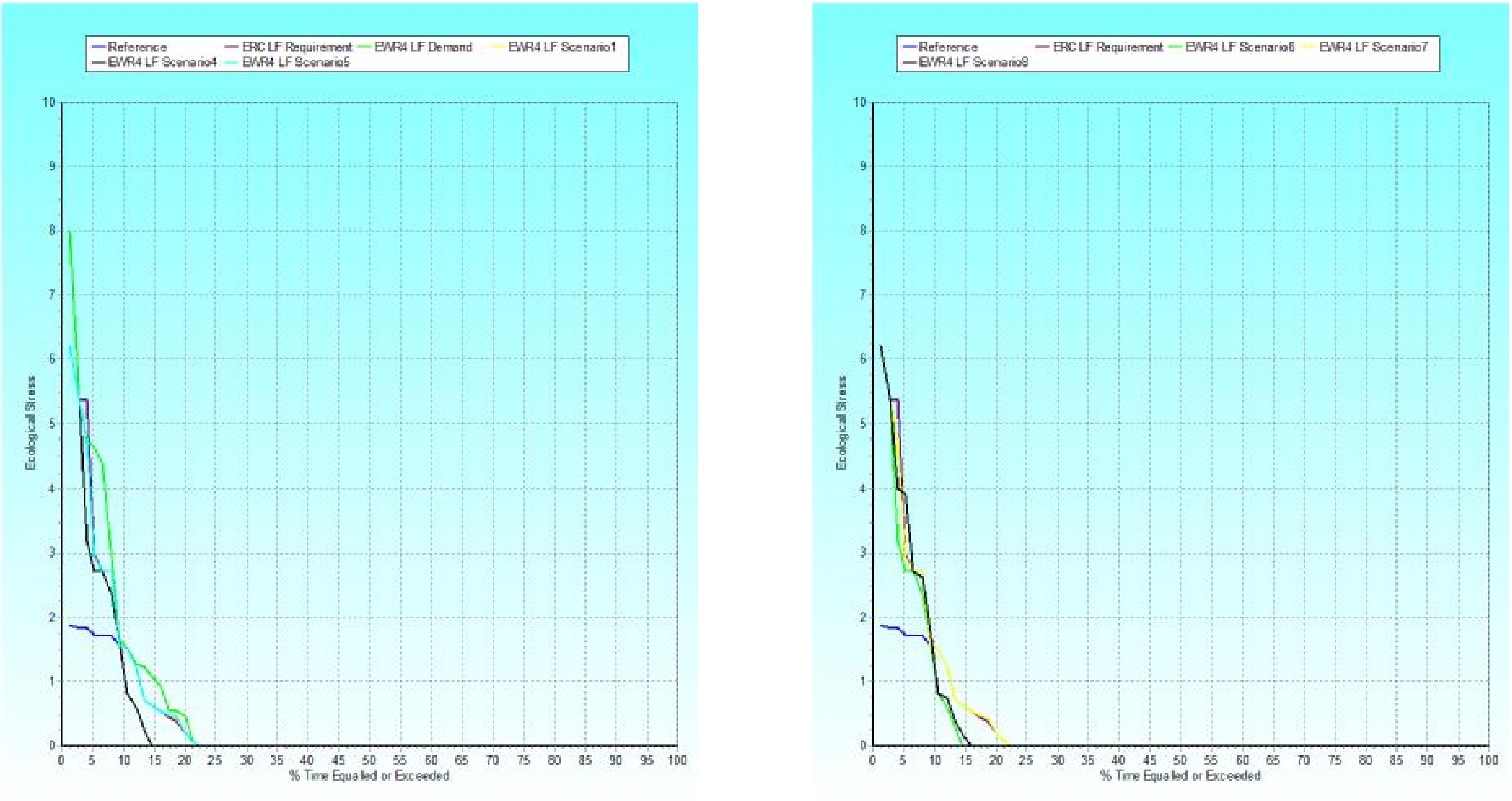


Figure 4.8: Stress curves for the wet season for operational scenarios (1, 4 & 5, and 6, 7 & 8) at EWR site 15

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

According to the available hydrological data, there is almost no difference between Present Day and Reference flow conditions in the Vet River. This is however unlikely to be correct; especially given the extent of irrigated agriculture and the presence of two large dams upstream which supply water for irrigation. The Reference Condition hydrology for this side was thus ignored.

The reach is characterised by an extensive floodplain with many associated wetland areas (floodplain pans and backwaters) adjacent to the main channel. The main impacts at the site are progressive narrowing of the active channel which is evident from the aerial photographs. This is likely to have been caused by a reduction in moderate, and possibly large, floods due to the large dams upstream which supply irrigation demands in the catchment. PES is in a C condition.

EC				ECOLOGICAL CONSEQUENCES	
PES	**REC**	**AEC a**	**Sc 1**	**DRY SEASON**	**WET SEASON**
C	C	-	C	Reduced baseflows	Reduced baseflows and a decline in floods have reduced sediment transport; so flushing of fines and scour is reduced.
The continued provision of small and moderate floods will maintain the PES at this site. The large annual 70 m^3/s flood that was requested will remove fines and activate some of the lower seasonal channels and backwaters to maintain in-channel conditions. Larger inter-annual floods are required for overtopping on to the floodplain in order to maintain other wetland areas.					

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 the provision of high flows which are large and frequent enough to meet the EWR requirements for geomorphology. This, combined with higher baseflows should improve the in-channel lower riparian and low-lying wetland areas along this floodplain reach, and reverse some of the channel narrowing that has occurred in this reach.

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4, 6, 8	DRY SEASON	WET SEASON
Specialist inputs					
C			B/C	Increased baseflows	Increased baseflows which we ASSUME will facilitate the provision of the EWR flood requirements, possibly even more (not possible to confirm the daily flood peaks since scenario data are generated as monthly average flows).
The continued provision of small and moderate floods will maintain the PES at this site. The large annual 70 m^3/s flood will scour the fines and activate the bed to maintain in-channel conditions, and this combined with the provision of higher baseflows should improve in-channel as well as associated wetland areas along this floodplain reach.					

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	C/D	Water from Allemanskraal Dam is used for agricultural irrigation as well as to meet the urban water requirements of Virginia Town. Virginia has a fixed allocation of 15.2 million m^3/a from Allemanskraal Dam but can also be supplied by Sedibeng Water through their abstractions at Balkfontein. Erfenis Dam supplies water to irrigation as well as urban water users. However, since the urban water users comprising of Brandfort, Theunissen, Bultfontein and Hoopstad, do not have access to water from alternative water resources, the supply to these towns have priority over the irrigation water use. High salts in winter due to low flows. Winter salt concentrations are double those of the summer despite the flows being 20 times less. Point sources of nutrients relate to the waste water treatment works associated with the many small towns and return flows from irrigation will increase due to the 2020 development scenario (Scenario 5). Low nutrients (but high growth of aquatic macrophytes, hence the ammonia higher than the nutrients). The high turbidity at this site reduces the	Summer salts are less than half the winter and the flows are 20 times higher than the winter flows. Nutrient levels diluted in summer and the potential for algal blooms increases due to summer temperatures but this is masked by the high turbidity's. Diffuse runoff from agriculture increases the potential for nutrients and salts during summer rains. Will increase due to the 2020 development scenario. Point and diffuse sources of nutrients relate to the waste water treatment works associated with the many small towns and return flows from irrigation will increase due to the 2020 development scenario (Scenario 5).

				algal growth opportunities in winter.	

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	Water from Allemanskraal Dam is used for agricultural irrigation as well as to meet the urban water requirements of Virginia Town. Virginia has a fixed allocation of 15.2 million m^3/a from Allemanskraal Dam but can also be supplied by Sedibeng Water through their abstractions at Balkfontein. Erfenis Dam supplies water to irrigation as well as urban water users. However, since the urban water users comprising of Brandfort, Theunissen, Bultfontein and Hoopstad, do not have access to water from alternative water resources, the supply to these towns have priority over the irrigation water use. These scenario's have higher winter base flows which result in 20% less salts in the winter due to EWR allocations. High salts in winter due to low flows. Winter salt concentrations are more than double those of the summer despite the flows being 20 times less. Point sources of nutrients relate to the waste water treatment works associated with the many small towns and return flows from irrigation will increase due to the 2020 development scenarios (Scenario 4, 6 and 8). Low nutrients (but high growth of aquatic macrophytes, hence the ammonia higher than the nutrients). The high turbidity at this site reduces the algal growth opportunities in winter.	Summer salts are less than half the winter and the flows are 20 times higher than the winter flows. Summer salts in these scenario's are 20% lower than the other scenario's including PD due to greater summer baseflows. Nutrient levels diluted in summer and the potential for algal blooms increases due to summer temperatures but this is masked by the high turbidity's. Diffuse runoff from agriculture increases the potential for nutrients and salts during summer rains. Will increase due to the 2020 development scenario. Point and diffuse sources of nutrients relate to the waste water treatment works associated with the many small towns and return flows from irrigation will increase due to the 2020 development scenario (Scenario 4, 6 and 8).

Riparian vegetation

The site at Fisantkraal on the Vet River consists of a relatively narrow area of flow with moderately sloping banks, on which vegetation would easily colonise and recruit. The vegetation at this site is varied, from a large number of woody species encroachments in areas of lesser disturbance to areas of denudation with a large proportion of herbaceous exotic species in areas more affected by disturbance. The site selection at this site is, however, not ideal as the vegetation in the area has been disturbed by farming practices in the area and a large degree of colonisation by exotic species. Land use in the area is predominantly agricultural and pastoral farming.

The marginal zone at Site EWR 15 is dominated by graminoid and cyperoid species including *Cyperus denudatus, Cyperus longus, Panicum coloratum* and especially *Cynodon dactylon, Cirsium vulgare, Datura ferox, Datura stramonium* and *Xanthium strumarium* while the lower non-marginal zone is dominated by mainly by graminoids and herbaceous species such as *Cynodon dactylon, Cirsium vulgare, Datura ferox, Datura stramonium* and *Xanthium strumarium* and woody species such as *Acacia karroo* and *Salix mucronata*. The upper non-marginal zone is dominated by tree and shrub species including *Acacia karroo, Salix mucronata, Ziziphus mucronata, Rhus lancea,* and *Grewia flava.*

Current status: The area is currently considerably degraded mainly due to the introduction of a number of exotic species. The exotic species in the area, in fact, contribute to a total of over 50% of the total number of species identified during the surveys. Furthermore, the lack of stochastic events, such as fire and flooding, are causing homogenization of the riparian vegetation at site EWR 15.

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**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
E	E	E/F	E	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 15. 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 15. 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					
E	E	E/F	D/E	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	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 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					
E	E	E/F	E	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 15. The flows anticipated for scenario 5 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 15. The flows anticipated for scenario 5 are, in fact, very similar to that of the flows experienced during the determination of the PES.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
E	E	E/F	D/E	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	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					
E	E	E/F	E	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 15. 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 15. 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					
E	E	E/F	D/E	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	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

Scenario present day (Sc 1)

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 1	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Loss of almost all taxa that prefers very fast flowing water. Loss of taxa that have a high and moderate requirement for good water quality.	Loss of almost all taxa that prefers very fast flowing water. Loss of taxa that have a high and moderate requirement for good water quality.

Scenario 4

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 4	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Higher base flows through the winter months, and improved water quality.	Higher floods and base flows during the summer months, and better water quality due to the higher flows.

Scenario 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 5	DRY SEASON	WET SEASON
Specialist inputs					

C/D	C	D	C/D	Loss of almost all taxa that prefers very fast flowing water. Loss of taxa that have a high and moderate requirement for good water quality.	Loss of almost all taxa that prefers very fast flowing water. Loss of taxa that have a high and moderate requirement for good water quality.

Scenario 6

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 6	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Higher base flows through the winter months, and improved water quality.	Higher floods and base flows during the summer months, and better water quality due to the higher flows.

Scenario 7

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 7	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Loss of almost all taxa that prefers very fast flowing water. Loss of taxa that have a high and moderate requirement for good water quality.	Loss of almost all taxa that prefers very fast flowing water. Loss of taxa that have a high and moderate requirement for good water quality.

Scenario 8

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC a	Sc 8	DRY SEASON	WET SEASON
Specialist inputs					
C/D	C	D	C/D	Higher base flows through the winter months, and improved water quality.	Higher floods and base flows during the summer months, and better water quality due to the higher flows.

Fish

Scenario 1, 5 and 7

Eight fish species would historically have occurred at this site at low to moderate abundances (Kleynhans *et al*., 2007). A further 2 species *L. kimberleyensis* and *A. sclateri* may occasionally have been recorded at the site at low abundances (Kleynhans *et al*., 2007). Seven of the expected species have a preference for either slow deep or slow shallow habitats suggesting that these are the predominant velocity depth classes that occur at this site. Two species: *L. aeneus* and *A. sclateri* have a preference for fast shallow habitat and *L. kimberleyensis* for fast deep habitats. Six of the expected fish species are either moderately tolerant or tolerant of reduced flow. Four of the expected fish species are moderately intolerant of reduced flow levels. These species would therefore have a requirement for flow at some stage of their lifecycle. The expected fish assemblage show high levels of preference for a wide range of cover types. Nine of the expected fish species are either moderately tolerant or tolerant of modified water quality. *L. kimberleyensis* is moderately intolerant of modified water quality. Four species have a requirement for movement between reaches/ fish habitat segments. These species 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 in the project area during the 2 Reserve Determination survey. The PES of the site was rated as a Class D. This can be attributed to the absence of three of the expected fish species (*A. sclateri, A. anoplus* and *T. sparmanii*) from the site during the 2 Reserve Determination surveys.

One exotic species *G. affinis* was recorded at the site. A further exotic species *C. carpio* has previously been recorded at the site but was not captured during the Reserve surveys.

EC				**ECOLOGICAL CONSEQUENCES**	
PES	**REC**	**AEC a**	**Sc 1,5,7**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
D	C	C	D	Four of the expected indigenous fish species were recorded at site EWR15 during the dry season survey	Six of the expected indigenous fish species were recorded at site EWR15 during the wet season survey
A PES of D was recorded at site EWR15 during the Reserve surveys					

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Austroglanis sclateri	**2.00**	**0.00**
Labeobarbus aeneus	**4.00**	**3.00**

Barbus anoplus	**5.00**	**0.00**
Barbus paludinosus	**4.00**	**4.00**
Clarias gariepinus	**4.00**	**4.00**
Labeo capensis	**4.00**	**4.00**
Labeo umbratus	**4.00**	**3.00**
Pseudocrenilabrus philander	**4.00**	**4.00**
Tilapia sparrmanii	**4.00**	**0.00**

Scenario 4, 6 and 8

Scenarios 4, 6 and 8 are very similar. Based on these scenarios increased base flows can be expected during both the wet and dry seasons. The increased base flows will result in reductions of 20 – 30% in salt loads during both seasons. The increased base flows and improved water quality may result in the increased abundance of *B. anoplus* at the site. *B. anoplus* was expected at the site in moderate abundance but was not recorded during either wet or dry season survey. The increased abundance of *B. anoplus* in the reach will result in an increase in the PES from a class D to a Class C.

EC				**ECOLOGICAL CONSEQUENCES**	
PES	**REC**	**AECa**	**Sc 4,6,8**	**DRY SEASON**	**WET SEASON**
Specialist inputs					
D	C	C	D	Increased base flows and 20 – 30% reduction in salt loads	Increased base flows and 20 – 30% reduction in salt loads
Increased base flows during both seasons and a 20 – 30% reduction in salt loads may result in the increased abundance of *B. anoplus* at the site. *B. anoplus* was expected at the site in moderate abundance but was not recorded during either of the surveys. The increased abundance of B. anoplus at the site results in an increase in the PES from a Class D to a Class E					

Scientific names	Reference Frequency of Occurrence	PES: Observed & Habitat Derived Frequency of Occurrence
Austroglanis sclateri	**2.00**	**0.00**

Labeobarbus aeneus	**4.00**	**3.00**
Barbus anoplus	**5.00**	**3.00**
Barbus paludinosus	**4.00**	**4.00**
Clarias gariepinus	**4.00**	**4.00**
Labeo capensis	**4.00**	**4.00**
Labeo umbratus	**4.00**	**3.00**
Pseudocrenilabrus philander	**4.00**	**4.00**
Tilapia sparrmanii	**4.00**	**0.00**

4.4.4 Summary of ecological consequences

The summary of the ecological categories for the operational scenarios at EWR 15 are provided in Table 4.4.

Table 4-4: Summary of ecological categories for operational scenarios at EWR site 15

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

5 SOCIO-ECONOMICS AND GOODS AND SERVICES

This is a summary of the Socio Economic Present State Evaluation Report (DWA, RDM/ WMA0910C000/01/CON/0410). 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 Middle Vaal WMAs. The relevant economic zones were:

- Middle Vaal WMA
- Vaal River main-stem;
- Rhenoster;
- Schoonspruit;
- Sand;
- Vet; and
- Vals.

Water use data were collected for various water users within the Middle Vaal WMA. 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. 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.

In 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 Vaal WMAs.

The implementation of the EWRs on the major tributaries will result in limited socio-economics impacts (mainly on irrigation).

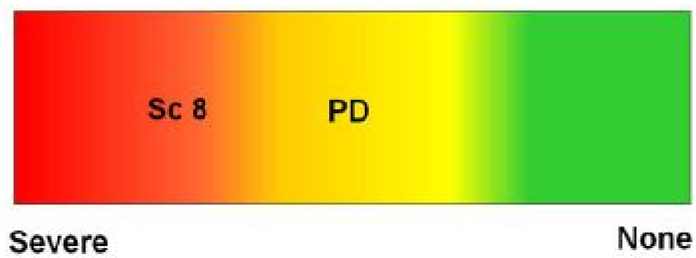


Figure 5.1: Traffic light diagram of overall socio-economic impacts of Scenarios 7 and 8 for Middle Vaal WMAs

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 Middle Vaal WMAs.

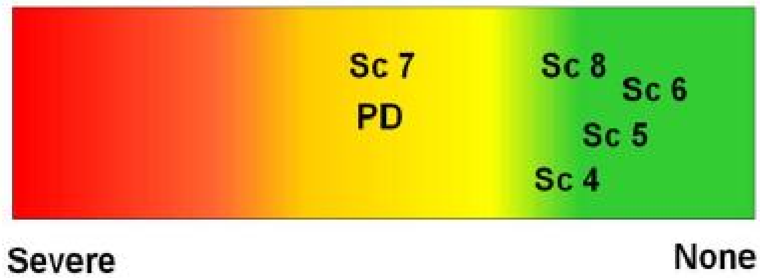


Figure 5.2: Traffic light diagram of overall Ecosystems Goods and Services impacts of Scenarios 4, 5, 6, 7 and 8 for Middle Vaal WMAs

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 scenario's.

There is currently too much flow in the main stem Vaal. Water quality impacts and seasonal flow changes also impacts on the ecological integrity of the system.

Water use on the tributaries needs to be controlled. The main stem benefits from the EWR contributions from the tributaries (i.e. you need to protect the tributaries in order to use the main stem).

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

Main Stem	**Sc 1 PD**	**REC**	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
12 Vermaasdrift	**D**	**D**	**C**	**C/D**	**C/D**	**D**	**C**
13 Regina	**C**	**C**	**C**	**C**	**C**	**C**	**C**
Tributaries							
14 Vals	**C/D**	**C/D**	**C/D**	**D**	**C/D**	**C/D**	**C/D**
15 Vet	**D/E**	**D**	**D**	**D/E**	**D**	**D/E**	**D**

7 CONCLUSIONS AND RECOMMENDATIONS

A summary of the ecological consequences per scenario for the main stem Vaal and the tributaries is shown in Figure 7.1 and Figure 7.2. In summary the following are concluded:

- Significant deviations between Scenario 7 and 8 were found for EWR R1 (Renoster), EWR 14 (Vals), EWR V1 (VET) and WR V2 (Vet)
- 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
- Little impact on Ecosystem goods and services – negative impact at Vals River for Scenario 5
- 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
- Increased flows but main stem Vaal has been altered for many years and the biota has adapted
- Tributaries less water and water quality issues

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

Table 7-1: Final recommendations per EWR site

EWR site	**Recommendation**
12 Vaal (Regina)	Sign off for PES=REC=D
13 Vaal (Vermaasdrift)	Sign off for PES=REC=C
14 Vals	Sign off for PES=REC=C/D
15 Vet	Sign off for REC=D (instream PES) with recommendation that no more abstractions upstream are allowed as the EWRs below Erfenis and Allemanskraal Dams are currently not being met. It was noted that the Reserve at the sites that were extrapolated by WRP on the Sand and upper Vet River would be unrealistic as this would require 70% reduction in irrigation. The management of this system should be investigated in more detail (e.g if the EWR on the Sand and Vet are not met, how will this affect the main stem, can these requirements be provided by other tributaries? Trade-off options should be explored here.

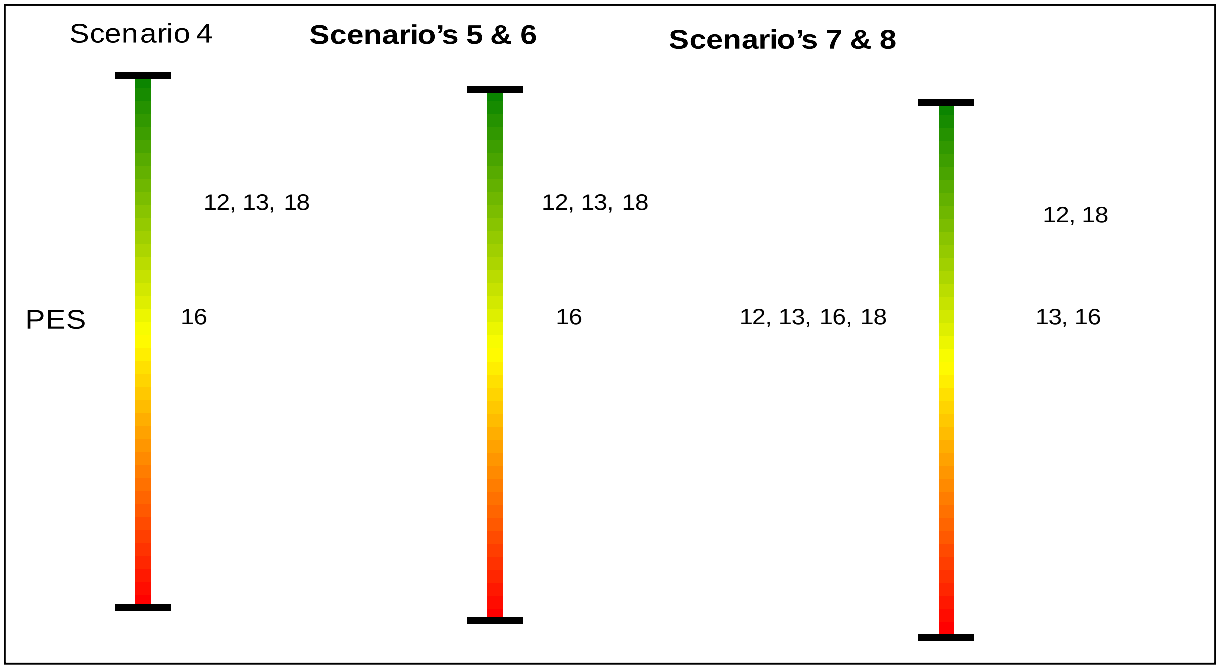


Figure 7.1: Summary of ecological consequences per scenario for the main stem of the Vaal EWR sites

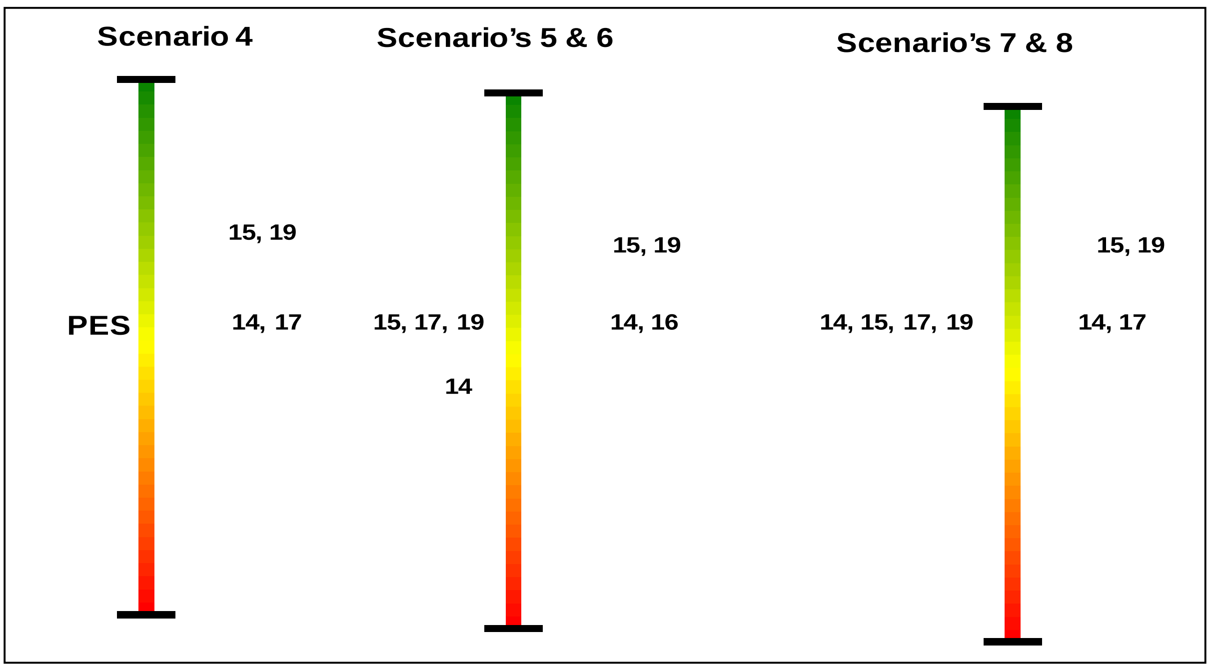


Figure 7.2: Summary of ecological consequences per scenario for the tributaries of the Vaal EWR sites

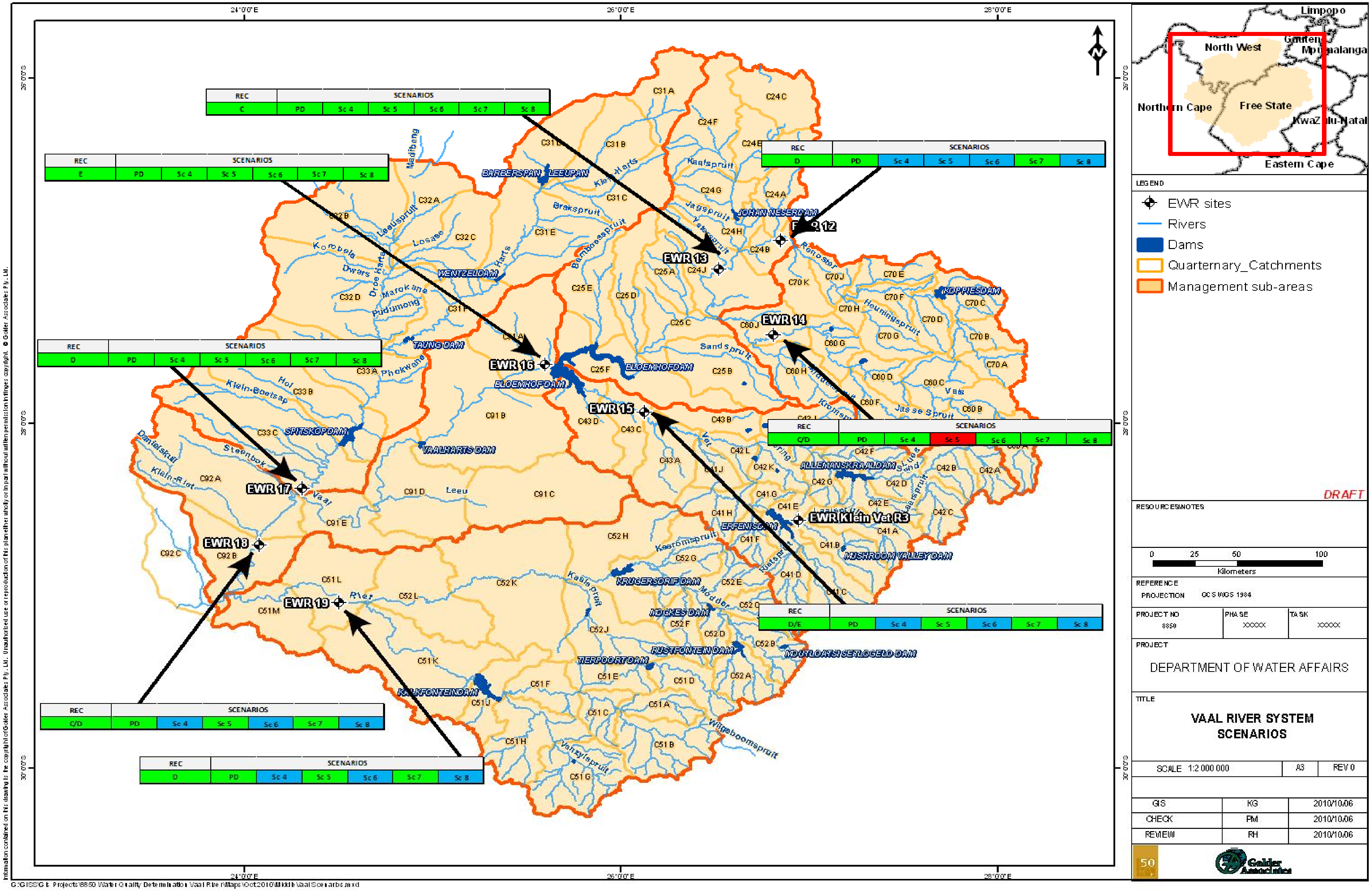


Figure 7.3: Summary of Ecological Consequences of Scenarios

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.

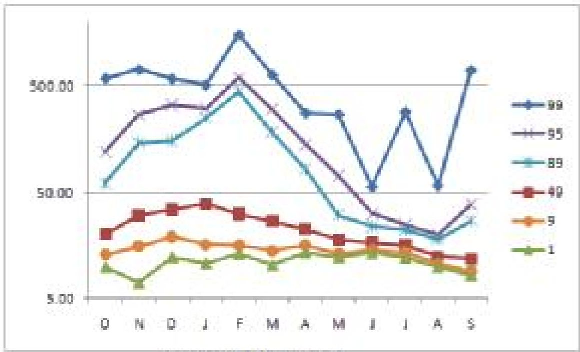
DWA (2010a): Hydrological inputs for the Reserve determination study for selected water resources in the Vaal Water Management Area. Report no: RDM/C000/01/CON/0607. Pretoria, South Africa.

APPENDIX A:

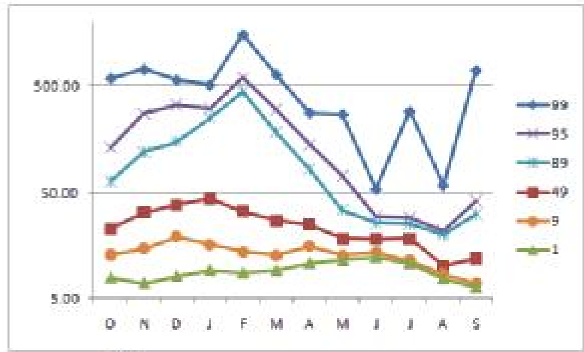
COMPARISON OF OPEARTIONAL SCENARIOS ON

FLOWS AT EWR SITES

EWR 12, Vaal River at Vermaasdrift



NEW PRESENT DAY (Sc 1)



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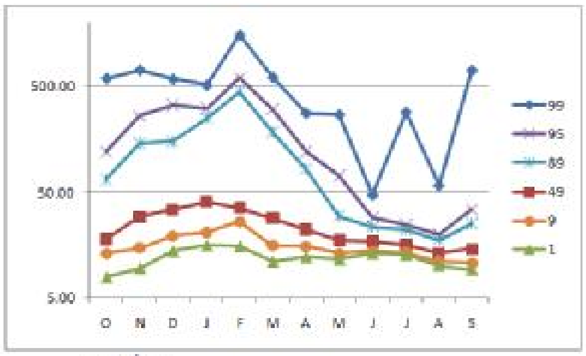
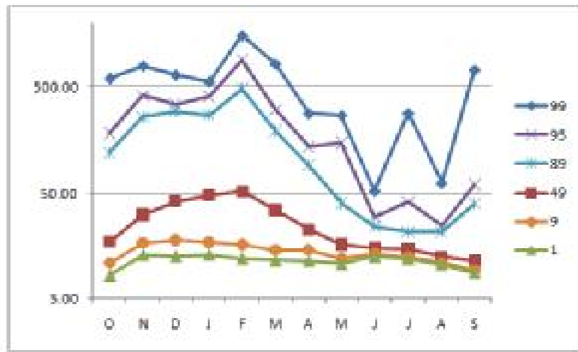
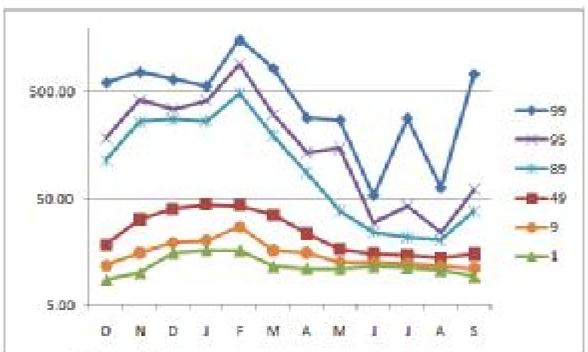


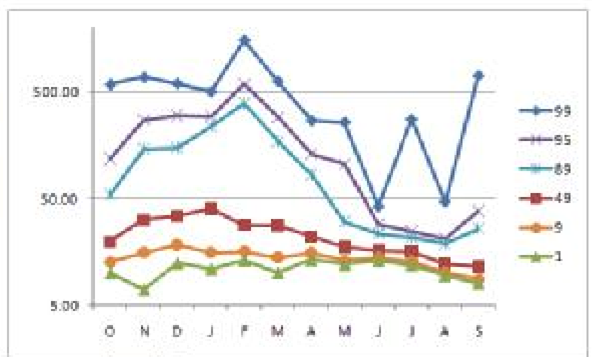
Scenario 4



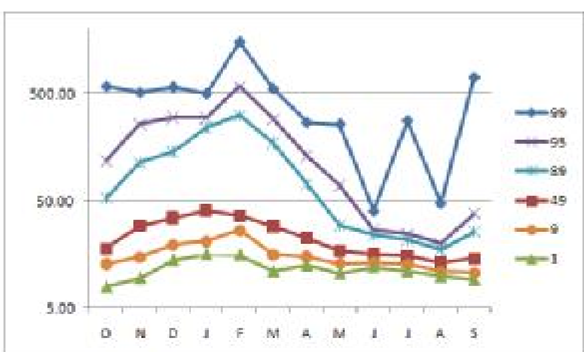
Scenario 5



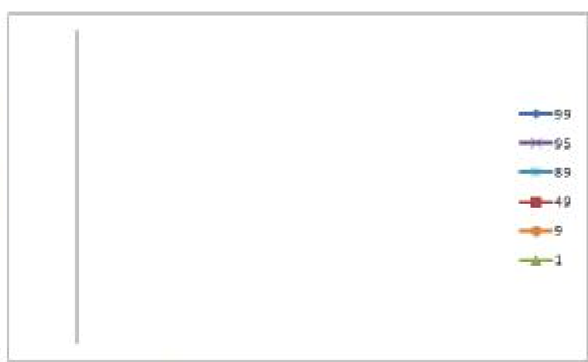
Scenario 6



Scenario 7



Scenario 8



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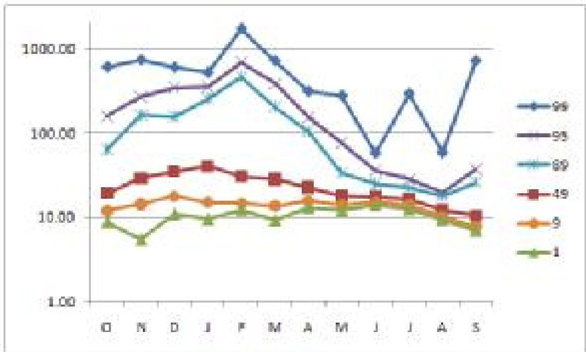
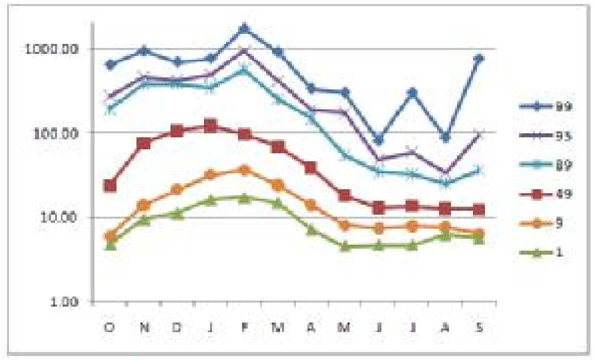
EWR 13, Vaal River at Regina Bridge



NEW PRESENT DAY (Sc 1)



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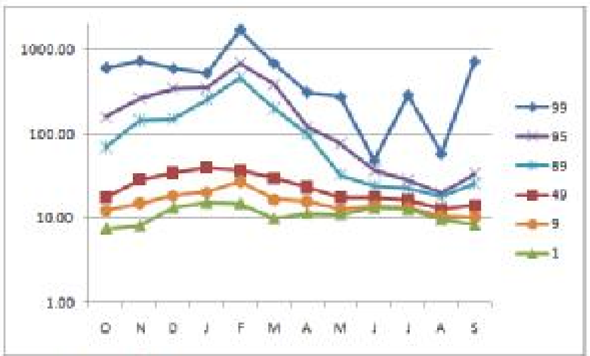
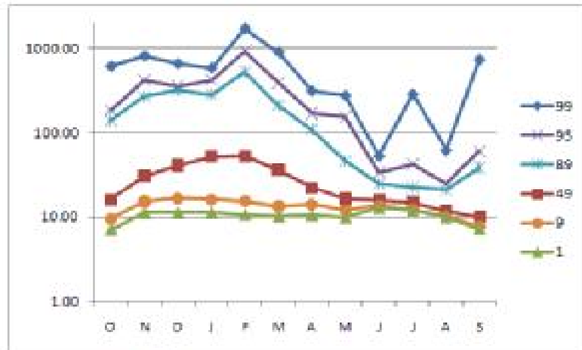
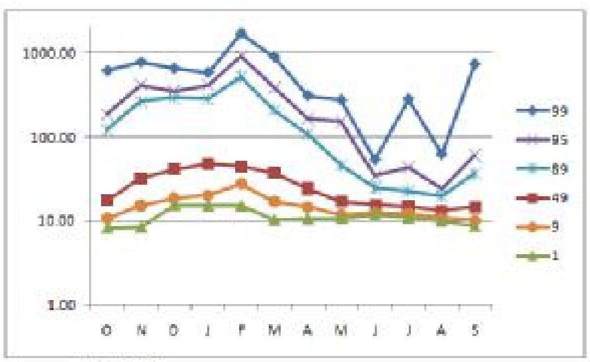


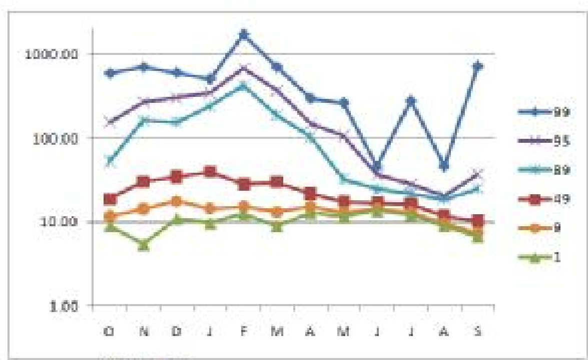
Scenario 4



Scenario 5



Scenario 6



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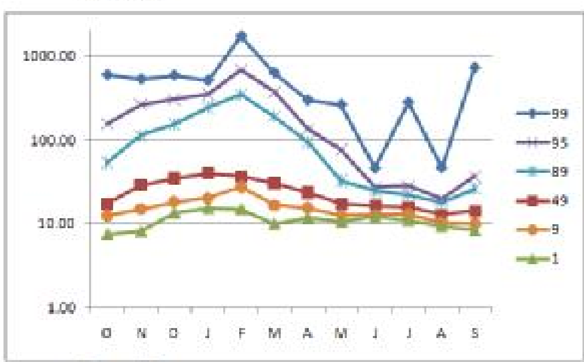
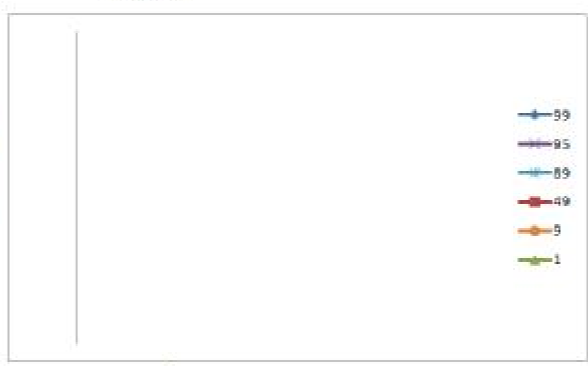


Scenario 8



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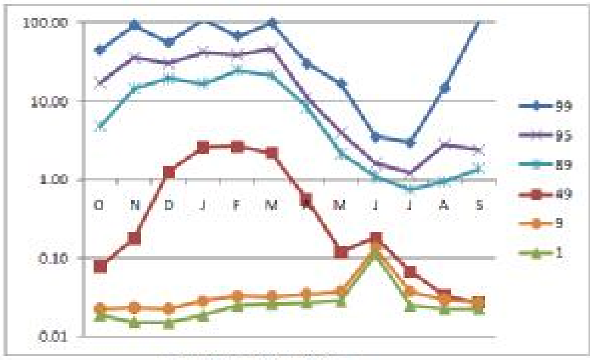
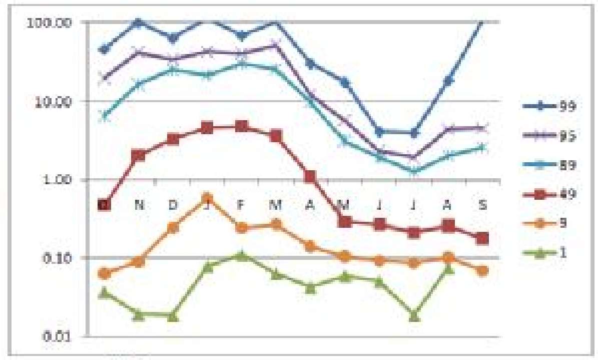
EWR 14, Vals River at Proklameersdrift



NEW PRESENT DAY (Sc 1)



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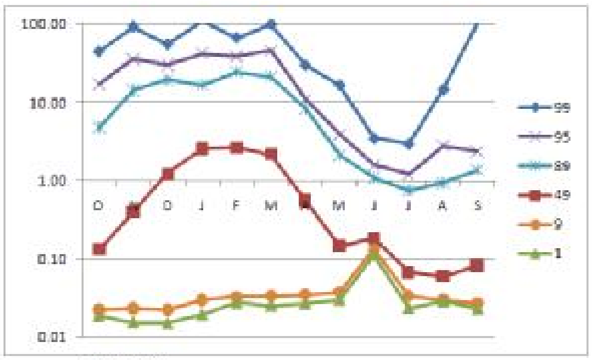
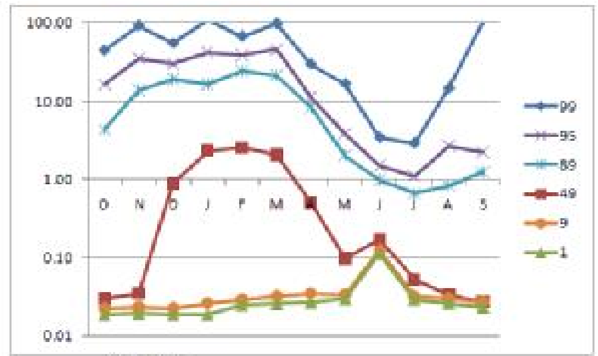


Scenario 4



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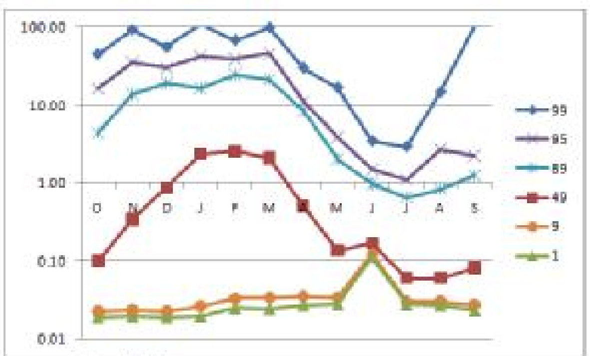

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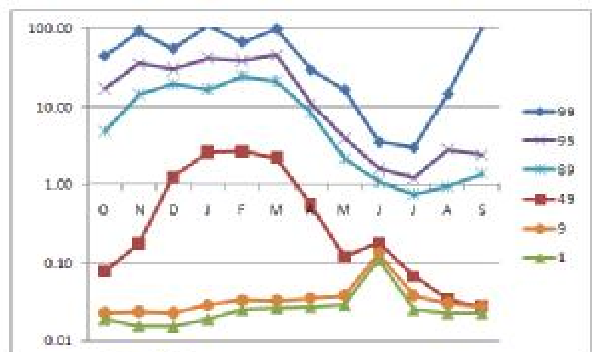
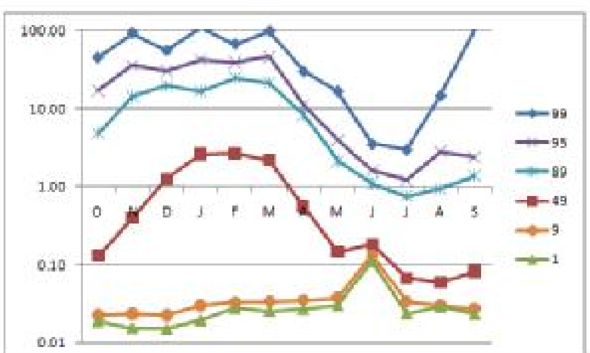
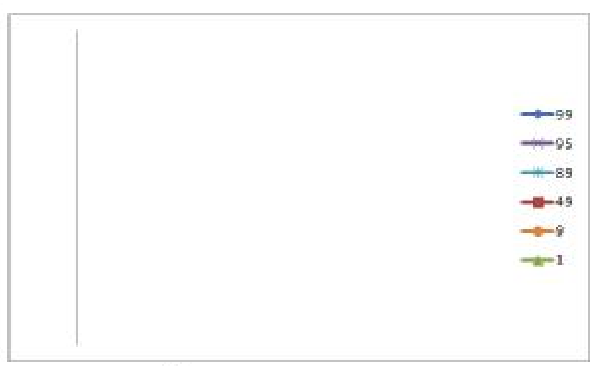


Scenario 7



Scenario 8



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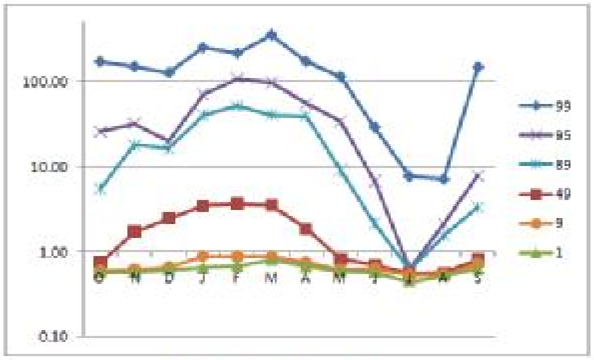
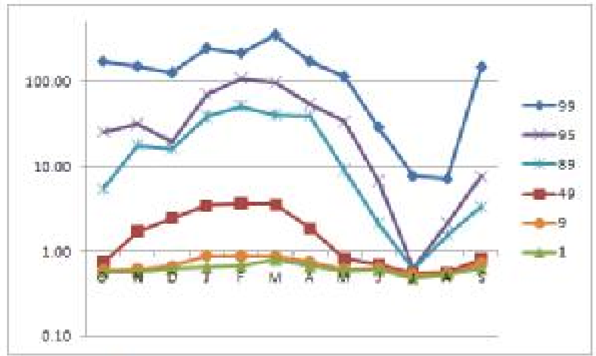
EWR 15, Vet River at Fisantkraal



NEW PRESENT DAY (Sc 1)



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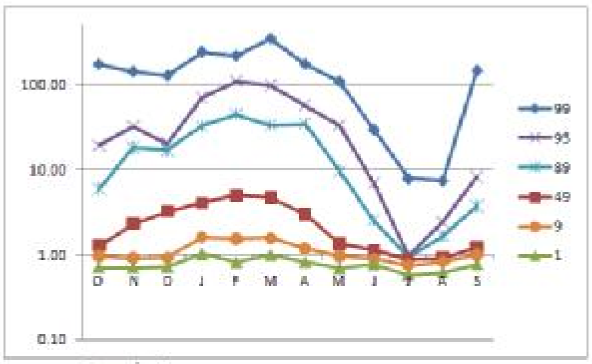
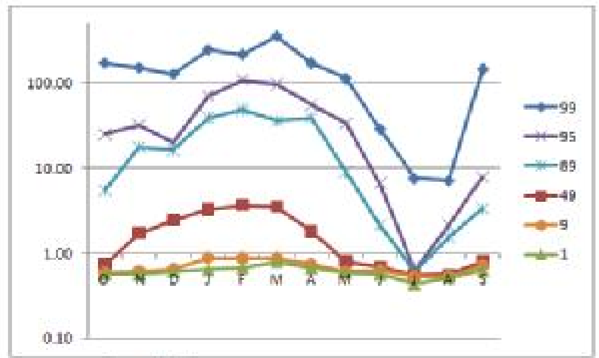
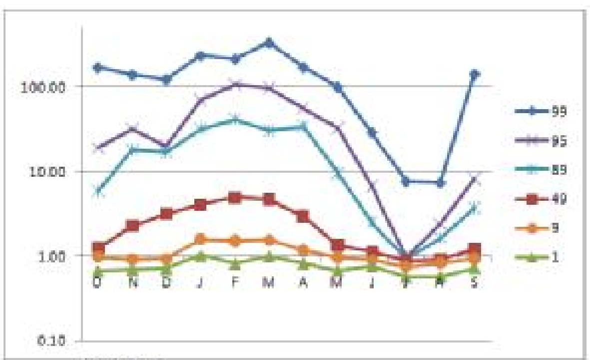


Scenario 4



Scenario 5



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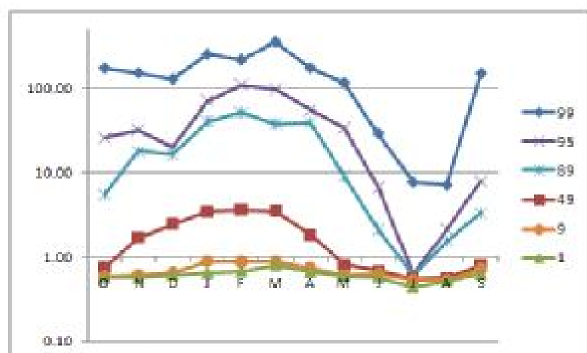
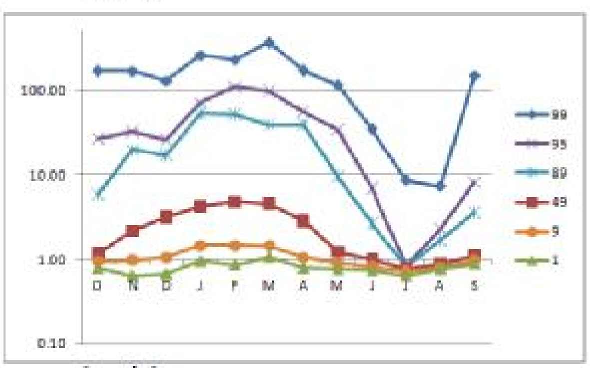


Scenario 7



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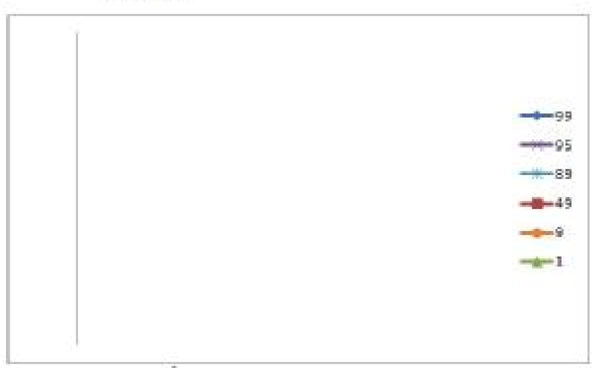

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