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Classification of Significant Water Resources(River, Wetlands, Groundwater and Lakes) in the Upper Middle and Lower Vaal Water Management Areas (WMA) 8,9,10

SCENARIO EVALUATION REPORT

June 2012

Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10

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Prepared by:

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1.1	RDM/WMA8,9,10/00/CON/CLA/0111	Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10, Inception Report
1.2	RDM/WMA8,9,10/00/CON/CLA/0211	Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10, Status Quo Report
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1.5	**RDM/WMA8,9,10/00/CON/CLA/0112**	**Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10, Scenario Evaluation Report**

Bold indicates this report.

Title: ***Scenario Evaluation Report***

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Study Name: ***Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10***

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Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10

Scenario Evaluation Report

Executive Summary

1. PURPOSE OF THE STUDY

*This study entitled "Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10" was commissioned by the Chief Directorate Resource Directed Measures of the Department of Water Affairs (DWA) in October 2010. The ultimate goal of the study is the implementation of the Water Resource Classification System (WRCS) in the above-mentioned three Vaal WMAs according to the 7-step process proposed by the WRCS (**DWAF, 2007**).*

2. STUDY AREA

*The core of the study area consists of the Upper, Middle and Lower Vaal River Water Management Areas (WMAs), however, due to the numerous inter-basin transfers that link this core area with other WMAs, the water resource assessments had to be undertaken in the context of the Integrated Vaal River System (IVRS) which also includes portions of the Komati, Usutu, Thukela, Senqu River (located in Lesotho) and Upper Orange (Riet-Modder River) catchments. The study area, therefore, comprises of the water resource and bulk supply systems of the entire IVRS as shown in **Figure A-1** of **Appendix A.** A detailed description of the IVRS and its operation is provided in the Water Resource Analysis report of this study (**DWA, 2012a**).*

3. PURPOSE OF THIS REPORT

*Step 5 of the WRCS which comprises of the evaluation of scenarios within the Integrated Water Resource Management (IWRM) process is the subject of this report. The purpose of this report is, therefore, to provide the ecological and socio-economic consequences of a range of operational scenarios, i.e. the impact on the Ecological Category of the Ecological Water Requirement (EWR) sites where applicable, based on the output from the water resource planning analyses (**DWA, 2012a**).*

4. DEFINITION AND EVALUATION OF OPERATIONAL SCENARIOS

*Pertinent protection objectives and specific water resource management variables that are relevant to the Integrated Vaal River System (IVRS) were identified as the basis for formulating alternative future management, water use and protection options (operational scenarios) for analysis in the study. The operational scenarios identified for analyses are listed in **Table 3.2** and described of **Section 2.3**. These scenarios were analysed with the Water Resource Planning Model and the ecological, water availability, socio-economic as well as the Goods and Services (G&S) implications were evaluated as part of Step 5 of the seven step process to implement the WRCS. The approach adopted for the scenario evaluation is described in **Section 2.4**.*

5. CONCLUSIONS AND KEY FINDINGS

Key findings in terms of the water resource availability, socio-economic implications, ecological consequences and G&S are summarised below.

(a) Water Resource Availability

The key findings with respect to water resource availability implications of the scenarios are given below:

- *Implementing the revised Sterkfontein Dam release rule (**Scenario 8**) reduces the firm supply capability of the system by 45 million m^3/annum. This reduction is due to higher evaporation losses in and spills from Vaal Dam.*
- ***Scenario 9b**, where releases are made to meet EWRs downstream of Douglas Weir (in combination with the revised Sterkfontein Dam release rule), reduced the firm supply from the system by 99 million m^3/annum. Furthermore, water balance assessments for Scenario 9b indicated that the next augmentation scheme will be required by 2043 (original date was 2049). This means that implementation of the Douglas EWR will cause the date of augmentation to move forward by 6 years.*
- *The only water supply implications in the tributary catchments occurred at three desktop biophysical nodes in the Klip River (Free State) integrated Unit of Analysis (IUA).*

(b) Socio-economic implications

The economic implication of the reduction in firm supply for Scenario 9b was determined on the basis of the increased costs as reflected by the time value of capital expenditure for augmentation that will need to be incurred earlier. The assumption is that the Thukela Water Project will be the next augmentation scheme to be implemented after Lesotho Water Highlands Water Project (LHWP) Phase 2.

The economic cost of providing the Reserve requirements at the Douglas EWR site is thus between R511 million and R569 million expressed in 2012 prices. Although it is a very large sum of money, it represents less than 4.9% of the total projected cost of the Thukela scheme (i.e. R11.3 billion). Furthermore, it represents less than 0.035% of the estimated annual turnover of the large water users in the three Vaal WMAs or less than 0.14% of the GDP generated by the water in the project area.

(c) Ecological Consequences

*The ecological consequences of the indicated scenarios are summarised in the **Table 1** below, indicating how the flows at the affected EWR sites compare to what is required to achieve the Recommended Ecological Category (REC). In general the ecological consequences evaluation of the EWR sites not listed in the table meet the Present Ecological State (PES).*

Table 1: Summary of ecological consequences

EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7	Opt Sc
EWR 1	✓	✓	✓	✓	✓	✓	
EWR 2	N/A	✓	✓	✓	✓	✓	
EWR 3	N/A	✓	✓	✓	✓	✓	
EWR 4	X	X	X	X	X	X	
EWR 5	X	X	X	X	X	X	
EWR 6	✓	✓	✓	✓	✓	N/A	
EWR 8	X	X	X	X	X	N/A	X
EWR 9	✓	X	✓	X	✓	N/A	
EWR 10	X	X	X	X	X	N/A	
EWR 11	X	X	X	X	X	N/A	
EWR 12	✓	✓	✓	✓	✓	✓	
EWR 13	✓	✓	✓	✓	✓	✓	
EWR 16	✓	✓	✓	✓	✓	✓	
EWR 18	✓	✓	✓	✓	✓	✓	

Legend:	Scale
√ : Meets REC, all components.	Good
√ : Meets REC, most components.	
X : Improvement to PES, below REC.	
X: Meets PES, REC is not achieved.	
X: EC below PES, above an E EC.	
X: EcoStatus is below a D EC.	Poor

(d) Goods and Services

The Ecological G&S in the Vaal River Catchment has pointed to the fact that, with a few notable exceptions, overall importance is relatively low. This is largely allied to the nature of the catchment and that there are few communities directly dependant on the G&S provided by the riverine system and for whom such dependence is linked to livelihood strategies.

In this context the scenarios were evaluated to determine which EWRs were likely to be associated with significant issues that could have implications for G&S. There are no significant impacts that are generated by the envisaged scenarios that would constitute a significant change to G&S for communities that are directly dependant. While some impacts on recreational fishing may be a consequence these are unlikely to *be significant.*

*It is proposed that the catchment configuration (set of Biophysical Node Ecological Categories) for **Scenario 3** and **Scenario 2** for EWR 9 be selected for recommendation.*

Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10

Scenario Evaluation Report

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ABBREVIATIONS

Acronym	Meaning
AEC	Alternative Ecological Category
AMD	Acid Mine Drainage
DSS	Decision Support System
DWA	Department of Water Affairs
DWAF	Department Water Affairs and Forestry
EC	Ecological Category
ELU	Existing Lawful Use
ESBC	Ecologically Sustainable Base Configuration scenario
EWR	Ecological Water Requirements
FRAI	Fish Response Assessment Index
G&S	Goods and Services
HFY	Historic Firm Yield
IUA	Integrated Unit of Analysis
IVRS	Integrated Vaal River System
IWRM	Integrated Water Resource Management
LHFP	Lesotho Highlands Future Phase
LHWP	Lesotho Highlands Water Project
LSR	Large Semi Rheophilic fish guild
MC	Management Class
MIRAI	Macroinvertebrate Response Assessment Index
MRU	Management Resource Unit
NFEPA	National Freshwater Ecosystem Priority Areas
NWA	National Water Act
NWRCS	National Water Resource Classification System
PD	Present Day
PES	Present Ecological State
PSC	Project Steering Committee
PSP	Professional Service Provider
RDM	Resource Directed Measures
REC	Recommended Ecological Category
Sc	Scenario
TEACHA	Tool for Ecological Aquatic Chemical Habitat Assessment
TDS	Total Dissolved Solids
VEGRAI	Vegetation Response Assessment Index
VRESAP	Vaal River Eastern Sub-system Augmentation Project
VRS	Vaal River System
VRSAU	Vaal River System Analysis Update
WC/WDM	Water Conservation and Water Demand Management
WMA	Water Management Area
WRCS	Water Resources Classification System
WRPM	Water Resources Planning Model

Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8, 9, 10

Scenario Evaluation Report

1 INTRODUCTION

1.1 PURPOSE OF THE REPORT

This report describes the evaluation of results obtained from the water resource scenario analyses carried out by the appointed Professional Service Provider (PSP) for undertaking the Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10 Study. The study was commissioned by the Chief Directorate: Resource Directed Measures of the Department of Water Affairs (DWA) in October 2010 and the main objective of the study is to determine the Management Class (MC) of the significant water resources in the three Vaal WMAs.

The Water Resources Classification System (WRCS), which is required by the National Water Act (NWA) (Act 36 of 1998), provides a set of guidelines and procedures for determining different classes of water resources. The WRCS (**DWAF, 2007**) comprises of 7 steps and prescribes a consultative process to classify water resources (Classification Process) to help facilitate a balance between the protection and use of the nation's water resources. The outcome of the Classification Process will be the approval of the MC by the Minister or her delegated authority for every significant water resource (river, estuary, wetland and aquifer) which will be binding on all authorities or institutions when exercising any power, or performing any duty under the (NWA. The MC outlines those attributes that the Department and society require of different water resources.

The objective of Step 4 of the classification procedure is to determine the Ecologically Sustainable Base Configuration scenario (ESBC) and to establish starter catchment configuration scenarios. The objective in establishing starter catchment configuration scenarios is three fold:

- To establish a feasible number of catchment configuration scenarios for assessment by the regulator (DWA) and the stakeholders;
- to incorporate planning scenarios (e.g. future use, equity considerations, existing lawful use (ELU)); and
- to establish Resource Directed Measures (RDM) starter catchment configuration scenarios (e.g. guided by the EcoClassification procedure).

The existing ecological consequences' results generated during the Comprehensive Reserve Study for scenarios that reflected the present state were used as a baseline for determining the ESBC scenario. The ESBC scenario in turn formed the basis for the execution of Step 5 of the WRCS which comprises of the evaluation of scenarios within the Integrated Water Resource Management (IWRM) process. Step 5, which is partly the subject of this report, includes the following sub-steps:

- Step 5a: Run yield model for ESBC and other catchment configuration scenarios and adjust if necessary;
- Step 5b: Assess water quality implications (fitness for use) for all users;
- Step 5c: Report on ecological condition and aggregate impacts per Integrated Unit of Analysis (IUA) for each scenario;
- Step 5d: Value changes in aquatic ecosystem and water yield;
- Step 5e: Describe the macro-economic and social implications of different catchment configuration scenarios;
- Step 5f: Evaluate overall scenario implications at an IUA-level and a regional level; and
- Step 5g: Select a subset of scenarios for stakeholder evaluation.

Step 5a was undertaken with the Water Resource Planning Model and although a brief description thereof is provided in **Section 2**, details of the water resource analyses are documented in a report compiled as part of this study (**DWA, 2012a**). The results of activities carried out as part of Steps 5b to 5f are presented in this report.

The purpose of this report is, therefore, to provide the ecological and socio-economic consequences of a range of operational scenarios, i.e. the impact on the Ecological Category (EC) of the Ecological Water Requirement (EWR) sites where applicable, based on the output from the planning model (**DWA, 2012a**).

1.2 STUDY AREA

The study area comprises of the water resource of the Vaal River System which includes the catchments of the Upper, Middle and the Lower Vaal Water Management Areas (WMAs) (see **Figure A-1** of **Appendix A)**. Other sub-systems that are linked to the Vaal River System are also shown in **Figure A-1**. The supporting sub-systems will form part of the water resource system analysis (either directly or indirectly) to ensure the MC is determined in an integrated manner.

1.3 INTEGRATED UNITS OF ANALYSIS AND BIOPHYSICAL NODES

Considerations for the identification and selection of the Integrated Units of Analysis (IUAs) are described in the Status Quo Report (**DWA, 2011a**) compiled as part of this study. The identified IUAs for the three Vaal Water Management Areas are shown in **Figures B-1**, **B-2** and **B-3** of **Appendix B**.

The key biophysical nodes are the Ecological Water Requirement (EWR) sites and the selection process of these sites is documented in the recent Reserve studies (**DWAF, 2008; DWAF 2009a and b**). Since large sections of the catchment were still unaccounted for additional biophysical nodes (referred to as desktop biophysical nodes) had to be selected. Various tools and information such as the Desktop EcoClassification results generated during the recent Reserve studies and the National Freshwater Ecosystem Priority Areas (NFEPA) were used to identify these additional nodes referred to as desktop nodes. All attempts were made to select nodes that fairly represent the different conditions and operational procedures in the catchment. A total of 115 biophysical nodes were selected in the three Water Management Areas. The locations of these biophysical nodes are shown in **Figures B-1**, **B-2** and **B-3** of **Appendix B**.

1.4 LAYOUT OF THE REPORT

A brief description of the Water Resource Planning Model (WRPM) scenarios is provided in **Section 2** of the report. **Section 3** describes the approach adopted for the scenario evaluation at the EWR sites. **Section 4** to **8** provides the Ecological consequences of the Classification scenarios at the various Comprehensive EWR sites in the study area and the results are summarised in **Section 9. Section 10** focuses on the Douglas EWR site, while **Section 11** provides the results of the consequences of the scenarios on the G&S in the study area. The socio-economic assessments are described in **Section 12**. Key findings are summarised in **Section 13**, whilst the references are listed in **Section 14**.

2 WATER RESOURCE PLANNING ANALYSES

2.1 BACKGROUND

Due to the highly developed nature of the Integrated Vaal River System (IVRS) and the various inter-basin transfers that exist in the system, operating rules were developed that regulate when and how much water is transferred. The management and implementation of these operating rules are undertaken by the application of the Water Resource Planning Model (WRPM). The WRPM was subsequently used as the Decision Support System (DSS) for this study.

The WRPM configuration of the IVRS includes the hydrological database resulting from the Vaal River System Analysis Update (VRSAU). The VRSAU hydrology covers the period October 1920 to September 1995. It is important to note that the hydrological analyses of the VRSAU study were not necessarily undertaken at quaternary catchment level as the focus was on the most representative modelling of relevant sub-catchments. The WRPM configuration was refined as part of the Reserve study to include explicit modelling of the identified Ecological Water Requirement (EWR) sites (see **Section 2.2**) below.

The WRPM database includes growing water requirements up to the year 2030. Since the IVRS is analysed on an annual basis, the water requirement projections of the major bulk water suppliers (Rand Water, Midvaal Water Company and Sedibeng Water), the strategic water user Eskom, as well as large industries such as Sasol and Mittal Steel, are also updated annually. The most recent water requirement projections of the above-mentioned users (revised as part of the 2011/2012 Annual Operating Analysis) were used for the WRPM scenario analyses undertaken for this study. Two levels of catchment development were considered: Present Day (2011) and a Future (2020) condition.

2.2 ASSESSMENT OF KEY BIOPHYSICAL NODES

The key biophysical nodes are the EWR sites and the selection process of these sites is documented in the recent Reserve studies (**DWAF, 2008**; **DWAF 2009a** and **b**). The location of the EWR sites were focussed on the main stem and key tributaries, i.e. the areas where there are water resource issues and where operational management of the system can be implemented. The locations of the EWR sites are shown in **Figures B-1**, **B-2** and **B-3** of **Appendix B**.

The quantification of EWRs at the key biophysical nodes (EWR sites) was undertaken at a Comprehensive Reserve assessment level and the results were summarised from the detailed reports available for this study. The EWR results of all previous Reserve studies were checked to ensure that accurate data could be applied during step 4 of the WRCS. The detailed results of the EWRs at all the sites are provided in the Quantification of the EWR report (**DWA, 2011b**).

The most realistic EWR to be modelled at each site was selected in consultation with the technical Reserve teams of the Comprehensive Reserve Determination study. Recommendations based on the evaluation of the EcoClassification results of the Reserve study, as documented in the Quantification of the EWR report (**DWA, 2011b**) of this study formed the basis for the definition of the EWR scenario to be used for the WRPM scenario analyses.

In terms of the EWRs, the Upper Vaal WMA results were recommended for use in this study. For the Middle and Lower Vaal EWR sites the review concluded that the present flow regime and operation of the system should be signed off as the Reserve as the present day flow regime will maintain the Recommended Ecological Category (REC) which is in all cases the same as the Present Ecological State (PES). In summary, the recommended EWRs for the sites determined in the Reserve Study provide a viable and practical Ecological Sustainable Base Condition Scenario (ESBC) against which relative changes can be evaluated.

The EWR scenario selected for inclusion in the WRPM analyses, therefore, comprised of the following combination of individual EWRs:

- The REC EWRs of the following Vaal River EWR sites were considered: RE-EWR1, EWR1, EWR2, EWR3, EWR6, EWR8, EWR9, EWR10, EWR11 as part of this study (EWR sites 4, 5 and 7 excluded);
- The EWRs for 8 additional EWR sites defined in the Waterval, Renoster, Schoonspruit and Harts, river catchments were included;
- The REC EWRs of the Thukela EWR site downstream of Driel Barrage were included; and
- The Senqu Sub-system EWRs were included.

The Douglas EWR was not included in the analyses undertaken for the Comprehensive Reserve Determination Study (**DWA, 2010d**). Since the Orange River plays an important role as a refuge area for aquatic biota and the migration and movement of the biota between the Orange and Vaal River it was recommended that the impact of including the Douglas EWR be considered.

Implementation of the Douglas EWR was expected to have a significant impact on the yield of the Vaal River System (VRS). WRPM scenario analyses representative of two different development levels (refer to descriptions of **Scenarios 9a** and **9b** in **Section 2.3**) were carried out to determine the impact of implementing the Douglas EWR. Various assessments were therefore undertaken to ensure that the WRPM configuration of the Douglas Weir and its operation is representative of the current conditions.

2.3 DESCRIPTION OF OPERATING SCENARIOS

Scenarios in the context of water resource management and planning are plausible definitions (settings) of all the factors (variables) that influence the water balance and water quality in a catchment and the system as a whole.

Each scenario represents either the Present Day or an alternative future condition, generally reflecting a change to the present condition, and the analysis thereof gives the ability to compare the implications of one scenario against another with the ultimate aim to make a selection of the preferred scenario. Pertinent protection objectives and specific water resource management variables that are relevant to the Integrated Vaal River System (IVRS) were identified as the basis for formulating alternative future management, water use and protection options (operational scenarios) for analysis in the study. The approach was therefore to define scenarios by considering the current framework of Integrated Water Resource Management (IWRM) as the point of departure.

Currently the system wide IWRM activities being implemented are those defined in the Vaal River Reconciliation

Strategy which consist of the following:

- Eradicate unlawful irrigation water use by the year 2013;
- Continue with the implementation of Water Conservation and Water Demand Management (WC/WDM) to achieve the target savings by the year 2015;
- Implement Phase 2 of Lesotho Highlands Water Project (LHWP) to deliver water by the year 2020; and
- Implementation of the Integrated Water Quality Management Plan and commissioning of a Feasibility Study to recommend the most suitable long term solution to the Acid Mine Drainage (AMD) problem.

A further important characteristic of the VRS is the continuous growth in the water needs of the urban areas particularly in Gauteng. This is captured in planning scenarios of future water requirements abstracted from the system and return flows which are discharged back into the rivers as treated sewage effluent.

The scenario analysis results from the Reserve Determination Study identified the following aspects that need to be considered in the scenario formulation for the Classification Study:

- There is a need for improved seasonal flow variability in the Wilge River by implementing alternative release rules to convey water from the Sterkfontein Dam to the Vaal Dam. In particular the flow in the winter months should be reduced to more closely resemble the natural seasonal flow pattern.
- Resolve the apparent flow balance anomaly between the EWR for the two sites downstream of Grootdraai Dam and confirm the appropriate release rule from the dam. The objective is to prevent additional releases from the Grootdraai Dam resulting in additional pumping through the Vaal River Eastern Sub-system Augmentation Project (VRESAP) pipeline while achieving the REC at both EWR sites.
- The EWR site downstream of the Balfour Dam on the Blesbokspruit requires flow releases from the dam to achieve the REC. The simulation analysis showed that the water is available however it could not be established if the river release capacity of the Balfour Dam is such that the required releases can be made.
- The scenario results indicated that the release rules applied from some of the dams in the tributary catchments of the Middle Vaal WMA resulted in significant negative socio-economic implications on the users receiving water from those tributaries. These analyses were based on simplified release rules from the dams that were determined through extrapolation and flow apportionment methods. The release requirements from these dams (if any) need to be revised and the implication thereof on the flow in the main stem of the Vaal River must also be assessed during the scenario analysis.
- The evaluation of the EWR for the sites in the Middle and Lower Vaal WMAs confirmed that by maintaining the present day flow the PES will be maintained.
- The year 2020 development scenario showed that unacceptable ecological consequences occur due to increased discharges from waste water treatment works in the Suikerbosrand and Blesbokspruit (both rivers are located in the incremental catchments of the Vaal Barrage).

Various first round scenarios were evaluated by the study team of which the results pointed to the need for further alternative scenarios (alternative variable settings) to improve particular aspects of the system's behaviour. An iterative scenario formulation and analysis approach was followed where the results of one scenario informed the definition of a further alternative. The results of selected scenarios were presented at the Project Steering Committee (PSC) meeting held on 17 May 2012 (referenced as **Scenarios A** to **F**) and where applicable an alternative scenario reference is provided to allow for comparison of results.

Salient descriptions of the ten scenarios selected for analysis with the WRPM are provided below and summarised in **Table 3.2**:

- **Scenario 1**: This scenario represents the Present Day (2011) development conditions excluding the EWRs.
- **Scenario 2** (***Scenario A***): This scenario represents Present Day developments where the year 2011 water requirements and return flows as well as current infrastructure are analysed. Specific river release rules are applied at selected dams to achieve the REC at relevant EWR sites (refer to the selected EWR scenario as defined in **Section 2.2**). This scenario served as the starter scenario against which other scenarios were compared. The results of **Scenario 2** showed that there were inconsistencies at the EWR sites downstream of Grootdraai Dam which led to the formulation of **Scenario 7** (Scenario B). **Scenario 2** was referenced as ***Scenario A*** at the PSC meeting held on 17 May 2012.
- **Scenarios 3 and 4**: These two scenarios were based on the future (2020) development conditions which include the Lesotho Highlands Future Phase (LHFP) development option which was identified as the most feasible future option to be considered for augmenting the water resources of the Vaal River System. The preferred LHFP development comprises the proposed Polihali Dam and its associated conveyance infrastructure. The desalination of mine water and the re-use thereof (as discussed in Water Resource Analysis Report **(DWA, 2012a)** was also included in the configuration used for these two scenarios. In other words limited dilution releases are required from Vaal Dam to maintain the TDS concentration downstream of Vaal Barrage at 600 mg/l. The eradication of unlawful irrigation water use in the Upper Vaal WMA is also included in the configuration of these two scenarios. **Scenario 3** was referenced as ***Scenario D*** at the PSC meeting held on 17 May 2012.
- **Scenarios 5 and 6**: These two scenarios represent the full utilisation of the available water resources. The development condition upon which these two scenarios is based, is therefore representative of a future development level that falls between the Present Day (2011) and Future (2020) development conditions (i.e. current infrastructure). Mine water is naturalised, discharged and diluted with releases from Vaal Dam. The purpose of these two scenarios is to evaluate the impact on the yield of the system when implementing the Ecological Reserve. **Scenario 5** was referenced as ***Scenario C*** at the PSC meeting held on 17 May 2012.
- **Scenario 7 (*Scenario B*)**: This scenario evaluates an alternative to the EWR releases from Grootdraai Dam. For all the WRPM scenarios where the EWRs are included, the Grootdraai Dam compensation release rule is replaced with the EWR for EWR site 2. The Reserve Determination Study results, however, showed an apparent flow balance anomaly between the EWR for the two sites downstream of Grootdraai Dam (see **Figure B-1** for location of EWR sites). Since the Reserve Study's PD scenario

excluding the EWRs (Sc R1) was found to be acceptable, **Scenario 7** applies the Grootdraai compensation rule without the EWRs at EWR2 and EWR3. **Scenario 7** has the same configuration as **Scenario 2**, however no specific EWR related releases rule is implemented downstream of Grootdraai Dam, eliminating the inconsistency between the EWR2 and EWR3 sites. **Scenario 7** was referenced as ***Scenario B*** at the PSC meeting held on 17 May 2012.

- **Scenario 8 (*Scenario E*)**: This scenario was a further attempt to improve the seasonal variability of flow at the EWR site on the Wilge River downstream of Sterkfontein Dam. In view of the Reserve Determination Study's findings and recommendations the Sterkfontein release rule was revised prior to undertaking the WRPM scenario analyses for this study. The adjusted rule was adopted for all the scenarios listed in **Table 3.2** except **Scenarios 8**, **9a** and **9b**. Evaluation of the ecological consequences at EWR8 for **Scenarios 1** to **7** gave rise to recommendations for further refinement of the Sterkfontein release rule. The **Scenario 8** analysis involved the optimisation of this release rule which is described in **Section 9.3**. **Scenario 8** was referenced as ***Scenario E*** at the PSC meeting held on 17 May 2012.
- **Scenario 9a**: This scenario includes only the Douglas EWR and was evaluated to assess the impact thereof on the yield of the Vaal River System.
- **Scenario 9b (*Scenario F*)**: This scenario evaluates the implementation of an additional EWR site downstream of Douglas Weir on the Vaal River – about 15 km upstream of the confluence with the Orange River. **Scenario 9b** was based on the 2020 development condition and includes only the Douglas EWR. The purpose of this scenario was to evaluate the impact of the Douglas EWR on the Vaal River System subsequent to the implementation of the LHWP Phase 2. This scenario also incorporates the desalination and re-use of mine water. **Scenario 9b** was referenced as ***Scenario F*** at the PSC meeting held on 17 May 2012.

2.4 SCENARIOS EVALUATION STEPS

The steps followed in evaluating the scenarios were as follows:

- Select and implement the required EWR distribution release rules for inclusion in the water resource model. This data defines the target level of protection and specifies the flow regime at each biophysical node to achieve a particular Ecological Category (EC) i.e. A to E.
- Configure the input data of the water resource model according to the scenario's description. This is to simulate the intended abstraction level, infrastructure configuration as well as the dilution and inter-basin transfer operating rules. (Note that the scenario definition data are compliant with the Vaal River System Reconciliation Strategy).
- Undertake simulation analysis of the system for the scenario and prepare monthly flow and reservoir level trajectory results for further analysis.
- Apply the Habitat Flow Stressor Response (HFSR) assessment method to determine the ecological consequences of the scenario at the relevant EWR sites. The output from this activity indicates what Ecological Category (EC) will be achieved when the particular scenario materialises.

- Evaluate if there are any Goods and Services implications for the scenario.
- Determine if there are water availability implications. This is expressed as a reduction in the firm supply in water abstractions (reduction in yield) that occur as a result of the particular scenario.
- Determine the socio-economic implications of the scenario. (Typically this represents increased costs of augmentation if the system yield is reduced or degradation in socio-economic metrics is experienced where the available water in a tributary catchment is reduced.)

2.5 SCENARIOS RESULTS IN TERMS OF WATER AVAILABILITY

In terms of the considerations for the EWR sites evaluated as part of the WRPM analyses the following should be noted:

- Improvement of the seasonal flow distribution at EWR8 on the Wilge River was one of the objectives of the water resource assessments of this study and resulted in the adjustment of the Sterkfontein release rule. The simulated monthly flow distribution at EWR8, which was based on the optimised Sterkfontein release rule (derived as part of **Scenario 8**) were found to be an improvement of the initial adjusted rule described. The implication on the system yield was evaluated, and although the Historic Firm Yield (HFY) was reduced by 5%, stochastic analysis indicated that the assurance of supply to users was not jeopardised by the implementation of the optimised release rule.
- The results for WRPM **Scenario 7** indicated that the discrepancy identified between the simulated flows at EWR2 and EWR3 during the Reserve Determination Study, was resolved by implementing the existing Grootdraai compensation release rule and excluding the EWRs for these two sites.
- Implementation of the EWR scenario as described in **Section 2.2** did not jeopardise the assurance of supply to users in the Vaal River System.
- As expected, implementation of the Douglas EWR has significant implications on the yield of the Vaal River System. Impact assessments were done for two development conditions. The reduction in yield for a future scenario (representative of development conditions between 2011 and 2020 (**Scenario 9a**)) amounted to about 70 million m^3/a (8%). For the 2020 development conditions (**Scenario 9b**) it was found that the augmented yield (resulting from the implementation of the proposed Polihali Dam in Lesotho) will be reduced by 99 million m^3/a (6.7%) due to the implementation of the Douglas EWR. Furthermore, water balance assessments for **Scenario 9b** indicated that the next augmentation scheme will be required by 2043 (original date was 2049). This means that implementation of the Douglas EWR will cause the date of augmentation to move forward by 6 years.

3 APPROACH TO SCENARIO EVALUATION AT EWR SITES

3.1 RESERVE DATA APPLICABLE TO THIS STUDY

3.1.1 Operational Scenarios

During Step 5 of the Vaal Comprehensive Ecological Reserve study, which refers to the ecological consequences of operational scenarios, the objective is to provide sufficient information to the decision maker regarding the operational scenarios and the consequences of these in terms of:

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

The purpose of this is to provide the decision-maker with sufficient information to make informed decisions regarding the implications of the flow scenario and the Ecological Category (EC) which will be signed off as the Ecological Reserve.

During this process eight scenarios were provided for analysis. Detailed information regarding operational scenarios is documented in **DWA (2010a)** and the ecological consequences of the operational scenarios are provided in **DWA (2010b, c and d)** respectively for the Upper, Middle and Lower Vaal.

Table 3.1 provides a summarised description of the scenarios evaluated at the respective EWR sites at the time of the Upper Vaal Comprehensive Reserve study. For the purposes of this study Sc 1 to Sc 8 was renamed Sc R1 to Sc R8. The R (for Reserve) is included to distinguish these from the scenarios evaluated during the current Classification study.

Table 3.1: Summary of the evaluated scenarios during the Comprehensive Reserve Study (DWA, 2010a) – Reserve Scenarios

Sc No	Dev Level	EWR Status	Scenario description
R1	2008	Excluded	Base scenario representing the status quo.
R4	2008	Included	Based on Scenario 1. EWR Scenario: With exception of EWR 4 and EWR 5[1], all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.
R5	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.
R6	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.
R7	Full utilization (Future development scenario)	Excluded	Scenario representing the full utilization of available water. Based on current infrastructure. Includes VRESAP pipeline from Vaal Dam to Eastern Sub-system.
R8	Full utilization	Included	Based on Sc 7. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in

Sc No	Dev Level	EWR Status	Scenario description
	(Future development scenario)		Thukela downstream of Driel Barrage were included.

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

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

3.2 OPERATIONAL SCENARIOS: CLASSIFICATION PROCESS

Starter scenario definitions were formulated based on the status quo information and the practical functioning of integrated water resource system. The recommended EWRs for the sites determined in the Reserve Study and the low confidence EWRs at the nodes provide a viable and practical Ecological Sustainable Base Condition Scenario (ESBC) against which relative changes can be evaluated. Eight scenarios were provided for further analysis in terms of determining ecological consequences. **Table 3.2** provides a summarised description of the scenarios, as well as reasoning for evaluating the specific scenario at the respective EWR sites within the Upper Vaal WMA. Similarities/differences between Reserve Scenarios are also provided.

Table 3.2: Summary of the evaluated scenarios during the Classification process (2011 Scenarios) and similarity/difference to Reserve Scenarios

2011 Scenarios	Similar Reserve Scenarios (2010)	Differences between new and Reserve scenarios	EWR status	Scenario description
Sc 1	Sc R1	Development levels to 2011 (previously 2008) and with VRESAP pipeline included.	Present day without EWRs	Base scenario representing the status quo.
Sc 2	Sc R4	New Renoster River and Upper Harts (H1) EWRs. Middle and Lower Vaal EWRs, with exception of Schoonspruit and Upper Harts (H1), excluded.	Present day with EWRs	Based on Scenario 1. Selected EWR Scenario: With exception of EWR 4, EWR 5, EWR 7 and RE-EWR 2, all EWRs in Upper Vaal, two EWRs in Renoster, one EWR in Harts, one EWR in Thukela downstream of Driel Barrage and all Senqu EWRs were included.
Sc 3	Sc R5	Future 2020 Scenario excluding EWRs. Definition of what future 2020 consists of differs from Reserve study (updated water requirements for major water users, revised mine water decant and no transfer to the Crocodile River). Similar to the equivalent Reserve Study scenario, this scenario includes the LHWP Future Phase development (includes Polihali Dam and associated conveyance infrastructure).	2020 without EWRs	Base scenario representing the future 2020 development conditions excluding the EWRs. Includes proposed Polihali Dam and conveyance infrastructure. Includes desalination of mine water and re-use. No dilution.
Sc 4	Sc R6	Same situation as Sc 2 and 3.	2020 with EWRs	Based on Scenario 3. Selected EWR Scenario: With exception of EWR 4, EWR 5, EWR 7 and RE-EWR 2, all EWRs in Upper Vaal, two EWRs in Renoster, one EWR in Harts, one EWR in Thukela downstream of Driel Barrage and all Senqu EWRs were included.
Sc 5	Sc R7	Same as 2011 Sc 1 (i.e. current infrastructure), but includes updated future water use representing full utilisation of available water. Excludes Lesotho meaning this is relevant prior to Sc 3 and between 2011 and 2020.	Future development scenario without EWRs	Scenario representing the full utilization of available water. Based on current infrastructure which includes VRESAP pipeline from Vaal Dam to Eastern Sub-system. Includes dilution of mine water additional to TDS release.
Sc 6	Sc R8	See Sc 5 with EWRs.	Future development scenario with EWRs	Based on Scenario 5. Selected EWR Scenario: With exception of EWR 4, EWR 5, EWR 7 and RE-EWR 2, all EWRs in Upper Vaal, two EWRs in Renoster, one EWR in Harts, one EWR in Thukela downstream of Driel Barrage and all Senqu EWRs were included.
Sc 7	N/A	Alternative to EWR releases from Grootdraai Dam. Since the Reserve Study indicated PD without EWR (Sc R1) was acceptable, this scenario applies the Grootdraai compensation rule without the EWRs at EWR 2 and EWR 3.	Grootdraai Dam releases	Implementation of Grootdraai Dam compensation rule releases results in: Compared to Sc 2: 10.25 MCM/a less will be released from Grootdraai (Impact: EWR 2). Transfers from Zaaihoek and Heyshope dams are slightly less as Zaaihoek Dam is more full (Impact: EWR 1). There is less inflow at Vaal Dam, therefore more releases from Sterkfontein Dam is needed (Impact: EWR 8). There is on average 2 MCM/a less flow at EWR sites below Vaal Dam (Impact: EWR 4, 5, 12, 13, 16 and 18).

2011 Scenarios	Similar Reserve Scenarios (2010)	Differences between new and Reserve scenarios	EWR status	Scenario description
Sc 8	N/A	N/A	Present day without EWRs	Optimization scenario developed specifically for EWR 8, aimed at improving the shape of the flow duration curve in the dry season.
Sc 9a	N/A	N/A	Future (full utilisation) Only Douglas EWR	Based on **Scenario 5**. Including the optimised Sterkfontein release rule.
Sc 9b	N/A	N/A	Future (2020). Only Douglas EWR.	Based on **Scenario 3**. Including the optimised Sterkfontein release rule.

3.3 DETERMINING ECOLOGICAL CONSEQUENCES – UPPER VAAL WMA

Operational scenarios are any flow scenario other than the present which could be implemented in future and the purpose of this task is to predict the driver and biota responses to each operational scenario and derive the Ecological Category (EC) for the EWR site and Management Resource Unit (MRU).

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

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

- The operational scenarios were modelled and a time series was provided for each scenario at each EWR site.
- The time series was converted to a flow duration table.
- The results of the new scenarios (referred to as 2011 Scenarios - Sc followed by number e.g. Sc 2) were compared to similar scenarios evaluated during the Reserve study (**DWA, 2010b**). The operational scenarios of the Reserve study are referred to as Sc R followed by the original number. The R (for Reserve) is included to distinguish these from the scenarios evaluated during this National Water Resource Classification (NWRC) study.
- An initial screening was undertaken to determine whether the National Water Resource Classification NWRC scenarios (2011 Scenarios) are similar to any Reserve scenarios.
- If scenarios were similar, the ecological consequences will be the same for the NWRC as determined during the Reserve study.
- If scenarios were not similar, and it was not obvious what the consequences were, the scenarios were then referred to specialists for detail evaluation. Please refer to **DWA (2010b)** for more information regarding the methods used for detail evaluation of each component.

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

3.3.1 Comparisons of the impact of the different Scenarios

A table is provided which compares the impact of each scenario per site against the PES and Recommended Ecological Category (REC). The resulting EC for each component is provided as well as the EcoStatus. An example of the scenario evaluation at EWR 1 during the Reserve study is provided below in **Table 3.3**.

Table 3.3: Example - EWR 1: Predicted ECs for each operational scenario

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

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

The following coding is used throughout the document and an example is provided in **Table 3.4**.

✓ REC EcoStatus or REC instream IS met.

X REC EcoStatus or REC instream is NOT met.

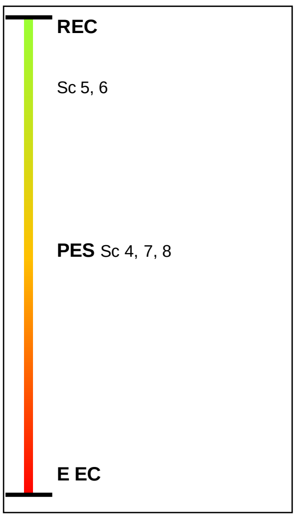
Light green with black ✓:	Meets REC EcoStatus including all components.
Dark Green with black ✓:	Meets the REC EcoStatus, but not all the components.
Turquoise with X:	The scenario is an improvement of the PES but does not meet any of the REC versions as in green above.
Orange with X:	The scenario does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

Table 3.4: An example of the operational scenario consequences summary for an EWR site

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

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

The results of **Table 3.4** are then illustrated on a scale from good (REC) to 'bad' (an E EC). In this case the REC is an improvement of the PES and the PES is therefore placed in the middle of the scale (**Figure 3.1**). The scale indicates the degree of improvement the scenarios are from the PES. This is for illustration purposes and comparing all the scenarios at each site in a system context. As the scale can be subjective, a typical explanation as provided below should accompany the figure.



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

Figure 3.1: Illustration of the degree to which a REC is met

3.4 DETERMINING ECOLOGICAL CONSEQUENCES – MIDDLE AND LOWER VAAL WMA

It was determined during the preliminary screening process of the Classification scenarios that, in the Middle and Lower Vaal WMAs, minimal changes in the flow regime will maintain the PES. The PES (and REC which is set to maintain the PES) will therefore be maintained. The focus for scenario evaluation is therefore on the Upper Vaal WMA.

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

4.1 ECOLOGICAL CONSEQUENCES: SC 2, 3, 5 AND 7

Initial screening indicated that the present day scenario (Sc 1) appears to be a more realistic present day than Sc R1 which was the present day scenario used during the Reserve study. If one assumes that the PES (pink curve) is to be maintained under current flow conditions, then the PES Ecological Category (EC) band stretches approximately from the PES to Sc 1 (**Figure 4.1**). Any scenario that falls within this band for most of the time will maintain the PES (**Figure 4.1**).

Scenario 2, 3, 4 and 7 falls largely within this band and will maintain the PES. Scenario 3 (yellow curve) is provided in **Figure 4.1** to illustrate the scenarios falling within the PES band. The ecological consequences are summarised in **Table 4.1** and shows that all consequences result in the same Ecological Categories as for the PES.

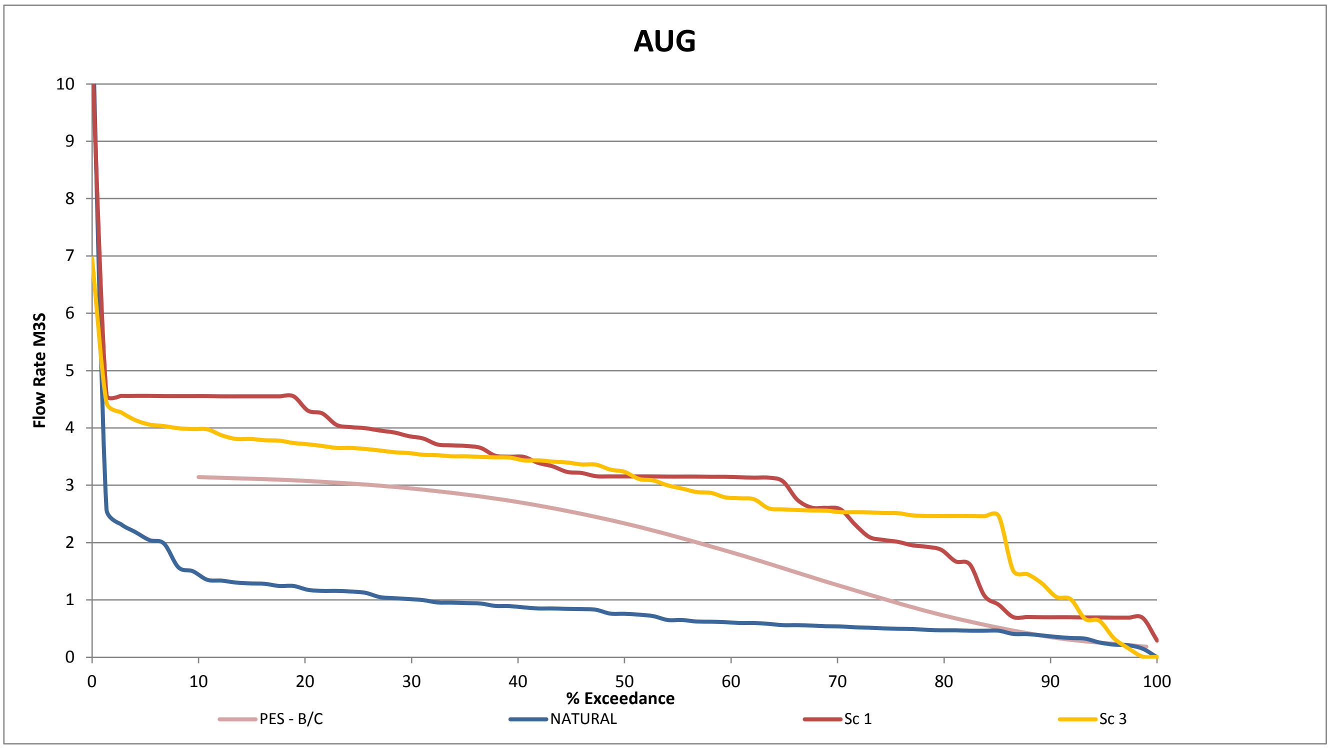


Figure 4.1: Flow duration graph indicating the PES EC band (from PES (B/C) to Sc 1) and Sc 3 as an example, representing Sc 2, 3, 5 and 7 which falls mostly within this band

4.2 ECOLOGICAL CONSEQUENCES: SC 4 AND 6

Scenario 4 (blue curve) and Sc 6 (yellow curve) lie above the upper level of the PES band (Sc 1) for most of the time and due to similarity assessed as one scenario (**Figure 4.2**). A more detailed evaluation was therefore required to determine whether the increased flows would still maintain the PES or result in a deteriorated ecological state. Note that the Sc 1 (Present Day) flows are only an indication of the upper band and there may be flows above this band that still maintains the PES.

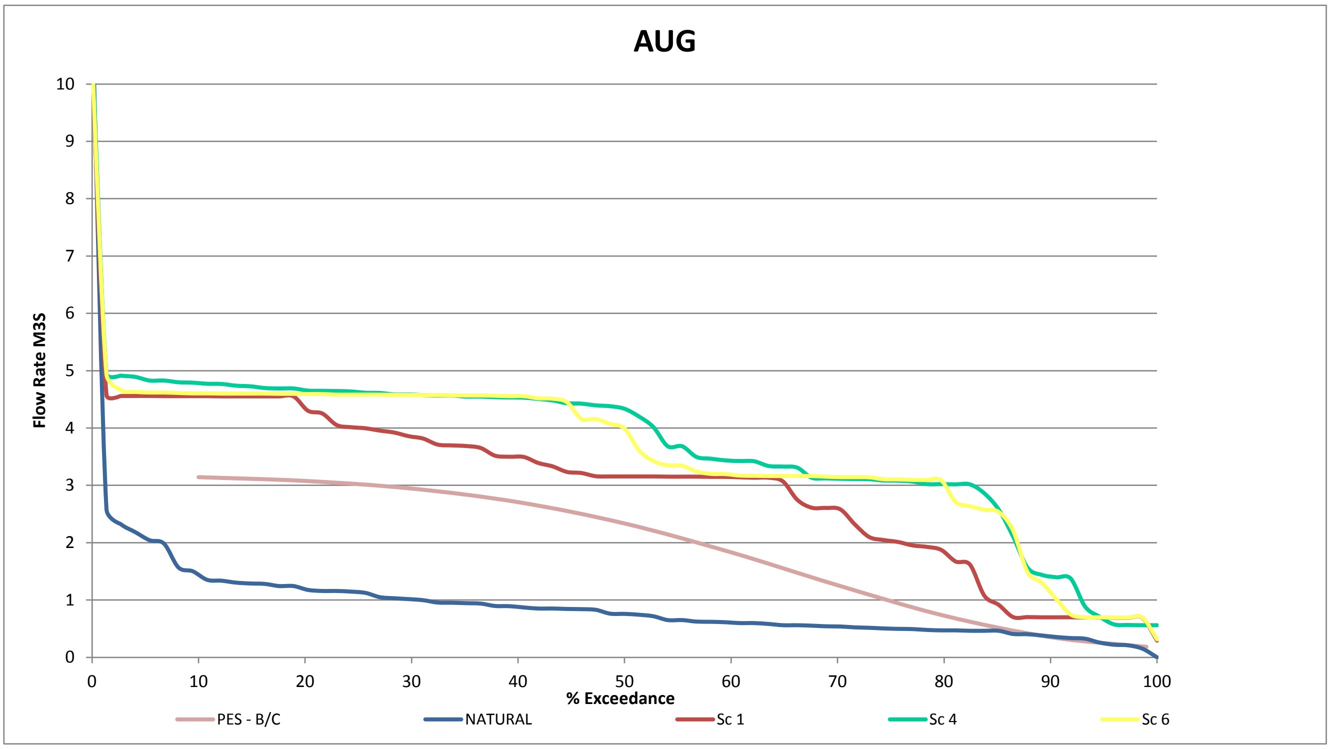


Figure 4.2: Flow Duration Graph representing Scenario 4 and 6

The results of the evaluation are summarised below and supplied in **Table 4.1**.

4.2.1 Fish and macroinvertebrates

The resolution is such that that one cannot distinguish between the Sc 1 which results in the PES and Sc 4 and 6. The assumption therefore is that the PES will be maintained.

4.2.2 Riparian vegetation

Dry season: Inundation stress is slightly increased compared to Present Day (PD) flows and results in small changes to riparian vegetation which includes a slight reduction of sedge cover in the marginal and lower zones (VEGRAI score 85.5%). Scenario 6 has less severe dry season droughts which will facilitate higher survival rates during droughts, but not likely to make a difference to the PES in the longer term.

Wet season: Similar to slightly more inundation of sedges occurs during wet season base flows. Inundation during the wet season is required and beneficial for *Cyperus marginatus* and *Gomphostigma virgatum* (the dominant species). Wet season drought flows are higher than PD and also tend more towards natural. This will result in a less stressed population and will maintain the current high density on both marginal and lower zones.

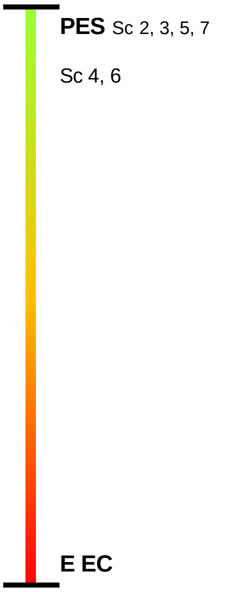
Conclusion: The VEGRAI indicated that the vegetation PES (A/B) will deteriorate to a B EC under Sc 4 and 6.

4.2.3 EcoStatus

The EcoStatus of a B/C is maintained. A summary of the results is provided in **Table 4.1**.

Table 4.1: Ecological consequences of scenarios at EWR 1

Driver Components	PES	Sc 2, 3, 5, 7	Sc 4, 6
WATER QUALITY	C	C	C
GEOMORPHOLOGY	B/C	B/C	C
Response Components	**PES**	**Sc 2, 3, 5, 7**	**Sc 4, 6**
FISH	C	C	C
MACROINVERTEBRATES	C	C	C
INSTREAM	C	C	C
RIPARIAN VEGETATION	A/B	A/B	B
ECOSTATUS	B/C	B/C	B/C



VAAL RIVER						
EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
EWR 1	✓	✓	✓	✓	✓	✓

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

5.1 ECOLOGICAL CONSEQUENCES: SC 2 - 6

The Classification scenarios at EWR 8 were developed in an attempt to mitigate the negative ecological consequences of the scenarios generated during the Reserve assessment. The original problems were that the Reserve scenarios resulted in discharge way in excess of the modelled natural flow regime during the dry season as presented by the dark purple curve (Sc R5) in **Figure 5.1**. The modified scenarios (Sc 2 - 6) as well as the optimised scenario (**Figure 5.2**) attempted to minimise this increase of flow during the dry season and to rather increase the flow in the wet season. The Classification scenarios however still resulted in excessively high flows for 50% of the time (**Figure 5.1**) during dry season.

Note that Sc 7 is not applicable at this site as it is relevant for the Vaal catchment downstream of Vaal Dam.

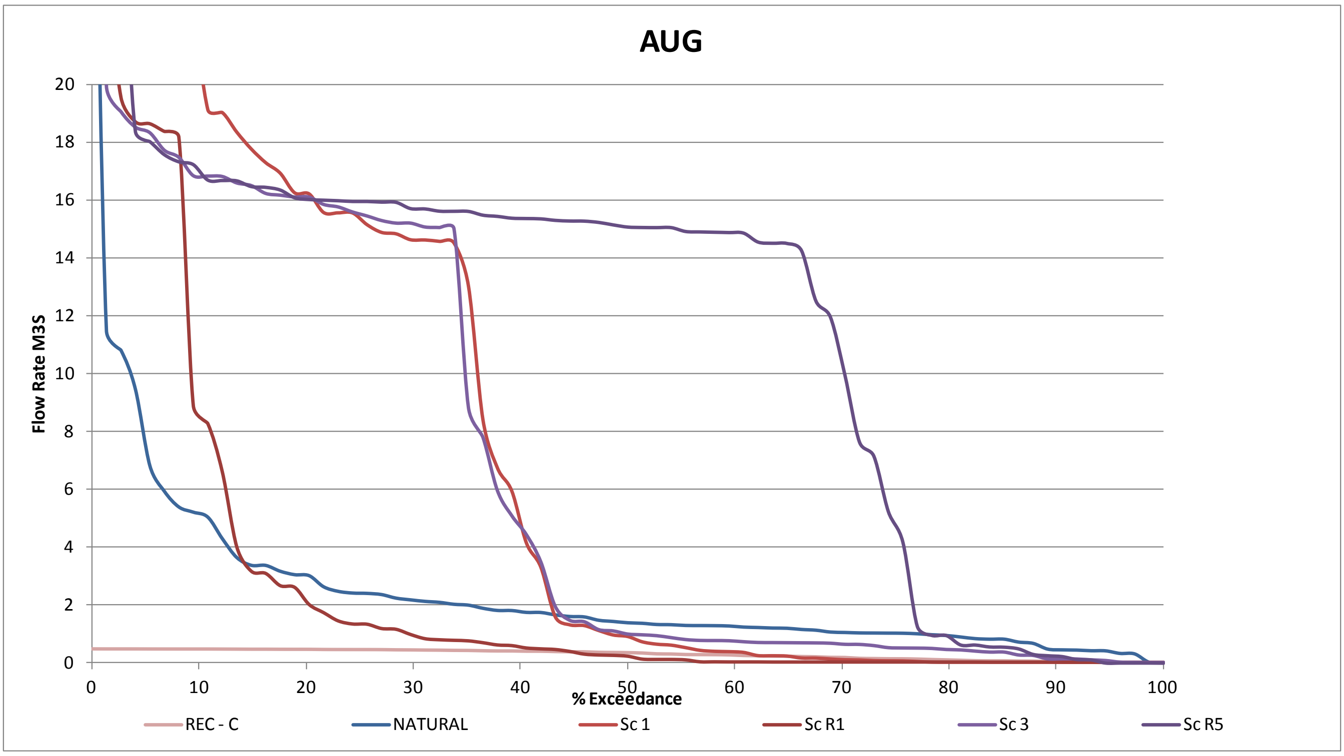


Figure 5.1: Flow Duration Graph depicting Scenario 3, which represents all Classification scenarios to illustrate the increased flows above natural for 50% of the time

A detailed evaluation was therefore undertaken to determine whether the ecological consequences of the Classification scenarios show an improvement of the Reserve scenarios. The results are provided below and summarised in **Table 5.4**.

5.1.1 Fish

The fish information is summarised in **Table 5.1** below which compares Sc R5 (representative of all the Reserve scenarios) to Sc 3 (representative of all the Classification scenarios).

Table 5.1: Fish ecological consequences at EWR 8

<table>
<tr><th rowspan="2"></th><th colspan="4">EC</th><th colspan="2">ECOLOGICAL CONSEQUENCES</th></tr>
<tr><th>PES</th><th>REC</th><th>AEC↓</th><th>Sc</th><th>DRY SEASON</th><th>WET SEASON</th></tr>
<tr><th></th><th colspan="6">FISH</th></tr>
<tr><td rowspan="2">Scenario R5</td><td>C</td><td>B</td><td>D</td><td>D</td><td>Drought conditions will be more severe than natural, as well as PD and PES conditions. Maintenance flows will be radically higher than natural, as well as PD and PES flows, resulting in significant deterioration in habitat suitability (especially for small semi-rheophilic and limnophilic species). Radical loss of slow habitats as well as marginal vegetation (especially on islands and bars) due to scouring and erosion will have a radical impact on the fish assemblage, and the overall fish assemblage can be expected to be reduced significantly from its PES.</td><td>Generally flows will be higher than natural, PD and PES, especially in the drought range. Again this will result in loss of natural habitat diversity for especially limnophilic fish species, and therefore overall decrease in habitat suitability for fish (although the semi-rheophilic species may be favored by these conditions). An overall deterioration in the fish assemblage is therefore expected under this scenario in the wet season.</td></tr>
<tr><td colspan="6">The significant higher flows (especially during dry season) will result in extensive bank erosion, loss of islands, loss of marginal/overhanging vegetation, increased velocities, and hence loss of slow habitats, decreasing habitat suitability for especially limnophilic and small semi-rheophilic species. The entire fish assemblage (including large semi-rheophilic species) will however be impacted negatively due to alteration of natural and present habitat compositions, and the PES is expected to be reduced from a C (76.1%) to a D (55.8%).</td></tr>
<tr><td rowspan="2">Scenario 3 (new)</td><td>C</td><td>B</td><td>D</td><td>D</td><td>Drought conditions will still be more severe than natural, as well as PD and PES conditions. Maintenance flows will be closer to natural, PD and PES flows, and should result in improved conditions for fish (50% of time). The overall impact on the habitats for fish (very high flows at times) will however not be significantly better to improve the fish towards a higher EC towards the PES.</td><td>The flows under this scenario will again be higher than natural, PD and PES, especially in the drought range, and higher than under Sc R5. It will therefore still result in increased stress on the fish assemblage (especially the limnophilic species). An overall deterioration in the fish assemblage is therefore still expected under Sc 3 in the wet season, and it may be further deterioration than under Sc R5.</td></tr>
<tr><td colspan="6">The impact of higher than natural, PD and PES flows (especially during dry season) will be lower (in terms of occurrence), but when these flows are high it will still result in extensive bank erosion, loss of islands, loss of marginal/overhanging vegetation, increased velocities, and hence loss of slow habitats, decreasing habitat suitability for especially limnophilic and small semi-rheophilic species. The slight improvement in the dry season is however thought to again be negated by the deterioration in wet season, and hence not result in overall improvement of the EC towards the PES.
Recommendation: Attempt to spread the flows for the entire flow duration to be closer (more similar) than present, natural or even PES flows.</td></tr>
</table>

5.1.2 Macroinvertebrates

The revised scenarios are expected to lead to a slight deterioration for macroinvertebrates during the dry season compared to the PES, but the overall PES category is expected to remain unchanged (Category C/D). The Classification scenarios have significantly less elevated dry season low flows compared to Sc R5 (Category D) This change is expected to improve conditions, particularly for taxa that have a preference for moderate flows, such as Leptophlebiidae, Atyidae and Hydroptilidae. Seasonal variation in low flows is closer to natural than Sc R5 seasonal variation, and this is expected to increase the diversity of macroinvertebrates. However, the distribution of dry season low flows has two distinct steps, one at around 0.7 m^3/s, and one at around 15 m^3/s. It would be preferable to modify the shape of the dry season duration curve to follow a more natural distribution.

5.1.3 Riparian vegetation

Dry season flows are an improvement from the Reserve scenarios, and closer to natural than PD, but only for a proportion of the time while wet season flows are much wetter (even wetter than natural) and flows at 50%

equate to small Class II floods. Increased inundation stress of vegetation will result in shrinkage of the marginal and lower zones as both woody and non-woody vegetation die off, particularly during the dry season, with a resultant VEGRAI score of 55.4% (D EC). Since plants generally deal with inundation stress better during the growing phase, rather than during the dormant phase, this score could be improved slightly if dry season flows at the 10 to 35% exceedance range were reduced and allocated to wet season.

5.1.4 EcoStatus

Although the Classification scenarios are an improvement on the Reserve scenarios for macroinvertebrates (the PES is maintained), the fish does not improve. The new scenarios therefore only represent a marginal improvement (compared to the Reserve scenarios) for the macroinvertebrates, but no improvement in the fish. The EcoStatus therefore is still a D EC compared to the PES of a C EC (**Table 5.4**).

5.2 ECOLOGICAL CONSEQUENCES: OPTIMISED SCENARIO

The above evaluation indicated that the modifications done to the Sterkfontein Dam operating rules were still insufficient to maintain the PES-REC. Further optimisation was undertaken and a scenario (referred to as Opt Sc) was developed and also evaluated. The optimisation aimed to improve the shape of the flow duration curve in the dry season. The problem is that any improvement in the dry season, result in additional water being released during the wet season (**Figure 5.2)**.

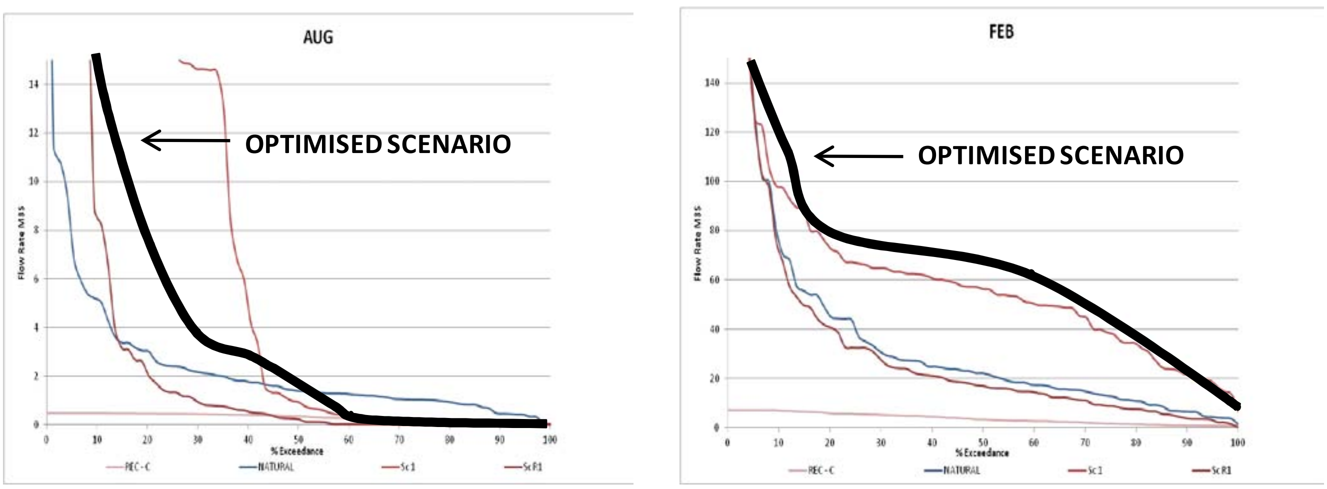


Figure 5.2: Flow Duration Graph showing the optimised scenario where flows are decreased during the dry season and increased during the wet season

The ecological consequences based on the detailed evaluation are provided below.

5.2.1 Fish

The fish ecological consequences are summarised below in **Table 5.2**.

Table 5.2: Fish ecological consequences of Opt Sc

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc	DRY SEASON	WET SEASON
FISH					
C 76.1%	B	D	C/D 60.9%	Drought conditions will still be more severe than natural, as well as PD and PES conditions. Maintenance flows (50% flow duration) will however be closer to natural (very similar) and should result in improved conditions for fish. The flows will still be higher than natural (50% of time) but will be less radical than those under previous scenarios, and therefore an improvement in the EC during the dry season can be expected.	The flows under the optimized scenario will again be significantly higher than natural, PD and PES, and higher than under Sc R5. It will therefore still result in increased stress on the fish assemblage (especially the limnophilic species). An overall deterioration in the fish assemblage is therefore still expected under Sc Opt in the wet season, and it may even further deteriorate than under Sc R5.
An improvement is expected in the dry season as conditions will be very favorable for fish at these flows. Further deterioration is however expected to occur in the wet season as a result of the very high flows. Since most of the fish species are used to faster flowing conditions in the wet season (warmer conditions, higher metabolism, natural occurrence of higher/faster flows), the fish can be expected to better deal with higher flows in the wet season than in the dry season. An overall improvement (from Sc R5: D = 55.8%) is therefore expected towards a C/D (60.9%), but will still be lower than the PES (C = 76.1%).					

5.2.2 Macroinvertebrates

The optimised Sc at EWR 8 is not expected to change the PES for macroinvertebrates. The optimised scenario follows the shape of the naturalised duration curve for the dry season, and is a significant improvement to the stepped shape of the revised dry season scenarios. The wet season under this scenario has significantly higher low flows than the original and revised PD flows. This increase in wet season flows is likely to lead to an increased abundance of macroinvertebrates, as water temperatures at this time of year should be suitable for macroinvertebrate production. However, the overall diversity is not expected to change significantly from PD conditions.

5.2.3 Riparian vegetation

The riparian vegetation ecological consequences are summarised below in **Table 5.3**.

Table 5.5.3: Riparian vegetation ecological consequences of Opt Sc

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc	DRY SEASON	WET SEASON
FISH					
C 63.5%	B/C	D	C/D 61.2%	Similar to Sc 3 except that flow patterns have improved in the dry season and are wetter in the wet season. As noted previously, this is an improvement since vegetation deal with inundation stress better during the growing phase. Flows in the wet season equate to small floods, so a response by vegetation is still slightly worse than present day, but better than Sc 3. Marginal and lower zone vegetation remains inundated in the wet season for extended periods and this is likely to reduce cover somewhat.	

5.2.4 EcoStatus

The optimised scenario is an improvement of Sc 2 - 6 due to the improved seasonality within the dry season. The excessively high flows during the wet season still prevent the scenario from achieving the REC. The EcoStatus is a C/D (**Table 5.4**).

Table 5.4: Ecological consequences of scenarios at EWR 8

Driver Components	PES-REC	Sc R5	Sc 2-6	Opt Sc
WATER QUALITY	C	C	C	
GEOMORPHOLOGY	C	D/E	D/E	
Response Components	**PES-REC**	**Sc R5**	**Sc 2-6**	**Opt Sc**
FISH	C	D	D	C/D
MACROINVERTEBRATES	C/D	D	C/D	C/D
INSTREAM	C	D	C/D	C/D
RIPARIAN VEGETATION	C	D	D	C/D
ECOSTATUS	C	D	D	C/D

PES-REC

Sc Opt

Sc 2-6
All Reserve Sc

E EC

WILGE RIVER							
EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Opt Sc	Sc 7
EWR 8	X	X	X	X	X	X	N/A

6 EWR 10 SUIKERBOS DS (SUIKERBOSRAND) AND EWR 11 BLESBOK (BLESBOKSPRUIT) - ECOLOGICAL CONSEQUENCES

6.1 EWR 11 BLESBOKSPRUIT: ECOLOGICAL CONSEQUENCES – SC 2 - 6

The Classification scenarios result in less flows and an improvement in Total Dissolved Salts (TDS) levels. Preliminary screening indicated that Sc 2, 5, and 6 were similar, and Sc 3 and 4 were the same. **Figure 6.1** provides an illustration of Sc 2 and 3 compared to Sc R1 (most realistic present day). Specialists assessed the scenarios and found that the consequences are the same for both sets of Classification scenarios. The results are provided below and summarised in **Table 6.1**.

Note that Sc 7 is not applicable at this site as it is relevant for the Vaal catchment downstream of Vaal Dam.

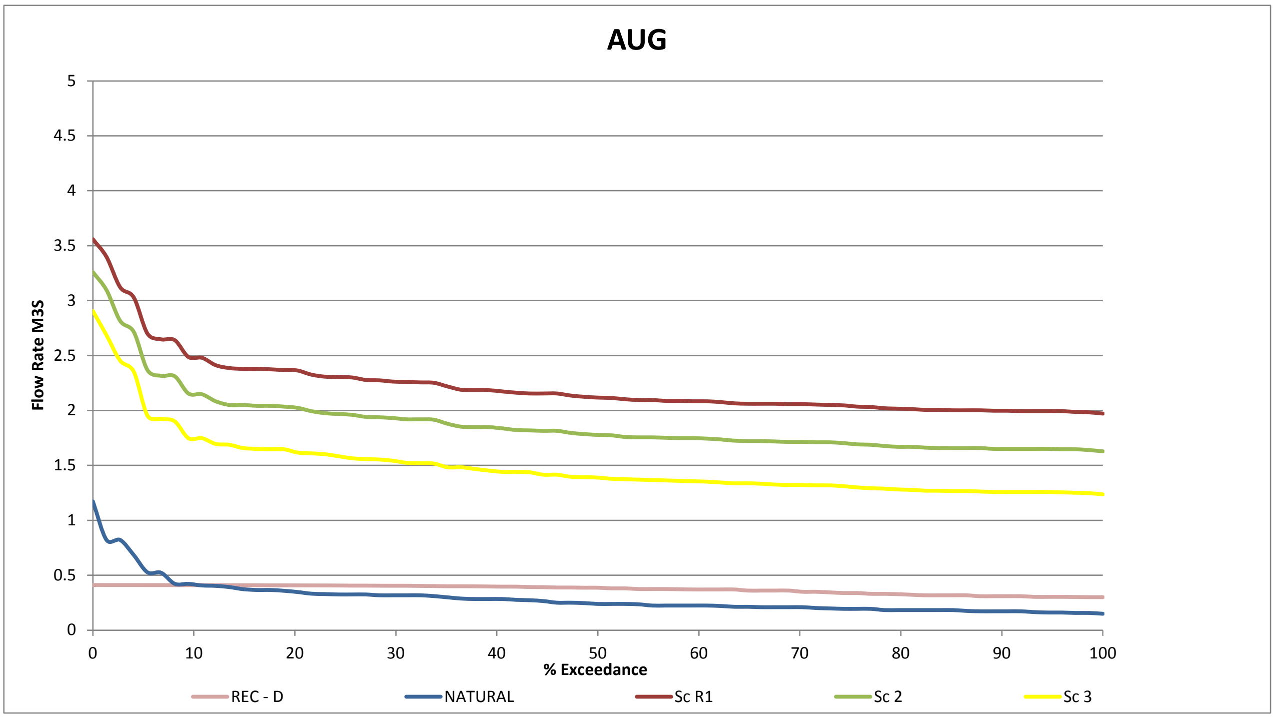


Figure 6.1: Flow Duration Graph presenting Sc 2 and 3 compared to the Reserve PD (Sc R1) and new PD scenario (same as Sc 2)

6.1.1 Physico-chemical

The consequences of Sc 3 on TDS concentrations result in Ecological Categories for the following variables (**Figure 6.2**).

$MgSO_4$: F EC

Na_2SO_4: F EC

$CaCl_2$: F EC

Electrical Conductivity: E/F EC

SRP: D EC

Ammonia: F WC

Water quality category D/E

The monthly TDS comparison under Sc 3 is provided in **Figure 6.2**.

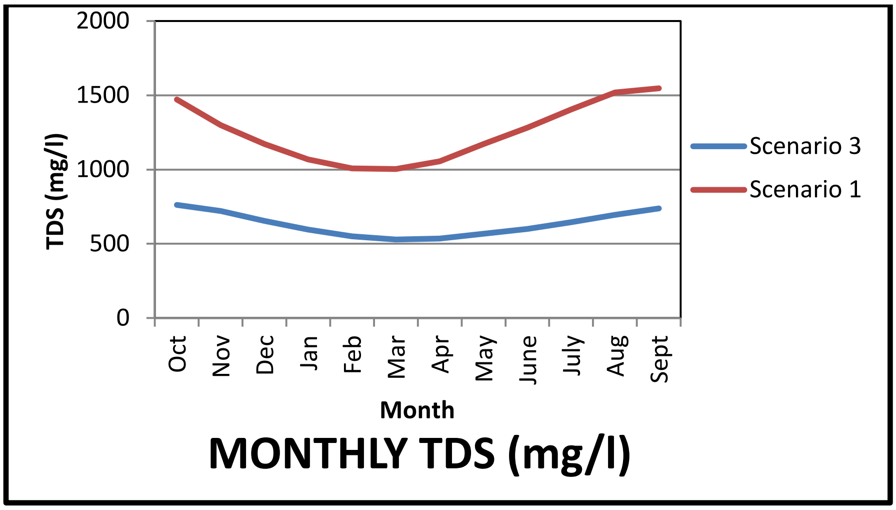


Figure 6.2: Comparison of monthly TDS concentrations under Sc 3

Lower flows for Sc 3 will exacerbate the nutrient issue (probably dropping the category below a D), although the salts should improve. It however appears likely that the overall status will stay in the same category.

6.1.2 Fish

The fish ecological consequences are summarised in **Table 6.1**.

Table 6.1: Fish ecological consequences at EWR 11

	EC			ECOLOGICAL CONSEQUENCES	
	PES	REC	Sc	DRY SEASON	WET SEASON
Scenario R5	D 44.8%	C	E 35.1%	Dry season flows extensively higher than natural and slightly higher than PD modeled hydrology. Habitat suitability and fish stress are however not significantly different from the PES status, and should fall in same EC than during the PES.	Wet season flows extensively higher than natural and slightly higher than PD modeled hydrology. Habitat suitability and fish stress will be significantly lower than present and a deterioration of at least one EC can be expected (E to F)
	Drought and maintenance flows similar regarding seasonality than PD hydrology. The conditions will largely remain similar to PES during the dry seasons but deteriorate during the wet season (will especially have critical impact on limnophilic species). Due to the alteration in flows, together with the deterioration in water quality, geomorphology as well as loss of vegetation as cover will result in the fish assemblage to deteriorate from the PES of a D to an E.				
Scenario 3 and 4	D	C	E	Dry season flow higher than natural and PES flows, but lower than PD. Habitat suitability for especially limnophilic species should improve (compared to Sc R5). An improvement in salt levels but deterioration in nutrients is expected. Increased nutrients may lead to further deterioration in habitat conditions due to further aggregation of filamentous algal growth. This result in loss of substrate quality and have a negative impact on all species with preference for this habitat. It is therefore assumed that under this scenario, the improvement of closer to natural flows and decreased salt levels will be negated by the increased nutrient loads, and therefore the EC should remain within the PES.	Sc 3 wet season flows very similar than Sc R5, and therefore expected to have same impact as described above (reduced by one EC).
	As described for Sc R5, the conditions will largely remain similar to PES during the dry seasons but deteriorate during the wet season (will especially have critical impact on limnophilic species). Due to the alteration in flows, together with the deterioration in water quality, geomorphology as well as loss of vegetation as cover will result in the fish assemblage to deteriorate from the PES of a D.				

	EC			ECOLOGICAL CONSEQUENCES	
	PES	REC	Sc	DRY SEASON	WET SEASON
Scenario 2, 5 and 6	D	C	E	Conditions very similar than under present day, and as described above for Sc 3 and 4, the changes in water quality, and resultant habitat quality alterations, not expected to result in decrease of PES under this scenario.	Wet season flows under these scenarios will be even higher than under Sc R5, and therefore conditions may even further deteriorate. The loss of slow habitats will especially impact on limnophilic fish species. It can therefore be expected that the EC will deteriorate to a F.
	The conditions will largely remain similar to PES during the dry seasons but deteriorate during the wet season (will especially have critical impact on limnophilic species). Due to the alteration in flows, together with the deterioration in water quality, geomorphology as well as loss of vegetation as cover will result in the fish assemblage to deteriorate from the PES of a D to E. Due to the even worse conditions (higher flows) in the wet season, it may result in a lower EC of an E than under Sc R5.				

6.1.3 Macroinvertebrates

The revised scenarios at EWR 11 are expected to lead to a slight deterioration for macroinvertebrates during the dry season, and an improvement during the wet season. The overall PES category is expected to drop below the D/E into a high E EC. The Classification scenarios Sc 1, Sc 2, Sc 5 and Sc 6 have median dry season low flows which are about 0.4 m^3/s lower than the historical PD flows (Sc R1). By comparison, the Classification scenarios Sc 3 and Sc 4 have median dry season low flows which are about 0.7 m^3/s lower than the historical PD flows (Sc R1). Although flows of the Classification scenarios are closer to natural than PD flows, and salinity concentrations are expected to halve, the reduced dry season flow is expected to increase nutrient concentrations because of reduced dilution. Low concentrations of dissolved oxygen, which are linked to elevated concentrations of nutrients, are likely to be the key determinant of macroinvertebrate composition in this part of the river.

6.1.4 Riparian vegetation

The riparian vegetation consequences are summarised in **Table 6.2**.

Table 6.2: Riparian vegetation ecological consequences at EWR 11

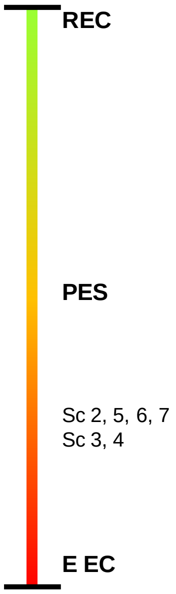
EC			ECOLOGICAL CONSEQUENCES	
PES	REC	Sc	DRY SEASON	WET SEASON
D 46%	D	D 49%	Scenarios have lower dry season base flows than PD (more so than Sc 1, 2, 5 and 6) but remain significantly higher than natural. A slight improvement (reduction) in vegetation inundation stress improves the cover and VEGRAI score slightly, but PES remains the same (D).	Scenarios have increased wet season flows with increased inundation stress, but vegetation deals with this better at this time of the year. VEGRAI score unlikely to change due to flow changes in the wet season.

6.1.5 EcoStatus

The fish and macroinvertebrates drop to an E EC (due to the deterioration in nutrient levels) which results in the instream condition deteriorating to an E EC. The EcoStatus is still a D (**Table 6.3**) due to the improved D for vegetation which reacts to the lower levels of inundation associated with decreased flows.

Table 6.3: Ecological consequences at EWR 11

Driver Components	PES	REC	Sc 2-7
WATER QUALITY	D/E	D	D/E
GEOMORPHOLOGY	C	C	C
Response Components	**PES**	**REC**	**Sc 2-7**
FISH	D	C	E
MACROINVERTEBRATES	D/E	D	E
INSTREAM	D/E	C/D	E
RIPARIAN VEGETATION	D	D	D
ECOSTATUS	D	D	D



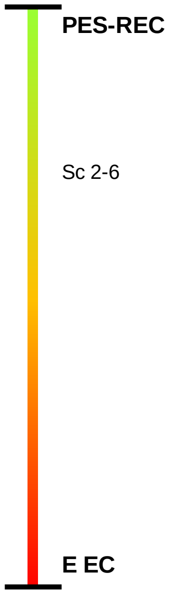
BLESBOKSPRUIT RIVER							
EWR SITE	Sc 1	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
EWR 11	X	X	X	X	X	X	N/A

6.2 EWR 10 SUIKERBOSRAND RIVER: ECOLOGICAL CONSEQUENCES – 2 - 6

Preliminary screening indicated that Sc 2 - 6 were all similar to modelled PD flows. The evaluation resulted in a similar trend at EWR 10 (downstream in Suikerbosrand River after confluence with Blesbokspruit River) as EWR 11 and is summarised in **Table 6.4**.

Table 6.4: Summary of ecological consequences at EWR 10

Driver Components	PES -REC	Sc 2-6
WATER QUALITY	D/E	D/E
GEOMORPHOLOGY	C	C
Response Components	**PES and REC**	**Sc 2-6**
FISH	C/D	C/D
MACROINVERTEBRATES	C/D	D
INSTREAM	C/D	D
RIPARIAN VEGETATION	C	C
ECOSTATUS	C/D	C/D



SUIKERBOSRAND RIVER RIVER						
EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
EWR 10	X	X	X	X	X	N/A

7 EWR 5: SCANDINAVIA (VAAL RIVER) - ECOLOGICAL CONSEQUENCES

7.1 ECOLOGICAL CONSEQUENCES: SC 2 - 7

EWR 5 is situated downstream of the Vaal Barrage. Preliminary screening indicated that Sc 2, 5, 6 and 7 were similar and Sc 3 and 4 were the same. All the scenarios (presented by Sc 2 and Sc 3 in **Figure 7.1**) represent a significantly increased flow above the current PD flow (Sc R1) and the Reserve scenario (R5) evaluated before. The issue is therefore to assess whether the increased flows, and associated water quality response cause a decrease from the Present Ecological State.

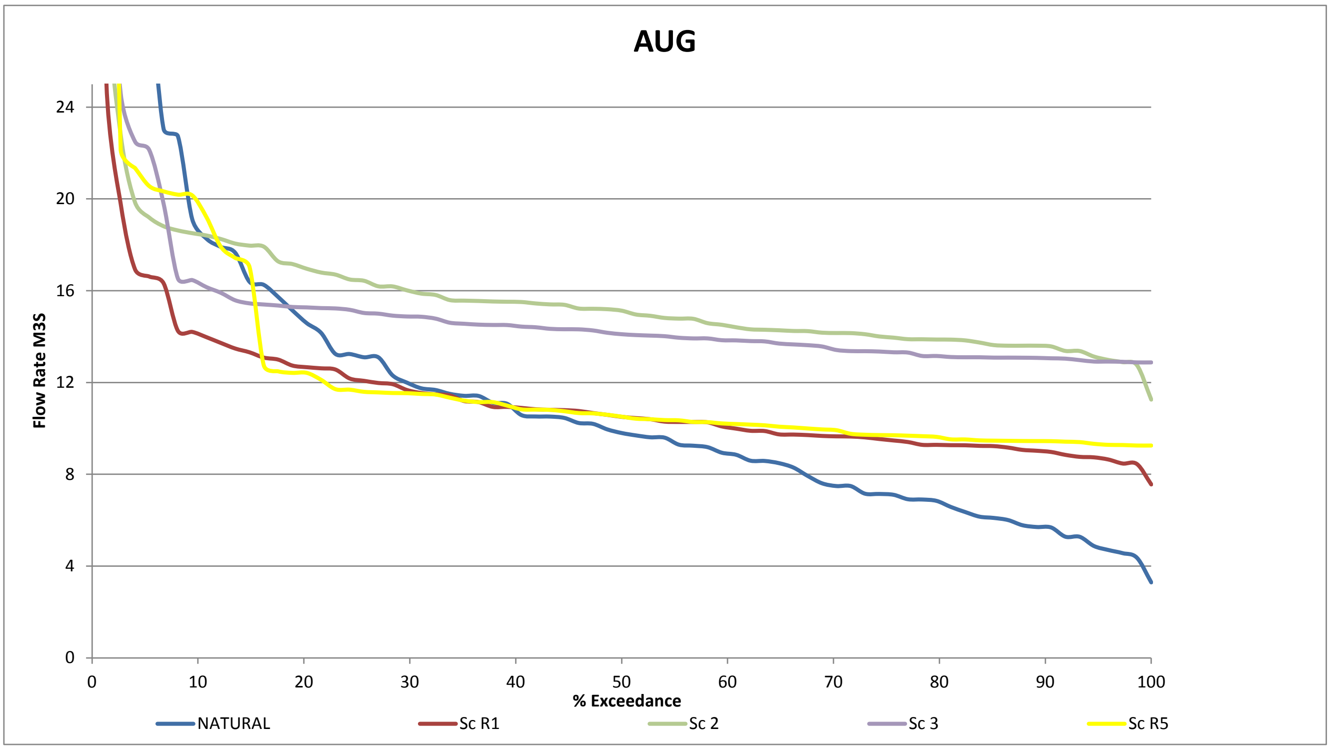


Figure 7.1: Flow Duration Graph depicting Scenario 2 and 3 compared to present day (Sc R1), Sc R5 and natural

7.1.1 Physico-chemical

The factors associated with Sc 3 which is important with regard to the water quality assessment is that the scenario includes 2020 development with higher populations, increased waste discharge and urban effluents with additional salt loads representative of the 2020 development level. Desalination is taking place but clean water is then diverted to Rand Water for use. Water from Far Western mining basin (approximately 700 mg/L TDS) is discharged into the Riet River and other tributaries.

The current water quality category is an E (present state; **DWA, 2010a**). Variables range from D to F categories:

$MgSO_4$: F EC

Na_2SO_4: F EC

$CaCl_2$: D EC

Electrical Conductivity: C EC

SRP: E/F EC

Chl-a periphyton: D EC

Ammonia: F EC

The monthly TDS comparison is provided in **Figure 7.2**.

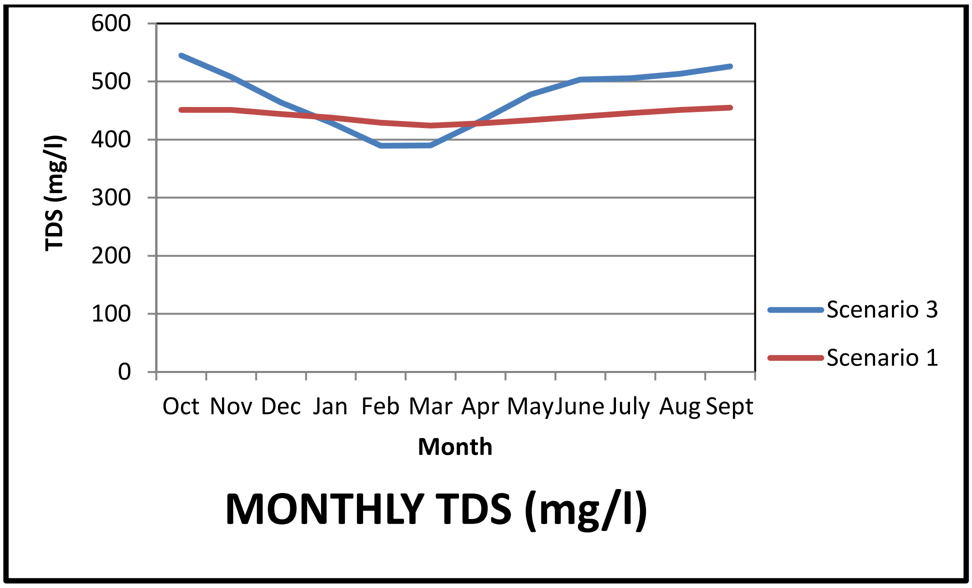


Figure 7.2: Comparison of monthly TDS from the present day situation (Sc 1 in figure above and R1 in other figures) and Sc 3.

From **Figure 7.2** it appears that there will be increased flows of poor quality under Sc 3, with a resultant increase in TDS levels, except when flows are particularly high and salts are diluted. The TDS is expected to increase from its present value of about 450 mg/l, to between 500 and 550 mg/l during the dry season. Conditions are therefore expected to worsen regarding salts, with electrical conductivity possibly dropping to a D category. It is assumed that the F EC for magnesium sulphate may represent some level of artificial elevation as electrical conductivity is a C, and the Tool for Ecological Aquatic Chemical Habitat Assessment (TEACHA) analytical package is known to elevate $MgSO_4$ levels.

If the additional water is of poor quality, an improvement in nutrient levels will probably not occur.

7.1.2 Fish

The fish ecological consequences are summarised in **Table 7.1** below.

Table 7.1: Fish ecological consequences at EWR 5

<table>
<tr><th></th><th colspan="4">EC</th><th colspan="2">ECOLOGICAL CONSEQUENCES</th></tr>
<tr><th></th><th>PES</th><th>REC</th><th>AEC→</th><th>Sc</th><th>DRY SEASON</th><th>WET SEASON</th></tr>
<tr><td rowspan="2">Scenario R5</td><td>C
69.2%</td><td>B</td><td>D</td><td>B/C
81.7%</td><td>Large semi rheophilic (LSR) guild: A EC. Overall conditions better than PES and AEC up, approaching natural for stress durations above 40 (therefore including maintenance flows). Conditions however significant worse than PES and even AEC down during stress durations <40% (therefore including droughts). Due to absence of rheophilic species that would be more vulnerable to drought or low flow impacts, it is estimated that the overall fish assemblage at the site will improve. A notable improvement from the PES can therefore be expected in the dry season.</td><td>LSR guild: B EC. Conditions under this scenario is overall better than PES (B/C to B) and overall similar than AEC up. Maintenance flows are slightly worse than PES/AEC up, (B EC vs. A/B EC), but drought conditions moving closer to natural. Overall improvement therefore expected under this scenario during the wet season.</td></tr>
<tr><td colspan="6">Natural seasonal variability has been altered seriously from natural conditions. Under this scenario, seasonality will be mostly similar or improved from PD. An overall slight improvement can therefore be expected in the fish assemblage and fish is expected to improve under this scenario from a C (69.2%) to a B/C (81.7%). If non-flow related impacts (alien fish and migration barriers) and water quality are addressed, the conditions may improve towards a B EC under this scenario.</td></tr>
<tr><td rowspan="2">Scenario 2 , 5- 7; Scenario 3 and 4</td><td>C
(69.2%)</td><td>B</td><td>D</td><td>C
(64.3%)</td><td>Higher flows than natural, and even higher than those of PES and Sc R5, resulting in increased stress and therefore deterioration from the PES can be expected during the dry season. Water quality is also expected to deteriorate during the dry season (especially salt loads). Overall the EC may therefore deteriorate in the dry season under Sc 2 and 3.</td><td>Scenario 2 has higher base flows than natural, and even higher than those of PES and Sc R5, but lower than PD flows, and therefore no further deterioration is expected. Sc 3 similar base flows than PES and Sc R5. Drought flows are better for both Sc 2 and 3, and an improvement can therefore be expected. Water quality is expected to generally improve in the late wet season (Feb and Mar), although the early wet season may deteriorate. The early wet season is an important period to maintain good water quality for activities such as spawning and creation of favorable nursery habitats. Overall the EC is expected to remain the same as the PES under Sc 2 and 3 during the wet season.</td></tr>
<tr><td colspan="6">Deterioration in the dry season (increased flows resulting in loss of slow habitats and water quality deterioration) is expected under scenarios 2 and 3, while conditions should remain the same in the wet season. Overall the EC expected to deteriorate slightly within the PES EC of C (64.3%).</td></tr>
</table>

7.1.3 Macroinvertebrates

The Classification scenarios at EWR 5 are expected to lead to deterioration for macroinvertebrates during the dry season, and an improvement during the wet season, but the PES is expected to remain unchanged in Category C (MIRAI 62%). The Classification scenarios are expected to elevate the median dry season low flows by about 4 m^3/s, and this is likely to increase the risk of outbreaks of pest blackflies because a larger population of these pest flies will be able to overwinter as larvae. Electrical conductivity is expected to increase, except for about three months during the wet season, when conductivity is expected to be lower than PD values because of increased dilution associated with higher flows. This magnitude of increase is unlikely to have measurable impacts on macroinvertebrate composition or abundance. Nutrient concentrations are also expected to be elevated, and this is likely to decrease the suitability of instream habitats for invertebrate colonisation. Instream habitats are already modified by elevated nutrient levels, and any further modification in this regard is unlikely to be measurable using current methods of assessing macroinvertebrate composition and abundance.

7.1.4 Riparian vegetation

The riparian vegetation consequences are summarised in **Table 7.2** below.

Table 7.2: Riparian vegetation consequences at EWR 5

EC				ECOLOGICAL CONSEQUENCES	
PES	REC	AEC↓	Sc 2-7	DRY SEASON	WET SEASON
D 48.1%	C	-D	-D 42.2%	Dry season is wetter than PD for 100% time and wetter than natural for 90% of the time.	Wet season is also wetter than PD for large proportions of the time but this is a positive move towards more natural flows. Scenarios only wetter than natural for about 5% of the time.
Although wet season flows are an improvement, increased inundation stress in the dry season deteriorates the VEGRAI score in the marginal and lower zones to an E and D respectively. This is due to loss of vegetation cover in these zones, although higher flows will also probably help to flush floating aquatic aliens as well. However, the overall VEGRAI score remains D with a decrease from 48.1% (PES) to 42.2%.					

7.1.5 EcoStatus

The evaluation results in a degradation of the PES, but probably within the Ecological Category. Water quality is below a D and problematic at this site. A summary of the results are provided in **Table 7.3**.

Table 7.3: Summary of ecological consequences at EWR 5

Driver Components	PES	REC	Sc 2-7
WATER QUALITY	E	D	E-
GEOMORPHOLOGY	C	C	C
Response Components	**PES**	**REC**	**Sc R4**
FISH	C	B	C-
MACROINVERTEBRATES	C	C	C-
INSTREAM	C	B/C	C-
RIPARIAN VEGETATION	D	C	D-
ECOSTATUS	C/D	C	C/D-

VAAL RIVER						
EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
EWR 5	X	X	X	X	X	X

8 UPPER VAAL WMA - EWR 2, 3, 4, 6, AND 9: ECOLOGICAL CONSEQUENCES

The Classification scenario flows were compared to the Reserve scenarios. If the Reserve scenarios were the same or very similar to the Classification scenarios, no further evaluation was required as the consequences would be the same. For more detail regarding the consequences of the Reserve scenarios, please refer to **DWA (2010b)**.

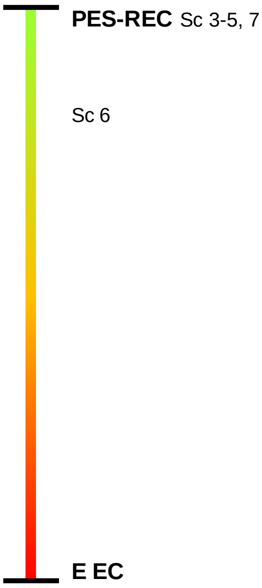
8.1 EWR 2: GROOTDRAAI (VAAL RIVER)

The Classification scenarios which are similar to the Reserve scenarios are listed below and the consequences of the Classification scenarios are summarised in **Table 8.1**.

- Sc 3 = Sc R5
- Sc 4 = Sc R6
- Sc 5 = Sc R7
- Sc 6 = Sc R8
- Sc 7 = Similar to Sc 1 which relates to slightly increased flows above the PD flows. The PES will therefore be maintained.
- Sc 2: This scenario consists of increased flows above natural in the dry season. Taking into account that this is present day flow with EWRs included, the assumption is that the increase in flows above natural and the revised PD is due to the way that the model deals with the EWRs as it is trying to cater for EWR 3. As PD flows maintain the EWRs, this scenario is irrelevant or not applicable as, from a yield perspective, it will have a worse impact than the present situation.

Table 8.1: Summary of ecological consequences at EWR 2

Driver Components	PES-REC	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
WATER QUALITY	B/C	B	B/C	C	C	B/C
GEOMORPHOLOGY	D	D	D	D	E	D
Response Components	**PES-REC**	**Sc 3**	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**
FISH	C	C	C	C	C	C
MACROINVERTEBRATES	C	C	B/C	C	D	C
INSTREAM	C	C	C	C	C	C
RIPARIAN VEGETATION	B/C	B	B	B/C	C	B/C
ECOSTATUS	C	B/C	B/C	B/C	C	C



VAAL RIVER						
EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
EWR 2	N/A	✓	✓	✓	✓	✓

8.2 EWR 3: GLADDEDRIFT (VAAL RIVER)

The Classification scenarios which are similar to the Reserve scenarios are listed below and the consequences of the new scenarios are summarised in **Table 8.2**.

- Sc 3 = Sc R5
- Sc 4 = Sc R6
- Sc 5 = Sc R7
- Sc 6 = Sc R8
- Sc 7 = Similar to Sc 1 which is relates to slightly increased flows above the PD flows. The PES will therefore be maintained.
- Sc 2: This scenario consists of increased flows above natural in the dry season at EWR 2. It is assumed that these releases are made to cater for the EWR at EWR 3. Sc 2 is very similar to Sc R4 which results in improved flows from PD. Improved flows are however not required as the PD flows will maintain the PES-REC. It is therefore recommended that this scenario not be used further in yield analysis.

Sc 7 was specifically designed to improve (in terms of yield) the negative impact of all the other scenarios and still maintain the PES-REC. The modified operating rules were successful as all the other scenarios indicate an improvement in the PES (not required as the REC is the same as the PES) whereas Sc 7 maintains the PES-REC (**Table 8.2**).

Table 8.2: Summary of ecological consequences at EWR 3

Driver Components	PES-REC	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
WATER QUALITY	C	C	C	C	C	C	C
GEOMORPHOLOGY	C	D	C	C	D	C+	C
Response Components	**PES-REC**	**Sc 2**	**Sc 3**	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**
FISH	C	B	B	B	B	B	C
MACROINVERTEBRATES	C	B	B/C	B/C	B/C	B	C
INSTREAM	C	B	B/C	B	B	B	C
RIPARIAN VEGETATION	C	C	C	C	C	B/C	C
ECOSTATUS	C	B/C	B/C	B/C	B/C	B	C

PES-REC Sc 2-7 — E EC

VAAL RIVER						
EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
EWR 3	✓	✓	✓	✓	✓	✓

8.3 EWR 6: KLIP (KLIP RIVER)

The Classification scenarios which are similar to the Reserve scenarios are listed below and the consequences of the Classification scenarios are summarised in **Table 8.3**.

- Sc 2, 5 and 6 = Sc R4, R7 and R8
- Sc 3 and 4 = Sc R5 and R6

Table 8.3: Summary of ecological consequences at EWR 6

Driver Components	PES-REC	Sc 2, 5-6	Sc 3-4
WATER QUALITY	B/C	B/C	B/C
GEOMORPHOLOGY	B	B	B
Response Components	**PES-REC**	**Sc 2, 5-6**	**Sc 3-4**
FISH	B	B	A/B
MACROINVERTEBRATES	B	B	B
INSTREAM	B	B	A/B
RIPARIAN VEGETATION	B/C	B/C	B/C
ECOSTATUS	B/C	B/C	B

PES-REC Sc 1 – 6

E EC

KLIP RIVER						
EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
EWR 6	✓	✓	✓	✓	✓	N/A

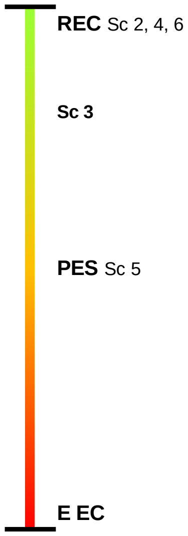
8.4 EWR 9: SUIKERBOS US (SUIKERBOSRAND RIVER)

The Classification scenarios which are similar to the Reserve scenarios are listed below and the consequences of the new scenarios are summarised in **Table 8.4**.

- Sc 2, 5 and 6 = Sc R4, R7 and R8
- Sc 3 = Sc R5
- Sc 4 = Sc R6

Table 8.4: Summary of ecological consequences at EWR 9

Driver Components	PES	REC	Sc 2, 4, 6	Sc 3	Sc 5
WATER QUALITY	C/D	C	C	C/D	C/D
GEOMORPHOLOGY	B/C	B	B/C	B/C	B/C
Response Components	**PES**	**REC**	**Sc 2, 4, 6**	**Sc 3**	**Sc 5**
FISH	D	C	C	C/D	D
MACROINVERTEBRATES	D	C	C	C	D
INSTREAM	D	C	C	C	D
RIPARIAN VEGETATION	B/C	B	B	B	B/C
ECOSTATUS	C	B/C	B/C	C	C



SUIKERBOSRAND RIVER						
EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
EWR 9	✓	X	✓	X	✓	N/A

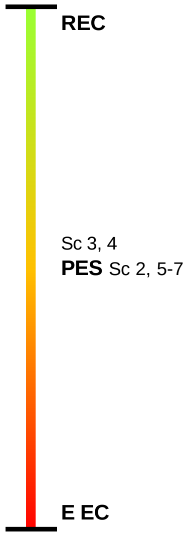
8.5 EWR 4: DENEYS (VAAL RIVER)

The Classification scenarios which are similar to the Reserve scenarios are listed below and the consequences of the Classification scenarios are summarised in **Table 8.5**.

- Sc 2, 5, 6 and 7 = Sc R4
- Sc 3 and 4 = Sc R5

Table 8.5: Summary of ecological consequences at EWR 4

Driver Components	PES	REC	Sc 2, 5-7	Sc 3-4
WATER QUALITY	C	C	C	C
GEOMORPHOLOGY	D	D	D	D
Response Components	**PES**	**REC**	**Sc 2, 5-7**	**Sc 3-4**
FISH	C	B	C	C
MACROINVERTEBRATES	C/D	C	C/D	C
INSTREAM	C	B/C	C	C
RIPARIAN VEGETATION	C	B/C	C	C
ECOSTATUS	C	B/C	C	C



VAAL RIVER						
EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7
EWR 4	X	X	X	X	X	X

9 SUMMARY OF SCENARIO EVALUATION RESULTS

The scenarios as a whole are evaluated to determine whether, on a catchment scale, they achieve the ecological objectives as defined by the REC. The summary is provided in **Table 9.1**.

Table 9.9.1: Summary of ecological consequences at all EWR sites

EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7	Opt Sc
EWR 1	✓	✓	✓	✓	✓	✓	
EWR 2	N/A	✓	✓	✓	✓	✓	
EWR 3	N/A	✓	✓	✓	✓	✓	
EWR 4	X	X	X	X	X	X	
EWR 5	X	X	X	X	X	X	
EWR 6	✓	✓	✓	✓	✓	N/A	
EWR 8	X	X	X	X	X	N/A	X
EWR 9	✓	X	✓	X	✓	N/A	
EWR 10	X	X	X	X	X	N/A	
EWR 11	X	X	X	X	X	N/A	
EWR 12	✓	✓	✓	✓	✓	✓	
EWR 13	✓	✓	✓	✓	✓	✓	
EWR 16	✓	✓	✓	✓	✓	✓	
EWR 18	✓	✓	✓	✓	✓	✓	

Legend:	Scale
√ : Meets REC, all components.	Good
√ : Meets REC, most components.	
X : Improvement to PES, below REC.	
X: Meets PES, REC is not achieved.	
X: EC below PES, above an E EC.	
X: EcoStatus is below a D EC.	Poor

The scenarios were ranked as illustrated in **Figure 9.1**.

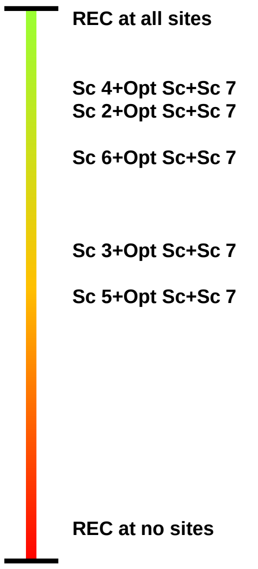


Figure 9.1: Ranking of scenarios

None of the Scenarios meet the REC at EWR 4, 5 10, and 11. This is largely due to the water quality problems as well as seasonal reversal of flow at EWR 4 and 5.

Of all the scenarios Sc 4 is the best with Sc 2 as second best. These scenarios must be combined with Sc 7 (which optimises releases from Grootdraai Dam) and the Optimised Sc in the Wilge River. Scenario 4 can be further improved if the same operating rules at EWR 1 as for Sc 2, 3, 5 or 7 are followed for Sc 4. This optimised scenario should therefore consist of the operating rules of Sc 7 at EWR 1, 2 and 3 and the optimised scenario at EWR 8 (i.e. the optimised Sterkfontein Dam release rule as included in the modelling for Sc 8).

10 DOUGLAS RAPID RESERVE

During the revision process of the Reserve results for the EWR sites located in the Upper, Middle and Lower Vaal Water Management Areas (WMAs), the refined results of the Douglas EWR site indicated a C/D PES rather than the reported D PES. Due to the HIGH evaluation of the Instream EIS, it was decided to investigate an improvement to the C/D PES EcoStatus. The revised EcoClassification results are summarised in table format (**Table 10.1**). The ECs indicated in red refer to components that have changed in category based on adjustments made during the review and therefore are different from the original Reserve study results.

Table 10.1: Revised EcoClassification results – Douglas Rapid Reserve

Driver Components	PES	AEC↑	EIS
GEOMORPHOLOGY	D	D	INSTREAM: HIGH RIPARIAN: MODERATE
WATER QUALITY	D	D	
Response Components		PES	
FISH	C	B/C	
MACRO INVERTEBRATES	D	C/D	
INSTREAM	D	C	
RIPARIAN VEGETATION	C	C+	
ECOSTATUS	C/D	C	

10.1 REVISION OF FLOW REQUIREMENTS SET IN 2001

The updated hydrology is significantly different to the hydrology used to determine the EWRs during 2001. The EWRs set previously could therefore not be used. The revised hydrology was provided by WRP and the ecological team were tasked to review the 2001 flow requirements in context of the revised hydrology.

The high instream EIS relates very specifically to the importance of this river stretch downstream of Douglas Weir as a migration corridor between the Vaal and Orange Rivers. Currently there is often zero flows in this river stretch. The key indicator species that would be potentially impacted by a change in flow regime would be *Labeobarbus kimberleyensis* (BKIM) which is a Red Data species and therefore the revision of flows focussed on setting the flow requirements for fish.

Table 10.2 provides a comparison between the 2001 and revised natural hydrology for the wet and dry season. From this table it is evident that the natural hydrology of 2001 is much higher than the revised hydrology.

Table 10.2: Comparison between the 2001 and revised natural hydrology for the wet and dry season

Wet season (Feb)		Dry season (Jul)	
2001	**revised**	**2001**	**revised**
1331.6	947.5172	99.4	34.431
707	452.3845	68.7	21.73686
599	293.8012	54.7	16.43519
464	156.3954	49.4	13.82168
362.7	126.5569	43.82	11.59648
307	118.5021	37.55	10.12545
201	99.77466	33.12	8.191458
125	69.7763	29.37	6.739098
75	42.39594	25.32	5.462216
37	15.99476	16.09	2.14307

The stress index determined during 2001 was used to revise the stress requirements for the fish. The main focus was to ensure sufficient habitat for migration and breeding. The revised stress and EWR values are provided in **Table 10.3** for the dry and wet season.

Table 10.3: Revised stress values for KIM during dry season

Season	Duration	BKIM Stress (2001)	BKIM stress (2011)	Revised Flow (m^3/s)
DRY	5%	7	**9.5**	**0.815**
	10%	6.4	**8**	**3.2**
	20%	5.2	**7**	**5.07**
	40%	3.8	**6**	**6.21**
WET	5%	7	**7**	**5.07**
	10%	6.9		
	20%	6.7		
	40%	5.9	**4 or 5**	**7.36 - 8.5**
	90%	4	**0**	**14.7**

Due to the low confidence in this revision, as well as low confidence in the present day hydrology, there was insufficient information to set flows for a half a category improved state. It was felt that these flows set were already an improvement on the current zero flow durations and that it is possible that an improved category could be achieved through this. Effort should rather be targeted towards monitoring than to improve the confidence in the flow requirements. The revised flow requirements are provided in **Table 10.4** and **10.5**.

Table 10.4: EWR table for REC: C/D

Desktop version:	2	
Virgin MAR (MCM)	3759.309	
BFI	0.301	
Distribution type	Vaal	
MONTH	LOW FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)
OCTOBER	5.5	0.5
NOVEMBER	6.3	3.5
DECEMBER	6.4	3.8
JANUARY	7	4.2
FEBRUARY	8.5	5.1
MARCH	7.6	4.6
APRIL	7	2.9
MAY	5.8	1.8
JUNE	5.4	1
JULY	5	0
AUGUST	5	0
SEPTEMBER	5.2	0.5
TOTAL MCM	195.808	72.723
% OF VIRGIN	5.2	1.93
Total IFR	195.808	
% of MAR	5.21	

Table 10.5: EWR table for REC: C/D

```
Desktop Version 2, Printed on 2012/02/29
Summary of IFR rule curves for: Vaal_1 New Nat flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal     REC = C/D

Data are given in m3/s mean monthly flow

       % Points
Month     10%      20%      30%      40%      50%      60%      70%      80%      90%      99%
Oct     8.534    8.275    7.733    6.782    5.404    3.784    2.279    1.214    0.675    0.551
Nov     9.569    9.320    8.796    7.912    6.730    5.492    4.490    3.875    3.599    3.539
Dec     9.726    9.483    8.971    8.108    6.954    5.745    4.766    4.166    3.896    3.838
Jan    10.639   10.375    9.819    8.881    7.627    6.313    5.250    4.598    4.305    4.241
Feb    12.918   12.598   11.923   10.784    9.261    7.666    6.375    5.583    5.227    5.150
Mar    11.551   11.267   10.666    9.653    8.300    6.882    5.733    5.030    4.713    4.644
Apr    10.905   10.647   10.106    9.159    7.786    6.172    4.673    3.612    3.075    2.951
May     9.348    9.254    9.016    8.502    7.566    6.161    4.482    2.977    2.066    1.847
Jun     8.431    8.400    8.270    7.972    7.363    6.287    4.704    2.883    1.451    1.046
Jul     7.205    7.205    7.205    7.120    6.899    6.371    5.264    3.342    0.963    0.045
Aug     7.801    7.768    7.632    7.319    6.680    5.550    3.888    1.977    0.473    0.049
Sep     8.374    8.276    8.027    7.491    6.515    5.049    3.298    1.728    0.777    0.549

Reserve flows without High Flows
Oct     8.534    8.275    7.733    6.782    5.404    3.784    2.279    1.214    0.675    0.551
Nov     9.569    9.320    8.796    7.912    6.730    5.492    4.490    3.875    3.599    3.539
Dec     9.726    9.483    8.971    8.108    6.954    5.745    4.766    4.166    3.896    3.838
Jan    10.639   10.375    9.819    8.881    7.627    6.313    5.250    4.598    4.305    4.241
Feb    12.918   12.598   11.923   10.784    9.261    7.666    6.375    5.583    5.227    5.150
Mar    11.551   11.267   10.666    9.653    8.300    6.882    5.733    5.030    4.713    4.644
Apr    10.905   10.647   10.106    9.159    7.786    6.172    4.673    3.612    3.075    2.951
May     9.348    9.254    9.016    8.502    7.566    6.161    4.482    2.977    2.066    1.847
Jun     8.431    8.400    8.270    7.972    7.363    6.287    4.704    2.883    1.451    1.046
Jul     7.205    7.205    7.205    7.120    6.899    6.371    5.264    3.342    0.963    0.045
Aug     7.801    7.768    7.632    7.319    6.680    5.550    3.888    1.977    0.473    0.049
Sep     8.374    8.276    8.027    7.491    6.515    5.049    3.298    1.728    0.777    0.549

Natural Duration curves
Oct   248.667  126.889   52.796   42.342   26.997   21.375   15.143   11.231    5.156    2.031
```

Nov	424.360	237.311	189.992	135.691	89.491	74.194	48.893	36.204	12.404	6.748
Dec	440.726	257.758	214.673	167.611	132.837	108.214	68.709	42.316	24.014	9.898
Jan	497.827	360.458	237.213	206.918	153.875	129.342	83.793	71.281	47.764	18.955
Feb	955.977	456.424	296.424	157.792	127.687	119.560	100.666	70.399	42.774	16.138
Mar	455.470	348.443	238.870	132.628	101.762	82.295	67.682	46.793	30.257	12.955
Apr	276.860	153.075	120.559	88.958	54.525	46.238	38.318	27.986	15.853	4.406
May	81.683	61.395	36.888	24.444	18.403	15.446	12.817	10.484	6.116	2.341
Jun	44.259	30.073	17.423	14.838	11.856	9.992	8.329	7.218	5.691	2.311
Jul	34.431	21.737	16.435	13.822	11.596	10.125	8.191	6.739	5.462	2.143
Aug	34.144	21.931	16.260	13.549	12.220	10.249	8.415	6.698	5.134	3.554
Sep	44.244	26.601	19.637	13.634	11.528	8.823	7.712	5.841	5.239	3.252

10.2 SCENARIO ASSESSMENT

These revised flows were used to determine the impacts on yield. The following two operational scenarios were analysed for this EWR site:

- **Scenario 9a:** Future development scenario based on full utilisation of water resources which includes the optimised Sterkfontein Dam release rule and only the Douglas EWR.
- **Scenario 9b:** 2020 development scenario based on full utilisation of water resources which includes the optimised Sterkfontein Dam release rule and only the Douglas EWR.

No Ecological consequences assessment was required as both these scenarios include the revised EWR requirements. The possible impact on yield and the economy will be the major factors to consider.

11 GOODS AND SERVICES: CONSEQUENCES OF SCENARIOS

Prior analysis of the Ecological Goods and Services (G&S) in the Vaal River Catchment has pointed to that fact that, with a few notable exceptions, overall importance is relatively low. This is largely allied to the nature of the catchment and the fact that there are few communities directly dependant on the G&S provided by the riverine system and for whom such dependence is linked to livelihood strategies. In this context the scenarios were evaluated by analysing **Table 9.1** to determine which EWRs were likely to be associated with significant issues that could have implications for G&S.

From **Table 9.1** it is evident that EWR sites 4, 5, 8, 10 and 11 are potentially impacted under the scenarios while EWR 9 is impacted under Scenarios 3 and 5. An overview of the scenarios and impacts against the G&S analysis for each of the EWRs are provided in **Table 11.1**.

Table 11.1: An overview of the impacts of the different Scenarios on the G&S in the Upper Vaal River Catchment

EWR Site	Overall Ecological Goods and Services evaluation associated with PES	Scenario Impact	Requirements for further action or research
EWR 4 de Neys (Vaal River)	The evaluation was scored as a 2.3 downstream of Vaal Dam. Recreational usage linked to development of the area is important usage but this would not extend to livelihoods.	The scenarios do not meet the REC but are consistent with the PES. Change to G&S not likely and not significant.	None
EWR 5 Scandinavia (Vaal River)	The evaluation was scored as a 1.9 – very similar profile to EWR 2 and 3. There is marginal usage of G&S with some recreational fishing but otherwise restricted to farm workers in communities nearby and not linked to livelihoods	As above, the scenarios do not meet the REC but are consistent with the PES. Change to G&S not likely and not significant.	
EWR 8 Bavaria (Wilge River)	The evaluation was scored as a 1.9 – very similar profile to EWR 5. There is marginal usage of G&S with some recreational fishing but otherwise restricted to farm workers in communities nearby and not linked to livelihoods.	Some impact but the scale is not consequential for G&S, particular within the context of utilisation and overall significance.	
EWR 9 Suikerbos US (Suikerbosrand River)	The evaluation was scored as a 1.7. There is marginal usage of G&S with possibly some restricted recreational fishing and otherwise usage by farm workers in communities nearby and not linked to high levels of dependence on livelihoods.	The scenarios do not meet the REC but are consistent with the PES. Some scenarios improve the PES. Change to G&S not likely and not significant.	
EWR 10 Suikerbos DS (Suikerbosrand River)	The evaluation was scored as a 1.6. There is marginal usage of G&S with possibly some recreational fishing and otherwise restricted to farm workers in communities nearby and not linked to high levels of dependence on livelihoods.	The scenario impacts are associated with in-stream and macroinvertebrates. The linkage and change to G&S is not likely to be significant.	
EWR 11 Blesbokspruit (Blesbokspruit River)	The evaluation was scored as a 1.7. There is marginal usage of G&S with possibly some recreational fishing and otherwise restricted to farm workers in communities nearby and not linked to high levels of dependence on livelihoods.	Some impact on fish and fishing but the scale is not consequential for G&S, particular within the context of utilisation and overall significance.	

In light of the above there are no significant impacts that are generated by the envisaged scenarios that would constitute a significant change to G&S use for communities that are directly dependant. While some impacts on recreational fishing may be a consequence these are unlikely to be significant.

12 SOCIO-ECONOMIC ASSESSMENT

12.1 BACKGROUND

For the purposes of this study it was assumed that, if in a section of the main stem of the river more water is necessary to maintain or improve the status of the ecology of a specific the river section, the water will be supplied from the present available sources. However the possibility exists that this could influence the implementation date of the next augmentation scheme to supply the VRS. The implementation date of the next dam in the Lesotho Highlands Water project (LHWP), Polihali, is fixed (2020) and it was accepted that if a scheme must be brought forward it will be the proposed Thukela scheme. The proposed approach to the estimation of the costs of bringing the project forward rests on the principle of “time is money”.

12.2 ECONOMIC IMPACT OF IMPLEMENTATION OF DOUGLAS EWR

In assessing the economic impact of providing the required EWR water volume from the Douglas Weir to the confluence with the Orange River and also the EWR site 8 on the Wilge River downstream of Sterkfontein Dam, it was stated that a new water source should be available from the Thukela. A shortage of 99 million m^3/a will have to be complimented by 2043 instead of 2049. It is necessary that notice be taken of the fact that the two proposed Thukela dams namely the Mielietuin and Jana dams differ in size, yields and projected construction costs. A second fact to be taken into consideration is that the order of implementation can differ, namely:

- Scenario 1: Jana first followed by the Mielietuin, or
- Scenario 2: Mielietuin first followed by the Jana.

For purposes of this analysis the following storage volumes were used for the two dams at 98% assurance:

- Mielietuin: 120 million m^3,
- Jana: 390 million m^3.

As far as the cost of the project is concerned the value that is quoted mostly in 1998 prices is a maximum of R5 billion which, in broad terms, is made up as follows:

- Jana Dam: between R1.2 – R2 billion depending on the final dam type and volume, using a linear formula the cost of the preferable option was estimated at R1.5 billion in 1998 prices.
- Mielietuin Dam: between R300 – R400 million also depending on the final dam type and volume, using a linear formula the cost of the preferable option was estimated at R372 million in 1998 prices.
- With the balance the different canal, pipeline and pump systems together with the planning and accompanying costs.

The R5 billion in 1998 prices converts to R11.3 billion in 2012 prices. Disaggregating the amount between the different segments the following amounts were used in the calculations for 2012 prices:

- The Jana Dam is estimated to cost around R4.521 billion and the accompanying canals, pipelines and pump stations R2.487 billion in 2012 prices.

- The Mielietuin Dam is estimated to cost around R904 million with the accompanying canals, pipelines and pump stations R1.695 million in 2012 prices.

It was decided to run both options to ensure that credibility in the answers is maximised. Using the same linear model the timing for the introduction of the two dams is used as follows in the analysis:

- Scenario 1: Jana in 2049 and Mielietuin in 2075, if the Douglas EWR and EWR 8 site EWR volumes are taken into consideration the implementation dates are Jana in 2043 and Mielietuin in 2069.
- Scenario 2: Mielietuin in 2049 and Jana in 2058, if the Douglas EWR and EWR site 8 EWR volumes are taken into consideration the implementation dates are Mielietuin in 2043 and Jana in 2051.

A simplified Least Cost Model was constructed to accommodate both options and the following answers were obtained expressed in 2012 prices:

- Scenario 1: With Jana introduced first followed by Mielietuin, the cost is estimated at R511 million in 2012 prices.
- Scenario 2: With Mielietuin introduced first followed by Jana, the cost is estimated at R569 million in 2012 prices.

From the results given above it is obvious that the difference between the two approaches are very small and that the final decision as to which dam will be introduced first will not be dependant on this issue alone.

The economic cost of providing the Reserve requirements at the Douglas EWR site is thus between R511 million and R569 million expressed in 2012 prices. It is a very large sum of money, but when compared to the total cost of the scheme (i.e. R11.3 billion) it represents less than 4.9% of the projected cost. Furthermore, since it is a fixed volume the impact over time after 2043 will, percentage wise also be getting smaller and smaller.

If the amount is expressed in terms of the total contribution of water to the three Vaal River Water Management Areas it represents less than 0.035% of the estimated annual turnover of the large water users or less than 0.14% of the GDP generated by the water in the project area.

13 SUMMARISED CONCLUSIONS

Key findings in terms of the water resource availability, socio-economic implications, ecological consequences and Goods & Services are summarised below.

13.1 WATER RESOURCE AVAILABILITY

The key findings with respect to water resource availability implications of the scenarios are given below:

- Implementing the revised Sterkfontein Dam release rule (**Scenario 8**) reduces the firm supply capability of the system by 45 million m^3/annum. This reduction is due to higher evaporation losses in and spills from Vaal Dam.
- **Scenario 9b**, where releases are made to meet EWR downstream of Douglas Weir (in combination with the revised Sterkfontein Dam release rule), reduced the firm supply from the system by 99 million m^3/annum. Furthermore, water balance assessments for **Scenario 9b** indicated that the next augmentation scheme will be required by 2043 (original date was 2049). This means that implementation of the Douglas EWR will cause the date of augmentation to move forward by 6 years.
- The only water supply implications in the tributary catchments occurred at three desktop biophysical nodes in the Klip River (Free State) IUA.

13.2 SOCIO-ECONOMIC IMPLICATIONS

The economic implication of the reduction in firm supply for Scenario 9b was determined on the basis of the increased costs as reflected by the time value of capital expenditure for augmentation that will need to be incurred earlier. The assumption is that the Thukela Water Project will be the next augmentation scheme to be implemented after LHWP Phase 2.

The economic cost of providing the Reserve requirements at the Douglas EWR site is thus between R511 million and R569 million expressed in 2012 prices. Although it is a very large sum of money, it represents less than 4.9% of the total projected cost of the Thukela scheme (i.e. R11.3 billion). Furthermore, it represents less than 0.035% of the estimated annual turnover of the large water users in the three Vaal WMAs or less than 0.14% of the GDP generated by the water in the project area.

13.3 ECOLOGICAL CONSEQUENCES

The ecological consequences are summarised in the **Table 13.1** below, indicating how the flows at the affected EWR sites compare to what is required to achieve the Recommended Ecological Category (REC). In general the ecological consequences evaluation of the EWR sites not listed in the table meet the Present Ecological State (PES).

Table 13.1: Summary of ecological consequences

EWR SITE	Sc 2	Sc 3	Sc 4	Sc 5	Sc 6	Sc 7	Opt Sc
EWR 1	✓	✓	✓	✓	✓	✓	
EWR 2	N/A	✓	✓	✓	✓	✓	
EWR 3	N/A	✓	✓	✓	✓	✓	
EWR 4	X	X	X	X	X	X	
EWR 5	X	X	X	X	X	X	
EWR 6	✓	✓	✓	✓	✓	N/A	
EWR 8	X	X	X	X	X	N/A	X
EWR 9	✓	X	✓	X	✓	N/A	
EWR 10	X	X	X	X	X	N/A	
EWR 11	X	X	X	X	X	N/A	
EWR 12	✓	✓	✓	✓	✓	✓	
EWR 13	✓	✓	✓	✓	✓	✓	
EWR 16	✓	✓	✓	✓	✓	✓	
EWR 18	✓	✓	✓	✓	✓	✓	

Legend:	Scale
√ : Meets REC, all components.	Good
√ : Meets REC, most components.	
X : Improvement to PES, below REC.	
X: Meets PES, REC is not achieved.	
X: EC below PES, above an E EC.	
X: EcoStatus is below a D EC.	Poor

13.4 GOODS AND SERVICES

The Ecological G&S in the Vaal River Catchment has pointed to the fact that, with a few notable exceptions, overall importance is relatively low. This is largely allied to the nature of the catchment and that there are few communities directly dependant on the G&S provided by the riverine system and for whom such dependence is linked to livelihood strategies.

In this context the scenarios were evaluated to determine which EWRs were likely to be associated with significant issues that could have implications for G&S. There are no significant impacts that are generated by the envisaged scenarios that would constitute a significant change to G&S for communities that are directly dependant. While some impacts on recreational fishing may be a consequence these are unlikely to be significant.

It is proposed that the catchment configuration (set of Biophysical Node Ecological Categories) for **Scenario 3** and **Scenario 2** for EWR 9 be selected for recommendation.

14 REFERENCES

DWAF, 2008 — Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Resource Unit. Report produced by Koekemoer Aquatic Services and Water for Africa. Authored by Louw, D. Report no: RDM/WMA8 C000/01/CON/0208.

DWAF, 2009a — Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Middle Vaal Water Management Area Technical Component: Resource Unit Report. Report no: RDM/WMA9 C000/01/CON/0407. Pretoria, South Africa.

DWAF, 2009b — Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Lower Vaal Water Management Area – Vaal River Catchment Technical Component: Resource Unit Report. Report no: RDM/WMA10 C000/01/CON/0407. Pretoria, South Africa.

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

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

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

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

DWA, 2010c — Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study for selected water resources in the Middle Vaal Water Management Area. Operation scenarios and consequence report. Report no: RDM/ WMA09C000/ 01/CON/ 1007. Pretoria, South Africa.

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

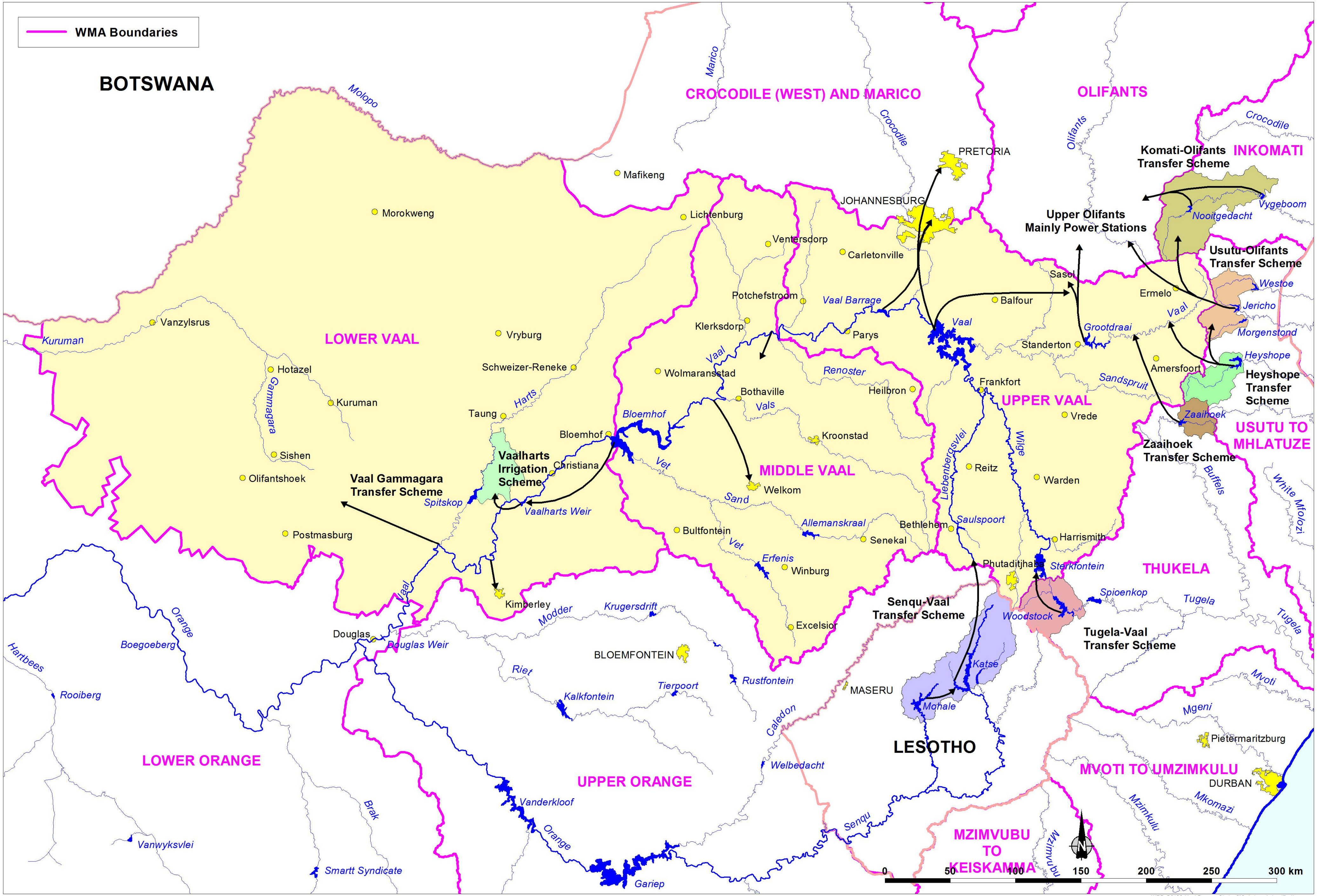
DWA, 2011a Department of Water Affairs (DWA), 2011. Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMAs) 8,9,10: Status Quo Report. Report No. RDM/WMA8,9,10/00/CON/CLA/0211. Pretoria, South Africa.

DWA, 2011b Department of Water Affairs (DWA), 2011. Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMAs) 8,9,10: Quantification of the Ecological Water Requirements. Report No. RDM/WMA8,9,10/00/CON/CLA/0311. Pretoria, South Africa.

DWA, 2012a Department of Water Affairs (DWA), 2012. Resource Directed Measures: Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10, Water Resource Analysis Report. Report No. RDM/WMA8,9,10/00/CON/CLA/0411. Pretoria, South Africa.

Appendix A:

Map of Study Area and Water Management Areas



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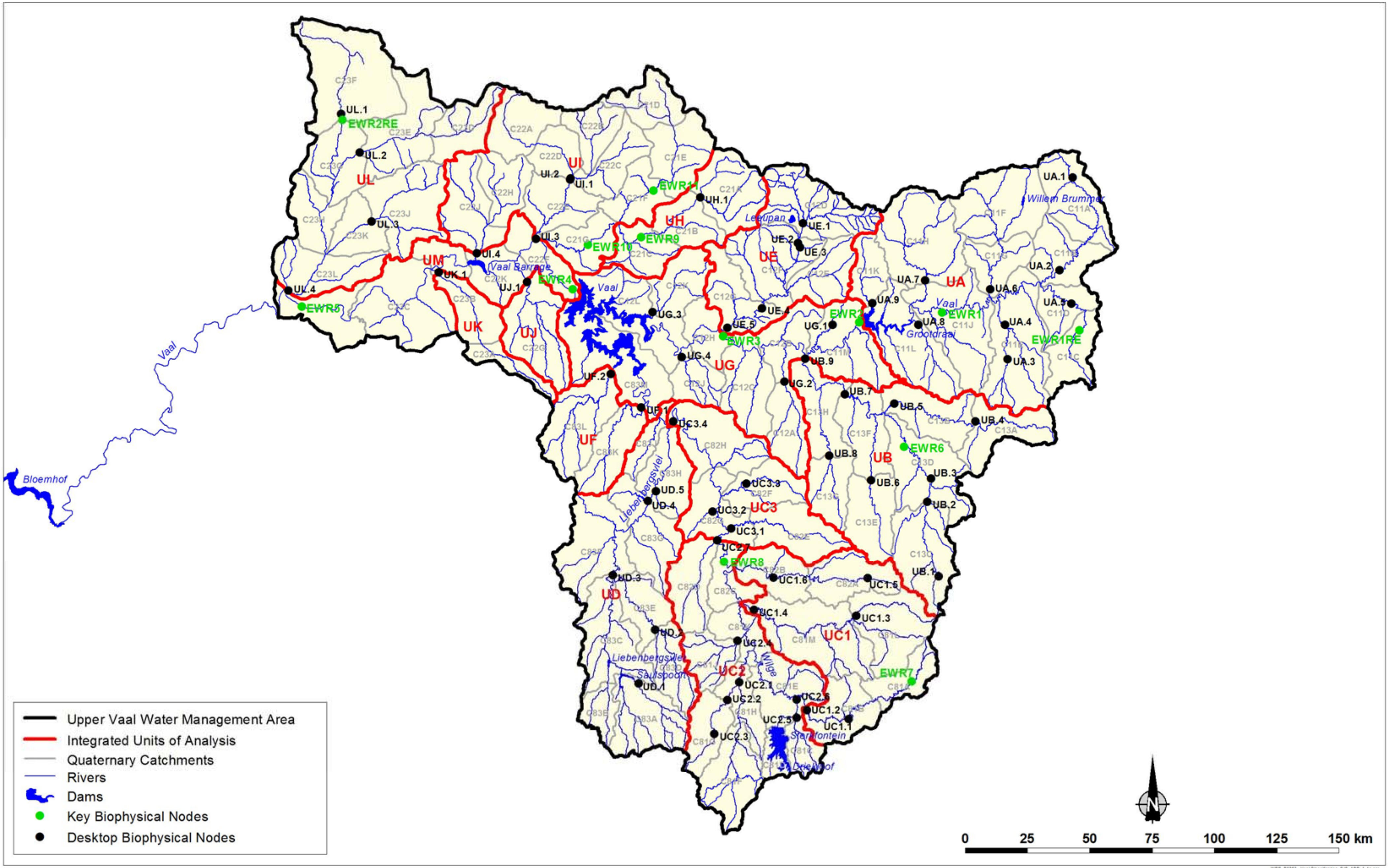
Integrated Vaal River System

A-1

Appendix B:

Catchment Maps of the Integrated Units of Analysis



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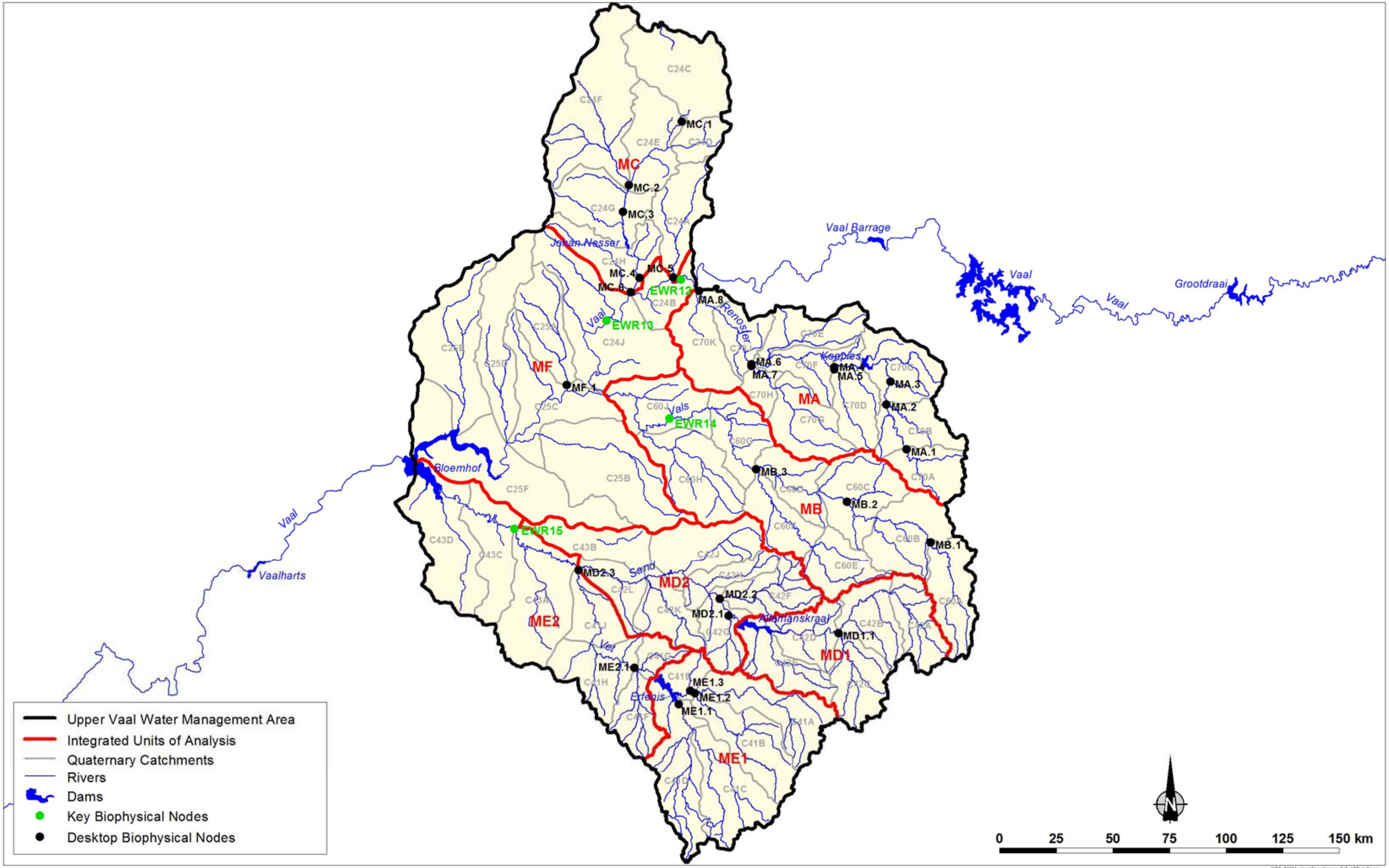
Upper Vaal Integrated Units of Analysis (IUA)

B-1



CLASSIFICATION OF SIGNIFICANT WATER RESOURCES (RIVER, WETLANDS, GROUNDWATER AND LAKES) IN THE UPPER, MIDDLE AND LOWER VAAL WATER MANAGEMENT AREAS (WMA) 8, 9, 10

Middle Vaal Integrated Units of Analysis (IUA)

B-2

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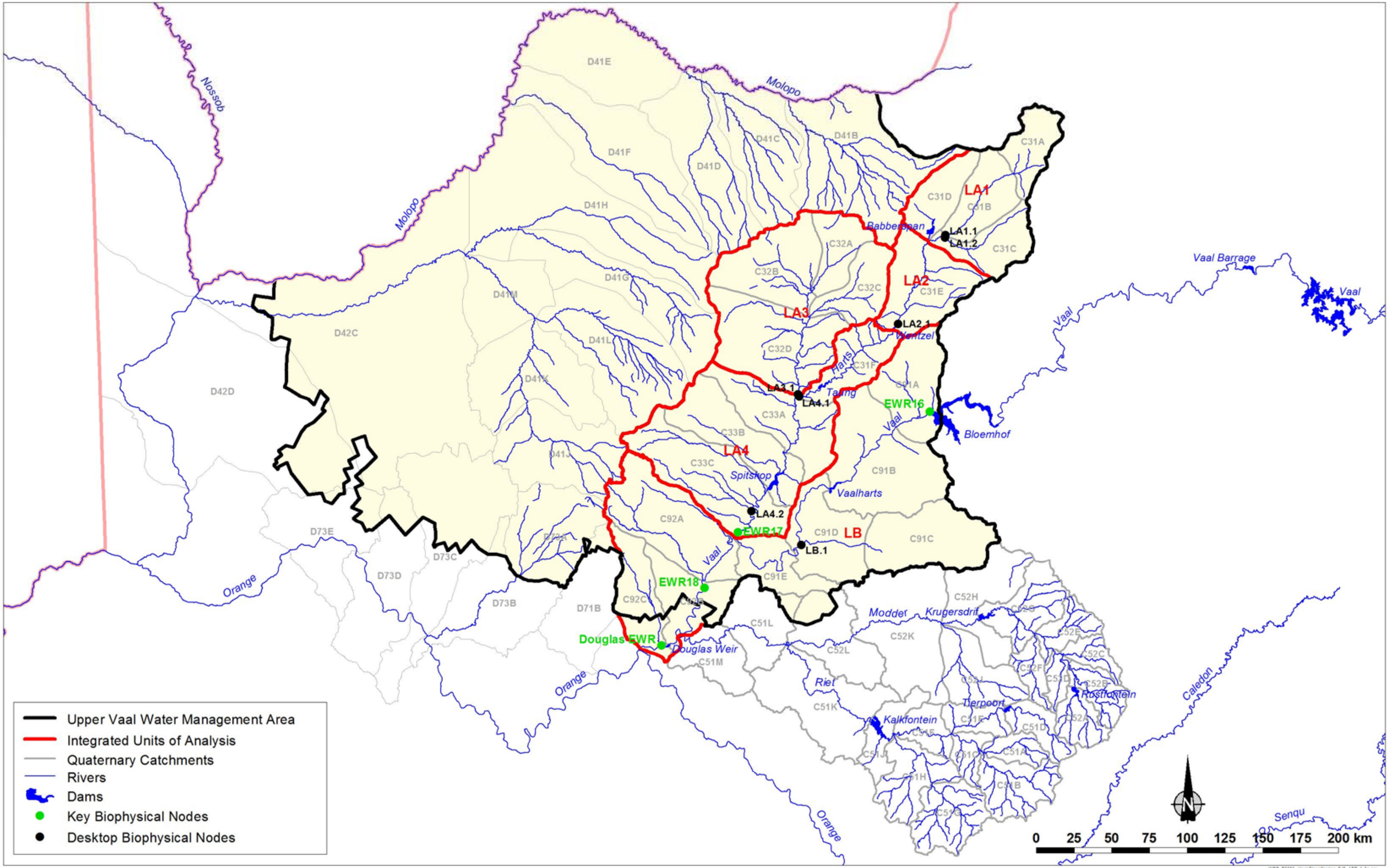

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Lower Vaal Integrated Units of Analysis (IUA)

B-3

Appendix C:

Members of Project Steering Committee

Last Name	First Name	Company
Aaron	Nontsikelelo	Lejweleputswa District Municipality
Abrahams	Abe	Department of Water Affairs (DWA)
Ah Shene Verdoorn	Carolyn	Birdlife South Africa
Armour	Jack	Free State Agriculture
Atwaru	Yakeen	Department of Water Affairs (DWA)
Augoustinos	Mario	Vaaldam Catchment Executive Committee
Bakane-Tuoane	Manana Anne	Emfuleni Local Municipality
Barnard	Hendrik	Ga-Segonyana Local Municipality
Basson	Noeline	Sedibeng Water
Batchelor	Garth	Department of Economic Development Environment and Tourism
Bezuidenhout	P J	Overberg District Council
Bierman	Bertus	Joint Water Forum and Anglo American Platinum
Blair	Vernon	Department of Water Affairs (DWA)
Boden	Denis	National Petroleum Refiners of S A (Pty) Ltd (NATREF)
Bosch	Gert	Sishen Iron Ore Mine
Bosman	Lourie	Agri Mpumalanga (Plaas Uitgezogt)
Botha	Hannes	Mpumalanga Tourism and Parks Agency
Bothes	Elizabeth	Department of Tourism, Environment and Conservation
Brink	Fanie	Grain South Africa
Broderick	Maylene	Economic Development, Environment and Tourism
Burger	Alwyn	City of Tshwane Metropolitan Municipality
Chamda	Yunus	Sedibeng District Municipality
Chauke	Lucia	Eskom
Chauke	Sydney	Emfuleni Municipality
Chewe	Victor	City of Tshwane Metropolitan Municipality
Claassens	Johan	TCTA
Cloete	Riekie	Conningworth Economists
Cogho	Vik	Optimum Coal Holdings
Collins	Nacelle	Free State Department of Tourism, Environmental and Economi
Cornelius	Steven	Gauteng Department of Agriculture and Rural Development
Critchley	John	Rand Water
Cronje	Barry	Rural Foundation
de Fontaine	Marc	Rand Water Rietspruit Blesbokspruit Forum
de Jager	Steyn	Greater Taung Municipality
de Klerk	Albert	Midvaal Local Municipality
De Kock	Abe	Farm: Mooidraai
de Villiers	D W	Koppieskraal Irrigation Board
Dhluwayo	Boy	Sol Plaatjie Municipality (Kimberley)
Dini	John	South African National Biodiversity Institute
Diniza	Maria	Gamagara Local Municipality
Dippenaar	Gideon	Sedibeng Water
Dippenaar	Gideon	Sedibeng Water
Dlabantu	Mpumelelo	Working for Water
Dlamini	Mavela	City of Johannesburg Metropolitan Municipality
Dlamini	Thami	Msukwaligwa Local Municipality
Donaldson	R	Manganese Mines
Driver	Mandy	SANBI
du Plessis	Rickus	Department of Agriculture and RuraL Development
du Toit	Hanke	Department of Water Affairs (DWA)
Du Toit	Tienie	Renoster River Water Users Association
Eilard	J	Dikgatlong Local Municipality
Eilerd	Johannes	Dikgatlong Local Municipality
Els	Nic	City Council of Klerksdorp
Erasmus	Coenie	Department of Tourism, Environment and Economic Affairs
Erasmus	Frik	Durban Roodepoort Deep Limited
Florence	Achmat	Frances Baard District Municipality
Fourie	A J	Griqualand Exploration & Finance Co Ltd
Fourie	Wynand	Department of Environmental Affairs (DEA)
Gabriel	Mary-Jean	Department of Agriculture, Forestry and Fisheries (DAFF)
Galane	Malesela	Environmental Justice Networking Forum (EJNF)
Gamede	Andries	Gert Sibande District Municipality
Gaobusiwe	Benjamin	Kgalagadi District Municipality
Gincane	Ruben	Mamusa Local Municipality

Last Name	First Name	Company
Ginster	Martin	Sasol
Gondo	Joe	National African Farmers Union (NAFU)
Gopane	Ruth	Dikgatlong Local Municipality
Gosani	Ntsikelelo	TCTA
Greeff	Henry	Kgalagadi District Municipality
Greyling	Jan	Matjhabeng Local Municipality
Greyling	S P J	Schoonspruit Irrigation Scheme
Grobler	Willem	Department of Water Affairs (DWA)
Gungubele	Mondli	Ekurhuleni Metropolitan Municipality
Hadebe	Slindokuhle	Ekurhuleni Metropolitan Municipality
Hall	Peter	Sasol Infrachem (Leeu Spruit, Taaibosch Spruit Forum)
Hanekom	Dirk	Eskom
Harrison	Pienaar	Department of Water Affairs (DWA)
Hauman	Louis	Kuruman Agricultural Union
Hendriksz	Johan	East Rand Water Company (ERWAT)
Itholeng	Kebalepile	Gauteng Department of Agriculture and Rural Development
Itumeleng	Clement	Gamagara Local Municipality
Izaaks	Saul	Siyanda Water and Sanitation District
Jacobs	Gideon	Distrik Boere Unie
Jooste	Sebastian	Department of Water Affairs (DWA)
Joubert	Andre	Zitholele Consulting (Pty) Ltd
Kadiaka	Mamogala	Department of Water Affairs (DWA)
Keet	Marius	Department of Water Affairs (DWA)
Kekesi	Albert	Bophirima District Municipality
Khan	Rafat	Midvaal Water Company
Kleynhans	Neels	Department of Water Affairs (DWA)
Kokobela	Mosimanegape	House of Traditional Leaders
Komape	Martha	Department of Water Affairs (DWA)
Kruger	Marina	Midvaal Water Company
Leeto	Nokwanje	Lejweleputswa District Municipality
Leeuw	David	Sol Plaatjie Local Municipality
Lekoko	Simon	Directorate of Traditional and Corporate Affairs
Lethoko	Itumeleng	Ditsobotla Local Municipality
Letlhogile	Tshiamo	Ditsobotla Local Municipality
Letsoalo	Mokopane	Waterberg District Municipality
Leuschner	Andries	Gold Fields South Africa Ltd
Liefferink	Mariette	Federation for a Sustainable Environment (FSE)
Liphadzi	Stanley	Water Research Commission
Lobelo	Govan	Dr Ruth Segomotisi Mompati District Municipality
Lodewijks	Henk	Anglo Coal Environmental Services
Louw	Delana	Rivers for Africa
Louw	Lonnox	Tosca Dolomite Water User Association
Mabalane	Itumeleng	Chamber of Mines
Maboe	Paul	Sasolburg Transitional Local Council
Mabuda	Solly	Department of Water Affairs (DWA)
Mafejane	Ariel	Johannesburg Water
Magodi	Omphemetse	Kgalagadi District Municipality
Mahonde	Kay	Birdlife South frica
Mahusi	Christopher	Molopo Local Municipality
Makape	G G	Tsantsabane Municipality
Makena	Gladys	Magareng Local Municipality
Makgalemane	Itumeleng	Greater Taung District Municipality
Makodi	Rebecca	Leekwa Teemane Local Municipality
Makuapane	Andrew	Leekwa Teemane Local Municipality
Malaka	Tebogo	Department of Water Affairs (DWA)
Malebye	Patrick	Dipaliseng / Balfour Local Municipality
Manamela	Sadimo	Department of Water Affairs (DWA)
Manele	Sorrious	Sedibeng District Municipality
Mapholi	Masindi	Maquassi Hills Local Municipality
Maposa		Delportshoop TLC
Marx	Karin	Wildlife and Environment Society of South Africa (WESSA)
Maseng	Benardo	Kgatelopele Local Municipality
Masondo	Amos	City of Johannesburg Metropolitan Municipality

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Maswuma	Zacharia	Department of Water Affairs (DWA)
Matseba	Mogale	Department of Water Affairs (DWA)
Mazwi	Nosie	Department of Water Affairs (DWA)
McCourt	Liz	Department of Environmental Affairs (DEA)
Meintjes	Louis	Transvaal Agricultural Union South Africa (TAUSA)
Mere	Shedrick	Magareng Local Municipality
Midgley	Ian	Eskom
Mlambo-Izquierdo-	Poppy	Kgatelopele Local Municipality
Mmarete	Charles	Department of Water Affairs (DWA)
Mmoiemang	Kenneth	Kgalagadi District Municipality
Mngomezulu	Willy	Pixley Ka Seme Local Municipality
Mnisi	Jones	Johannesburg Water (Pty) Ltd
Mochware	Ontlametse	Kagisano Local Municipality
Modisakeng	Busisiwe	Lesedi Local Municipality
Mofokeng	Mahole	Sedibeng District Municipality
Mofokeng	Mpho	Greater Taung District Municipality
Mofokeng	Puleng	Department of Agriculture, Forestry and Fisheries
Mogotlhe	Paul	North West Department of Agriculture, Conservation, Environment and Tourism
Mohapi	Ndileka	Department of Water Affairs (DWA)
Mokadi	Andrew	Vaal University of Technology
Mokgosi	Mantebo	Moqhaka Local Municipality
Mokgosi	Mantebu	Moqhaka Local Municipality
Molema	Kemonna	Tribal Authority
Molema	Shelley	Bophirima District Council
Mompati	Rose	Naledi Local Municipality
Mongake	Monty	Fezile Dabi District Municipality
Mongolola	Gift	Ga-Segonyane Municipality
Moraka	William	South African Local Government Association (SALGA)
Mosai	Sipho	Rand Water
Mothibi	Dimakatso	Department of Agriculture and Land Reform
Motlhale	Kelehile	Tswelopele Local Municipality
Motoko	Phihadu	Ratlou Local Municipality
Mshudulu	S A	Emfuleni Local Municipality
Mthimunye	George	Naledi Local Municipality
Mtsuku	Samuel	Department of Tourism, Environment and Economic Affairs
Mudau	Stephinah	Chamber of Mines South Africa
Mulangaphuma	Lawrence	Department of Water Affairs (DWA)
Muller	Anton	Bloemhofdam Kom
Mutyorauta	J J	Department of Agriculture
Mutyorauta	Julius	Department of Tourism, Environment and Conservation (DTEC)
Mvula	Obed	Department of Land Affairs
Mwaka	Beason	Department of Water Affairs (DWA)
Mweli	Zandisile	Maquassi Hills Local Municipality
Nagel	Marius	Government Communication and Information Systems (GCIS)
Naidoo	Shane	Department of Water Affairs (DWA)
Nakana	Lesego	Greater Taung Local Municipality
Namusi	Sedirilwe	Molopo Local Municipality
Nast	Timothy	Midvaal Local Municipality
Naude	Piet	Free State Agricultural Water Committee
Nengovhela	Rufus	Department of Water Affairs (DWA)
Ngamole	G	Masilonyana Municipality
Ngangelizwe	Sebenzile	Matjhabeng Local Municipality
Ngcobo	Mbuleleni	Gert Sibande District Municipality
Ngcobo	Sonwabo	Tswaing Local Municipality
Ngema	Khaya	Ekurhuleni Metropolitan Municipality
Ngila	Zelna	Siyanda District Municipality
Ngomane	Lulu	Gauteng Water Sector Forum
Ngxanga	Eric	Siyanda District Municipality
Nkonyane	Martha	
Nkwane	Oupa	City of Tshwane Metropolitan Municipality
Nosi	Thabo	Frances Baard District Municipality
Ntili	Tseliso	Department of Water Affairs (DWA)
Ntsepe	Sello	Mantsopa Local Municipality

Last Name	First Name	Company
Ntsizi	Thembile	Wes Vaal Chamber of Commerce
Ntwe	Francisco	Ratlou Local Municipality
Nyamande	Tovhowani	Department of Water Affairs (DWA)
Oagile	Mothus	Kagisano Local Municipality
Oosthuizen	Christo	Louwna/Coetzerdam Water User Association
Opperman	Dirk	Land Affairs
Opperman	Nic	Agri SA
Peek	Bobby	GroundWork - Friends of the Earth South Africa
Petersen	Thabo	Matjhabeng Local Municipality
Phukuntsi	Rosy	Tswelopele Local Municipality
Pienaar	Harrison	Department of Water Affairs (DWA)
Pienaar	P G	Vyf Hoek South Management Board
Pillay	Nava	Metsweding District Municipality
Potgieter	Ampie	Sasol Mining Rights Department (SMRD)
Potgieter	Jan	Department of Agriculture, Forestry and Fisheries
Potgieter	Sandra	Dow Plastics
Pretorius	Theuns	Kaalfontein Boerevereniging Distriks Landbou Unie
Pyke	Peter	Department of Water Affairs (DWA)
Radebe	Khulu	Male Development Agency
Rademeyer	Seef	Department of Water Affairs (DWA)
Ramaema	Lowrence	Department of Tourism, Enviroment and Economic Affairs
Ramokgopa	Kgosientsho	City of Tshwane Metropolitan Municipality
Ramokhoase	Jonas	Fezile Dabi District Municipality
Rampai	Constance	Mantsopa Local Municipality
Rampine	M K	South African National Civic Organisation (SANCO) Boikhotsong
Reinecke	C J	Potchefstroom Univ for CHE
Reitz	J J C	Kalahari East Water User Association
Rossouw	Lourens	Tokologo Local Municipality
Rust	Nelia	Matjhabeng Local Municipality
Sales	Malcolm	Lebalelo Water User Association
Samson	Paballo	Moshaweng Local Municipality
Sebusho	Sipho	Kgalagadi District Municipality
Seikaneng	Tefo	Moshaweng Local Municipality
Shabalala	Sam	Emfuleni Local Municipality
Shone	Steve	Grain SA
Sindane	Jabulani	Lekwa Local Municipality
Slabbert	Nadene	Department of Water Affairs
Smit	Hennie	Department of Water Affairs (DWA)
Snyders	Louis	Department of Water Affairs (DWA)
Stoch	Leslie	Geotech (Lower Wonderfonteinspruit Forum)
Stoltz	Gert	Molopo Farmers Union
Surendra	Anesh	Eskom
Sutton	Malcolm	Anglogold
Swart	Susan	WRP Consulting Engineers (Pty) Ltd
Takalo	Mmabatho	City of Tshwane Metropolitan Municipality
Terrè-Blanche	Riana	Namaqualand Water and Sanitation Support Group (NAWASAN)
Thakurdin	Manisha	Department of Water Affairs (DWA)
Theron	Danie	Christiana Farmers Association
Theron	J H	Vaalharts Water Users Association
Theron	Piet	Munisipaliteit van Delportshoop
Thirion	Christa	Department of Water Affairs
Thompson	Isa	Department of Water Affairs (DWA)
Tlhape	Manketse	Tswaing Local Municipality
Tshipelo	Kenneth	Mamusa Local Municipality
Tsotetsi	Mabalone	Dipaliseng Local Municipality
Ubisi	Makumu	Sedibeng Water
van Aswegen	Johann	Department of Water Affairs (DWA)
van den Berg	J W	Saamstaan Agricultural Union
van den Berg	Ockie	Department of Water Affairs (DWA)
van den Bon	Patrick	Vadex Consulting cc
van der Heever	Piet	Lesedi Local Municipality
van der Merwe	Ben	Emfuleni Local Municipality

Last Name	First Name	Company
van der Merwe	Danie	Ekurhuleni Metropolitan Municipality
van der Merwe	Johan	Rand Water
van der Walt	Philip	City of Tshwane Metropolitan Municipality
van der Westhuizen	Walther	Department of Water Affairs (DWA)
van Rooyen	Johan	Department of Water Affairs (DWA)
van Rooyen	Pieter	WRP Consulting Engineers (Pty) Ltd
van Schalkwyk	V	South African Rivers Association
van Tonder	Dean	Sasol Mining
van Vuuren	Hennie	Regina Farmers Union
van Vuuren	J L	Frankfort TLC
van Wyk	Francois	Rand Water
van Wyk	Jurgo	Department of Water Affairs (DWA)
van Wyk	Niel	Department of Water Affairs (DWA)
van Zyl	Andre	Fezile Dabi District Municipality
Van Zyl	Chris	TAU SA Agricultural Union
van Zyl	J F C	Bloemhof TLC
Venter	Gerda	Department of Water Affairs (DWA)
Venter	Petrus	Department of Water Affairs (DWA)
Vilakazi	Bheki	Msukwaligwa Local Municipality
Viljoen	Peter	Vereeniging Refractories Ltd
Vorster	Albert	Kimberley Agricultural Union
Watson	Marie	Centre for Environmental Management
Wepener	Lotter	River Property Owners' Association - Save the Vaal
Williams	Bruce	Klerksdorp Irrigation Board
Woodhouse	Philip	Goldfields (West Driefontein Gold Mine)
Yawitch	Joanne	Department of Environmental Affairs (DEA)

Appendix D:

Comments and Responses